Technical Assistance Consultant’s Report

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PRC: Development of Biomass Power Generation in Rural Areas
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Prepared by Landell Mills Development Consultants
United Kingdom

For the Heilongjiang Province

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Asian Development Bank
Development of Biomass Power Generation in Rural Areas

TA 7006-PRC

EXECUTIVE SUMMARY

September 2009
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The overall objectives of the Asian Development Bank funded, 'Development of Biomass Power Generation in Rural Areas [TA 7006-PRC]', are to contribute to the sustainable development of rural areas, improvement of national energy security, promotion of renewable energy and reduction of greenhouse gases emissions in the People’s Republic of China (PRC).

Four components have been included in the Project:

1. BPG: Barriers and Lessons Learned (Page 2);
2. Biomass Power Plant Technical Studies (Page 19);
3. Provincial Biomass Power Generation Strategy (Page 22);

Component 4 was accomplished through a series of successful multi-stakeholder workshops and training seminars, in addition to an international conference in November 2009. Components 1-3 are summarized in the remainder of this document.
1. BPG: BARRIERS AND LESSONS LEARNED

BPG market share is being driven by, amongst other things, its potential to improve energy security and contribute to sustainable rural development in China. BPG is one of the few technologies currently available that has the potential to utilize agriculture residues and provide tangible benefits to farmers and rural communities. This report presents the results of the TA Component 1, addressing and analyzing the barriers to development and lessons learnt from previous BPG activities in China. Both technical and non-technical barriers have been identified and reviewed. In addition, international experiences have also examined.

The key issues raised in the report are of importance for multiple stakeholders including investors, developers, farmers, governments, industry and the agriculture and forest sectors for a successful future of rural development and renewable energy development in PRC.

The report begins with a brief introduction to the objectives and methodology used in this study, followed with an overview of recent trends in power generation, especially BPG in China. A detailed review of the current development of BPG is presented in terms of different conversion technologies such as direct combustion, co-firing and biomass gasification technologies.

The report focuses primarily on the development of BPG that would be needed to improve efficiency and reduce the financial risks of investments in the sector. Analysis suggests that there is considerable potential to improve the performance of BPG in China. However, this improvement is contingent on the application of clear incentives to shift towards BPG and a wholesale acceleration in development of a range of technologies across the biomass feedstock supply and conversion chain. In this manner, BPG stakeholders can ensure that most viable, energy-efficient and cost-effective technologies are brought to the market as quickly as possible and progress made against the key objectives.

1.1. STATUS OF BIOMASS POWER GENERATION DEVELOPMENT

In 2006, China’s primary energy supply accounted for 1,913 Mtoe (approx. 16.3 percent of the world total). It is projected by the IEA that the future energy increase in China will be 2,000 Mtoe by 2030. In the power sector, China’s overall installed capacity has increased from 138 GW in 1990 to 713 GW in 2007 (over 500 percent in 17 years), generating 3,278 TWh of electricity in 2007. It is estimated that this rapid growth will continue and electric power generated will exceed 7,100 TWh by 2030. Currently coal is the major energy source for power generation and industry (approx. 70 percent). However, according to the government plans, renewable energy is expected to supply 10 percent of the total primary energy by 2010 and 15 percent by 2020. Nuclear power is projected to increase from 8.7 GW in 2007 to 40 GW in 2020.

BPG development represents an important pillar of future renewable energy contributions to China’s electricity mix. Based on China’s mid- and long term renewable energy targets, BPG installation capacity shall be 5.5 GW and 30 GW in 2010 and 2020, respectively. To reach these strategic targets, development and deployment of BPG, from feedstock resources to conversion and utilization technologies are all in need of enhancement, whilst taking due consideration of key sustainability factors such as environmental and social impacts.

Biomass conversion technologies include direct combustion, gasification, pyrolysis, extraction, fermentation, and anaerobic digestion. Products consist of heat and power, methanol, biodiesel, ethanol, bio-oil, biogas and hydrogen. For BPG, the main technology implemented in China is direct combustion using agricultural residues as feedstock. Current technologies include both grate fired and circulated fluidized bed combustion developed by China or imported from Denmark. Up to the end of 2007, the total approved projects by National Development and Reform Commission (NDRC) are 81, of which 17 plants were in commission.
The power industry has established a strategic plan for BPG development. However, due to ambiguous regulations, policy incentives and subsidies for co-firing plants, most projects are focused on power generation only. National Biomass Energy Co. Ltd (NBE) is one of the industrial pioneers who have been aggressively promoting BPG implementation and commercialization. There are 12 plants in commission with total installed capacity of 324 MWe. Seven plants are under construction with a combined capacity of 84 MWe.

1.2. POTENTIAL OF BIOMASS RESOURCES FOR BPG

The main biomass resources for BPG in China include agriculture and forest residues. Although the total amount of agricultural residues varies by estimation, it is widely accepted that the present available agriculture residues in China totals approx. 500-600 million tons per year. The main grain production is mainly located in Hebei, Inner Mongolia, Liaoning, Jiling, Jiangsu, Henan, Shandong, Hubei, Jiangxi, Sichuan and Yunnan.

The estimation of the agricultural residues available for energy use can be carried out by following three steps: estimation of straw based on grain production; collectable residues resources, and; biomass resources for energy uses. The amount of biomass available for energy use is estimated at approx. 240 million tons per year (120 million tce) annually. If by-products from agricultural processing are considered, the total biomass for energy use is about 3 million tons (1.5 million tce).

Forest-based bioenergy resources include mainly fuelwood, residues from stand improvements (such as culling trees, removing rotten, dead trees or undersized trees), non-commercial tree species and trees from thinning performed on growing stock. Estimated forest residues during harvesting are about 1,620 million tons. Other wood-based biomass includes residues from economic forest, bamboo, garden trees and city trees, etc, which account for about 100 million tons. In total, about 161 million tons can be used for energy uses, which is equivalent to about 92 million tce.

To achieve China’s national target of 30 GWe in 2020, 19 GW could be supplied by agricultural or forest biomass resources totaling approx. 100 million tons. This is less than the available estimated biomass resources for energy use. However, uncertainty exists in the estimated biomass resources and sparse distribution of residues. The study suggests that more detailed investigations on the biomass resources available in provinces and cities/counties should be conducted to provide solid and reliable data for BPG strategic planning.

1.3. TECHNICAL ASSESSMENT

Conversion technology for BPG involves the following steps:

- Biomass supply and feedstock management;
- Biomass feeding to the boiler;
- Combustion technologies, and;
- Operation and maintenance.

This study is focused on feedstock management for agricultural residues though forest-based biomass can also be used for BPG.

1.3.1. Biomass supply and feedstock management

An agricultural biomass supply system involves several steps including, harvesting, collection, transport and storage before the biomass enters the plant. Mechanized harvesting methods are not widely used for biomass collection, despite some equipment having already been developed for the market. The wider industrial infrastructure has not yet been developed. The TA project observed that the selection of collection sites for biomass trading is critical to ensuring stable feedstock supply. A dedicated discussion (Chapter 5) on biomass collection and supply is included herein as this is one of the major bottlenecks identified for BPG development.
Handling of biomass feedstock is the process of converting residues into suitable forms for use by a biomass power plant. Rice husks and wood chips may be used directly for power plants. However, most biomass needs to be processed somewhat, especially in terms of dehumidification. The transport of biomass from the field to the gate of a BPG plant is carried out by modified or specially designed vehicles for that purpose. The gate price of biomass feedstock is determined not only by the transport distance but, more importantly, by the status of biomass supply and demand in the locality.

Biomass storage facilities help to buffer fluctuations in biomass feedstock prices and ensure a stable supply of fuel for a BPG plant. The scale of storage is determined by the feedstock collection, processing and transportation chain as well as the plant’s capacity. The biomass is stored after it has been chopped and partly dried. The processed biomass is normally stored inside the plant while un-processed biomass is managed by a dealer. Such an approach is approved as a good method for reducing the risks resulting from lightning, fire or decomposition. Dealers are encouraged to store residues for subsequent sale to the plant at a higher price after drying, etc. This provides additional benefits for dealers while saving storage space inside the plant. The dedicated services for biomass storage thus becomes a new business opportunity and enhanced revenue stream for dealers/farmers.

1.3.2. Biomass boiler feeding
Biomass is delivered to feed a boiler by one of a variety of conveyer belt designs. The selection of delivery methods is determined by the type of biomass and the combustion requirements of furnaces/boilers. Unfavorable materials might be mixed in with the feedstock. Metal and other materials which cannot be combusted should be filtered out. Experiences and practices of operational plants show that the biomass handling and feeding system is one of the key technical challenges to be resolved. Development of a stable system able to handle various feedstocks is one of the future areas for R&D focus. It is necessary to improve the reliability of the feeding system in order to ensure the requirements on feeding materials for boilers.

1.3.3. Combustion technologies
The BPG system implemented in China currently uses the conventional steam turbine system. The steam turbine units are standard and thus do not present any major technical challenges. However, because the feedstock is different from conventional (coal-fired) power plants, the combustion behavior of agriculture residues in terms of stability of combustion, corrosion and erosion of the heat transfer surface inside the boiler is relatively new for designers and manufacturers in China. Therefore, the technical challenges lie mainly in the combustion process in the biomass boiler. Biomass power plants in China are mainly based on direct combustion boilers, including two types of biomass boilers, grate fired and fluidized bed combustion boilers.

Because BPG is still in the early stages of development, technical issues/problems related to the operation of biomass plants, especially for those with domestic boilers, should be further investigated, focusing on the following aspects:

- corrosion, tar removal and efficiency of power generation;
- biomass feeding systems;
- ash removal, combustion stability and construction materials for pre-heaters and superheaters, and;
- advancing automation.

1.3.4. Operation and maintenance
Due to several reasons including the quality of the feedstock, equipment performance (mainly boiler) and the competence of the operators, some biomass power plants cannot operate under the designed condition.

Unfavorable materials such as sand and dust mixed with the feedstock can also block the biomass feeding mechanism. The preparation and handling of the biomass feedstock is one of the bottlenecks to be overcome for more effective operation of biomass power plants. This study
suggests that long-term monitoring and recording of the operation and maintenance (O&M) parameters for BPG plants should be established for accumulating and disseminating experiences which would be significant for both existing and new plant operations.

### 1.4. TECHNICAL ISSUES TO BE ADDRESSED

The main technical issues that needs to be further addressed include:

- How to design a boiler with high flexibility in its use of different types of biomass resources? The type of biomass feedstock might be different due to seasonal changes and feedstock supply during the summer season of May to September is often insufficient to run a biomass power plant.
- How to improve the preparation and handling of biomass for removing non-combustible substances? How much of the feedstock processing and feeding system can be automated?
- How to measure moisture content accurately (and thus determine an accurate and fair feedstock quality / price standard)? This is one of the critical techniques that needs to be further developed especially considering the wide variety of agricultural residues.

The following R&D needs are recommended by this study:

- **Biomass preparation and handling technologies.**
- **Improvement of combustion technologies.** The development of combustion technologies is still ongoing both nationally and internationally. The prime goals are to minimize the total costs of power production, improve safety and operational performance and increase efficiency. For example, using higher temperatures and pressures of steam turbines will give higher total efficiency. This will require boilers to use more advanced combustion technology, especially to be able to handle the enhanced corrosion and erosion during the combustion at higher temperatures. In addition, boilers which can handle different biomass fuels will increase the flexibility of the furnace. Research on new and advanced construction materials is also needed.
- **Co-firing in large coal fired power plants.** Co-combustion of biomass in a coal fired power plant has been regarded as one of the most cost-effective and efficient technologies for BPG but a number of policy issues need to be addressed.
- **New collection machinery for agricultural residues** to increase the effectiveness of collection.
- **Innovative micro- and small-scale CHP technologies.** In addition to large-scale biomass power plants based on conventional steam turbines, new technologies for small-scale power generation by innovative engines, for example, the Stirling engine, have been demonstrated which may have the potential for future application in CHP production.

### 1.5. BIOMASS COLLECTION AND SUPPLY SYSTEM ANALYSIS

#### 1.5.1. Market mechanism and stakeholder analysis of biomass supply system

The main stakeholders in biomass collection and supply systems include farmers, dealers and plant operators/owners. Because the long distance transport of raw biomass is not feasible, this determines that the market of biomass will be local or regional. A national biomass market does not exist at the present state in China yet. The study suggests that a long-term agreement among stakeholders is essential to stabilize the biomass feedstock price, which can be beneficial not only for the plant operators but also for dealers and farmers who are involved in biomass trading.

How well developed the market is directly influences if biomass can be effectively collected and supplied to the BPG plant. This will have further impacts to farmers as well as dealers in the BPG system. An analysis has been conducted to understand the roles and perspectives of stakeholders in the biomass supply chain, including farmers, dealers, plant owners, local / central government, and investors, etc. The results show that BPG generates significant benefits to farmers which should thus be encouraged and supported by both local and central governments. Biomass market establishment should feature close collaboration, clear communication and transparent information.
dissemination among stakeholders regarding biomass price, demand, business performance and other key indicators.

1.5.2. Biomass supply and price
The current price of biomass in most BPG plant gates is about 300 CNY/t. Based on an average heating value of 3,000 kcal/kg, this can be attributed a coal-equivalent ratio of 0.64 coal (5,000 kcal/kg). The price of biomass is equivalent to a price of 469 CNY/t of coal, which is similar to the price of coal transported from Shanxi to Jiangsu. From this point of view, the price of biomass is higher than its value based on the fuel quality and energy content.

The relationship between BPG plants and dealers is critical. Practices of using incentives of bonuses and/or penalties work fine to stimulate and enhance market competition among different dealers. At present, biomass value is based on two methods: weight or volume. Both methods consider the moisture content whereby a discount is applied for higher moisture contents in the biomass. However, no accurate standard method of moisture content determination has been developed. A pilot test to determine the biomass price is recommended which includes all costs for collection, processing, transport, electricity and dealer’s margins, etc.

1.5.3. Experience and lessons learned in biomass collection
A ‘farmer-based price system’ should be promoted alongside enhanced relations between dealers and farmers. Farmers should be trained and equipped with special equipment for the collection of biomass. Ensuring benefits to farmers will enable the whole biomass supply chain to deliver a long-term stable stream of biomass feedstock. The following issues should be carefully considered when establishing a farmer-based price system:

- The relationship between dealers and farmers should be one of good cooperation. The reputation and trust credibility of dealers at the local level is of importance;
- Farmers’ benefits should be given high priority in BPG business. Subsidies to the sector should be transferred on to farmers. According to a document issued by the State Council, the central government is to establish an agricultural residues collection system in 2015 and develop related businesses in this sector. The utilization rate of agricultural residues should reach 80 percent. The central government’s strategic goals on biomass residue utilization should be transferred to the local level;
- Training for farmers should be enhanced on how to effectively collect biomass residues, while considering other needs (especially fertilizer and soil improvement). Technical service and support to farmers by local governments should be available to assist farmers to attain maximum benefits from the biomass resource utilization business;
- Policy enhancement and implementation should be made at the local level. The policies for BPG should be integrated with those for rural development with the ultimate goal of increasing rural incomes.

1.5.4. NBE’s Experience
Based on studies of existing plants operated by the NBE, the stable and long-term agreement between the dealer and the plant is critical for securing biomass supply at a reasonable price.

The following experiences and lessons can be useful for the future:

- Agreement: An agreement should be signed between the dealer and the BPG plant for the required amount of biomass. The plant pays 80 percent of the biomass on first delivery and the rest (20 percent) during the second delivery;
- Competition and quality: At the outset, more collection sites can be established to create a competitive market. The better dealers can then be selected to ensure maximum cost and collection efficiency;
- Pre-requirements for dealer: Requirements should be given for the dealers: i) dealers should have sufficient cash flow to prepay for biomass collection. This is also important for the trust between dealer and farmer which will reduce the risk to biomass resource supply; ii) The dealer has the storage capacity to store biomass of, for example 2,000 to 5,000 tons.
This will ensure the quantity of the feedstock available; and, iii) the dealer should have the capacity to deal effectively and fairly with local stakeholders;

- **Rational location to avoid over competing**: Collection sites should consider the local agricultural behavior. It is recommended that less sites be established at the county of the plant, and more sites in other counties;
- **Selection of the dealer** should be based purely on market requirements and capacity. It is good that the local government does not get involved this process.

1.6. ENVIRONMENTAL AND SOCIAL IMPACTS OF BPG

Guidelines for the implementation of the Renewable Energy Law request that power generation enterprises should take the responsibility for performing conscientious preparatory work in their new operations. Such work includes due attention to sustainable design, land use and water resource management, as well as complying with state regulations on management of renewable power generation projects and the need for administrative licenses. Construction should not be started without the approved licenses or permits.

In principle, a BPG plant has similar technology to a conventional coal-fired power plant. Therefore the same regulations regarding environmental impacts should be applied. The main environmental regulation for BPG, "Notice on strengthening management of BPG project’s environmental impact assessment (EIA)", was first introduced in June 2006 jointly issued by the former State Environmental Protection Administration and the NDRC. This document gives detailed provisions for BPG projects. In 2008, the Ministry of Environmental Protection (MEP), NDRC and the National Energy Administration issued "Notice on further strengthening BPG project management of EIA" which expands on the previous notice.

EIAs of BPG in both construction and operation phases include many steps such as: site selection; technology requirements; assessments of atmospheric, water, noise and land impacts, etc. This has been common practice in China for all large-scale engineering projects.

BPG uses agricultural residues which are thus removed from the field. This means that the residues available for soil replenishment and fertilization will be reduced. However, this other impact is that residues are no longer burned in-situ by farmers, thus averting emissions of certain GHGs and particulate matter. This issue has not been considered in the present EIA framework but should be further addressed in the future when a large number of BPG plants are to be built.

The social impacts of BPG are mostly positive and include, for example: job creation in rural areas; the increase of farmers’ incomes; enhancement of the rural economy and market; and generation of alternative business opportunities for rural areas. BPG requires large amounts of biomass collection which will encourage the farmers to use more equipment. This will promote industrialization in rural areas which is of importance for the wider agricultural modernization in China.

A 25 MW BPG plant will use about 200,000 tons of agricultural residues, generate about 1,000 jobs and create additional revenue for farmers. In addition, traditional collection and use of biomass for cooking and heating are part of the household burden of woman. BPG development will provide a modern method to use biomass and thus is of importance to reducing the heavy workload of women in rural areas.

Some negative social impacts also exist. BPG will increase competition for biomass resources which will likely result in a high costs for energy use by other stakeholders, due to increased feedstock prices. In addition, straw residues have traditionally been returned to the field as organic fertilizer for soil improvement or as feed for livestock. Increased use of biomass for BPG may create more competitive uses of the resources. Thus local conditions should be carefully considered on these issues to avoid negative impacts.
1.7. COST BENEFITS AND FINANCIAL ANALYSIS

1.7.1. Cost Benefits Analysis

In 2006, NDRC released the policy document, ‘Regulation of REN Price and Cost Share’ in which it states that BPG can receive favorable a feed-in tariff of 0.25 CNY/kWh which also applies to co-firing plants with over 80 percent biomass. The survey of BPG plants conducted by Chinese government, suggests major challenges including: i) high investment costs; ii) weak capacity of domestic manufacturing, and; iii) problematic biomass collection, storage and management. Most BPG is operating with negative economic benefits based current fuel price and overheads. This situation becomes an obstacle for potential investors into this sector.

The following table lists the main economic data of a BPG plant based on imported or domestic technologies.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Imported</th>
<th>Domestic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100 million</td>
<td>2.4</td>
<td>1.92</td>
</tr>
<tr>
<td>Unit</td>
<td>CNY/kW</td>
<td>10000</td>
<td>8000</td>
</tr>
<tr>
<td>(VAT, Income tax)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>%</td>
<td>(17%,25%)</td>
<td>(0%,0%)</td>
</tr>
<tr>
<td>Self capital</td>
<td>%</td>
<td>(17%,25%)</td>
<td>(0%,0%)</td>
</tr>
<tr>
<td>Calculated electricity tariff</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>After tax</td>
<td>CNY/MWh</td>
<td>818</td>
<td>677</td>
</tr>
<tr>
<td>Before tax</td>
<td>CNY/MWh</td>
<td>701</td>
<td>677</td>
</tr>
</tbody>
</table>

The electricity production price is at the level of 620 – 820 CNY/MWh depending upon VAT and initial investment. By adding 25 CNY/MWh based on the biomass feed-in tariff, the electricity cost to the grid in Shanxi, Shandong and Jiangsu is between 448 to 646 CNY/MWh as shown in the following table.

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit</th>
<th>Shanxi</th>
<th>Shandong</th>
<th>Jiangsu</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local grid electricity desulfurization price in 2005</td>
<td>CNY/MWh</td>
<td>274</td>
<td>343</td>
<td>396</td>
</tr>
<tr>
<td>Actual grid electricity price for biomass power plants</td>
<td>After tax</td>
<td>524</td>
<td>593</td>
<td>646</td>
</tr>
<tr>
<td></td>
<td>Before tax</td>
<td>448</td>
<td>507</td>
<td>552</td>
</tr>
</tbody>
</table>

The results of the cost-benefit analysis of several BPG plants show that, except for a co-firing plant, the current production costs of biomass power range from 0.6 – 0.7 CNY/kWh and generate negative profit. The main reasons are:

- The strategic plan of BPG plant distribution is not rational. The over-competitive uses of biomass resources by different plants exist which makes the biomass price higher than predicted, which further increases the cost of electricity;
- Initial capital costs are relatively higher than other power plants;
- Operational costs are high. For instance, tax of BPG is at 14.5 percent which is even higher than a coal fired plant (in the range of 6-8 percent);
- By-products such as the ash fertilizer production have not been fully developed;
- The baseline of a coal plant for calculating the final tariff is not fully reasonable.

In fact, the investment needed for BPG is much higher than for fossil fuel-based plants such as coal-fired plants. For typical biomass with the cost of USD 3 - USD 3.5 /GJ, the electricity cost may exceed USD 30 - USD 50/MWh. Due to their small size, dedicated biomass power plants are more expensive (USD 1500 - USD 3000/kW) than coal plants. According to the IEA, co-firing in coal power plants requires limited incremental investment (USD 50 - USD 250/kW) and the electricity cost may be competitive (USD 20/MWh) if local feedstock is available at low cost.
However, due to the introduction of high energy taxes on fossil fuels in many countries, the economic and environmental benefits of biomass fuel are realized due to the cheaper feedstock and tax incentives. Favorable policy incentives are needed for the promotion and development of BPG. Internationally, favorable tariffs, green electricity certificates, tax reduction or waivers and carbon taxes have been implemented for supporting BPG implementation. This suggests the need for further studies on how to address policy instruments for China’s BPG by introducing international experiences.

The main investment for a BPG plant is the boiler equipment for use with biomass feedstock supply system. According to statistical data of BPG projects, specific investment is about 10,000-13,000 CNY/kW. The investment for a new BPG plant is much higher than the retro-fit from a small coal-fired power plant. For example, the total investment of Chang’ge Power Plant in Henan province is only 30 million CNY, the specific investment was as low as 2500 CNY/kW, which was reconstructed with a new 75 ton/h biomass-fired boiler replacing the old coal-fired boiler. This reveals a cost-effective opportunity in that the retro-fit of old coal-fired boilers can significantly reduce the investment costs and thus improve the feasibility of BPG projects.

Based on experiences of biomass power plant construction and by giving consideration of reliability of biomass resource supply, the major trend of China’s BPG development is to use units with 2 x 12MW, including two boilers and two steam turbines. The total investment of a typical BPG plant (approx. 24 MW) is about 190-240 million CNY. According to the financial requirements of Project Economic Evaluation Methodology and Parameter (Version 3) issued by the Chinese government, a minimum of 20 percent of capital for a new power plant must come from the developer themselves. Therefore, for a new BPG plant, an investor should have capital of at least 38-48 million CNY in addition to a loan of 152-192 million CNY from a commercial bank or other financial institution.

It is estimated that during the year of 2010-2020, the total amount of biomass resources that can be utilized for BPG projects are about 60-100 million tons in the 16 provinces to the north of the Yangtze River. This can satisfy the resource needs of 350-600 power plants with total installed capacity of 8 - 14 GW. However, it should be noted that BPG technology is only one of the technologies for biomass utilization. With the development of technologies, especially the second-generation technologies like lignocellulosic bio-ethanol production from straw, it is estimated that by the end of 2020, only 1/3 or 1/4 of such biomass resources will be available for biomass direct combustion power plants. The total investment needs of building all these BPG plants will be about 17-50 billion CNY.

At present, NBE is the largest investor of BPG projects in China, with 39 approved projects by the government and 10 projects in operation (2008). Besides NBE, State-owned energy enterprises also tap the BPG field. Although some private-owned BPG projects such as Jiangsu Baoying, Jiangsu Lianyungang, Henan Chang’ge projects have been put into construction, the number of private-owned BPG projects is much less than the ones invested by state-owned energy enterprises. Because of the high capital cost, high risk and low perceived benefit of BPG projects, investors and commercial banks are lacking in confidence to invest in BPG.

1.7.2. Financial Analysis

The following table shows the different types of financial instruments generally available, the barriers and risks associated with each one and the potential financial role for donor funds in structuring the financing for new biomass plants.

The most important international financial instruments are loans and guarantees from multilateral development banks. The loans have traditionally been low-cost, but their attractiveness under current global economic conditions is their ability to attract co-investors and co-financiers in projects that might otherwise be considered too risky on a purely commercial basis.
<table>
<thead>
<tr>
<th>Financial mechanism</th>
<th>Description</th>
<th>Barriers and risks</th>
<th>Financial role of donor funds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sovereign term loans</td>
<td>Loans provided by international financial institutions directly to, and secured by, Government of China, which passes the funds to BPG developers, e.g. NBE.</td>
<td>Since loan would not be dependent on the technical or financial performance of the BPG developer or its plants, the only risk is the unlikely possibility of loan default by the Government of China</td>
<td>None</td>
</tr>
<tr>
<td>Unsecured term loans to BPG developer</td>
<td>Loans provided by international financial institution directly to BPG developers with no sovereign guarantee from the Government of China; repayment by BPG developers not dependent on performance of financed biomass plants</td>
<td>Moderately high credit risk due to uncertain performance by BPG plants; willingness of lender based on BPG developers’ balance sheet. Additional security has to be provided</td>
<td>Provide partial loan guarantee</td>
</tr>
<tr>
<td>Non-recourse loans to specific biomass projects</td>
<td>Loans provided by commercial bank(s) to specific projects, secured by PPA, CER sales</td>
<td>Very high risk due to uncertainty / adequacy of the biomass plant’s revenues</td>
<td>Provide partial loan guarantee</td>
</tr>
<tr>
<td>Partial credit guarantee (PCG)</td>
<td>Share credit risk with commercial banks; PCG could also be provided to leasing companies</td>
<td>High credit risks; lack of experience with credit enhancements among commercial lenders</td>
<td>Provide reserves to back a portion of the guarantees</td>
</tr>
<tr>
<td>Contingency loans</td>
<td>Loans provided to BPG developers with part or all the debt forgiven in exchange for specified action by borrowers</td>
<td>High credit risks; weak political environments for ensuring contract enforcement</td>
<td>Cover cost of forgiven loans</td>
</tr>
<tr>
<td>Operating leases</td>
<td>Leases provided by private sector arms of international finance institutions directly to BPG developers for acquisition of boiler and other major components</td>
<td>BPG developers’ lack of experience with leases; illiquidity &amp; high perceived risks in market &amp; consequent short lease terms provide by lesers</td>
<td>Provide partial guarantee on lease</td>
</tr>
<tr>
<td>Equity</td>
<td>Equity investments in BPG plants</td>
<td>Difficulty of exit from investments</td>
<td>None</td>
</tr>
<tr>
<td>Carbon finance</td>
<td>Monetization of future cash flows from the advanced sale of CERs (or Verified Emissions Reductions - VERs) to finance SME project investment costs</td>
<td>Unavailability of underlying financing for projects; inadequate institutional capacity to host CDM project or enforce contracts. Lack of project development capital; lack of cash flow for additional security; uncertain delivery of carbon credits</td>
<td>Sign Emission Reduction Purchase Agreement (ERPA) with projects at a guaranteed floor price</td>
</tr>
<tr>
<td>Carbon transactions post-2012</td>
<td>Contract by international finance institution or broker for purchase of CERs to delivered after 2012</td>
<td>All of the above carbon finance risks, plus lack of international regulatory framework</td>
<td>Guarantee floor price for re-sale of post-2012 CERs</td>
</tr>
</tbody>
</table>

The most important incentives, or sources of grants and other funds, lie in the carbon finance world. The selling of Certified carbon Emission Reductions (CERs) pursuant to the UN’s Clean Development Mechanism (CDM) is already being very actively pursued by China for biomass plants and a whole host of other projects.
The investment obstacle is one of the main barriers that limit the development of BPG in China. High capital costs, high risk and low economic benefits results in low confidence and interest levels from investors and commercial banks. Main financial barriers include:

- **High capital costs**: today’s BPG specific capital cost is about 10,000 CNY/kWe which is higher than coal fired plant in China.
- **High and fluctuating price** of biomass feedstock: a market mechanism for biomass has not been established yet. The price of biomass feedstock is high and unstable. In some cases, the price is even higher than coal.
- **Favorable policy and regulation** for BPG needs further improvement. For example the electricity tariff cannot fully compensate for the loss of electricity production. No specific incentives are implemented for the investment and taxation reduction.
- **International investment** in this sector has not been fully explored including, e.g. CDM.

The major financial and investment risks associated with the construction and operation of new biomass power plants will be technology, fuel supply and credit. There is more technology risk with BPG plants compared to conventional power plants because there is less experience and operating hours with them.

Technology risks also involve faults in design, material and workmanship. To the extent that developers choose plant technologies that are relatively new and untested, investors will place relatively larger emphasis on these risks. Underwriters will often exclude coverage for these risks, although technologies that have years of operating experience will reduce concerns, as will availability of service warranties and performance guarantees from longstanding and creditworthy manufacturers and service providers.

Additional risks of concern to investors and underwriters will have to do with whether fuel is available at adequate volume and price, and whether plant operating hours can be maximized. Of course, the ability to increase hours of operation - and thus increase revenues from power sales – is partially dependent on adequacy of fuel supplies. Although fuel cost/availability and operating hours are not strictly financial and investment risks, they affect the economic viability of a plant and thus become financial and investment risks.

Depending on how the financing is structured, there could be a major credit risk as well. If the intention is to attract debt, projects financed on a non-recourse basis will result in greater risk for debt providers. However, if the plants are financed on a limited recourse basis or on developers' balance sheets, then the risks faced by the debt provider are shared with the developer and its owners. Many investors will have increased comfort if they are co-financing with a multilateral development institution such as the ADB or World Bank Group.

### 1.7.3. Recommendation to overcome financial barriers

Following recommendations to overcome financial barriers are suggested:

- **Implementation Rules of Fiscal Preferential Policies for BPG Project**: It is recommended that BPG projects should also enjoy financial subsidy from national renewable energy funds as the other renewable energy projects.
- **Modification and improvement of price subsidy policy** for BPG projects: By the end of 2008, there have been over 30 BPG plants in operation in China. This project recommends conducting a case study of the implemented BPG projects in China to reveal the problems of insufficient electricity subsidy and inconsistent criteria for calculating electricity subsidy. This is critical for future commercialization of BPG projects in China to attract investors commercial banks in BPG business.
- **Biomass Resource Assessment Regulation and Prepare Biomass Development Plan of BPG Projects**: Because stable biomass supply becomes one of bottlenecks for BPG projects in China. It is important to establish an assessment regulation to follow when building a new BPG plant. This will be helpful to reduce the financial risk of the investment to manage the
biomass feedstock costs for BPG by optimized location with considerations of the available biomass resources.

- **Attracting private investment:** To be able to attract private investment in BPG projects in China, it is important to provide transparent experiences and lessons learnt from the previous implemented projects. Good documents including project plan, construction, operation, financial benefits and risk etc should be recorded.

- **Selection of reliable technology and technology provider:** The financial risk is partly associated with the technology selection and provider of the technology. Because the BPG development in China is still in early stage, it is important to review and evaluate the implemented technologies and the technology providers.

### 1.8. REGULATIONS / POLICY REVIEW AND ANALYSIS

Policy and regulations related to BPG is strongly linked to China’s future renewable energy strategic development and policies, which fall into three categories managed by both central and local government.

- **First-level policies:** general direction and guidance is provided, for example, speeches of state leaders about development of renewable energy and the Chinese government's standpoint on the global environment.

- **Second-level policies:** specify goals/objectives and development plans, and focuses on rural electrification, renewable energy-based generation technologies and fuel wood. These policies attempt to standardize the directions, focal points, and objectives of renewable energy development from different viewpoints. Some departments propose concrete policies and regulations. Second-level policies have played a very important role in promoting renewable technologies in China.

- **Third-level policies:** consist of practical and specific incentives and managerial guidelines. These outline specific supporting measures for developing and using renewable energy. These third-level government policies provide crucial support to help develop renewable energy in its early growth stages. Since the mid-1990s, many provinces and autonomous regions of China have adopted policies for developing renewable energy, including subsidies and tax reduction. The central government also issued several effective regulations.

Since 2005, central coordination on renewable energy development has been made in the PRC. The most important policy and regulation documents include the:

- **Renewable Energy Law;**
- **11th Five-Year Development Plan (including both Energy and Renewable Energy), and;**
- **Medium and Long-Term Renewable Energy Development Plan.**

Those regulations and policy documents are important factors in solving policy conflicts and uncertainty which existed before 2005. BPG has been included into the renewable energy portfolio in the policy settings. However, it can also link to other policies in agriculture and forest sectors. Various supporting policy documents have been issued by the central government which promote the development of renewable energy, including bioenergy. However, due to the significant differences regarding the geographic conditions, biomass types, resource data, investments, markets and institutional arrangements, etc, more specific policies and regulations at the provincial level are needed.

At present, policy and regulation regarding BPG is setting principles and guidelines rather than specific implementation rules and methodologies. Successful developments and deployments require targeted and end-use specific policy prescriptions. Coordination of the R&D and demonstration, industrial development and research institutions, power sector, agriculture and forest sectors should be further enhanced.

R&D in biomass energy development should be further enhanced. Technology transfer has been successfully made in BPG by the power generation industry. Central government should support
such transfer by giving more favorable policy, institutional and financial incentives and interventions to speed up technology transfer. Research on the fundamental data for resource assessment on biomass quantities, quality and geographic distribution should be enhanced by the provision of government research grants. This issue has been recognized as a bottleneck for the rational planning of future BPG, as well as the implementation of other technologies. Technical standards should be established with the support of the central government. Because BPG implementation has taken place at a relatively fast pace, most of the technical standards that have been used are related to coal-fired power plants. With consideration of the biomass characteristics, new technical standards are of importance for the success of future implementation.

The study recommends enhancing coordination and harmonization of policy and regulations in BPG. The Chinese Ministry of Finance has set up renewable energy development funds and issued ‘Interim Administration Rules on Funds for Renewable Energy Development’. The other renewable energy projects including wind power, solar power and ocean power have been listed as key subsidy targets while BPG is not included. A BPG plant with multiple social and environmental benefits should be added to the subsidy list. Other recommendations include further reform of the electricity market, enhanced government support and guidance for the sector, tax reduction and incentivization to encourage CHP and co-firing development.

1.9. INTERNATIONAL EXPERIENCES AND LESSONS IN BPG

Internationally, BPG including CHP is steadily expanding in Europe, mainly in Austria, Germany, the United Kingdom, Denmark, Finland and Sweden, where electricity is mostly produced from wood residues and MSW in cogeneration plants. The main driving forces for such development are due to resource abundance and favorable national policies. These policies are generally linked to renewable energy promotion and climate change mitigation agendas.

The United Kingdom has seen recent growth in ‘co-firing’. The use of biomass for district heating and CHP has been expanding in Austria, Denmark, Finland, Sweden, and the Baltic countries, and provides substantial shares (5–50 percent) of district heating fuel. In Europe two thirds of biomass is used for heating. Approximately 85 percent of the total wood processing waste biomass in the United States is are used for power generation.

Due to the varieties of biomass resources, the feedstock biomass for power and CHP are different among different countries. Technologies for BPG can also be different. Fluidized bed combustion and grate fired boilers are the two most widely used technologies for BPG. For co-firing with coal fired power plant, the biomass can be mixed with coal in pulverizing mills to be used for pulverized coal fired plants. BPG has raised a number of the issues covering fuel compatibility and logistics, design, operation and construction difficulties, the security of incentives and the availability of economic capital.

The five main barriers identified that impede growth of the bioenergy markets in the European Union. These are:

- Reluctance among major energy and fuel suppliers, vehicle and boiler manufacturers.
- Lack of appropriate policies in some countries, and political uncertainty over the duration as well as the level of financial support given to biomass energy.
- Technology and process costs, meaning that biomass is uncompetitive, and new fuel chains addressing more complex resources, new conversion routes such as gasification and pyrolysis, and new applications are required.
- Lack of awareness among consumers about the benefits of bioenergy and negative attitudes with some concern regarding pollutant emissions.
- The fuel chain complexity.
- Slow market and trade development requiring the development of market tools so that the fuel can become a tradable commodity.

There are consistent strategies and interventions for overcoming barriers. These include:
Investment grants and policy measures (such as green certificate schemes and carbon taxes) are critical to altering economic conditions and making bioenergy sufficiently competitive with fossil fuels.

Developing know-how and institutional capacity often requires pilot projects to stimulate learning processes. Local initiatives on climate change, environmental protection, and regional development are also the foundations in many of the case studies for local involvement from the public and politicians in bioenergy systems.

Local champions are able to build networks and guide supply chain co-ordination. Supply contracts are observed in the case studies as significant to establishing functioning bioenergy systems.

To overcome the above barriers for the development of biomass market, the main policy tools of the EU to address the above barriers include feed-in tariffs, renewable obligations, fiscal incentives and tender schemes. In Sweden, green certificate has been used. In UK, Renewable Energy Obligations Certificates (ROCs) is applied.

BPG systems require sufficient, reliable, long-term, and affordable biomass supplies (and frequently) of a standard quality. Management of biomass supply and quality control are of importance to ensure the success of BPG projects. Multifunction/products based bioenergy systems have attracted recent attention due to the increased interests of biofuel production.

1.10. MAIN EXPERIENCES AND BARRIERS OF BPG IN CHINA

1.10.1. Renewable Energy Law Significantly Enhances the Development of BPG
Since 2006 when China initiated the Renewable Energy Law and the associated regulations and incentives, new business opportunities have been provided for the power utility sector. This has stimulated and promoted the fast development of BPG. Under the framework of the REN Law, a series of regulations and policy have been established.

A regulation on the EIA of BPG has also established. In principle, it is similar to the EIA of a coal fired plant, whilst considering the different characteristics of biomass compared to coal.

The regulatory process promotes the development of BPG in the following aspects:

i) national targets and responsibilities have been clearly defined as government strategy;

ii) the market for BPG has began to be opened to more developers and electricity generated from biomass can be sold to the main grid;

iii) although investment risk still exists, the regulations and policy on the REN tariffs have reduced the risk. This further improves the situation in attracting the investment in the sector;

iv) the public acceptance to REN has been significantly improved which contributes to the positive social impacts.

The REN Law provides a feed-in tariff for some technologies and establishes grid feed-in requirements and standard procedures. It establishes cost-sharing mechanisms so the incremental costs of production will be shared among utility consumers. It also creates new financing mechanisms and supports rural uses of renewable energy. Since 2006, the implementation of BPG has been developed at a very fast rate due to policy encouragement and the recognition of BPG as a new business opportunity for the power sector in China.

1.10.2. Technology transfer and development
Since 2006, direct combustion technologies based on grate-fired boiler and CFB boilers are the main two combustion technologies in China for BPG fuelled by agricultural and forestry residues.

The unit size of the power plant is around 25 MWe. Co-firing combustion with fossil fuels such as coal has also been demonstrated. The most widely implemented system of BPG is that of direct combustion technologies, imported from Denmark or developed by domestic institutions. Up to the
end of 2007, the total approved projects by NDRC were 81, of which 17 plants were in commission. Of the 17 biomass plants, there are 10 plants which are based on the imported technology from Denmark.

Technology advances in the BPG sector have been rapidly advanced during the last decade, thanks to the active involvement of the industrial power sector. It is crucial to continue technological innovation to further improve the performance of biomass power plants. Government support in both policy and R&D for technology development, deployment and demonstration are crucial at this point.

Improvement in manufacturing and retrofit of existing direct combustion technology should be supported by national R&D funding. Detailed documentation and recording of operating biomass plant data and best practice should be made to find out the real technical problems. It should be encouraged to share technical solutions among plants, even those of different owners. By doing such, a national program on the monitoring the performance of biomass power plant might be possible, organized and initiated by a central governmental agency.

Technological innovation in collection machinery, biomass feeding systems and combustion technology should be integrated with the national energy R&D program. China has strong research competences in those areas but integration of the research efforts to the industrial realm should be further promoted in order to address technical problems.

New technical standards for BPG should be studied and established if necessary. Biomass feedstock characteristics and standard requirements for various biomass combustion boilers, biomass supply systems and operational systems of biomass plants should be considered.

1.10.3. Active involvement of large state power enterprises
Because of the large power enterprises’ involvement and implementation, BPG technologies have been rapidly developed in the past decade. NBE, Huaneng, Datong, China State Power and China Power Invest are all involved in BPG. In addition, other companies such as CBCIC, Hebei Contracture Invest, Jiangsu GouXing New Energy are also active in the BPG business. Because BPG is at the early period of development, large companies’ involvement will be helpful in reducing the investment risk for others. In addition, large enterprises are also more easily able to access credit from commercial banks, a critical step in the further development of BPG.

NBE is the standalone pioneer for BPG in China with over 40 approved BPG plants located at Shandong, Hebei, Henan, Jiangsu, Leilongjiang, Jiling, Liaoning, Xinjiang, Hubei, Anhui, Shaanxi and other provinces. There are 12 plants that have been in commission with total installed capacity of 324 MWe. Seven plants are under construction, totaling 84 MWe.

With the involvement of large companies in BPG implementation, technologies have been further improved while accumulating operational experience; important for further development and deployment of BPG in China. NBE initiated an engineering center for biomass energy development. This kind of enterprise-led engineering R&D center is very unique in the world of bioenergy development. It is worthy to follow-up the experience of the R&D which might bring a successful model for national and/or international application in BPG development.

1.10.4. Successful demonstration of initial model for biomass feedstock supply
By practice, NBE has established an effective model for the collection, transport and storage of biomass, termed the ‘farmer-dealer-plant’ model. The model encompasses the following features:

i) biomass collection and transport: a business agreement is arranged between a dealer and a plant. The dealer collects biomass from farmers and also transports it to the storage or gate to the plant;

ii) biomass storage: the dealer and farmers are the main players while a BPG plant only store limited biomass resources.
From the viewpoints of power plant, the security of biomass can be improved though a slightly higher price being paid to the dealer compared to farmers. Dealers have the benefits by providing the service to the plant while also share the benefits with farmers. The ‘farmer-dealer-plant’ model ensures greater stability of price and consistency of supply.

1.10.5. Barriers for the Implementation of BPG in China
Through the above analysis and case studies, a summary of the results can be made as follows:

i) Through the development and demonstration of BPG, the fundamental technologies have been gradually adapted by Chinese manufacturers. The boiler is one of the key component under further improvement by many manufacturers and R&D institutes.

ii) Market competitiveness is still weak for BPG. Biomass power plants are still under a stage of demonstration and development. Different lessons and experiences have been collected from different plants.

iii) The electricity price framework for BPG has been established and has stimulated the development of BPG though an enhanced policy incentive is still needed for further improving the market benefits.

iv) Some of the challenges have been identified during the feasibility study, construction, construction management and feedstock management as shown in the following table.

<table>
<thead>
<tr>
<th>Areas of Focus</th>
<th>Challenges</th>
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<tbody>
<tr>
<td>Feasibility Studies</td>
<td>▪ Lack of development procedures and feasibility guidelines</td>
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<tr>
<td></td>
<td>▪ Big gap between early stage feedstock investigation and purchase reality</td>
</tr>
<tr>
<td></td>
<td>▪ Unable to realize full favorable policy commitment</td>
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<tr>
<td>Construction</td>
<td>▪ Contracting method should be reviewed with consideration of the biomass characteristics which is different from the coal or natural gas</td>
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<td></td>
<td>▪ Managing equipment procurement methods well developed for smaller projects and rural areas</td>
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<td></td>
<td>▪ Contractors are not properly managed</td>
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<tr>
<td></td>
<td>▪ Cost control need improvement</td>
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<tr>
<td></td>
<td>▪ Design problem feed back need be improved, design to be optimized</td>
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<tr>
<td>Construction</td>
<td>▪ Operation responsibility to be emphasized</td>
</tr>
<tr>
<td>Management</td>
<td>▪ Plant reliability to be improved</td>
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<tr>
<td></td>
<td>▪ Operation skill to be improved</td>
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<tr>
<td></td>
<td>▪ Housekeeping to be improved</td>
</tr>
<tr>
<td></td>
<td>▪ Operation preparation during construction stage to be improved</td>
</tr>
<tr>
<td>Feedstock</td>
<td>▪ Feedstock management system including procurement, packing, transportation and storage is not yet established</td>
</tr>
<tr>
<td>Management</td>
<td>▪ Quality standards are not well established or followed</td>
</tr>
<tr>
<td>CDM Trade</td>
<td>▪ CDM quality control system to be established</td>
</tr>
<tr>
<td>Information</td>
<td>▪ Lack of management and coordination system</td>
</tr>
<tr>
<td>Management</td>
<td>▪ Government policies</td>
</tr>
<tr>
<td>Information</td>
<td>▪ Substantial financing difficulties</td>
</tr>
<tr>
<td>Management</td>
<td>▪ Government policy issuance behind development</td>
</tr>
<tr>
<td>Information</td>
<td>▪ Power transmission construction cost to be back charged from government</td>
</tr>
<tr>
<td></td>
<td>▪ Management procedures and system to be improved</td>
</tr>
<tr>
<td>Basic Management</td>
<td>▪ Division of responsibility to be streamlined</td>
</tr>
<tr>
<td></td>
<td>▪ Staff training to improved</td>
</tr>
<tr>
<td></td>
<td>▪ Staff levels to be reduced and optimized</td>
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</table>

1.10.6. Technology Development
Collection of Biomass: Collection of biomass is still a labor-intensive process at present in China. The two main reasons include the relatively cheaper labor and the lack of collection machinery. Upgrading of collection machinery is one of the approaches to increasing the efficiency of biomass collection. In the short term, the combination of labor and mechanized methods will remain as the main approach. The use of harvesting machinery is not common for biomass collection, though some of equipment is already available in the market. However, it is still in the early period of development overall and the industrial infrastructure has not yet been fully developed.
**Feeding of Biomass**: For biomass feeding, many technical issues need to be solved. Some examples are as follows:

- Due to seasonal changes, the biomass feedstock might differ and, during May to September, may be in short supply. How to make a boiler with high adaptability to be able to use all different types of biomass?
- Pre-treatment by removing non-combustible material. Feeding is completed by machine with manual support at about 90 percent reliability. Further improvement is necessary.
- Moisture content in the biomass feedstock is significant for the biomass price as well as the operation of a biomass plant. How to measure and control accurately the moisture content of the feedstock is one of the critical technologies that need for further investigation.

**Conversion technologies**: Because the BPG is still in the early development, technical issues/problems related to the operation of the biomass plants especially for those domestic boilers should be further investigated.

1.10.7. Finance and Investment
Enhanced financial support should be provided by the central and provincial governments which should consider not only the benefits of BPG to renewable energy, but also the impacts on the environment and rural development. The main barriers in finance and Investment in BPG include:

- High capital costs for biomass power plant;
- High price of biomass feedstock;
- Fiscal and financial policy and regulations need to be further improved;
- Problems attracting international and private investment.

1.10.8. Policy and Regulations
Although the strategic policy and regulations to promote BPG development have been established, there are still many aspects that should be further improved. Many of these aspects act as barriers to reaching the strategic targets of BPG, for example:

- Lack of coordination and harmonization of policy and regulations;
- Domination of the electricity market by large state-owned enterprises and investors. Small and private investors face a high barrier to entry into the sector;
- Government support and guidance in resource inventory and planning is relatively weak;
- Co-firing and CHP are not attractive mainly due to the lack of clear policy and regulations for those technologies and energy price systems in China.

The combination of the high biomass price, weak market mechanism, unstable supply system, technical issues associated with combustion and O&M, financial and policy barriers call for the innovative solutions to simulate and promote BPG development in China.

1.11. RECOMMENDATIONS FOR BPG DEVELOPMENT IN CHINA

The development of a strong, stable and successful BPG industry calls for the urgent formulation and application of government policies. These policies should promote the commercialization of BPG technologies and stimulate the development of new technologies that are efficient and environmentally beneficial. In particular, the following recommendations are of key importance.

1.11.1. Enhanced research and development in BPG
Further R&D in BPG to investigate and adapt more advanced and innovative technologies, including:

- Biomass pre-treatment technologies;
- Development of improved combustion technologies;
- Technology development of co-firing of biomass in large power plants;
- Development of new equipment which are more suitable for collection of Chinese agriculture residues to increase the effectiveness of the collection;
- Innovative micro/small scale CHP technologies based on biomass combustion.
1.11.2. Clear and Coherent Policy and Regulation Framework
A long-term and favorable policy framework should be further improved for BPG including, for example,
- Coordination and harmonization of policy and regulations for BPG should be further improved.
- Further reform of electricity market should be further implemented in particular in the new BPG sector.
- Government’s support and guidance for the sector should be further enhanced.
- Taxation Reduction for BPG should be included in the taxation policy as a key technology in the renewable energy portfolio;
- Policies and incentives to encourage biomass CHP development and co-firing should be established to solve the issues related to energy price, monitoring of the biomass supply in the co-firing plant etc.

1.11.3. Explore More Financial Instruments and Incentives
Investment and financial instruments should be further exploited for the development of BPG to attractive multiple investors from enterprises, financial institutions and government to access both domestic and international investments.
- The economic performance should be further improved by all different means including technology and policy in order to attract wider investments in BPG;
- Government support to BPG will be significant for stimulating the involvement from the institutional investors;
- More development should be conducted to attract international funding and investment in BPG. The institutions include for example, GEF, CDM and other bilateral or international investments and grants;
- Utilization of the loans from ADB and World Bank etc.
2. BIOMASS POWER PLANT TECHNICAL STUDIES

2.1. TECHNICAL STUDY 1: COMMODITY MARKET ANALYSIS FOR BIOMASS FEEDSTOCK UTILIZATION

Many people view bioenergy as a great opportunity. In developing countries, investment in bioenergy can create jobs, reduce poverty and generate income in rural areas. Bioenergy contributes to development and diversification within the agricultural sector and strengthens the role of that sector in overall economic development. Bioenergy can help solve domestic energy problems, increase export earnings and reduce foreign currency spending for energy imports. Other persons voice fears of social, environmental and economic impacts and point out the risk of increased demand for biomass and bioenergy. The pressure on ever-scarcer natural resources, land and water is growing. The combination of decreasing global food supplies and increasing food prices threatens food security. Social risks attend the formation of new dependencies by smallholders.

The extension of biomass production to rainforests and ecologically sensitive areas threatens biodiversity. The promotion of bioenergy must take these risks into account and provide a coherent political framework, investor-friendly concepts, and socially, economically and environmentally sustainable standards for biomass production.

To achieve targets and objectives in the production and use of bioenergy, a wide range of activities in the bioenergy value chain needs to be included:
- Policy on biomass and bioenergy issues, legal and institutional frameworks, strategies for sustainable biomass production and use
- Assessment of biomass resources and analysis of bioenergy potential
- Identification of opportunities and risks of bioenergy
- Design and promotion of biofuel value chains
- Participatory elaboration and introduction of social and ecological standards and obligatory certification schemes with the involvement of all stakeholders
- Fostering of cooperation with the private sector through public-private partnership (PPP) programs that support companies and stimulate investment in developing countries
- Design and implementation of services delivery and extension schemes and of farmer organization and out-grower schemes for sustainable biomass production
- Identification and promotion of transfer of appropriate technologies for rural energy supply and the transport sector
- Knowledge management, capacity development and networking.

Biomass energy feedstock covered by this study are agricultural residues deriving from field activities after harvesting the main product such as straw, stover, cob and pruning; and forest biomass. Forest biomass included are only residues from harvest operations that are left in the forest after stem wood removal, such as branches, foliage, roots, and complementary felling which describe the difference between the maximum sustainable harvest level and the actual harvest needed to satisfy round wood demand.

In northern Europe (e.g. Sweden, Finland) it has been demonstrated in long-term forest experiments that the potential sustainable harvest level can be drastically increased by means of fertilization, which will increase the amount of biomass available for bioenergy and round wood for the industry. However, in China, one of the present major problems facing forestry is that the total amount of forest resources is insufficient, resources available for harvesting are almost exhausted, the forest structure is unbalanced and the capability for supplying forest products is low.

Another market topic that is widely discussed is the nexus of bioenergy and food security, along with the resulting potential for competition. Analysis here is focused on income and price changes.
These changes depend mainly on variations in land use patterns, on bioenergy and food production levels and on food and energy market prices.

As commodity market analysis for biomass feedstock utilization, a national, provincial and district-specific scenario could be carried out, incorporating the five steps outlined below:

i) **determine the potential for bioenergy and food production**
   given biophysical characteristics, agricultural productivity and input levels. The area that could be used and amount of bioenergy production that could be derived, represents the 'technical biomass potential';

ii) **calculate the costs of food and bioenergy production**.
    Within a country, cost levels of food and biomass production are not uniform as yields and agricultural management can vary by region and by production system. This heterogeneity can be described by cost-supply curves of agricultural production. Ultimately cost-supply curves of **food and biomass production** within the country are determined;

iii) **estimate the amount of biomass and food that is produced** in the country under the given economic conditions. The economic conditions are described by the cost-supply curves of food and biomass production, as well as the international and domestic energy and food prices. Results of step 3 are the ‘economic biomass potentials’;

iv) **estimate the changes in incomes, employment, prices by sector** and the resulting production changes due to the additional production of biomass. These economic impacts are based on the economic potentials in step 3. Thus, in step 4 the **macro-economic impacts of additional biomass production** are analyzed;

v) **evaluate the impact of income, price and employment changes on food security**.
   This evaluation looks at different population groups that can be affected differently by bioenergy development. The selection of population groups is conducted according to country and bioenergy specific scenarios.

The present study comes out with a number of market-based recommendations for biomass feedstock utilization, including:

- Biomass residue collection should rely on existing harvested grain collectors: they can receive stalk from farmers, bale or chop and sell directly to power plant;
- BPG plants should create straw and stalk removal companies that lease out their services to farmers, chop or bale on site and ship directly to the plant;
- Chopped stalk should be stored in loose bulk silos (reference: bulk storage silo for soy bean) and rain / fire protected baled straw storage;
- BPG plants should be strategically located, according to where grain or cotton is planted;
- BPG plants should be spaced at distances of at least 50 to 100 km to avoid overlapping with other power plants command areas;
- BPG plants should be placed near to infrastructure hubs, commanding larger areas of biomass production.

A two-pronged approach will best secure feedstock and will increase profit for farmers:

i) direct sale of biomass feedstock to power plants, cutting out the middle men. One option would be for a village cooperative to aggregate and sell their collective straw and stalk biomass and divide the revenue among the village proportionately.

ii) direct transport of biomass feedstock to the power plant to save intermediate storage related costs.

An overall conclusion drawn from this study are the enormous opportunities relating to the utilisation of biomass as a resource for global energy use in the coming decades. The current use of bioenergy is about 40 exajoules (EJ) per year, and the range of biomass potential as an energy source in 2050 is between 100 EJ/y to 500 EJ/y. This range is so wide that serious questions are raised relating to conclusions based on these estimates. More research is needed to understand

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1 Copernicus Institute, Utrecht University United Nations Food and Agriculture Organisation (FAO), Modelling the Bioenergy and Food Security Nexus: An Analytical Framework, Draft for comments January 2008
the future of bioenergy evolution. Key issues in the sector can already be defined: (i) global economic growth, including the growing need for energy; (ii) environmental forces in the global evolution; (iii) possibilities of technological development to solve global problems; (iv) growing capability of the international community to find solutions for global issues, and; (vi) the complex interdependencies of all these driving forces.

These key issues indicate that there is not only one pathway to take towards ensuring a vital bioenergy market in 2020, but several alternatives. Different scenarios may eventuate in parallel and might help to identify possible future events and development in the coming decades.

2.2. TECHNICAL STUDY 2: CELLULOSIC ETHANOL TECHNOLOGY ASSESSMENT

Bioethanol is a fuel for the future. Alongside biodiesel, it is currently recognized as the leading technology in the search for viable next generation liquid fuels. As a substitute for petrol, bioethanol is the obvious choice in terms of its blending ability and it enjoys largely positive public opinion. Within the context of widespread public and government support, the near future is likely to feature bioethanol as a globally-significant fuel with a wide user base. There is a considerable body of ongoing research into bioethanol, improving the technology and understanding year on year. This can only enhance the potential of bioethanol as a viable and cheap alternative fuel. With the development of lignocellulosic bioethanol, the efficiency of this fuel looks set to continue to improve. Environmentally, the carbon footprint of bioethanol will undoubtedly decrease, helping reduce global carbon emissions.

This investigation, which should be considered in association with Component 2a, summarizes the wide range of bioethanol options that have been trialed over the last 30 years and looks at key market factors, both in China and internationally, associated with the process.

The report presumes that there are no technical advantages in using lignocellulose rather than sugar or starch for ethanol production. Once the feedstock supply has been produced, the process of fermentation and ethanol recovery are identical in terms of cost, energy use and potential yield. However, production of feedstock from lignocellulose is more complex, gives lower yields and requires more energy than production from sugar and starch crops, resulting in a more expensive end product. The main reason for investigating/investing in lignocellulose hydrolysis is the fact that this option addresses concerns about competition between food and fuel. However, the use of lignocellulose feedstock raises further questions of competition, since straw and woody biomass find many alternative uses in construction, paper production, livestock husbandry, etc. If the organic fractions of municipal waste or waste from agro-industrial processes are used, then there may be additional benefits of turning a waste with negative (disposable) costs into an asset.

From the data collected and analyzed, this investigation concludes that cellulosic ethanol produced under current market and technological conditions is not cost effective and that the net energy output is negative. Research and development work should be promoted in this sector with the support of governments. Three principle technological hurdles must be overcome: pre-treatment processing; identification and development of new enzymes for effective cellulose hydrolysis, and; co-fermentation of pentose and hexoses.

The following strategies are proposed for China’s domestic cellulosic ethanol industry:

- to establish a national biofuel research platform to integrate academia and industry in the study of cellulosic ethanol;
- to fund basic research on enzyme innovation and engineer microorganisms to co-metabolize pentose and hexose;
- to fund selected cellulosic ethanol pilot plants to improve technologies and knowledge of operational processes;
- to train young researchers and technicians.
3. PROVINCIAL BIOMASS POWER GENERATION STRATEGY

The objectives of this strategy are to:

- increase general awareness of agricultural and forest residue-based BPG;
- advance the development of the rural economy;
- increase the income of farmers and improve conditions in rural areas of Heilongjiang province.

Heilongjiang province is characterized by advantageous climatic, geomorphological, infrastructural and economic conditions. However, despite abundant agricultural and forestry biomass resources, the energy sector remains heavily dominated by fossil-fuel fired power generation. With a rapidly increasing energy demand linked to fast socio-economic development, the conflict between energy consumption and environmental protection is increasingly acute. It is recommended that the potential for use of biomass as feedstock for conversion to energy be developed as soon as possible. At present, the direct-fired technique of biomass conversion is well developed, which can effectively use the biomass resources on a large-scale to produce clean power. Such a strategy would act to improve the energy consumption structure; reduce greenhouse gas (GHG) and sulphur dioxide emissions; promote the development of the local rural economy; supply job opportunities; improve the rural environment, and; realize sustainable socio-economic development.

The primary technical approach applicable in this strategy is the direct-combustion BPG technique, excluding combined firing, gasification, biogas power generation techniques and biofuel production. The strategy focuses only on agricultural and forestry biomass resources as feedstock for biomass power generation, excluding animal waste and municipal organic waste. Agricultural biomass is defined as straw and stalk from agricultural crops such as corn stalk, wheat straw, rice straw and cotton stalk. Forestry biomass is defined as residues from forestry production and timber processing, which includes fruit tree branches produced through pruning, forest maintenance and hedge trimming.

The scope and scale of the associated biomass resource assessment (BRA) with this study allowed for the surveying of six counties of Heilongjiang - sufficient for development of a provincial-scale framework strategy, but not detailed enough to plan and prepare specific BPG projects. From this investigation, the installed capacity of BPG is identified at the provincial level, including BPG plants in operation and / or those with the necessary prior approvals already in place.

The main document stipulates eight strategic recommendations:

i) **Set up special department to manage biomass energy utilization and development**

As a burgeoning industry, the development of BPG requires significant support from the national and local government. The necessary work relates to resource investigation, formulation of policy and regulations, technological development, popularization of advanced technology, management experimentation, planning and implementation of special funds, construction of demonstration projects and international communication. All these issues should be put under centralized management by specialized departments. Under the framework of the provincial government, it is suggested that the Heilongjiang Biomass Power Generation Centre be established to manage biomass energy utilization and development.

ii) **Establish local BPG regulations suitable for Heilongjiang province**

With national management measures and specifications not having been published yet, it is recommended that Heilongjiang establish a series of laws and regulations to rationalize the development, construction and operation of agro-forestry BPG projects. These laws and regulations would include: administrative measures; guidelines for scope and scale of BPG development applications; technical rules for the construction of BPG projects, and; administrative framework for the special support fund for BPG in Heilongjiang province.
iii) **Provide public financial support to local BPG projects**

Lead and support the BPG industry by provision of local public sector financing. Provincial authorities would be empowered to disburse capital from the current special fund for energy conservation and carbon emission reduction, to support the development of the BPG industry. Establish a special fund for BPG development in Heilongjiang province step-by-step, by means of soft loans, investment subsidies and research funding. Give emphasis to the various fields such as resource investigation, demonstration project construction, technological barrier breakthroughs and trialling and capacity building.

iv) **Energetically support the demonstration of BPG**

Heilongjiang should take advantage of supportive policies and promote the construction of demonstration projects. Relying on such demonstration projects, the BPG sector can: (i) focus on strengthening R&D for the increased mechanization of biomass collection and the pre-treatment technology, along with improvement of the existing equipment and BPG system technology; (ii) establish and complete feedstock storage and transport systems; (iii) support the development of a more robust biomass trading and delivery system, and; (iv) complete the trialling of improved biomass processing equipment in facilities.

v) **Stimulate creation of a scientific development plan in key regions**

In areas such as Suihua, Harebrain and Qiqiha’er, which have high concentrations of agricultural biomass resources and in areas such as the Greater and Lesser Hinggan Mountains, which are well endowed with forestry biomass resources and agro-forestry processing industries, Heilongjiang should establish a local BPG development plan. Such plans should include development targets and strategic frameworks to ensure that the geographical distribution and construction of BPG projects are properly rationalized.

vi) **Promote strategic domestic and international cooperation**

At present, large scale enterprises in Heilongjiang province do not take part in the construction of BPG projects. Most projects are invested and constructed by NBE and the China Longyuan Electricity Power Group Corporation. On one hand, the enterprises who have the advantage of proven capital and technological resources should be encouraged to develop and construct BPG projects. However, on the other hand, actively and continually strengthening the cooperation between specialized domestic BPG companies (such as NBE) and strategic domestic and international investors, in the fields of project construction, technological R&D, industrial development and capacity building.

vii) **Support technical innovation**

Under the support of scientific research institutions such as Harbin Institute of Technology, Harebrain Electrical Group and North-Eastern Forestry University, a technical innovation centre on biomass direct combustion should be established. Coupled to the technology department in the Heilongjiang provincial government, this centre would implement a technological breakthrough program, organize experts to study and develop technologies of biomass collection, pre-treatment and highly efficient burning, along with related equipment.

viii) **Support capacity building and awareness raising programs and disseminate advanced technologies and experiences**

Through the Heilongjiang Biomass Power Generation Centre, organize various regular seminars and workshops to disseminate information, advanced technologies and management experiences in BPG to relevant stakeholders in the finance, local and national government, agriculture, forestry and energy sectors in order to increase understanding and reduce the perceived risk of BPG.

The implementation of the strategy as detailed above and in the main Component 3b report, would result in Heilongjiang province fulfilling the province’s maximum potential BPG capacity of 800 MW per year, with the associated utilization of more than seven million tons of agricultural and forestry biomass residue resources.