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Scoping Study of Biomass Energy Development in Inner Mongolia, China

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CONTENT

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ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
AFBC	Atmospheric fluidised bed combustion
AIC	Average incremental cost
APL	Adaptable programme loan
BAU	Business as usual
BTU	British Thermal Unit
CCCT	Combined cycle combustion turbine
CCT	Clean coal technology
CDM	Clean Development Mechanism (of the Kyoto Protocol)
CIF	Cost insurance freight
Cumec	Cubic metres per second
DEDE	Department of Alternative Energy and Efficiency
DSCR	Debt service cover ratio
DSRA	Debt service reserve account
EPC	Engineering, procurement and construction
FGD	Flue gas desulfurisation
FL	Feed law
FOB	Free on board
GAR	Gross as received
GC	Green certificate
GEF	Global Environment Facility
GHG	Greenhouse gas
GW	1000 MW
ICB	International competitive bidding
IDC	Interest during construction
IGCC	Integrated gasification combined cycle
IPP	Independent power producer
IRR	Internal rate of return
LFG	Landfill gas
LRMC	Long run marginal cost
MCM	Million cubic metres
mmBTU	Million British Thermal Units
MMS	Mandated market share
MoU	Memorandum of understanding
NFFO	Non Fossil Fuel Obligation
PFBC	Pressurised fluidised bed combustion
PPP	Purchase power parity
PT	Provincial targets
PTC	Production tax credit
REDP	Renewable Energy Development Project
RPS	Renewable portfolio standard
SCR	Selective catalytic combustion
SDPC	State Development Planning Comstudy
SPERC	State Power Economic Research Centre
TCE	Ton coal equivalent
TGC	Tradable green certificates
THB	Thai Baht
TSP	Total suspended particulate matter
VAT	Value added tax (in China normally levied at 17%)
WB	World Bank
WTO	World Trade Organisation

SUMMARY AND MAIN FINDINGS

Objectives

This study is intended to assist the local government in Xing'an Meng, Inner Mongolia, in developing a biomass development program in the region. The objectives of the study include:

- Assessing biomass resources for power/heat;
- estimating technical and economically viable biomass energy potential to provide power and heat;
- evaluating two pilot biomass co-generation projects; and
- recommending a biomass energy development strategy in Xing'An Meng.

Methodology

This study first assessed biomass resource availability for power and heat generation from agriculture residues, wood residues, and energy plantations in six counties of Xing'An Meng, based on estimates of total annual biomass resources from all categories and available biomass resources for power and heat due to competing uses. The delivered costs of biomass resources for all categories are also calculated.

Given the biomass resource availability, the study estimated technical potential for biomass co-generation based on heat demand analysis in the capital cities (with a population of 30,000 - 234,000) of the six counties, and technical potential for biomass heat-only boilers based on heat demand analysis in smaller cities (with a population of 2,000 – 10,000) of the six counties. The remaining biomass resource potential, in addition to those for biomass co-generation and heat-only boilers, could be used to generate power only.

Next, this study conducted economic analysis for biomass co-generation, power-only, and heat-only technologies. Then, it examined economically viable potential for biomass co-generation, heat-only, and power-only options by developing three separate cost-supply curves, in comparison to the baseline costs of power import from Northeast grid and coal-fired heat-only boilers with external costs.

Subsequently, the study conducted financial and economic analysis for the two proposed pilot biomass co-generation plants, based on the assumption that the existing heating and steam tariff is fixed as inputs to generate revenues, and the cost of electricity is calculated. This costs of biomass electricity were then compared with the baseline cost of power import from the Northeast grid to determine whether this is the least-cost option.

Finally, based on the cost-supply curve, a strategy to develop biomass energy for Xing'An Meng was recommended. In addition, the report conducted financial analysis for biomass co-generation, power-only, and heat-only technologies, and recommended tariff levels to provide the needed financial incentives at the national level to encourage biomass energy development.

Available Biomass Resource Potential for Power and Heat

One principal conclusion of the biomass resource assessment in Xing'An Meng is that there is sufficient biomass energy available to establish a number of power and heat plants. The total biomass resource available for power and heat in Xing'An Meng is estimated to be 4.1 million tonnes, of which 1.6 million tonnes come from agriculture residues, 1.5 million tonnes from wood residues, and 1 million tonnes from energy plantations.

Within 30 km radius from fuel sources to the biomass plant, biomass resources from all categories are cost competitive with the alternative fuel coal in Xing'An Meng. The cheapest biomass fuel is sawmill waste at a delivered cost of 10.3 Yuan/GJ, but with very limited resources. The second least-cost resources are straw at a delivered cost of 13.4 Yuan/GJ, with abundant supply. The most expensive biomass resources are energy plantations at a delivered cost of 27.2 Yuan/GJ with a large resource base.

Power and Heat Market in Xing'An Meng

The total power demand in Xing'An Meng is around 900 GWh, of which 180 GWh is generated from a 36 MW local coal-fired co-generation plant at a power purchase price of 0.327 Yuan/kWh and a small hydro power plant, while the rest is imported from the China Northeast Grid at a power purchase price of 0.256 – 0.31 Yuan/kWh. The average end-user tariff for industry, for example, is 0.39 Yuan/kWh in Ulanhot (capital city) and 0.47 Yuan/kWh in Arxan (forest area). The local government plans to build additional coal-fired co-generation plants to meet the future growing demand. In addition, Xing'An Meng has a high heating demand, with a heating season of 6-8 months. Only three district heating plants are currently in operation, two in Ulanhot and one in Arxan, while the rest of the heating demands are met by decentralized small-scale coal-fired heating boilers (1-4 ton/h). The heat tariff is 21 Yuan/m^2 in Ulanhot, which is expected to increase in the near future, and 32.6 - 44 Yuan/m^2 in Arxan.

Technical Potential for Biomass Co-generation, Power-only, and Heat-only

The study found that East Xing'An Meng and Northwest Xing'An Meng have distinct characteristics, and deserve separate analysis. Almost all the agriculture residues (99%) are located in East Xing'An Meng, where biomass resources are close to local demand and grids. In Northwest Xing'An Meng, or Arxan area, where the majority of the forestry resources (80%) are located, local demand for heat and power is limited. Only 10% of the available biomass resources in this region would be used to meet local demand, while the rest could be used to generate electricity and export to the grid. However, the study concluded that exporting power from Arxan to Ulanhot through a 300 km transmission line is not an economical option (with an economic cost of 0.85 Yuan/kWh, compared to a baseline cost of 0.375 Yuan/kWh for power import from the Northeast Grid with external costs), and requires upgrading the existing 66 kV transmission line.

Given the total biomass resource availability for power and heat, it is estimated that Xing'An Meng has a total technical potential for biomass co-generation of 300 MW, biomass power-only options of 208 MW, and biomass heat-only boilers of 123 MW by the year 2015. However, if the biomass resources in Arxan would only be used for meeting local demand and not exported to Ulanhot, the total technical biomass potential is estimated to be 270 MW for co-generation, 138 MW for power-only, and 123 MW for heat-only options in 2015.

Comparison of Economic Costs of Biomass Co-generation, Power-Only, and Heat-Only with Baseline Costs

First, economic analysis was conducted for 1) a 12 MW and a 25 MW biomass cogeneration plant; and 2) a 5 MW and a 20 MW biomass power only plant, in comparison with the baseline cost of power import from the Northeast grid including externalities. This study conducted heat design optimization for both co-generation plants to maximize the heat and steam production. As shown in Figure 1, the 25 MW biomass cogeneration plant is the least-cost option, while the 12 MW biomass cogeneration plant and the biomass power only options are not found to be economically viable.

Figure 1. Comparison of Economic Costs of Biomass Co-generation and Power-Only with Baseline Cost

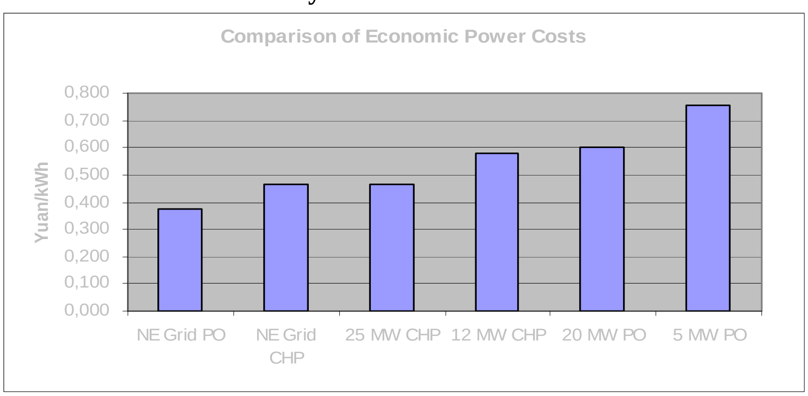


Figure 2. Comparison of Economic Costs of Biomass Heat-Only Boilers with Baseline Cost

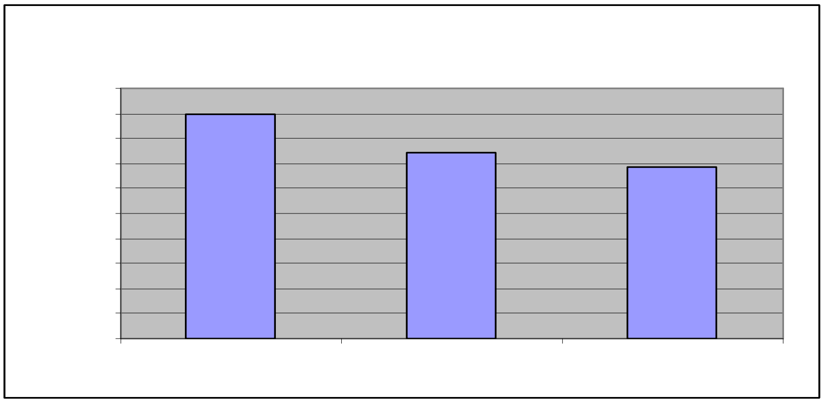


Figure 3. Cost Supply Curve for Biomass Cogeneration

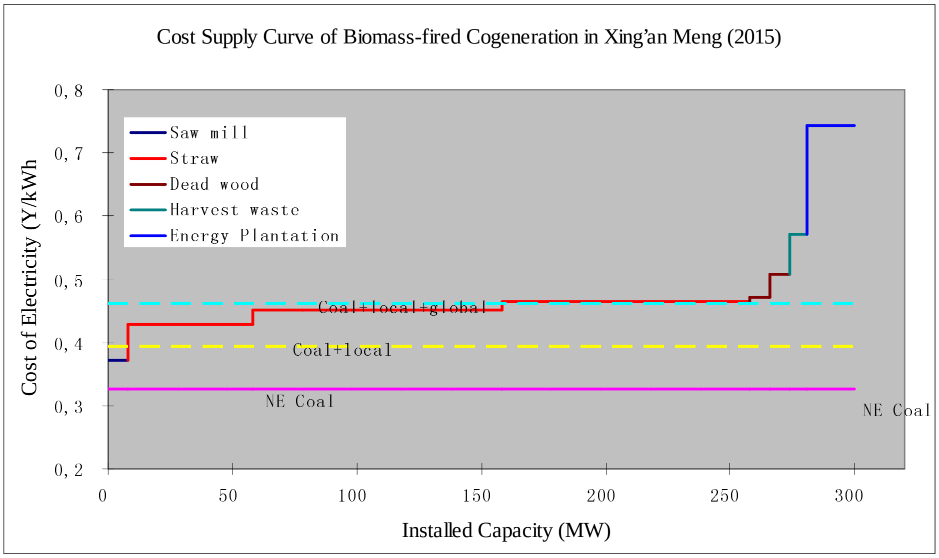


Figure 4. Cost Supply Curve for Biomass Power Only

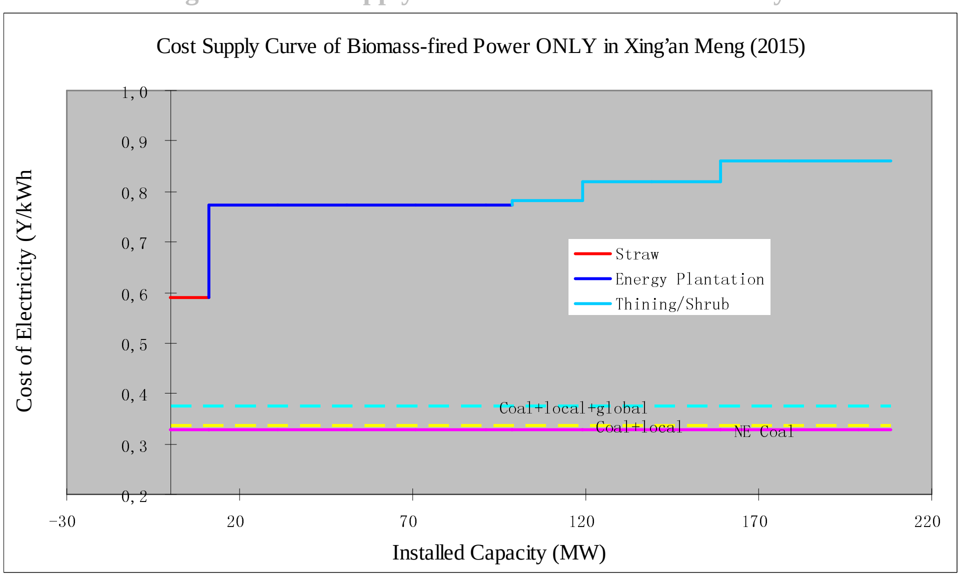
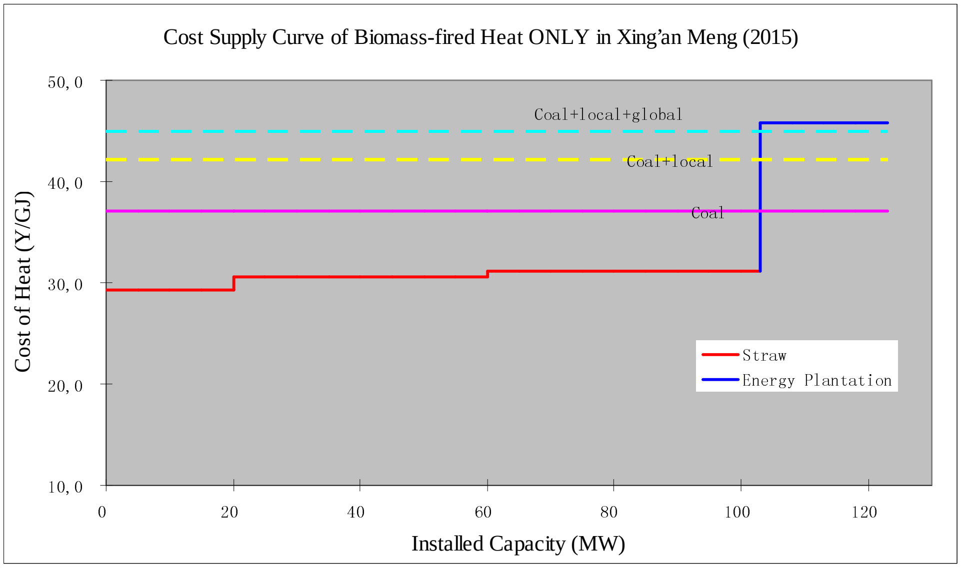


Figure 5. Cost Supply Curve for Biomass Heat Only



Two Pilot Biomass Cogeneration Projects

Xing'An Meng proposed two pilot biomass energy projects: a 24 MW straw co-generation plant in Ulanhot and a 12 MW wood co-generation plant in Arxan. Xing'An Meng government is keen to request for World Bank loans to support these two pilot projects. The power off-taker for both plants is the Inner Mongolia Power Group. The study conducted economic and financial analysis for both projects, and concluded that the Ulanhot straw co-generation plant is economically attractive, while the Arxan wood co-generation plant is not economically viable. Both projects have a FIRR higher than their expected Weighted Average Cost of Capital (WACC) of 7%[2], and therefore are financially viable.

For the 24 MW Ulanhot straw co-generation plant, the total capital investment was estimated to be $40 million, and the cost of electricity to be 0.37 Yuan/kWh[3]. With a proposed power tariff of 0.50 Yuan/kWh, the project FIRR is 9.1% and IRR on equity is 23.9%. With CDM revenues at $6/ton CO_2, the project FIRR can be improved to 10.3%. The study concluded that there is sufficient straw supply within 30 km radius of the proposed site, while the straw collection mechanisms remain to be an issue and deserve more investigation.

For the Arxan 12 MW wood co-generation plant, the total investment requirement was estimated to be $26 million, and the cost of electricity to be 0.43 Yuan/kWh. With a proposed power tariff of 0.50 Yuan/kWh, the project FIRR is 7.0% and IRR on equity is 14.8%. With CDM revenues at $6/ton CO_2, the project FIRR can be improved to 7.9%. The study concluded that there is sufficient wood supply within 15 km radius of

[2] WACC is calculated on the basis of the financing sources of both pilot projects -- 80% loan from the World Bank (the interest rate was assumed as 5%) and 20% equity with its target rate of return of 15%.

[3] In the financial analysis for both pilot biomass cogeneration plants, it was assumed that both projects would be financed with 20% equity and 80% World Bank loans.

the proposed site, and the three forestry bureaus in the region expressed interests in signing long-term fuel supply contracts with the co-generation plant.

Recommendations for Xing'An Meng Biomass Development Strategy

In sum, this study confirmed that Xing'An Meng has a large biomass resource potential. The total economic potential for biomass co-generation was estimated to be 258 MW and biomass heat-only boilers to be 103 MW by 2015. The option to utilize biomass for power generation only proved to be economically unviable. Therefore, the study recommended that the Xing'An Meng government should place priorities on biomass co-generation development in the capital cities and biomass heat-only boilers in smaller cities of the six counties.

Based on the cost-supply curve, this study suggested the following strategies for biomass energy development in Xing'An Meng in the future:

- To meet future growing demand for power and heat, this study recommended that Xing'An Meng should develop biomass co-generation plants in the capital cities of the six counties. This will replace the future coal-fired co-generation plants under planning, as well as reduce power import from the Northeast Grid. The optimum size for such a biomass co-generation plant would be 20 – 25 MW, fuelled by sawmill residues and straw.

- This study also found that optimizing the heat design for biomass co-generation plants to generate revenues for both heat and steam is essential to substantially improve the economical viability of the plants. For example, "constant" steam demand for industries and decentralised hot tap water as part of the heat supply, particularly in new developments zones, can significantly reduce the power generation costs of biomass cogeneration plants.

- It should be emphasize that a reliable fuel supply to biomass co-generation plants at a low price is critical to the success of such plants. Worldwide, this is a common constraint to large-scale biomass co-generation plants. This study recommended that a fuel supply company shall be established to be responsible for managing the logistics and delivery of the biomass resources to the plant. The co-generation plant should sign a fuel supply contract with the straw supply company, who could then sign fuel supply subcontracts with farmers in the area, or with the forestry bureaus for wood fuel supply. The study also suggested that the delivered biomass price should be based on its heating value (or moisture content), instead of weight, to control the quality of the delivered fuel.

- In smaller cities of the six counties, this study recommended that Xing'An Meng should develop biomass heat-only boilers to replace existing coal-fired heating boilers, which have resulted in serious air pollution in the winter, as well as meet future growing heating demand. The optimum size for such a biomass heat-only boiler would be 1-10 MW, fuelled by straw.

- While Arxan has more biomass resources to meet its local demand, the study concluded that exporting power from Arxan to Ulanhot through a 300 km transmission line is not an economical option.

- While biomass resources are cost competitive with the alternative fuel coal in Xing'An Meng, there is a large variation in costs for biomass fuels from different sources, ranging from the lower cost sawmill wastes and straw to the most expensive energy plantations.

Finally, the study conducted preliminary financial analysis to assess the needed financial incentives to attract investors in biomass energy projects. While biomass co-generation technologies are the least-cost option compared to the baseline cost with externalities, only biomass co-generation from sawmill residues is economically viable compared to baseline cost without external cost. Given the market distortion, this study conducted financial analysis for biomass co-generation, power-only, and heat-only technologies[4]. We concluded that there are incremental financial costs for biomass co-generation and power-only options, compared to the baseline coal-fired co-generation, while biomass heat-only boilers are least-cost option compared to the baseline cost. Therefore, the primary policy barrier to large-scale development of biomass co-generation is who should pay for the incremental financial costs. Under current circumstances, the utility is reluctant to purchase power from biomass co-generation.

National renewable energy policies are required to address this issue. The newly passed Chinese Renewable Energy Law requires the utilities mandatory purchase of power from renewable energy sources. However, the Regulation of the Law should set a feed-in tariff level high enough to attract biomass energy investors, and specify who will absorb the incremental financial costs. The financial analysis in this study assumed that an IRR on equity should be above 15% to attract investors in biomass energy projects. Based on this assumption, it was estimated that the tariff needed to make biomass cogeneration plants (both 12 MW and 25 MW) and power-only plants (20 MW) financially feasible would be in a range of 0.54-0.65 Yuan/kWh, as shown in the following table. Compared to the baseline power purchase tariff of 0.29 Yuan/kWh in Xing'An Meng, the needed incremental tariff is in a range of 0.25-0.36 Yuan/kWh.

Table: Proposed power tariff to get 15% internal rate of return on equity

	CHP 12 MW	CHP 25 MW	PO 5 MW	PO 20 MW
Power tariff to get 15% IRR on equity (Yuan/kWh)	0.67	0.54	0.77	0.61

[4] In the financial analysis of a typical 25 MW and a 12 MW biomass co-generation plants, it was assumed that the general biomass co-generation plants would be financed with 20% equity and 80% domestic bank loans. Heat design optimization was also conducted for both general biomass co-generation plants in the financial analysis. This study also conducted financial analysis for a 5 MW and a 20 MW biomass power-only plants, as well as a 2 MW and a 5 MW biomass heat-only boilers.

1. BACKGROUND

o Objective of this Project

The objective of this study is to assist the local government in Xing'An Meng, Inner Mongolia, in developing and implementing of an action plan for large-scale biomass development in the region. The objectives of the study include:

- Conducting biomass resource assessment;
- Estimating technical and economically viable biomass energy potential to provide power and heat;
- Evaluating two pilot biomass co-generation projects; and
- Recommending a biomass energy development strategy in Xing'An Meng.

o Biomass Resources in China

China has a rich biomass resource base, with a total available biomass resource for power and heat of around 100 million tonnes of coal equivalent (tce), of which agriculture residues 50 million tce, wood residues 25 million tce, biogas from animal wastes and industrial wastewater 18 million tce, and municipal solid wastes (MSW) 8 million tce, as shown in Table 1. In 2003, biomass power installed capacity reached more than 2,000 MW, primarily coming from bagasse and biogas.

Table 1. Biomass Resources in China

Types	Resources (million tonne)	Available resources (million tonne)	Available resources for power and heat (million tonne)	Available resources for power and heat (million tce)
Agriculture residues	650	250	112	50
Wood residues	900	300	50	25
Biogas from animal wastes and industrial wastewater	63 billion m^3	50 billion m^3	24 billion m^3	18
Municipal Solid Wastes	150	120	60	8
Total				100

Sources: Tsinghua University and Ministry of Forestry.

With growing incomes in rural areas, farmers are using less straw for cooking and heating. Field burning of straw has resulted in serious air pollution and highway accidents. Therefore, many provinces are now interested in utilizing straw for power generation. A reliable supply of straw at a reasonable price delivered to the power plant is a key factor to success. The top 10 provinces with straw resources are: Shandong, Henan, Hebei, Jilin, Heilongjiang, Sichuan, Anhui, Jiangsu, Inner Mongolia, and Liaoning. In addition, the large-scale agriculture farms, mostly located in the Northwest, are also good candidates for power generation due to the concentrated straw resources.

China has a total forest area of 175 million hectares, with a forest coverage of 18%. The total wood standing stock is estimated to be 13.6 billion m^3. Most of the forest resources are located in Helongjiang, Jilin, Inner Mongolia, Tibet, Sichuan, Yunnan, and Fujian. In addition, according to the Ministry of Forestry, 20 million hectares of land could be available for energy plantations, which would produce 150 million tonnes of wood resources each year. This can be part of the effort of the West Development, Desert management, and re-conversion of agriculture land to forest.

- **Biomass Energy Development Planning in China**

At the recent International Conference for Renewable Energy in Beijing held in November 2005, the Chinese government announced a target of 20 GW of biomass power capacity by 2020, as part of the national plan to reach 15% of total energy consumption from renewable energy by 2020. Currently, a study commissioned by NDRC is under way to develop a "road map" for biomass energy in China to achieve this ambitious target. In addition, the newly passed Renewable Energy Law and its implementation regulation, which is under development and plans to take effect on January 1, 2006, is expected to provide sufficient financial incentives for biomass energy development. At present, the most abundant biomass resources in China are agriculture residues and wood residues, however, the Ministry of Forestry expects that energy plantations will play a larger role to provide fuels for power generation in the future. Up to now, NDRC has approved three straw power generation projects as demonstration in Rudong, Jiangsu; Shanxian, Shandong; and Jinzhou, Hebei province; each with a 24 MW installed capacity. The Ministry of Forestry is currently planning a number of 12-48 MW power plants fuelled by energy plantations over the next few years.

- **Biomass Resource Potential in Inner Mongolia**

Inner Mongolia has a large biomass resource potential, with 18 million tonnes of straw and 660 million tonnes of woody biomass standing stock. Hulunbeier and Xing'An Meng have extensive forest resources, while Tongliao and Chifeng have extensive agriculture residues. Inner Mongolia DRC is interested in replicating Xing'An Meng's experience to other parts of Inner Mongolia.

- **Scope of This Report**

This report examined the biomass energy potential for Xing'An Meng. The study evaluated biomass resource availability for power and heat, conducted financial and economic analysis of biomass co-generation, power-only, and heat-only technologies, estimated the technical and economic optimal quantity of biomass energy potential for Xing'An Meng, and recommended a biomass energy development strategy in Xing'An Meng.

Chapter 2 presents the methodology, the key assumptions and the limitations of this study such as discount rate, economic cost of fuels, economic production cost of fossil-fuelled power generation and derivation of the fossil and renewable externality costs.

Chapter 3 follows with a biomass resource assessment for Xing'An Meng with estimates biomass resource availability for power and heat from wood residues, agriculture residues, and energy plantations. The delivered costs for biomass resources from all categories are also estimated.

Chapter 4 presents the power and heat supply in Xing'An Meng, including power and heat supply, power off-takers, and tariff analysis.

Chapter 5 assesses the technical and economically viable biomass energy potential for Xing'An Meng. The Chapter starts with heat demand analysis for biomass cogeneration in capital cities and biomass heat only in smaller cities, and then estimates the technical potential for biomass cogeneration, power only and heat only boilers. Next, the Chapter evaluates the economic costs of biomass heat and power technologies and compares them with the baseline costs. Then, it develops cost supply curves for biomass cogeneration, power only and heat only, and assesses the economic quantity of biomass energy potential.

Chapter 6 examines the two proposed pilot projects -- a 25 MW straw fired cogeneration plant in Ulanhot and a 12 MW wood fired cogeneration plant in Arxan. This Chapter includes assessment of heat demand, sizing of cogeneration plant, fuel supply and costs, and economic and financial analysis of the two projects.

Chapter 7 presents final conclusions of this study and recommendations for biomass energy development strategy in Xing'An Meng. Finally, it conducts financial analysis for biomass co-generation, power-only, and heat-only options, and evaluates the need financial incentives (tariff level) to attract investors.

There follow detailed technical and economic annexes on

- Annex 1: Heating demand in Xing'An Meng
- Annex 2: Cost-supply curve

2. METHODOLOGY AND KEY ASSUMPTIONS

This chapter presents the methodology and key assumptions for the study. It begins with an explanation of the methodology used for this study. Section 2.2 highlights the key assumptions such as economic discount rate, economic production cost of fossil-fuelled power generation and the externality values. Section 2.3 discusses the limitations of this study.

Methodology

This study first assessed biomass resource availability for power and heat generation from agriculture residues, wood residues, and energy plantations in six counties of Xing'An Meng. For agriculture residues, the study adopted annual crop production and the ratio of straw to crop for major crop species (maize, rice, sorghum, and others) in Xing'An Meng from the Statistic Bureau. Then, the available straw potential for power and heat was estimated, considering the competing uses for biomass resources such as household cooking and heating, animal feeding, fertilizer/soil improver, and paper making, based on Xing'An Meng Agriculture and Energy Plans, discussions with the Chinese counterparts, and field visits[5].

Wood residues are broken into four categories: 1) residues from forest harvest and sawmill processing; 2) deadwood from natural forest and fire; 3) wastes from forest thinning; and 4) residues from shrub. First, standing stock of woody biomass is adopted from Xing'An Meng forestry statistic bureau, and annual woody biomass resources are estimated. Then, the available wood residues potential for power and heat was assessed on the basis of discussions with local counterparts, Xing'An Meng statistics, field visits, experience and information from other countries. Biomass potential from energy plantation is estimated from land areas suitable and available for energy crops and annual yield. The detailed methodology is described in Chapter 3.

In addition, the delivered costs of biomass resources for all categories were also calculated, assuming an average transportation distance to deliver the fuel to the biomass co-generation plant. The delivered cost of straw is broken into resource price, baling, cutting, and transport cost. The delivered cost of wood residues is broken into resource pricing, processing in forest, extraction to road, chipping, storing, and transport cost. The delivered cost of energy plantation was calculated with a cash flow analysis.

[5] After this final report was produced, the results of the required field surveys to investigate the availability of biomass resources for power and heat from different categories and the resource costs of biomass resources became available. The survey confirmed the resource costs adopted in this report, but concluded a larger biomass resource base available for power and heat. The project team decided to keep the conservative estimates of the biomass availability for power/heat, given the uncertainty around the field survey results.

Given the biomass resource availability, the study estimated technical potential for biomass co-generation based on power and heat demand analysis in the capital cities (with a population of 30,000 - 234,000) of the six counties, and technical potential for biomass heat-only boilers based on heat demand analysis in smaller cities (with a population of 2,000 – 10,000) of the six counties. The remaining biomass resource potential, in addition to those for biomass co-generation and heat-only boilers, could be used to generate power only.

Next, this study examined economically viable potential for biomass co-generation, heat-only, and power-only options. Economic theory holds that renewable energy should be implemented to the point at which the incremental economic cost of the marginal renewable energy project exactly equals the avoided damage costs. Phrased differently, the comparison between renewable energy and fossil-based energy should be on the basis of economic cost (economic production costs plus externalities). The economically optimum quantity of renewable energy is therefore the sum of renewable energy whose economic costs (net present value of economic costs) are lower than the economic costs of the fossil-fuelled baseline generation. Based on this theory, the economic costs of biomass co-generation, power-only, and heat-only technologies were first calculated. Then, three separate cost-supply curves for biomass co-generation, power-only, and heat-only were developed, in comparison to the baseline costs of power import from Northeast grid and coal-fired heat-only boilers with external costs (including both local and global environmental costs). Based on the cost-supply curve, the economically optimum quantity of biomass heat and power for Xing'An Meng was derived.

Next, the study conducted financial and economic analysis for the two proposed pilot biomass co-generation plants, based on the assumption that the existing heating and steam tariff is fixed as inputs to generate revenues, and the cost of electricity is calculated.

Finally, the study recommended a strategy to develop biomass energy for Xing'An Meng. Based on financial analysis of biomass co-generation, power-only, and heat-only options, this study assessed the needed financial incentives to attract biomass energy investors.

- **Key Assumptions**

The economic and financial analysis requires several key assumptions, which are discussed in this section:

- The choice of **economic discount rate** is critical for the economic analysis and can be a controversial subject. Choosing a high discount rate will treat capital-intensive projects like RE power production in an unfavourable manner compared with less capital-intensive projects (conventional power production). Nowadays, most economists tend to use a social time preference or even an inter-generational time preference by choosing a lower economic discount rate. The discount rate used in the economic analysis is 12%, which in China have been used by the World Bank for some time. The level of the economic discount rate is similar to discount rates in other Asian developing countries (15% in the Philippines, 12% in India, 10% in Sri Lanka and Vietnam).

- The analysis of generation expansion plan in Xing'An Meng showed that the proposed biomass generation would mainly serve as a reduction to power import from NE power grid. So the economic cost of power import from NE grid was estimated as the **baseline generation cost** in the economic analysis. A typical 2*600MW coal-fired thermal power plant, which acts as the backbone plant in NE power grid and major type of new expanded power plant in the coming years, was analyzed. All costs were expressed at their economic prices. The difference of pollutants study between the coal-fired thermal in NE grid and biomass-fired cogeneration or power plant in Xing'an Meng was also analyzed.

- The **externality value** was used to estimate the environmental benefits of biomass-fired cogeneration compared with coal-fired power plant in NE grid. As there were few China-specific air-estudy externality valuations reported in the literature, the Benefit Transfer Method (BTM) was adopted in this study to derive externality values for NOx, SO2 and TSP. The case study of New York State was selected and adjusted by the ratio of per capita GDP and population density in China. For carbon, a valuation of $6/ton of CO2-reduction was adopted considering the recent market price of some CDM projects ($5-7/ton of CO2-reduction) in China.

o **Limitations of this Study**

This study is subject to a number of limitations:

- The assessment of biomass energy potential and derivation of power supply curves for a region like Xing'An Meng requires many assumptions that will need confirmations and more detailed assessment in the future. However many necessary assumptions on resources, heat demand and other information have been made available by Authorities in Xing'An Meng.
- The level of environmental damage cost of the North East grid power import (baseline) is subject to some uncertainty. However detailed studies of this subject are out of the scope of this project.
- The economic quantity of biomass energy depends on a number of assumptions such as discount rate, fuel prices, investments etc, and the economic quantity will of course change with adjusted assumptions.

In order to address these uncertainties, the report includes sensitivity analysis to identify the robustness of the estimates, wherever possible.

3. BIOMASS RESOURCE ASSESSMENT IN XING'AN MENG

o Land Use in Xing'An Meng

Xing'An Meng borders Mongolia to the west and China Northeast to the east. Xing'An Meng covers an area of 5.98 million hectares (ha). A satellite imagery map covering whole Xing'An Meng was obtained in the US, and left with the Xing'An Meng government. Prints of the area were presented to government representatives in Ulanhot and Arxan. The eastern plains are mainly arable agricultural areas. These plains gradually increase in elevation with grasslands and shrub lands in the central areas and mountains in the west: these rolling hills and mountains are covered with mixed deciduous and evergreen forests, plantations, woodlands, shrubs/scrub and grasslands. A breakdown of the area by broad land-use types is given in Table 2.

Table 2. Land Use in Xing'An Meng

Land use type	Area 000 ha	Growing stock 000 tonne	Stocking per ha tonne/ha
Forest	1,440	43,600	30
Scrub/Shrub	227	3,405	15
Grasslands (useable)	2,612	2,612	1
Un-useable grasslands	822	822	1
Agriculture	608	608	1
Water	43	0	0
Other	228	0	0
Total	**5,980**	**55,917**	

Source: Xing'An Meng Statistics Yearbook, 2004.

The average stocking in forests and woodlands is only 30 t/ha. This is well below the normal stocking of 100 t/ha or more. Similarly, the shrub/scrub land has a low stocking. Some of this land has degenerated into scrub and shrub from woodlands through over-cutting and intense grazing. Many of these areas could be restored to woodlands and forests and some could be turned into plantations, including energy plantations.

The estimated population of Xing'An Meng is 1.64 million of which about 1.28 million live in rural areas. Agriculture, both arable and pastoral is the main occupation, although in the west, forestry and forest industries are important.

o Biomass Resource Potential in Xing'An Meng

One principal conclusion of the biomass resource assessment in Xing'An Meng is that there is sufficient biomass energy available to establish a number of power and heat plants, which amount to 4.1 million tonnes in total. Table 3 shows a break-down of biomass resource potential available for power and heat by each resource category. This could supply 550 MW installed power capacity if all the available biomass is utilized. Another important factor is the delivered costs of the biomass energy to the power plant, which the study calculated for each resource category. The main alternative fuel in Xing'An Meng is coal.

Table 3. Available Biomass Resource Potential in Xing'An Meng (tonne/year)

Biomass Resources	**Available Biomass Resources for Power and Heat**
Agriculture residues	**1,637,000**
Maize	1,183,000
Rice	130,000
Sorghum	160,000
Others	163,000
Wood residues	**1,502,000**
Sawmill wastes	80,000
Harvest wastes	210,000
Deadwood from natural forests and fire in 2003	310,000
Thinning and Shrub	1,200,000
- competing uses from all categories (household cooking/heating and small heating boilers)	**-** 300,000
Energy Plantation	**1,000,000**
Total	**4,139,000**

The study estimated the available biomass resources in Xing'An Meng based on discussions with local counterparts, Xing'An Meng statistics, field visits, experience and information from other countries[6]. The following sections discuss in details the methodology and assumptions used to estimate available biomass resources for each category.

- **Biomass Resources - Wood**

The total standing stock of woody biomass resources in Xing'An Meng are estimated to be 49 million tonnes, of which standing stock of stem and braches is 43 million tonnes, shrub 3.4 million tonnes, dead wood from natural mortality 2 million tonnes, and dead wood from the fire occurred in 2003 is 0.8 million tonnes. The supply of wood energy by category is given in Table 4, together with the estimated competing uses by households, industry and the service sector.

Table 4. Available Wood Resources for Power/Heat in Xing'An Meng.

Units 000t

Source of wood energy	**Resource**	**Percentage**	**Available**	**Available**

[6] As mentioned in Chapter 2, this is a conservative estimate of biomass resource availability for power and heat in Xing'An Meng.

	base	available for power and heat (P & H)	resources for P & H In 2005	resources for P & H In 2010
Sawmill waste		100%	80	80
Forest harvest waste[1]	318	100%	210	210
Dead wood in forest/shrub areas[2]	2,000	50%	180	180
Salvaged wood from burnt forests[3]	800	80%	130	0
Wood from forest thinning[4]	1,080	50%	540	540
Wood from harvesting shrubs[5]	3,400	60%	660	440
Proposed energy plantations[6]	2,500	40%	0	1,000
Total wood energy supply			1,800	2,450
Estimated existing competing use for wood energy[7]			300	300
Net wood energy available for P & H			**1,500**	**2,150**

Note 1. Annual harvest logwood amount is 540,000 m^3 (318,000 tonnes) in Xing'An Meng, of which 50% is round wood while the other half is poles. It is assumed that 50% of annual round wood amount is sawmill wastes. It is also assumed that 40% of the total harvest standing stock is left in the forest, while 60% is the annual harvest logwood.
2. It is assumed that 8% of the growing stock of stem and braches is dead wood. The dead wood resource will decrease after 10 years, when most of the accessible reserve has been removed. However, trees and branches are continually dying and therefore, there will be a steady addition to the dead wood. This could amount to between 1% and 2% of the standing stock. It is also assumed that about half the dead wood was too remote to be economically accessible.
3. The standing stock of the wood burned in the 2003 fire is 1.4 million tonnes, of which 0.9 million tonnes have been harvested. The rest is available for power and heat. In addition, 40% of the harvest amount is wastes that are available for power and heat purposes. It is assumed that these wastes would be collected over 5 years, and 80% of these wastes are economically accessible.
4. It is assumed that 5% of the standing stock of stem and branches is the annual growth that can be removed annually without reduction in total standing stock, and thinning accounts for 50% of this amount. About half the thinning wastes are economically accessible.
5. Woody biomass in shrub areas is estimated to be 3.4 million tonnes, and 65% of the standing stock can be removed. About half of this standing stock would be annual growth over a three-year rotation, and 60% of shrub is economically accessible.
6. There are 5 million mu (333,000 ha) land area suitable for plantation under the statistics from the Forestry Bureau in Xing'An Meng, and potentially more land areas from riverbed and desert. Based on our discussions with local

counterparts, it is assumed that 2 million mu would be used for energy plantation over the next five years, with a yield of 7.5 tonne/ha-year.
7. Please see Section 3.5 for detailed assumptions for estimating competing uses.

The study found that it is not easy to estimate wood biomass resources available for power and heat, because of limited data available on woody biomass as well as different resource categories and methodologies used in China compared to international experience. For example, no Chinese data are available on the volume of branches, small trees, and deadwood, nor the annual growth of the wood in the natural forest, woodlands, and plantations. In these cases, assumptions are made on the basis of international experience and discussions with Chinese counterparts. In addition, woody biomass is measured by volume in China, and no measurement has been made on the volume/weight ratio. From data in other countries, a tonne of air-dry softwood with 15% moisture has a volume of about 1.9 m^3. Similarly for hardwoods, the relationship is about 1.5 m^3 per air-dry tonne. The average between these two figures, namely 1.7 m^3/tonne was taken as the conversion factor. This may be on the conservative side as there appeared to be a higher percentage of hardwoods. The following sections describe in details the methodologies and assumptions used to estimate the available wood resources for power and heat for each category.

3.3.1 Woody Growing Stock and Annual Growth in Forests and Woodlands – Wastes from Forest Thinning

Based on Xing'An Meng statistics, the total stem wood volume in the forest and woodland areas is estimated to be 53.00 million cubic meters (m^3). International experience demonstrated that annual growth is about 5% of the standing stock (equivalent to a 40-year rotation); this gives an annual growth of about 2.65 million m^3. This is a low growing stock - about 40 m^3/ha - as a result of over-cutting in the past, leaving open or sparsely covered areas; the stocking could be increase by not removing all the annual growth and replanting the bare areas.

While stem wood is the most desirable wood for sawmilling and pole production, all above-ground biomass, especially dead wood, branches, and small tress can be used for energy purposes. Therefore, estimates of total above-ground biomass should be undertaken. From surveys in Benin (Annex 2) and after discussions with forestry department staff, it was agreed that about 40% of stem volume/weight should be added to account for branches and small diameter wood. Thus, the estimated above-ground biomass growing in the forests and woodlands is 74.20 million m^3 or 43.60 million tonnes. This will give an annual growth of about 2.18 million tonnes of woody biomass. In theory, this amount of wood could be removed annually without affecting the standing stock. However, because considerable areas are under-stocked and many areas are in watersheds and other environmentally sensitive spots, it is the policy of the government not to undertake normal felling, rather the forests should be allowed to increase their stocking and watersheds etc. should be protected. Therefore, at present only about 20%, or 540,000 m^3 (318,000 tonnes) of the annual stem growth – an estimated 2.65 million m^3 - is felled for sawlogs and poles.

However, both in the natural forest and in planted areas some trees are too densely spaced and if the numbers are not reduced through thinning, trees will die because of competition and this may affect the health of the forest and increase the fire danger. In standard forest practice, about half the volume (and 90% of the trees) is periodically removed before final felling. This improves the value of the remaining trees and brings in early returns. Based on international experience and discussions with the Chinese counterparts, it is assumed that 50% of the annual growth of woody biomass, or 1.08 million tonnes of wood, including branches and tops, could be removed each year as thinning. It was agreed that about 50% of this total is accessible. Thus 540,000 tonnes could be available annually: undertaking thinning is a necessary sanitary measure for the overall health of the forest. Currently, the forest bureaus are not undertaking thinning due to the shortage of funding. They hope that thinning will be undertaken once the wastes have a market value by selling to power plants in the future. Therefore, even though it may be one of the most expensive options, it has an intangible benefit for sustainable forestry management.

3.3.2 Woody Growing Stock and Annual Growth (yield) in Shrub and Scrub Areas

There are an estimated 227,000 ha of shrub and scrub areas, much of which was previously covered with trees many years ago. It has degraded over time through over-cutting and over-grazing. It could be restored to its former self, but this would be expensive and should only be carried out in environmentally sensitive areas and areas that are easily assessable. The estimated total above-ground woody biomass growing stock is about 3.4 million tonnes. If these areas are to be managed for wood energy, about 65% of the wood is removed periodically, leaving the remaining volume to coppice and form the next generation. Because the shrub/scrub areas are more accessible than the forest areas, it was estimated that 60% of the resource should be economically accessible, namely 1.33 million tonnes. These shrubs and scrub areas could be managed on a three year rotation. Therefore, at harvest time, one half of the volume/weight should be 3 years old, with one-third 2 years old and 17% one year old. Thus, in theory, one half of the weight could be removed annually, equivalent to 660,000 tonnes. After about three to five years, once it is fully managed on a 3-year rotation, the standing stock will be reduced to about 2.27 million tonnes and using the same percentages as assumed above, the annual removals would be an estimated 440,000 tonnes.

3.3.3 Harvested Wood in the Forest and at the Sawmill/Wood Yard

Wood, either as poles or processed sawnwood, is used for building, construction, furniture, joinery and fencing etc. Each year about 540,000 m^3, or 318,000 tonnes, of roundwood are harvested from the forest for processing into poles and sawlogs. The estimated split is 50% each for poles and sawlogs. The annual production of sawlogs, therefore, is estimated to be 160,000 tonnes. At sawmills, about 50% of the sawlogs will become the final wood products, while the rest would be sawmill residues. This is equivalent to 80,000 tonnes of sawmill residues produced. Some ‘off-cuts’ are used for fencing and a little wood residue is used for board/paper production (as is some straw), but most can be used for energy. Unfortunately, there is not a single large-scale sawmill in the region where sawdust can be centrally generated, but there are more than 250 small-scale sawmills scattered across the region. Furthermore, during the harvesting process, 60% of the woody biomass is harvested as roundwood, while the other 40% is left in the field as wastes. This is equivalent to about 210,000 tonnes of stem wood and branches left behind in the forest, which can be used to generate power and heat.

3.3.4 Salvaged wood from burnt area

In May 2003, the annual burning of grasslands in Mongolia got out of control and the fire spread across the border into Xing'An Meng and burnt 65,000 ha of forests close to Arxan. Valuable sawlogs and poles have been removed from these areas, but some logs, small wood and the harvest waste have been left and can be extracted for fuel. The estimated quantity of salvageable wood is 1.4 million tonnes, of which 0.9 million tonnes have been harvested while the rest is available for energy purposes. Of the 0.9 million harvested wood, about 40% is wastes. Thus, about 825,000 tonnes (air-dry) of wood wastes are generated from the fire, and about 80%, or 650,000 tonnes, is economically accessible and therefore available for energy purposes. The consensus is that this wood waste can be harvested over a five-year period and be available to meet some of the demand from the proposed 'power/heat' plant at Arxan. This would supply 130,000 tonnes each year for five years.

3.3.5 Dead Wood in the Forest Areas

Dead wood, including wind-blown trees, is rarely measured when undertaking forest inventories. Yet from an energy perspective it is the most desirable fuel because the moisture content is about 15% or less and the energy value is about 16 GJ/tonne. This compares to freshly cut wood, which has an energy value of about 10 GJ/tonne and contains about 45% water. Thus, one tonne of dry wood has 60% more energy than a wet tonne[7]. On an energy basis it is cheaper to transport dry wood than wet wood and less energy is wasted expelling the water during the combustion process! A recent study was undertaken in Benin (West Africa) for a World Bank and Global Environmental Facility project to determine the amount of carbon in different forest types. Measurements were taken of the weight of all above-ground biomass, including dead wood. Annex 2 gives a summary of the results in tabular form. It was found that 8% of the total above-ground biomass was dead wood ranging from 4% of trees over 15 cm diameter at breast height (dbh) to 123% of trees and shrubs below 15 cm dbh. As Benin has a similar rainfall to that of Xing'An Meng (400 to 450 mm) the above average figure of 8% dead wood was adopted after consultation with local foresters. The total above ground growing stock is an estimated 43.60 million tonnes, thus the estimate of dead wood is 3.49 million tonnes. From a fire hazard viewpoint, it is better to clear deadwood from the forest floor, thus reducing the incidence of fire danger. Assuming 50% accessibility, then the annual off-take could be 1.74 million tonnes. Similarly, there is an estimated 272,000 tonnes of deadwood in scrub and shrub areas. With an accessibility of 60%, the amount available is 194,000 tonnes. Thus, a total of 1.81 million tonnes of dead wood is available for energy purposes. While new dead wood will be added to this stock, it is assumed that the accessible deadwood will be harvested over a 10-year period, namely at the rate of 180,000 tonnes per year. At the end of this period, there may be more dead wood to salvage from additional stem and branch wood mortality.

[7] However, on a volume basis, one cubic meter of wet wood will have about 7 GJ of energy, whereas that of dry wood will contain about 10 GJ/ m^3 or 42% more energy per m^3. Thus, cutting and extraction costs are less per t of wet wood as compared to dry wood, because the dry wood has a greater volume.

3.3.6 Energy Plantations

It would be prudent for the owners of the power/heat plants to have their own source of wood close to the proposed sites. Energy plantations could be grown on marginal land, some of which are owned by farmers while others are owned by the state. The developers of the energy plantations can sign a long-term land lease with land owners. There are 5 million mu (333,000 ha) of land areas suitable for plantation, according to the Xing'An Meng forest bureau, and the study is informed of potentially more land available for energy plantations from river bed and desert areas. After discussions with local counterparts, it was agreed that 2 million mu (133,333 ha) could be used for energy plantations. An annual yield of 7.5 tonne/ha-year is assumed, based on Chinese and international experience. This would be planted over a five-year period, thus by 2010, the anticipated annual production will be 1.0 million tonnes.

- **Biomass Resources – Crop Residues**

Annual crop production in Xing'An Meng is around 1.5 million tonnes, of which two thirds come from Maize. As shown in Table 5, given the ratio of straw to crop obtained from Xing'An Meng Statistics Bureau, it is estimated that annual straw production is 2.73 million tonnes. Based on Xing'An Meng Agriculture and Energy Plans, discussions with the Chinese counterparts, and field visits, about 40% of the straw is currently used for other purposes -- household cooking and heating, animal feeding, fertilizer/soil improver, and paper making. Therefore, this study assumed 60% of the straw production is available for centralized power and heat. This is equivalent to 1.6 million tonnes, primarily from maize, rice, and sorghum. In addition, there are 0.35 million tonnes of cobs and husks, which are all used for household cooking and heating purposes.

Table 5. Available Straw Resources for Power/Heat in Xing'An Meng

Units: 000t

Production	Maize	Rice	Sorghum	Other	**Total**
Crop production	986	109	133.5	272	1,498
Ratio of straw to crop	1:2	!:2	1:2	1:1	
Straw production	1,972	218	267	272	**2,729**
Available for power/heat	1,183	131	160	163	**1,637**

- **Biomass Resources for Competing Uses**

There are two principal biomass resources used for energy, namely crop residues (grain straw and grain cobs/husks) and wood, although a little dung is used for cooking and a very small amount of charcoal is used for grilling meat. At present, biomass energy is mainly used by householders for cooking throughout the year and heating, during the 7-month cold winter period. Some biomass is used in cottage industries and the service sector to provide heat for schools and government offices. The estimated household consumption is the equivalent of 8 to 10 cubic meters of wood per year per rural household or about 5.3 tonnes (t) of wood or crop residues.

However, in some areas, coal is also used for heating and LPG for cooking, with some households having an electric rice cooker. These could account for about 10% of the household energy demand (in wood equivalent terms), so the average household demand for biomass energy is approximately 4.8 tonnes for a household size of six. This is equivalent to annual rural household demand of about 1.02 million tonnes of biomass energy (213,000 households) with another 150,000 tonnes for non-household use, giving an estimated rural consumption of 1.17 million tonnes. Some biomass energy is used in towns; this could account for another 0.31 million tonnes, giving an estimated total of 1.48 million tonnes. Wood energy supplies about 300,000 tonnes, maize cobs/crop husks supply an estimated 347,000 tonnes, with straw providing the remaining 735,000 tonnes. Crop residues have other uses, especially for animal feed and fertilizer/soil improver when added to the soil as straw and/or ash. The estimated 'other use' consumption is 257,000 tonnes (Table 6), but at present there is a considerable surplus of straw, most of which could be used as fuel. Table 6 gives an estimate of current biomass energy consumption by sector and energy type.

Table 6: Estimated Biomass Energy Consumption by Sector and Type

Units 000t

Sector	Wood			Agriculture residues			Total		
	Rural	Urban	Total	Rural	Urban	Total	Rural	Urban	Total
Household	200	50	250	822	200	1,022	1,022	250	1,272
Non-household	25	5	30	125	35	160	150	40	190
Heating boilers	0	20	20	0	0	0	0	20	20
Total	225	75	300	947	235	1,182	1,172	310	1,482

- **Biomass Resource Cost**

To compare the delivered costs of biomass resources from each category, the study assumed an average transportation distance for straw and wood to deliver to the plant and calculated the delivered costs. Based on information from Ulanhot and Arxan, there are sufficient supplies of straw and wood wastes for a 24 MW co-generation plant within 30 km radius, with an average transportation distance of 15 km. The transportation cost is about 0.5 Yuan/tonne-km in Ulanhot and about 1 Y/tonne-km in Arxan. The breakdown delivered cost of straw in Ulanhot is provided by Xing'An Meng Statistics Bureau, while the breakdown cost of wood wastes is provided by Arxan Forestry Bureau. The resource cost for straw is estimated on the basis of existing straw price for alternative uses, for example, animal feeding, and confirmed by field visits during the study. The resource cost for wood is based on discussions with Forestry Bureaus in Arxan. The processing costs (baling and cutting/chipping) are consistent with international experience. The delivered cost of energy plantation is calculated with a cash flow analysis, based on cost inputs of preparation, planting, seedling, fertilizer, overhead, harvesting, etc. from the Arxan Forestry Bureau. However, detailed surveys are required as follow-up to confirm these cost estimates. Tables 7a and 7b give the best estimate of the cost components to deliver wood and straw to centralized power and/or heat plants.

Table 7a. Delivered Cost of Straw to Power/Heat Plant in Ulanhot

Units: Yuan/t unless otherwise stated

Operation	Agriculture straw
Distance from plant	15 km
Resource price	100
Baling	25
Cutting	68
Transport	7
Delivered cost	**200**
Moisture content	15.0
Energy value GJ/t	15.0
Delivered cost: Yuan per GJ	**13.4**

Table 7b. Delivered Cost of Wood to Power/Heat Plant in Arxan

Units: Yuan/t unless otherwise stated

Operation	**Sawmill waste**	**Harvest waste**	**Dead wood**	**Thinnings shrubs**	**Energy plantation** (12% discount rate)
Distance from plant	15 km				15 km
Resource price	40	30	30	30	85
Processing in forest	0	0	35	50	50
Extraction to road	0	50	50	50	5
Sub-total	40	80	115	130	140
Chipping	70	70	70	70	70
Storing	25	25	25	25	25
Transport	15	15	15	15	15
Sub-total	110	110	110	110	110
Delivered Cost	**150**	**190**	**225**	**240**	**250**
Moisture content %	20	40	15	45	45
Energy value GJ/t	14.5	10.3	15.5	9.2	9.2
Delivered cost: Y/GJ	**10.3**	**18.5**	**14.5**	**26.1**	**27.2**

Table 8 lists the available biomass resources for power/heat and delivered costs for each resource category. However, given that transportation distance is a key variable in delivered cost of biomass resources, the study also assumed different transportation distances, and calculated the cost of biomass resources for each resource category. Please see Chapter 5.7 on the cost-supply curve for details.

Table 8 Available Biomass Resources for Power/Heat and Costs by Category

Units: 000t.

Resource	Sawmill waste	Straw	Dead wood	Harvest waste	Thinning & shrubs etc.	Energy plantation
Available resources	80	1,637	310	210	1,200	1000
Cost	10.3	13.4	14.5	18.5	26.1	27.2

Normally, biomass residues from centralized facilities are the cheapest and most reliable resources. Table 8 shows that the cheapest biomass resources are sawmill wastes at 10 Yuan/GJ (150 Yuan/tonne), unfortunately, the resources are very limited with more than 250 small-scale sawmills scattered across the region. The second least-cost resources are scattered agriculture residues at 13 Yuan/GJ (200 Yuan/tonne), with a substantial amount of resource availability. Dead wood from natural forests and the fire that occurred in May 2003 stands in the middle, with a cost of 15 Yuan/GJ (225 Yuan/tonne) and has limited availability. This is followed by forest harvest wastes with a cost of 19 Yuan/GJ (190 Yuan/tonne), with insufficient supply. The most abundant resources are thinning/shrubs and energy plantations, however, they are also the most expensive options at 26 and 27 Yuan/GJ respectively (240 and 250 Yuan/tonne). The alternative fuel in Xing'An Meng is coal (lignite), which has a price at 28 Yuan/GJ (350 Yuan/tonne with 12.6 GJ/tonne). Therefore, biomass fuels are cost competitive with coal.

The study stressed the importance of setting delivered biomass fuel prices on a Yuan/GJ basis, or requiring a fuel standard of minimum moisture content, because the heating value resulting from moisture content can substantially affect the delivered cost. In Denmark, for example, biomass co-generation or power plants purchase fuels on a $/GJ basis, rather than $/tonne.

4. POWER AND HEAT SUPPLY IN XING'AN MENG

This chapter presents the power and heat suppliers and tariffs in Xing'An Meng. It begins with a description of the power supply. Section 4.2 presents the power-off taker and the power tariffs. Section 4.3 presents the heat supply and Section 4.4 present the heat tariffs for Xing'An Meng.

o Power Supply

The two existing power plants in Xing'An Meng are: 1) a 3 x 12 MW coal-fired co-generation plant with an efficiency of 21%, which produces 195 GWh in 2004 and sold 120 GWh to the Xing'an Meng Power Supply Company; and 2) a 12.8 MW hydro plant situated in Chaersen reservoir near Ulanhot, which produced and sold 60 GWh per year to the Xing'an Meng Power Supply Company.

The local government plans to build additional coal-fired co-generation plants to meet the future growing demand, and intends to reduce the imports from the Northeast Grid. The existing CHP plant in Ulanhot is planned expanded to 2 x 50 MW cogeneration units. These two units are already approved by the provincial authorities and will be comstudyed this year. Two new coal fired cogeneration plants with 2 x 300 MW and 400 MW installed capacity each are also under planning in Xing'an Meng.

o Power Off-taker and Power Tariff

Xing'an Meng Power Supply Company, which is under the Inner Mongolia Power Group, is the power off-taker in Xing'An Meng. The average producer purchase tariff is informed to be 0.29 Yuan/kWh for Xing'An Meng Power Grid, while 0.23-0.25 Yuan/kWh for Inner Mongolia Power Grid. Table 9a lists power purchase prices for the power producers in Xing'an Meng, and Table 9b lists end-user power tariff in Xing'an Meng. As shown in Table9b, the consumer power tariff is higher in Arxan than that in Ulanhot.

Table 9a. Power Purchase Prices for the Power Producers in Xing'an Meng

Power Producers	Yuan/kWh
Coal fired Cogeneration in Ulanhot	0.327
Hydro Power Plant	0.273
China North East Grid	0.256 for the first 280 GWh 0.310 for additional GWh

Table 9b. Consumer Power Tariffs in Xing'an Meng (Yuan/kWh)

Power Consumers	Ulanhot	Arxan
Residential	0.394	0.456
Industry	0.390	0.469
Agriculture	0.614	0.62
Commercial	0.774	0.81

- **Heat Supply**

The heat capacities in Xing'an Meng can be divided into three groups:

- Centralised heating producers
- Decentralised heating producers (1-4 ton/h)
- Stoves in individual houses

Only three district heating plants are currently in operation, two in Ulanhot and one in Arxan - No.1 cogeneration plant, No.2 heat supply plant in Ulanhot, and a district heat plant in Arxan. The No.1 cogeneration plant in Ulanhot supplies yearly 2.6 million GJ to the local district heating network (2.6 million m^2). The No.2 heat supply plant is 3 x 40 t/h and supplies heat to the local district heating network (1.0 million m^2). In addition, a large number of small decentralised coal fired heating boilers and individual household stoves burning coal and wood meet the remaining heating demand.

- **Heat Tariff**

The average consumer heat tariff in Xing'An Meng was 28 Yuan/m^2 in 2004. In Ulanhot the heat tariff was 21 Yuan/m^2 for residential consumers and 24 Yuan/m^2 for commercial consumers. This tariff is planned increased to 24 Yuan/m^2 for residential consumers and 30 Yuan/m^2 for commercial consumers. In Arxan, for the heat supplied from a local coal fired district heating, the approved consumer heat tariff plant is 32.6 Yuan/m^2. For the heat supplied from small coal-fired or wood-fired boilers operated by the local Forestry Bureaus, the heat tariff for employees is 15.4 Yuan/m^2 (subsidized by the local Forest Bureaus) and 44 Yuan/m^2 for nearby residential consumers. The cost for heat from such small heating boilers was informed to be 40 Yuan/m^2.

The study concluded that the heating tariff in Xing'An Meng is mostly subsidized and does not reflect the economic cost of the heat production. It seems that the tariff is mainly based on the fuel costs and often does not include other cost such as depreciation, O&M costs, and network investments. The team calculated the financial heat generation cost to be 32 Yuan/GJ for a new 5 MW biomass fired heating plant, and 41 Yuan/GJ for a new 5 MW coal-fired heating plant.

5. BIOMASS POTENTIAL ASSESSMENT IN XING'AN MENG

This chapter presents the biomass potential assessment for Xing'An Meng. It begins with an explanation of the methodology used for this biomass potential assessment. Section 5.2 presents the biomass resources in six counties in Xing'An Meng. Section 5.3 assesses the power demand for Xing'An Meng. Section 5.4 assesses the heat demand potential for biomass cogeneration and biomass heat only boilers in six counties in Xing'An Meng. In Section 5.5 we present the technical potential for biomass cogeneration, power only and biomass heat only for Xing'An Meng. In Section 5.6 economic analysis is performed for a number of biomass cogeneration, biomass power only and biomass heat only technologies and economic power generation costs are compared. In Section 5.7, three cost supply curves are developed for biomass co-generation, power-only, and heat-only in Xing'An Meng derived from the estimated economic generation costs, as well as potential for biomass. Section 5.8 presents the economic optimal quantity of biomass power and heat for Xing'An Meng.

5.1 Methodology

The project team estimated the biomass energy potential for heat and power in Xing'An Meng, based on the biomass resources and heat demand in capital cities of the six counties - Ulanhot, Tuquan, Arxan, Yinder, Baiyinhushuo and Dabagou as well as the heat demand in smaller cities.

The methodology included the following steps:

- Estimate the power demand for Xing'An Meng.
- Assess the heat demand for biomass cogeneration in capital cities of the six counties.
- Assess the heat demand for biomass heat only in smaller cities of the six counties.
- Assess the technical potential for biomass cogeneration, power only and heat only.
- Assess economic generation cost for power and heat.
- Derive cost supply curves for biomass power and heat in Xing'An Meng using estimated economic generation costs, as well as potential for biomass cogeneration, power only and heat only.
- Analyse the economic optimal quantity of biomass energy

5.2 Biomass Resources in Xing'An Meng

The biomass resources in Xing’An Meng have been assessed in details in chapter 3. The resources have been mapped for each of the six counties - Ulanhot, Tuquan, Arxan, Yinder, Baiyinhushuo and Dabagou. The amount of straw is estimated to be 1.6 million tonnes per year and the amount of wood resources to be 1.5 million tonnes per year in 2005 and 2.1 million tonnes per year in 2010, as shown in table 10. The wood resources are estimated to significantly increase from 2005 to 2010 due to energy plantations. It is assumed that biomass resources will remain the same level in 2015 as those in 2010.

Table 10. Biomass Resources in Six Counties.

City	**Biomass resources**				
	Straw ton/y	Wood ton/y	Wood ton/y	2005 MWh/y	2010 MWh/y
		2005	2010		
Ulanhot	53.814	10.127	11.288	250.905	254.005
Tuquan	380.840	22.565	18.495	1.644.543	1.633.676
Yinder	538.144	131.677	167.486	2.590.257	2.685.867
Baiyinhushuo	209.048	49.887	166.177	1.002.838	1.313.332
Dabagou	442.934	268.996	635.977	2.560.825	3.540.664
Arxan	12.419	1.018.748	1.152.637	2.771.720	3.129.204
Total	1.637.199	1.502.000	2.152.060	10.821.088	12.556.748

5.3 Power Demand in Xing’An Meng

The total power demand for Xing’an Meng in year 2004 was 900 GWh, of which 120 GWh was produced at the coal fired cogeneration plant in Ulanhot, 60 GWh was produced at the hydro power plant in Chasuer, and the remaining power was bought from the China Northeast Grid.

Xing’an Meng Power Supply Company has informed that the forecasted power demand will increase rapidly to nearly 2,500 GWh in year 2010, mainly resulting from the planned large-scale chemical and iron industry in Xing’An Meng. Given the current low industry base and uncertainty over future growth, it is difficult to forecast the future power demand in Xing’an Meng Region.

5.4 Heat Demand in Xing’An Meng

Xing’An Meng has a high heating demand, with a heating season of 6-8 months. The heat demand was estimated for the capital city of the six counties and for smaller cities in Xing'An Meng. Based on the population in each city, heated areas, and specific heat demand factors, the total heat demand was estimated for year 2005 and year 2015. The heat demand assessment was divided into two sections - one for the six largest cities in Xing'An Meng suitable for biomass cogeneration and one for smaller cities convenient for biomass heat only.

5.4.1 Heat Demand for Biomass Cogeneration

The heat demand analysis was started with a mapping of the present heating area in the six largest cities in Xing'An Meng. These cities have a size (30,000 - 234,000 inhabitants) suitable for biomass cogeneration. The mapping was divided into present type of heat supply, such as central heating plant, small boiler stations and stoves.

Then the future development of the heating area in year 2015 in each of the six cities was estimated, using an annual growth rate of 6 to 12 percentage. The total heating area will increase from current 23.0 million square meters to 60.1 million square meters in year 2015, as shown in table 11.

Table 11. Heated Area for Six Largest Cities in Xing'An Meng.

		Present heating system					2015	
	Citizen	Heated area	Development in heated area	Central heating plant	Small boiler stations	Stoves	Total	New heat demand
City		Million m^2	% per year	Million m2				
Ulanhot	234000	12,976	12	3,59	4,50	4,88	40,30	27,33
Tuquan	49700	2,599	7	0,00	0,20	2,40	5,11	2,51
Arxan	37000	2,039	6	0,00	0,40	1,64	3,65	1,61
Yinder	57300	2,946	9	0,00	0,40	2,55	6,97	4,03
Baiyinhushuo	46400	1,912	7	0,00	0,34	1,57	3,76	1,85
Dabagou	10000	0,523	7	0,00	0,26	0,26	1,03	0,51
Total	**434,400**	**22.99**		**3.59**	**6.10**	**13.30**	**60.83**	**37.83**

Sources: Local Authorities in Xing'An Meng.

The annual heat demand for year 2005 and 2015 was calculated with the assumption of a specific heat demand factor of 0.66 GJ/m^2 and 0.60 GJ/ m^2 respectively[8] (1.10 GJ/ m^2 and 0.99 GJ/ m^2 for Arxan respectively because of colder climatic conditions). The lower specific heat demand factor for 2015 was used because of an average 10% of energy savings. The total heat demand will increase from current 16.1 million GJ to 39.7 million GJ in year 2015, as shown in Table 12.

[8] These assumptions are estimated with international experience and adjusted for different outdoor temperatures in Xing'An Meng.

Table 12. Heat Demand for Six Largest Cities in Xing'An Meng.

City	Present: Central heating plant	Present: Small boiler stations	Present: Stoves	Present: Total	2015: Central heating plant	2015: Small boiler stations	2015: Stoves	2015: New demand	2015: Total
	Million GJ				Million GJ				
Ulanhot	2,38	2,98	3,23	8,60	2,14	2,68	2,91	16,29	24,03
Tuquan	0,00	0,13	1,59	1,72	0,00	0,12	1,43	1,50	3,05
Arxan	0,00	0,44	1,80	2,24	0,00	0,40	1,62	3,62	5,63
Yinder	0,00	0,27	1,69	1,95	0,00	0,24	1,52	2,40	4,16
Baiyinhushuo	0,00	0,23	1,04	1,27	0,00	0,20	0,94	1,10	2,24
Dabagou	0,00	0,17	0,17	0,35	0,00	0,16	0,16	0,30	0,61
Total	2.38	4.22	9.53	16.13	2.14	3.80	8.57	25.21	39.73

Then the percentage of each heat supply method (central heating plant, small boiler stations, stoves and new heat demand) was estimated, which could be supplied with biomass cogeneration in year 2015. It is assumed that biomass co-generation can replace 30% of present small boiler stations and 20% of present coal-fired heating stoves, as well as meet 40% of future heat demand in 2015. Therefore, the total heat demand for biomass cogeneration is 12.9 million GJ in 2015, out of a total heat demand of 39.7 million GJ, as shown in table 13.

Table 13. Heat Demand for Biomass Cogeneration.

City	Percentage for biomass energy: Central heating plant	Small boiler stations	Stove	New	2015: Central heating plants	2015: Small boiler stations	2015: Stoves	2015: New demand	2015: Total
					Million GJ				
Ulanhot	0%	30%	20%	40%	0,00	0,81	0,58	6,52	7,90
Tuquan	0%	30%	20%	40%	0,00	0,04	0,29	0,60	0,92
Arxan	0%	30%	20%	40%	0,00	0,12	0,32	1,45	1,89
Yinder	0%	30%	20%	40%	0,00	0,07	0,30	0,96	1,34
Baiyinhushuo	0%	30%	20%	40%	0,00	0,06	0,19	0,44	0,69
Dabagou	0%	30%	20%	40%	0,00	0,05	0,03	0,12	0,20
Total					**0.00**	**1.14**	**1.71**	**10.09**	**12.94**

5.4.2 Heat Demand for Biomass Heat Only

The heat demand analysis for biomass heat only was started with mapping of the present heated area in cities with a population of 2,000 to 10,000 inhabitants, which is suitable for biomass heat only. The mapping was divided into present type of heat supply, such as central heating plant, small boiler stations and stoves. Then the future development of the heated area in year 2015 was estimated, using an annual growth rate of 3 to 8 percentage. The total heated area will increase from present 4.03 million square meters to 6.96 million square meters in year 2015, as shown in table 14. Please see Annex 2 for details.

Table 14. Heated Area for Smaller Cities in Xing'An Meng.

		Present heating system					2015	
	Citizen	**Heated area**	**Development in heated area**	**Central heating plants**	**Small boiler stations**	**Stoves**	**New heat demand**	**Total heat demand**
		Million m^2	**% per year**	**Million m2**				
Total	154,567	4.03	3 - 8	0.00	0.41	3.62	2.93	6.96

Sources: Local Authorities in Xing'An Meng.

The annual heat demand for year 2005 and 2015 was calculated with an assumption of a specific heat demand factor of 0.66 GJ/m^2 and 0.60 GJ/m^2 respectively (1.10 GJ/m^2 and 0.99 GJ/m^2 for cities in Arxan respectively because of colder climatic conditions). The lower specific heat demand factor for 2015 was used because of an estimated average of 10% energy savings. Therefore, the total heat demand will increase from present 2.82 million GJ to 4.42 million GJ in year 2015, as shown in table 15.

Table 15. Heat Demand for Smaller Cities in Xing'An Meng.

	Present				2015				
	Central heating plant	**Small boiler stations**	**Stoves**	**Total**	**Central heating plants**	**Small boiler stations**	**Stoves**	**New demand**	**Total**
	Million GJ				**Million GJ**				
Total	0.00	0.290	2.533	2.823	0.00	0.261	2.280	1.578	4.418

Then, the percentage of each heat supply method (central heating plant, small boiler stations, stoves and new heat demand) was estimated, which could be met by biomass heat only boilers in year 2015. It is assumed that biomass heat-only boilers can replace 50% of present small boiler stations and 25% of present coal-fired heating stoves, as well as meet 80% of future heat demand in 2015. Therefore, the total heat demand for biomass heat only boilers was estimated to 2.20 million GJ in year 2015, out of a total head demand of 4.42 GJ, as shown in table 16.

Table 16. Heat Demand Available for Biomass Heat Only.

					2015				
					Central heating plants	Small boiler stations	Stoves	New demand	Total
	Central heating plant	Small boiler station	Stove	New	Million GJ				
Total	0%	50%	25%	80%	0.00	0.131	0.570	1.502	2.203

5.5 Technical Biomass Energy Potential

5.5.1 Resources and Demand Analysis

As the location of biomass cogeneration and biomass heat only plants closely depends on geographical areas with a heat demand, while biomass power only plants can be located either near a power demand or near a large high voltage grid, the assessment of potential for biomass energy started with a resource and demand analysis for biomass cogeneration and biomass heat only. Table 17 shows 1) the total biomass resources in each counties; 2) those resources to meet the demand for biomass co-generation and heat-only boilers as estimated in section 5.4; and 3) the remaining biomass resources for power only options.

Table 17. Biomass Resources and Resource Demand for Cogeneration and Heat Only.

City	Biomass Resources	Resource Demand for Cogeneration	Resource Demand for Heat Only	Remaining Biomass Resources
	MWh	MWh	MWh	MWh
Ulanhot	254.005	5.355.259	107.864	-5.209.118
Tuquan	1.633.676	624.230	70.786	938.660
Arxan	3.129.204	1.280.011	123.014	1.726.179
Yinder	2.685.867	905.107	156.076	1.624.684
Baiyinhushuo	1.313.332	467.027	131.012	715.294
Dabagou	3.540.664	134.535	176.036	3.230.093
Total	12.556.748	8.766.168	764.787	3.025.793

As shown in Table 17, there is a lack of biomass resources in Ulanhot county. It is assumed that Ulanhot county will import 3.6 million MWh biomass from surrounding counties. The import/export of biomass is shown in Table 18, as well as the resources available for biomass cogeneration, power only and heat only.

Table 18. Resources and Resource Demand after Import and Export of Biomass

City	Import/ Export	Resources after Import/export	Resource for Cogeneration	Resource For Heat Only	Resource for Power Only
	MWh	MWh	MWh	MWh	MWh
Ulanhot	3.614.716	3.868.721	3.760.857	107.864	0
Tuquan	-657.062	976.614	624.230	70.786	281.598
Arxan	-172.618	2.956.586	1.280.011	123.014	1.553.561
Yinder	-812.342	1.873.525	905.107	156.076	812.342
Baiyinhushuo	-357.647	955.685	467.027	131.012	357.647
Dabagou	-1.615.047	1.925.617	134.535	176.036	1.615.047
Total	0	12.556.748	7.171.766	764.787	4.620.195

5.5.2 Potential for Biomass Cogeneration, Power-Only, and Heat-Only

The technical potential for biomass cogeneration, power only and heat only boilers in each of the six counties is shown in table 19. Due to realistic import/export limitations, only a heat demand of 5.6 million GJ, out of total 7.9 GJ in Ulanhot can be met by biomass cogeneration plants.

Table 19. Technical Potential for Biomass Cogeneration, Power Only and Heat Only

City	Cogeneration			Power Only		Heat Only	
	MW	GWh	GJ	MW	GWh	MW	GJ
Ulanhot	157	865	5.551.024	0	0	17	310.649
Tuquan	26	144	921.363	13	76	11	203.864
Arxan	54	294	1.889.296	70	419	20	354.280
Yinder	38	208	1.335.938	37	219	25	449.498
Baiyinhushuo	20	107	689.331	16	97	21	377.313
Dabagou	6	31	198.574	73	436	28	506.983
Total	300	1.650	10.585.527	208	1.247	123	2.202.587

As shown in Table 19, the total technical potential for biomass co-generation in Xing’An Meng is estimated to be 300 MW in 2015, equivalent to 1,650 GWh per year, with 246 MW, or 1,355 GWh per year in the Eastern part of Xing'An Meng, and 54 MW, or 294 GWh per year in the North Western part of Xing'An Meng.

The total technical potential for biomass power only in Xing’An Meng is estimated to be 208 MW in 2015, equivalent to 1,247 GWh per year, with 138

MW, or 828 GWh per year, in the Eastern part of Xing'An Meng, and 70 MW, or 419 GWh per year in the North Western part of Xing'An Meng.

The total technical potential for biomass heat only boilers in Xing'An Meng is estimated to be 123 MW in 2015, equivalent to 2.2 million GJ per year, with 103 MW, or 1.8 million GJ per year, in the Eastern part of Xing'An Meng, and 20 MW, or 0.4 million GJ per year in the North Western part of Xing'An Meng.

5.6 Economic Analysis of Co-generation, Power-Only, and Heat-Only

Economic analysis was conducted for 1) a 12 MW and a 25 MW biomass cogeneration plants; 2) for a 5 MW and a 20 MW biomass power only plants, in comparison with the baseline cost of power import from the Northeast grid including externalities. As shown in Figure 1, the 25 MW biomass cogeneration plant is economically viable compared to the power import from the Northeast grid, whereas the 12 MW biomass cogeneration plant and the power only plants are not found to be economically attractive.

Figure 1. Comparison of Economic Costs of Biomass Co-generation and Biomass Power-Only with Baseline Costs

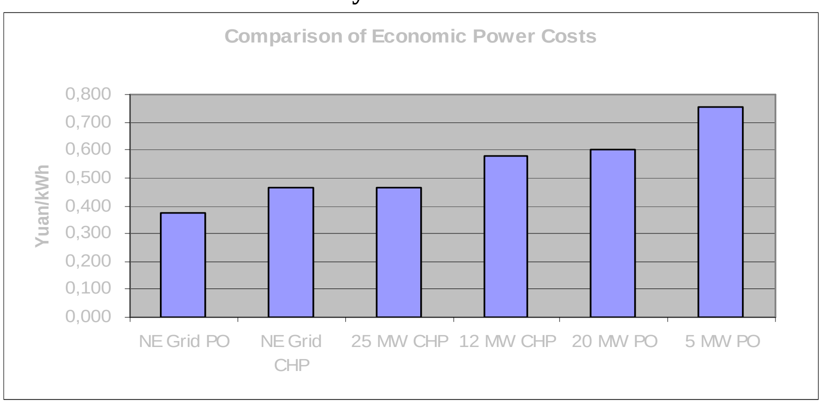
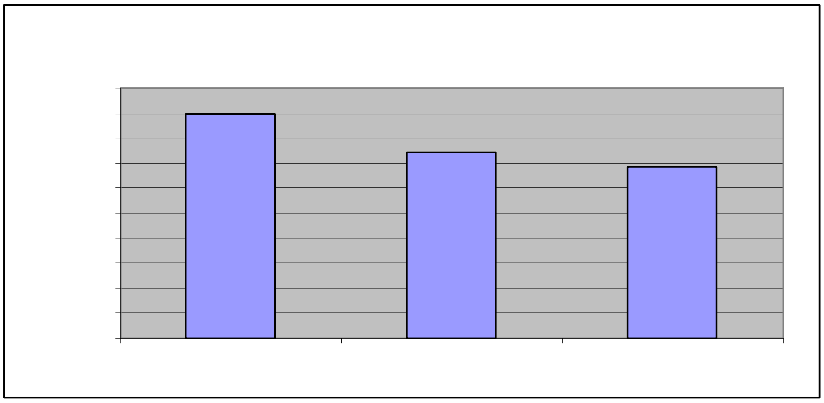


Figure 2. Comparison of Economic Costs of Biomass Heat-Only Boilers with Baseline Costs



estimated to be 258 MW. Figure 4 demonstrated that biomass power only technology is not economically justified compared to the baseline costs even with external costs.

Figure 3. Cost Supply Curve for Biomass Cogeneration

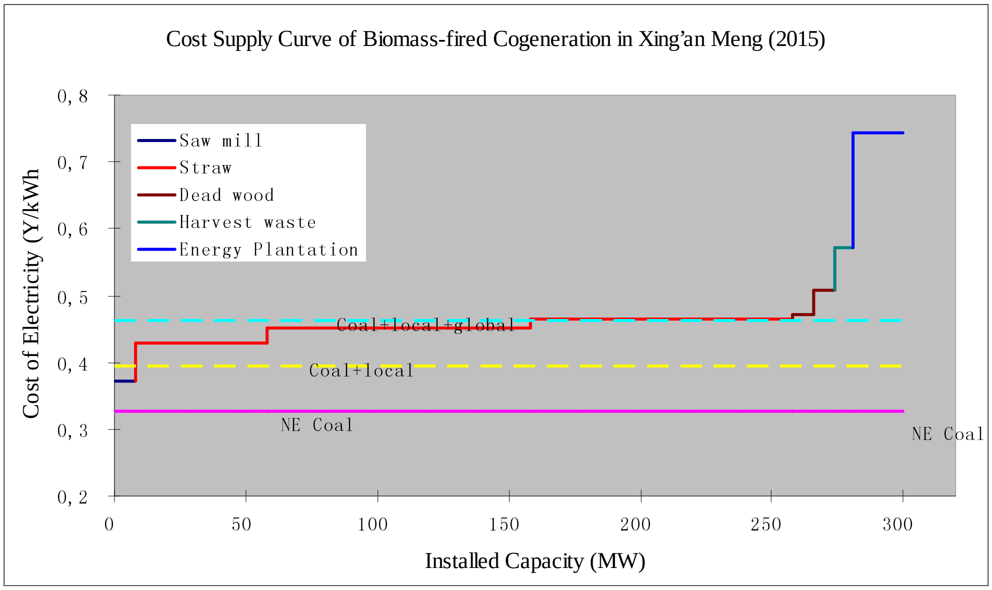
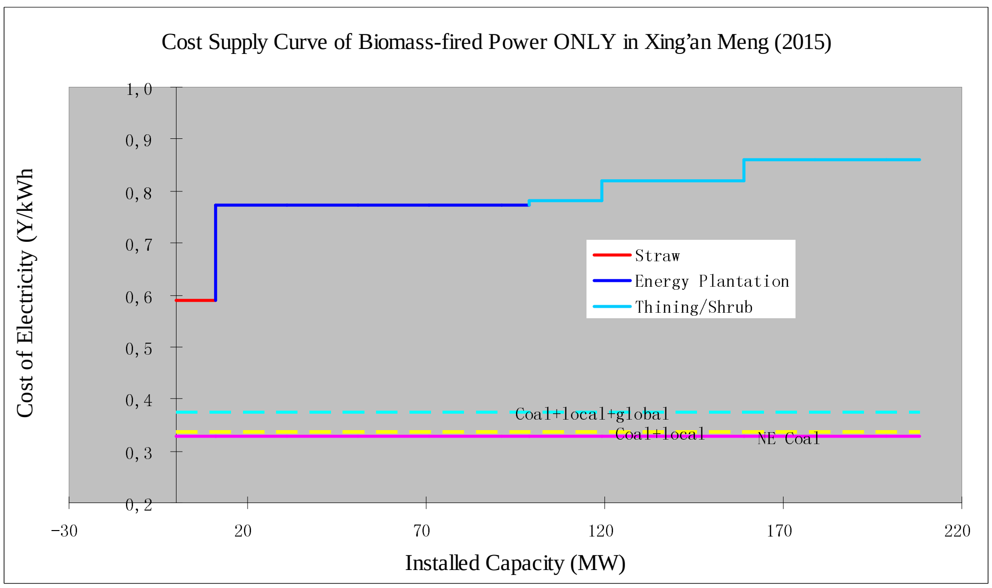
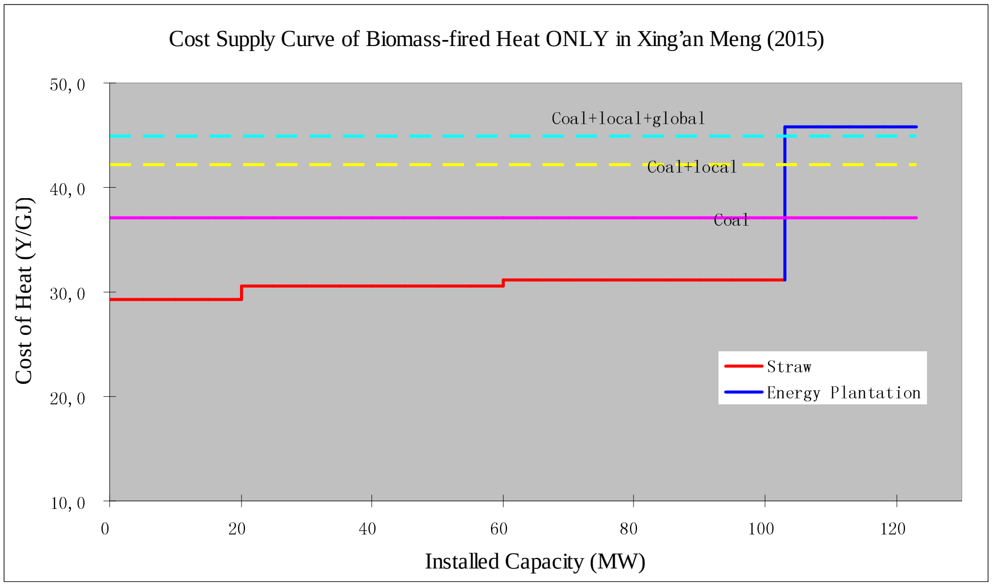


Figure 4. Cost Supply Curve for Biomass Power Only



As shown in Figure 5, the total economically viable potential for biomass heat-only boilers is estimated to be 103 MW fuelled by straw, compared to the baseline costs even without externalities. Biomass heat-only boilers fuelled by energy plantations, however, cannot be economically justified even with externality costs.

Figure 5. Cost Supply Curve for Biomass Heat Only



5.8 Economic Optimal Quantity of Biomass Energy

Economic theory holds that renewable energy should be implemented to the point at which the incremental **economic cost** of the next renewable energy project (marginal project) exactly equals the avoided damage costs. Phrased differently, the comparison between renewable power/heat and fossil-based power/heat should be on the basis of economic cost (economic production costs plus externalities). The economically optimum quantity of renewable power and heat is therefore the sum of renewable power and heat whose economic generation costs are lower than the economic costs of the fossil-fuelled baseline generation. Table 20 summarises the economic viable potential for biomass co-generation, power-only, and heat-only options by six counties in Xing'An Meng.

Table 20. Economic Quantity of Biomass Energy for Xing'An Meng

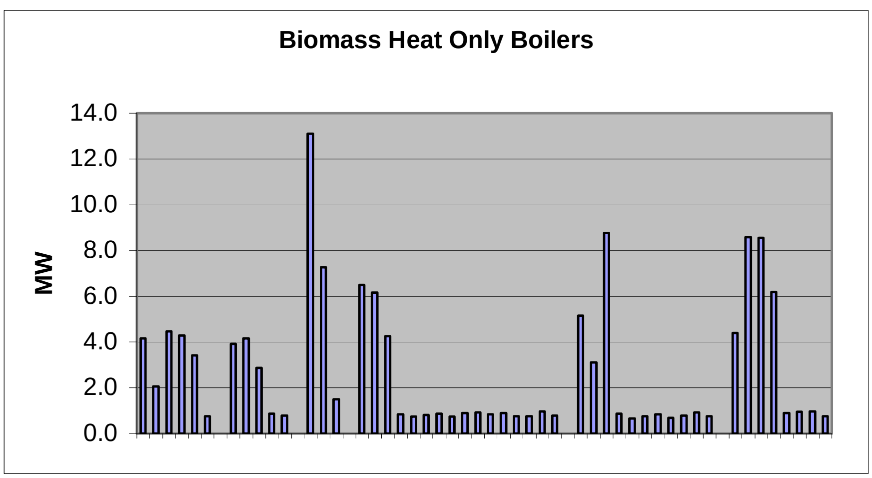
City	Cogeneration			Power Only		Heat Only	
	MW	**GWh**	**GJ**	**MW**	**GWh**	**MW**	**GJ**
Ulanhot	157	865	5.551.025	0	0	17	310.649
Tuquan	26	144	921.363	0	0	11	203.864
Arxan	12	66	423.548	0	0	0	0
Yinder	38	208	1.335.938	0	0	25	449.498
Baiyinhushuo	20	107	689.331	0	0	21	377.313
Dabagou	6	31	198.574	0	0	28	506.983

Total	258	1.421	9.119.779	0	0	103	1.848.307

As shown in Table 20, the total economic potential for biomass co-generation in Xing'An Meng is estimated to be 258 MW in 2015, equivalent to 1,421 GWh per year, with 246 MW, or 1,355 GWh per year in the Eastern part of Xing'An Meng, and 12 MW, or 66 GWh per year in the Northwest part of Xing'An Meng. The biomass cogeneration plant size is recommended to be 20 to 25 MW power each. Smaller plants down to 5 MW is found not to be economic compared to the baseline cost, but may be able to be justified by other reasons. Since biomass power-only technology is not economically viable, the total economic potential for biomass power only in Xing'An Meng is zero.

The total economically viable potential for biomass heat only boilers in Xing'An Meng is estimated to be 103 MW in 2015, equivalent to 1.8 million GJ per year, all located in the Eastern part of Xing'An Meng. In the North Western part of Xing'An Meng, there is no economic potential for biomass heat only boilers in 2015 due to the fact that all the cheaper biomass resources as saw mill waste, dead wood and harvest wastes are used for cogeneration. The biomass heat only boilers plant size is recommended to be between 0.6 and 10 MW each. The estimated capacity of the biomass heat only boilers for all the small cities is shown in figure 6. The horizontal axis represents each small city, which is listed in Annex 2.

Figure 6. Capacity of the Biomass Heat Only Boilers for the Small Cities



5.8.1 Used and Unused Biomass Resources

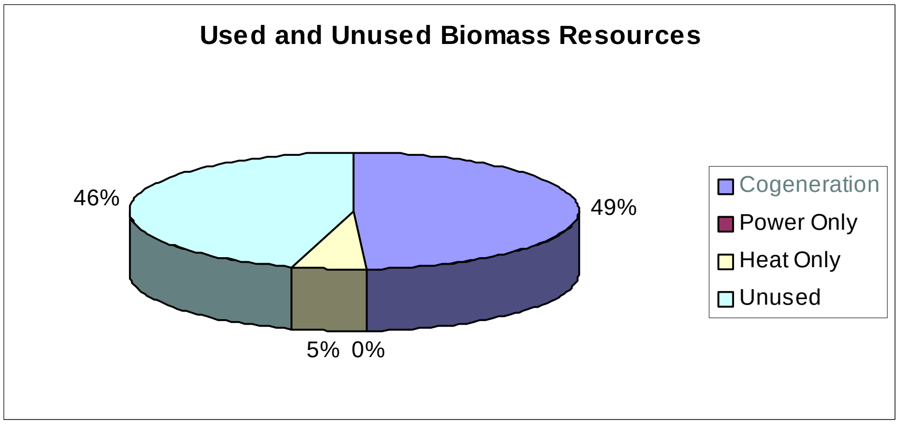
Figure 7 shows the used and unused biomass resources if the total economic biomass energy potential presented above is implemented. As shown in Table

21, a large portion of the available biomass resources, particularly in Arxan and Dabagou, is assessed not to be economically viable to use.

Table 21. Used and Unused Biomass Resources

City	Import/ Export	Resources after Import/export	Used by Cogeneration	Used By Heat Only	Used by Power Only	Unused Resources
	MWh	MWh	MWh	MWh	MWh	MWh
Ulanhot	3.614.716	3.868.721	3.760.857	107.864	0	0
Tuquan	-657.062	976.614	624.230	70.786	0	281.598
Arxan	-172.618	2.956.586	286.957	0	0	2.669.629
Yinder	-812.342	1.873.525	905.107	156.076	0	812.342
Baiyinhushuo	-357.647	955.685	467.027	131.012	0	357.647
Dabagou	-1.615.047	1.925.617	134.535	176.036	0	1.615.047
Total	0	12.556.748	6.178.712	641.773	0	5.736.263

Figure 7. Used and Unused Biomass Resources



5.8.2 Net Economic Benefits to Xing'An Meng

The net economic benefits to Xing'An Meng by achieving the economically viable biomass potential can be estimated by calculating the areas between the baseline costs with externalities and economically viable biomass costs on the cost-supply curves. In another word, implementing the total economic biomass energy potential of 258 MW biomass cogeneration and 103 MW biomass heat only boilers, rather than adopting the baseline, would generate 46 million Yuan (at present price levels) net economic benefits to Xing'An Meng in year 2015.

6. TWO PILOT BIOMASS CO-GENERATION PROJETS

6.1 Ulanhot Straw Co-generation Plant

6.1.1 Introduction

The Ulanhot local government proposed a 25 MW straw fired cogeneration project located near Ulanhot city. The plant is planned to cover heat demand to a new development zone and supply power to the grid. The proposed site for the straw power plant is located 1 km from Wulanhada Town, 1.5 km from a new development zone for industrial and residential purposes, and 5 km from Ulanhot city. The heat supply area includes the Wulanhada Town and the new development zone for industrial and residential. The road to the site seems sufficient for medium sizes trucks, and the distance to the 220 KV transformer station is 1-2 km. The proposed site is on state-owned land, and no resettlement is required. The project developer is yet to be identified, and the power off-taker is the Inner Mongolia Power Group. Under existing Chinese regulations, power generators cannot directly sell electricity to consumers.

6.1.2 Heat Demand and Duration Curve

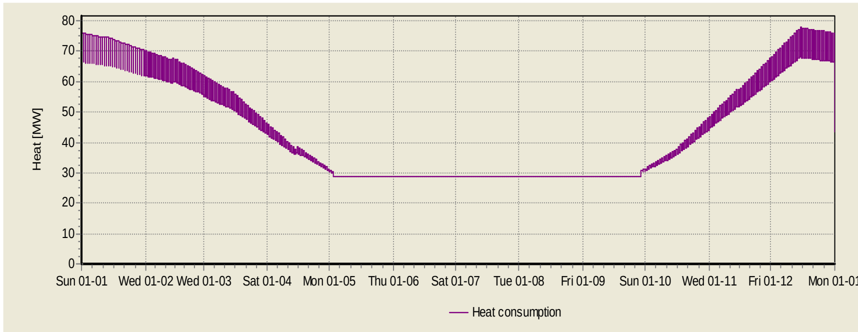
Based on the information provided from the Xing'An Meng local authority, the Ulanhot straw co-generation plant is expected to meet heating demand for a total heating area of 934,375 m^2, and the steam demand is estimated to be 260,000 ton per year. As no information is available for specific heat and steam demand in Ulanhot, the specific heat demand was estimated to be 0.53 GJ/m2, based on experience from other countries and winter temperature and duration in Ulanhot, and steam demand is assumed to be 260,000 tons per year for 24 hours a day and 365 days a year. Table 22 shows the detailed assumption of heat and steam demand as well as heat loss used in the financial analysis, and Figure 8 is the duration curve, which includes the net heat demand, the steam demand and the network loss.

Table 22. Heat and Steam Demand

	2007	2008	2009	2010	
Heated area	934.375	934.375	934.375	934.375	m2
Factor	53,00	53,00	53,00	53,00	GJ/100m2
Net heat demand	495.219	495.219	495.219	495.219	GJ/y
Steam demand	260.000	260.000	260.000	260.000	t/y
Steam demand	624.000	624.000	624.000	624.000	GJ/y
Heat + steam	1.119.219	1.119.219	1.119.219	1.119.219	GJ/y
Heat loss	279.805	279.805	279.805	279.805	GJ/y
	1.399.023	1.399.023	1.399.023	1.399.023	GJ/y
Total	388.618	388.618	388.618	388.618	MWh/y

Source: Heated area and steam demand from Chinese Ulanhot Project proposal.

Figure 8. Duration Curve for Net Heat /steam Demand and the Network Loss.



6.1.3 Technical Design and Size of the Biomass Co-generation Plant

The heat capacity of a biomass CHP plant is normally designed to cover 50-60% of the peak load demand, based on a heat demand duration curve. A peak load boiler will normally cover the remaining heat demand.

The Ulanhot CHP has a power heat/ratio of 1:1.8 (power efficiency 25% and heat efficiency 45%) and a heat/steam capacity of approximately 45 MW, which will meet 60% of the peak load demand. This means that it will be necessary to install a straw fired peak load boiler of approximately 34 MW. Figure 9 demonstrates the heat production from the straw CHP unit shown in red colour (with a heating capacity of 45 MW and annual operating hour of 5500 hours) and the heat production from the proposed straw fired peak load boiler shown in green colour (with a heating capacity of 34 MW), while the blue colour shows the necessary heat blow off in case the CHP unit will operate 5500 hours per year on full load. Table 23 shows the heat and power production as well as the necessary blow off in case the CHP unit is in operation 5500 hours per year at full load.

Figure 9. Heat Demand and Heat Productions.

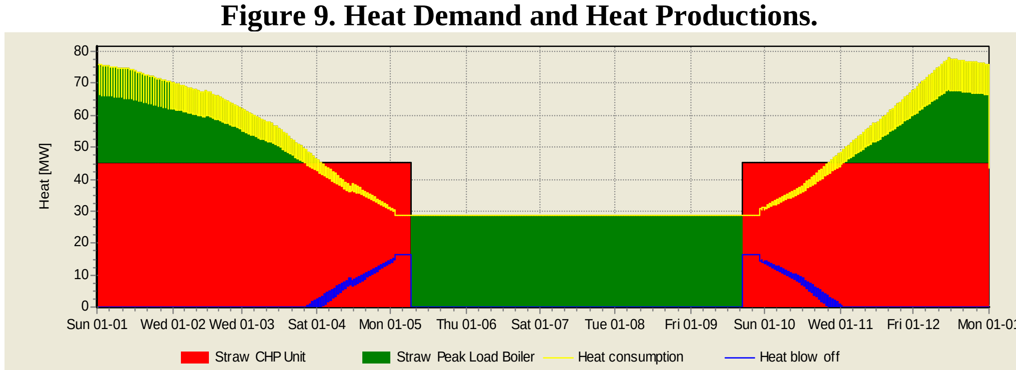


Table 23. Heat and Power Production.

		CHP unit	Peak load boiler
Power	MWh/y	137.500	

Heat/steam	MWh/y	247.500	158.459
Blow off	MWh/y	-17.341	

6.1.4 Fuel Supply and Price for the Ulanhot Straw Co-generation Plant

It is estimated that the 25 MW Ulanhot straw co-generation plant will require approximately 192,000 tonnes of straw per year (of which 25% is used by the peak load boiler), which can be supplied within 20-30 km radius. The main fuel supply would be straw from maize. Table 24 shows the amount of available agriculture residues for the cogeneration plant within 10, 15, and 30 km radius from the proposed site.

Table 24. Straw Supply for the Ulanhot Plant

Distance from plant	Available Resource in ton/year
10 km	105,000
15 km	198,000
30 km	324,000

Table 25 lists a break-down cost for straw fuel delivered to the plant. The average moisture content for the delivered straw should not be higher than 15 % - equivalent to a low calorific value of 15 GJ/ton. The straw price delivered to the power plant is 200 Yuan/ton, or 13.4 Yuan/GJ. The straw is planned delivered at the power plant as big bales of 500 kg. If the plant is running on full load 24 hours a day, around 700 tonnes of biomass a day shall be transported to the plants, equivalent to 70 truck loads every 10 tonne.

Table 25. Delivered Straw Prices

	Maise	Rice	Other	Total	
Resource	100	100	100		Yuan/t
Cutting	68	68	68		Yuan/t
Balling	25	25	25		Yuan/t
Transport	7	7	7		Yuan/t
Total	200	200	200		Yuan/t
Amount	160,000	11,000	29,000	200,000	ton/y
Lower calorific value	14.97	14.97	14.97		GJ/t
Price per GJ	13.36	13.36	13.36		Yuan/GJ
Average distance	14	14	14		
Yuan/t/km	0.50	0.50	0.50		

While there is sufficient fuel available in the neighbourhood of the co-generation plant, worldwide experience demonstrated that a reliable supply of biomass fuel to the co-generation plant at a low price over a 20-year period is a common constraint to large-scale biomass co-generation plants, particularly for scattered biomass fuels like straw. Therefore, the straw collection mechanism is critical to the success of this proposed plant. This study recommended that a fuel supply company should be established to be responsible for managing the logistics and delivery of the biomass resources to the plant. The co-generation

plant should sign a fuel supply contract with this fuel company, which could then sign fuel supply subcontracts with farmers in the area. The study also suggested that the delivered straw price should be based on its heating value (or moisture content), instead of only by weight, to control the quality of the delivered fuel.
A straw storage is planned built at the plant site to cover the fuel demand for 2-3 weeks. This means that the timing and delivery of the fuel supply to the power plant shall be in accordance with the demand. Given the limited storage area at the plant site, it would require the fuel supply company or the local farmers to store the biomass fuels.

6.1.5 Financial Analysis

This study conducted financial and economic analysis for the Ulanhot straw co-generation plant. The methodology of the economic and financial analysis for the co-generation plant is that the existing heating tariff is fixed as inputs to generate heating revenues, and then the cost of electricity is calculated.

In Ulanhot the heat tariff is 21 Yuan/m^2 for residential consumers and 24 Yuan/m^2 for commercial consumers, which is expected to increase to 24 Yuan/m^2 for residential consumers and 30 Yuan/m^2 for commercial consumers respectively. Since the Ulanhot co-generation plant will meet future heating demand, the planned increased residential heating tariff of 24 Yuan/m^2 is adopted for the financial analysis. It is assumed that the Heat Supply Company will invest and construct the district heating network, and purchase the heat from the biomass co-generation plant. Assuming that the costs for the heating transmission and distribution network are roughly estimated to be 25% of the co-generation plant cost and adding estimated O&M costs for the network, this gives a heating tariff of 18.02 Yuan/m^2 at the plant gate. A steam tariff of 66.4 Yuan/t is applied for the financial analysis, based on information provided by the Chinese team.

The total investment cost for the project is estimated to be 335 million Yuan, or about US$40 million[9], including US$32.5 million for the turnkey EPC contract cost for the biomass cogeneration unit (equivalent to $1300/kW installed power capacity) and US$3 million for the 34 MW peak load biomass boiler. Since the heat generated will be sold to the heat supply company, the cost of heating transmission and distribution network is not included in the CHP plant investment cost.

On financing terms, China requires a minimum equity of 20%. Xing'An Meng government is keen to request for World Bank loans to support these two pilot projects. Therefore, the World Bank loan term to China -- an interest rate of

[9] The investment cost is quoted from Dragon Power in Beijing, who is building a similar biomass co-generation plant in China. The company is a partner with two Danish biomass power plant suppliers - BWE and BIOENER.

4.96% and a repayment period of 20 years[10] -- is used for the financial analysis. To assess the commercial viability of the pilot project, this study also conducted a financial analysis scenario, using domestic banking loan terms with an interest rate of 5.5% and a repayment period of 10 years.

As shown in Table 26 of the assumptions and results of the financial analysis, if the power tariff is set at 0.50 Yuan/kWh, which is proposed by the Chinese team, the project FIRR is 9.1% and IRR on equity is 23.9%. The project FIRR exceeds its expected Weighted Average Cost of Capital (WACC) of 7%[11], and the project is financially viable.

Table 26. Financial Analysis for the Ulanhot Co-generation Plant

Assumptions:		
Power capacity	25	MW
Heat capacity	45	MW
Power efficiency, total	25	%
Power efficiency, annual average	23	%
Power production, net	123,750	MWh/year
Heat/steam production	406,000	MWh/year
Heat blow-off	17,000	MWh/year
Equity capital	20	%
Loan	80	%
Loan period	20	years
Average loan interest	4.96	%
Heat tariff to plant	18.02	Yuan/m^2
Power tariff to plant	0.50	Yuan/kWh
Fuel cost	13.4	Yuan/GJ
Results:		
Power generation cost	0.37	Yuan/kWh
FIRR by power tariff 0.50 Yuan/kWh	9.1	%
IRR on equity	23.9	%

6.1.6 Sensitivity Analysis

The financial viability of the Ulanhot biomass co-generation plant critically depends on a few assumptions made in the financial analysis, including desired financial internal rate of return for the project, biomass fuel price, heating tariff, and loan terms. This study conducted sensitivity analysis to assess these uncertainties.

[10] The World Bank interest rate is LIBOR rate plus 0.39% for variable-spread loan. The LIBOR rate as of November 15, 2005 was 4.57%. Repayment period includes 15 years repayment plus 5 years grace period.

[11] WACC is calculated on the basis of the financing sources of both pilot projects -- 80% loan from the World Bank (the interest rate was assumed as 5%) and 20% equity with its target rate of return of 15%.

As shown in Table 27, if the project FIRR is expected to be above 10% to attract private investors, the power purchase tariff would increase to 0.53 Yuan/kWh, which gives an IRR on equity of 27.5%. With biomass fuel price varying 20%, the financial cost of electricity is sensitive to fuel price (16%). As shown in Table 28, if biomass fuel price can reduce to 160 Yuan/ton, then the financial cost of electricity would reduce to 0.31 Yuan/kWh.

If the project is financed by local bank with an interest rate of 5.5% and a repayment period of 10 years, the financial cost of electricity will substantially increase to 0.41 Yuan/kWh.

Table 27. Proposed Tariff to get 6, 10 and 15% Financial Internal Rate of Return.

Feed-in tariff (Yuan/kWh)	0.413	0.527	0.695
Generation cost, power, Yuan/kWh	0.37	0.37	0.37
Financial internal rate of return, %	6.2	10.0	15.0
IRR on equity, %	11.2	27.5	49.0

Table 28. Sensitivity on the Biomass Price.

Biomass, Yuan/ton	160	200	240
Generation cost, power, Yuan/kWh	0.31	0.37	0.43

6.1.7 Economic Analysis

The heat and power generated from the Ulanhot straw co-generation plant will be used to meet the future demand from the nearby new development zone to be built. The economic analysis adopted the same assumptions of investment cost, fuel price, and plant efficiency as those in the financial analysis. The economic analysis adopted the avoided cost of 5 MW heat-only boilers as the heating cost, which is estimated to be 24.6 Yuan/m^2. A discount rate of 12% is used.

The levelized economic cost of electricity is estimated to be 0.420 Yuan/kWh. The baseline of power import from the Northeast Grid has an economic cost of 0.455 Yuan/kWh including the external costs. The Northeast Grid has sufficient capacity to export power to Xing'An Meng region in the future. As shown in Table 29, the study concluded that the Ulanhot Straw Co-generation plant is economically attractive.

Table 29. Economic Analysis for the Ulanhot Co-generation Plant (Yuan/kWh)

	Economic cost excluding external costs	Economic cost including external costs
Ulanhot 24 MW biomass cogeneration	0.420	0.420
Power import from Northeast Grid	0.327	0.455

6.2 Arxan Wood Co-generation Plant

6.2.1 Introduction

The Arxan Local Government proposed a 12 MW wood chip fired cogeneration plant located near Arxan city in the Northwestern part of Xing'an Meng region. The cogeneration plant is planned to meet the present and future heat demand in two development zones in Arxan and supply power to the grid. Two potential project sites are proposed. The first site is situated 3 km outside the city, 3 km from the 66 KV grid, and with good road conditions. The disadvantage of this site is its relatively long distance to the city, the power grid and the railway. The heat demand for this site is expected to be 400,000 m^2. This site is on state-owned land, and no resettlement is required.

The second site is situated on the outskirts of the city, 1.5 km from the grid but with bad road conditions. The advantage of this site is that it is close to the city, the 66 KV grid and the railway. The heat demand is expected to be 700,000 m^2, which will partially replace existing dispersed small-scale inefficient coal-fired or wood-fired heating boilers and meet future heating demand. This site is on the land owned by the Arxan forestry bureau, and requires relocation of a few households. The second site is located 3 km North-East of the first option. From the survey, the second site is promising due to the greater heat demand and closer to the heat consumers.

The power plant will be connected to the nearest a 66 kV transformer station which is further connected to the North East Grid. The grid from Aershan to Ulanhot has available capacity up to 24 MW. The local power demand is informed to be approximately 85 GWh per year, which nearly can be covered by the proposed plant.

The project developer is yet to be identified, and the power off-taker is the Inner Mongolia Power Group. Under existing Chinese regulations, power generators can not directly sell electricity to consumers.

6.2.2 Heat Demand and Duration Curve

According to the Xing'An Meng local authority, the planned Arxan wood co-generation plant is expected to meet heating demand for a total heating area of 700,000 m^2, including an existing heating area of 400,000 m^2 that will be replaced by the biomass plant, and additional heating area of 200,000 m^2 for new development zone as well as 100,000 m^2 for port area. The heat demand will reach 1 million m^2 after finalization of new administration, residential and economic area.

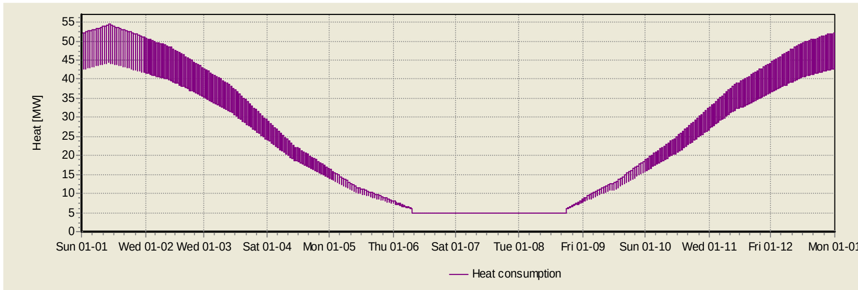
As no information is available for specific heat demand in Arxan, the specific heat demand was estimated to 0.88 GJ/m2 based on international experienced and winter temperature and duration in Arxan. Table 30 shows the detailed heat demand and the heat loss used in the financial analysis, and Figure 10 is the duration curve, which includes the net heat demand and the network loss.

Table 30. Heat and Steam Demand

	2007	2008	2009	2010	
Heated area	700.000	700.000	700.000	700.000	m2
Factor	88,00	88,00	88,00	88,00	GJ/100m2
Net heat demand	616.000	616.000	616.000	616.000	GJ/y
Steam demand	0	0	0	0	t/y
Steam demand	0	0	0	0	GJ/y

Heat + steam	616.000	616.000	616.000	616.000	GJ/y
Heat loss	154.000	154.000	154.000	154.000	GJ/y
Total	770.000	770.000	770.000	770.000	GJ/y
Total	213.889	213.889	213.889	213.889	MWh/y

Figure 10. Duration Curve for Net Heat /steam Demand and the Network Loss.



6.2.3 Technical Design and Size of the Biomass Co-generation Plant

Similar to the Ulanhot straw co-generation plant, the heat capacity of a biomass CHP plant is normally designed to cover 50-60% of the peak load demand, based on a heat demand duration curve. It is a common practice to install a back-up peak load heating-only boiler to meet the rest of the peak load demand.

The Arxan CHP has a power/heat ratio of 1:2.5 (power efficiency 25% and heat efficiency 58%) and a heat/steam capacity of approximately 30 MW, which will meet 55% of the peak load demand. This means that it will be necessary to in stall a wood fired peak load boiler of approximately 25 MW. Figure 11 demonstrates the heat production from the wood CHP unit shown in red colour (with a heating capacity of 30 MW and an annual operating hour of 6500 hours, and heat production from the proposed wood fired peak load boiler shown in green colour (with a heating capacity of 25 MW), while the blue colour shows the necessary heat blow off in case the CHP unit will operate 6500 hours per year on full load. Table 31 shows the heat and power production as well as the necessary blow off in case the CHP unit is in operation 6500 hours per year at full load.

Figure 11. Heat Demand and Heat Productions.

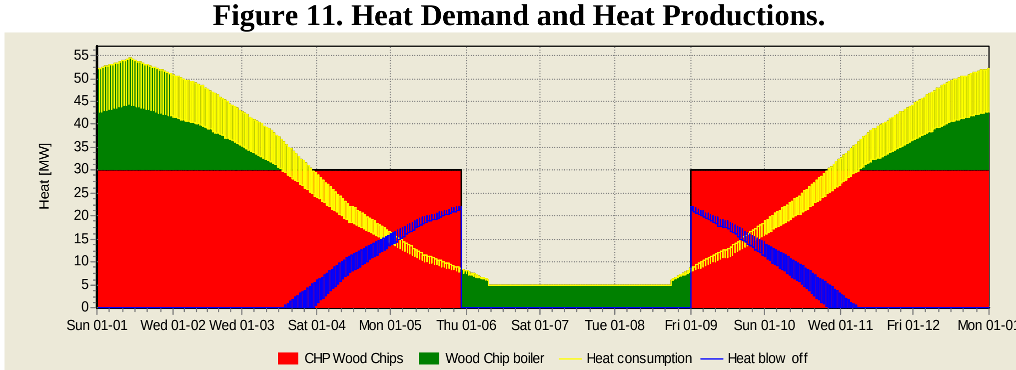


Table 31. Heat and Power Production.

		CHP unit	Peak load boiler
Power	MWh/y	78.000	
Heat/steam	MWh/y	195.000	56.043
Blow off	MWh/y	-37.154	

6.2.4 Fuel Supply and Price for the Aershan Wood Co-generation Plant

It is estimated that the 12 MW Arxan wood co-generation plant requires about 110,000 tonnes of wood per year (of which 17% is used by the peak load boiler), which can be supplied within a 15 km radius. Table 32 shows the amount of wood residues available for the plant within 10 and 15 km radius from the proposed site.

Table 32 Available Wood Supply for the Plant

Distance from plant	Available Resource in tonne/year
10 km	99,000
15 km	225,000

Table 33 lists a break-down cost for wood fuel delivered to the plant. The average moisture content for the delivered wood chips should be in the range of 10 - 40 % - equivalent to an average low calorific value of 13.2 GJ/ton. The delivered wood price to the power plant is estimated to be 208 Yuan/ton, or 15.8 Yuan/GJ. The wood chips are planned delivered at the co-generation plant based on an agreed-upon standard. If the plant is running on full load 24 hours a day, around 400 tonnes of biomass a day shall be transported to the plant – equivalent to 40 truck loads of each 10 tonne.

Table 33. Delivered Wood Price

	Saw Mill waste Yuan/ton	Harvest waste Yuan/ton	Dead wood Yuan/ton
Resource	40	30	30
Processing in forest	0	0	35
Extraction to road	0	50	50
Total	40	80	115
Chipping	70	70	70
Storage	25	25	25
Road side costs	135	175	210
Transport	7	7	7
Total	142	182	217
Average distance	7	7	7
Yuan/t/km	1	1	1
Amount for plant (ton/year):	13,000	37,000	75,000
GJ/t	15.5	10.8	15.5
Yuan/GJ	9.16	16.85	14.00

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To ensure a reliable fuel supply, the three Forest Bureaus in Arxan area have expressed interests in signing long-term fuel supply contracts with the co-generation plant. The study considers this arrangement an excellent idea, and recommended that the fuel supply contract should be based on the heating value of the fuel in terms of Yuan/GJ. A wood storage is planned built at the plant site to cover the fuel demand for 2-3 weeks. This means that the timing and delivery of the fuel supply to the co-generation plant shall be in accordance with the demand. Given the limited storage area at the plant site, it would require the forest bureaus to store the biomass fuels.

6.2.5 Financial Analysis

This study conducted financial and economic analysis for the Arxan wood co-generation project. The methodology of the economic and financial analysis for the co-generation plant is that the existing heating tariff is fixed as inputs to generate heating revenues, and then the cost of electricity is calculated.

In Arxan the residential heating tariff is 32.6 Yuan/m^2, which is adopted in the financial analysis. It is assumed that the Heat Supply Company will invest and construct the district heating network, and purchase the heat from the biomass co-generation plant. Assuming that the costs for the heating transmission and distribution network are roughly estimated to be 25% of the co-generation plant cost and adding estimated O&M costs for the network, this gives a heating tariff of 27.51 Yuan/m^2 at the plant gate.

The total investment for the project is estimated to be 213 million Yuan, or US$26 million[12], including US$20.4 million for the turnkey EPC contract cost for the biomass cogeneration unit (equivalent to $1700/kW installed power capacity) and US$2 million for the 25 MW peak load biomass boiler. Since the heat generated will be sold to the heat supply company, the cost of heating transmission and distribution network is not included in the CHP plant investment cost.

On financing terms, China requires a minimum equity of 20%. Xing'An Meng government is keen to request for World Bank loans to support these two pilot projects. Therefore, the World Bank loan term to China -- an interest rate of 4.96% and a repayment period of 20 years (15 years repayment period plus five years grace period) -- is used for the financial analysis. To assess the commercial viability of the pilot project, this study also conducted a financial

[12] The investment cost is quoted from Dragon Power in Beijing, who is building a 25 MW biomass co-generation plant in China. They are partners with the two Danish biomass power plant suppliers - BWE and BIOENER. The number is also confirmed with Danish experience of similar scale of biomass co-generation plants.

analysis scenario, using the domestic banking loan terms with an interest rate of 5.5% and a repayment period of 10 years.

As shown in Table 34 of the assumptions and results of the financial analysis, if the power tariff is set at 0.50 Yuan/kWh, which is proposed by the Chinese team, the project FIRR is 7.0% and IRR on equity is 14.8%. With CDM revenues at \$6/ton CO_2, the project FIRR can be improved to 7.9%. Therefore, with carbon credit, the project FIRR exceeds its expected Weighted Average Cost of Capital (WACC) of 7%, and the project becomes financially viable.

Table 34. Financial Analysis for the Arxan Co-generation Plant

Assumptions:		
Power capacity	12	MW
Heat capacity	30	MW
Power efficiency, total	25	%
Power efficiency, annual average	23	%
Power production, net	70,200	MWh/year
Heat/steam production	251,000	MWh/year
Heat blow-off	37,150	MWh/year
Equity capital	20	%
Loan	80	%
Loan period	20	Years
Average loan interest	4.96	%
Heat tariff to plant	27.51	Yuan/m^2
Power tariff to plant	0.50	Yuan/kWh
Fuel cost	15.8	Yuan/GJ
Results:		
Power generation cost	0.43	Yuan/kWh
FIRR by power tariff 0.50 Yuan/kWh	7.0	%
IRR on equity	14.8	%

6.2.6 Sensitivity Analysis

The financial viability of the Arxan biomass co-generation plant critically depends on a few assumptions made in the financial analysis, including desired financial internal rate of return for the project, biomass fuel price, heating tariff, and loan terms. This study conducted sensitivity analysis to assess these uncertainties.
As shown in Table 35, if the project FIRR is expected to be above 10% to attract private investors, the power purchase tariff would increase to 0.60 Yuan/kWh, which gives an IRR on equity of 27.5%. With biomass fuel price varying 20%, the financial cost of electricity is sensitive to fuel price (16%). As shown in Table 36, if biomass fuel price can reduce to 166 Yuan/ton, then the financial cost of electricity would reduce to 0.36 Yuan/kWh.

If the project is financed by local bank with an interest rate of 5.5% and a repayment period of 10 years, the financial cost of electricity will substantially increase to 0.47 Yuan/kWh.

Table 35. Feed-in Tariff to get 6, 10 and 15% Financial Internal Rate of Return.

Feed-in tariff (Yuan/kWh)	0.475	0.603	0.790
Generation cost, power, Yuan/kWh	0.43	0.43	0.43
Financial internal rate of return, %	6.2	10.0	15.0
IRR on equity, %	11.3	27.5	48.8

Table 36. Sensitivity on the Biomass Price.

Biomass, Yuan/ton	166	208	250
Generation cost, power, Yuan/kWh	0.36	0.43	0.49

6.2.7 Economic Analysis

The heat and power generated will be used to meet future demand from the nearby new development zone where the local government will move to, and replace some of the existing small-scale coal-fired heating boilers in the nearby old town. The economic analysis adopted the same assumptions of investment cost, fuel price, and plant efficiency as those in the financial analysis. The economic baseline cost of small coal-fired heat-only boilers is estimated to be 26.4 Yuan/m^2, which is adopted as heating cost at plant gate.

Then, the heating revenues are calculated and fixed, and the levelized cost of electricity is derived. A discount rate of 12% is used. The economic cost of electricity is estimated to be 0.603 Yuan/kWh. The economic baseline cost of power import from the Northeast Grid is estimated to be 0.377 Yuan/kWh without external costs, and 0.519 Yuan/kWh including the external costs of particulates, SO_2, NOx, and CO_2 emissions from the power import and small coal-fired heating boilers. Therefore, biomass co-generation is concluded to be not economically viable. Table 37 demonstrates the economic analysis of Arxan wood co-generation plant.

Table 37. Economic Analysis of Arxan Wood Co-generation Plant (Yuan/kWh)

	Economic cost excluding external costs	Economic cost including external costs	
Arxan 12 MW wood cogen	0.603	0.603	
Power import from Northeast Grid	0.377	0.519	

7 RECOMMENDATIONS FOR XING'AN MENG BIOMASS ENERGY DEVELOPMENT STRATEGY

7.1 Biomass Energy Potential in Xing'An Meng

This study confirmed that Xing'An Meng has a large biomass resource potential, with 4.1 million tonnes of total biomass resources available for power and heat, of which 1.6 million tonnes agriculture residues, 1.5 million tonnes wood residues, and 1 million tonnes energy plantations.

The total **technical biomass energy potential** based on biomass resources, power and heat demand is estimated to be 300 MW of cogeneration, 208 MW of power only, and 123 MW heat only boilers in 2015. However, if the biomass resources in Arxan would only be used for meeting local demand and not exported to Ulanhot, the total technical biomass potential is estimated to be 270 MW for co-generation, 138 MW for power-only, and 123 MW for heat-only options in 2015.

The total **economically viable biomass energy potential** is estimated to be 258 MW co-generation and 103 MW heat only boilers in 2015. The biomass power-only option is found not to be economically viable.

7.2 Xing'An Meng Biomass Energy Development Strategy

To achieve the economically viable biomass potential in Xing'An Meng, this study recommended Xing'An Meng government to develop a master plan for biomass energy in the future. The future heat and power planning at both Xing'An Meng level and municipality level should include renewable energy, particularly biomass energy. Such a biomass energy development program should include the following considerations:

To meet future growing demand for power and heat, this study recommends that Xing'An Meng should develop biomass co-generation plants in the capital cities of the six counties. This will replace the future coal-fired co-generation plants under planning, as well as reduce power import from the Northeast Grid. The optimum size for such a biomass co-generation plant would be 20 – 25 MW, fuelled by sawmill residues and straw.

The power generation cost from a biomass cogeneration plant depends on the size of the plant and the heat design optimization. The study found that a 12 MW biomass co-generation is not economically viable. Optimizing the heat design for the biomass co-generation plants to generate revenues for both heat and steam is essential to substantially improve the economical viability of the plants. For example, "constant" steam demand for industries and decentralised hot tap water as part of the heat supply, particularly in new developments zones, can reduce the power generation costs of cogeneration plants.

It should be emphasize that a reliable biomass fuel supply to the biomass co-generation plants at a low price is critical to the success of such plants. Worldwide, this is a common constraint to large-scale biomass co-generation plants. This study recommends that a fuel supply company shall be established to be responsible for managing the logistics and delivery of the biomass resources to the plant. The co-generation plant should sign a fuel supply contract with forestry bureaus or the straw supply company, who could then sign fuel supply subcontracts with farmers in the area. The study also suggested that the delivered biomass price should be based on its heating value (or moisture content), instead of weight, to control the quality of the delivered fuel.

In smaller cities of the six counties, this study recommends that Xing'An Meng should develop biomass heat-only boilers to replace existing coal-fired heating boilers, which have resulted in serious air pollution in the winter, as well as meet future growing heating demand. The optimum size for such a biomass heat-only boiler would be 1-10 MW, fuelled by straw.

While Arxan has more biomass resources to meet its local demand, the study concluded that exporting power from Arxan to Ulanhot through a 300 km transmission line is not an economical option.

While biomass resources are cost competitive with the alternative fuel coal in Xing'An Meng, there is a large variation in costs for biomass fuels from different sources, ranging from the lower cost sawmill wastes and straw to the most expensive energy plantations.

7.3 Financial Analysis and Recommendations for Financial Incentive Policies

This study conducted financial analysis for biomass co-generation, biomass power-only, and biomass heat-only options. Based on the results of the financial analysis, we made a preliminary assessment of the needed financial incentives to attract investors in biomass energy projects.

7.3.1 Financial Analysis

Financial analysis was conducted for 1) a 12 MW and a 25 MW biomass cogeneration plants; 2) a 5 MW and a 20 MW biomass power only plants; and 3) a 2 MW and a 5 MW biomass heat only plants, as shown in Table 38 and 39 respectively. Figure 12 compares financial cost of electricity for a 12 MW and a 25 MW biomass cogeneration plants as well as for a 5 MW and a 20 MW biomass power only plants.

It is concluded that there are incremental financial costs for biomass co-generation and power-only options compared to baseline coal-fired co-generation, while biomass heat-only boilers are financially viable compared to baseline.

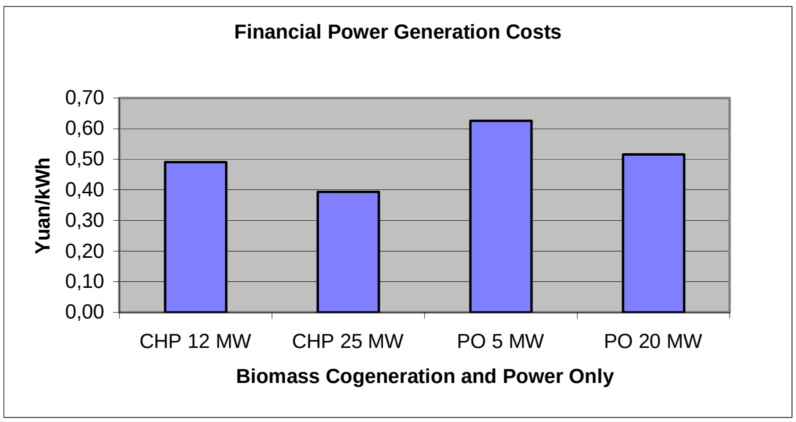
Table 38. Comparison of Financial Cost of Biomass Co-generation, Power-Only and Heat-Only

Production Unit	Yuan/kWh[13]
Baseline (coal fired CHP)	0.31
12 MW Biomass CHP	0.49
25 MW Biomass CHP	0.39
5 MW Biomass power Plant	0.62
20 MW Biomass power Plant	0.52

Table 39. Comparison of Financial Cost of Biomass-fired and Coal-fired Heating Boilers

Production Unit	Yuan/GJ
New 5 MW coal fired Heating Plant	41
New 2 MW Biomass Heating Plant	34
New 5 MW Biomass Heating Plant	32

Figure 12. Comparison of Financial Power Generation Costs



7.3.2 Recommendations for Financial Incentive Policies

The financial analysis demonstrated that the main barrier to large-scale development of biomass energy is who should pay for the incremental financial costs. The Inner Mongolia Power Group, the power off-taker, has expressed reluctance to purchase the power. While biomass co-generation is the least-cost option compared to baseline cost with external cost, only biomass co-generation from sawmill residues is economically viable compared to baseline cost without externalities. The financial analysis demonstrated that at a baseline power purchase tariff of 0.29 Yuan/kWh in Xing'An Meng, biomass co-generation and power-only options are not commercially viable.

National renewable energy policies are required to address this issue. The newly passed Chinese Renewable Energy Law requires the utilities mandatory purchase of power from renewable energy sources. However, the Regulation of the Law should set

[13] This calculation assumes 45 Yuan/GJ heating tariff. For comparison, consumer heat tariff in Ulanhot is expected to increase to 27 Yuan/m2 (51 Yuan/GJ), while in Arxan, the actual cost per square meter was informed to be 40 Yuan/m2 (45 Yuan/GJ).

a feed-in tariff level high enough to attract biomass energy developers, and specify who will absorb the incremental costs.

This study assumed that an IRR on equity should be above 15% to attract investors in biomass energy projects. Table 40 shows the proposed power tariff level for biomass co-generation and power-only options, based on this assumption. The results demonstrated that the tariff needed to make biomass cogeneration plants (both 12 MW and 25 MW) and power-only plants (20 MW) financially feasible would be 0.54-0.65 Yuan/kWh. Therefore, the needed incremental tariff is in a range of 0.25-0.36 Yuan/kWh.

Table 40. Proposed power tariff to get 15% internal rate of return on equity

	CHP 12 MW	CHP 25 MW	PO 5 MW	PO 20 MW
Power tariff to get 15% IRR on equity (Yuan/kWh)	0.67	0.54	0.77	0.61

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ANNEX 1 – Heat Demand in Xing'An Meng

Largest Cities - Table one

City	Citizen	Heated area (Million m^2)	Present heating system				
			Central heating plant %	Small boiler stations %	Stoves %	Development in heated area % per year	Heated area can in future be heated by biomass (by the end of 2010) %
Ulanhot	234,000	12.976	27.7	34.7	37.6	15	9.6
Tuquan	49,700	2.599	__	7.7	92.3	10	45.0
Aershan	37,000	2.039	__	19.6	80.4	9	28.0
Yinder	57,300	2.946	__	13.6	86.4	12	24.0
Baiyinhushuo	46,400	1.912	__	17.8	82.2	10	40.0
Dabagou	__	__	__	__	__	__	__

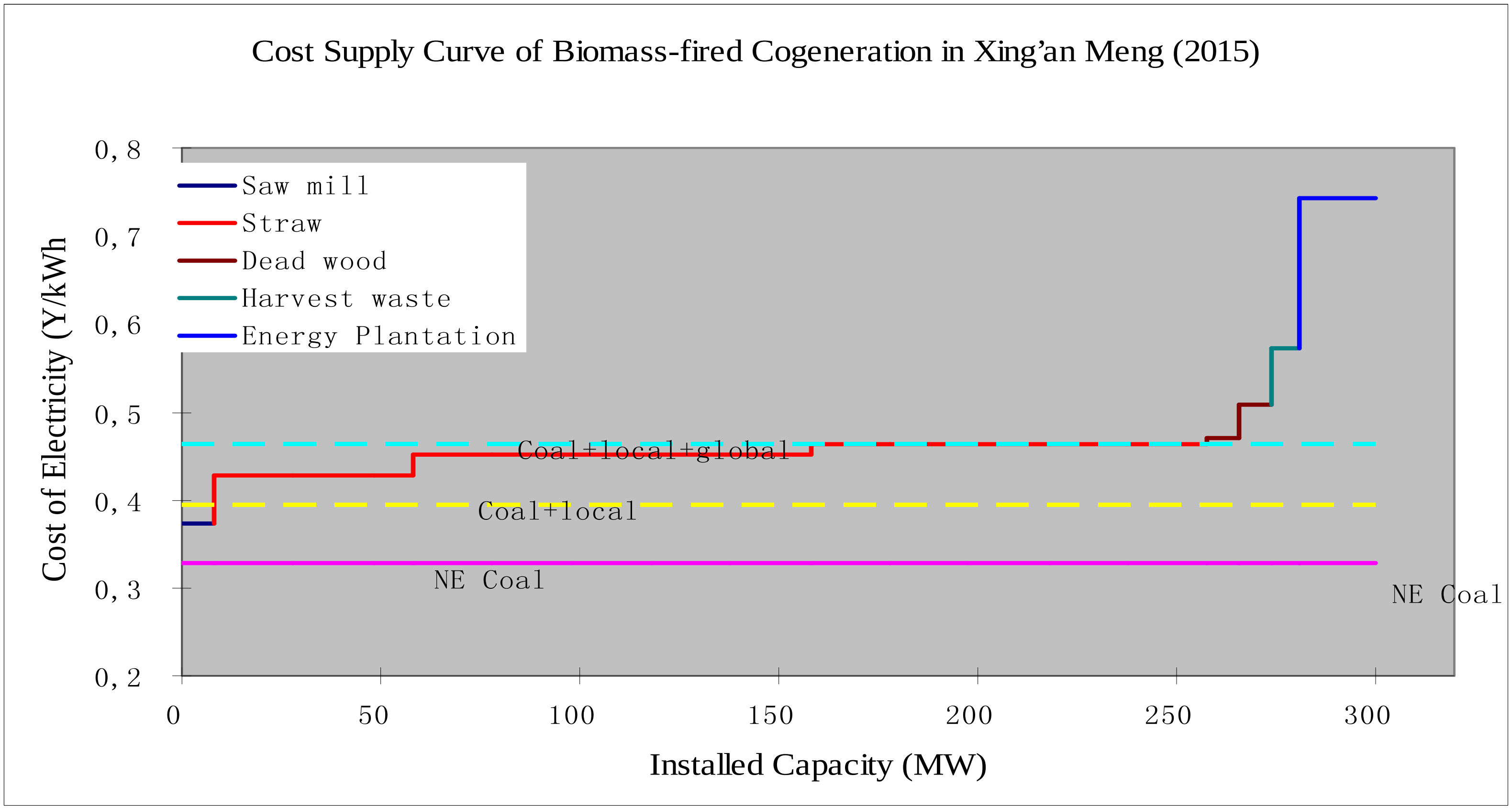
Cities With A Population Over 3000 - Table two

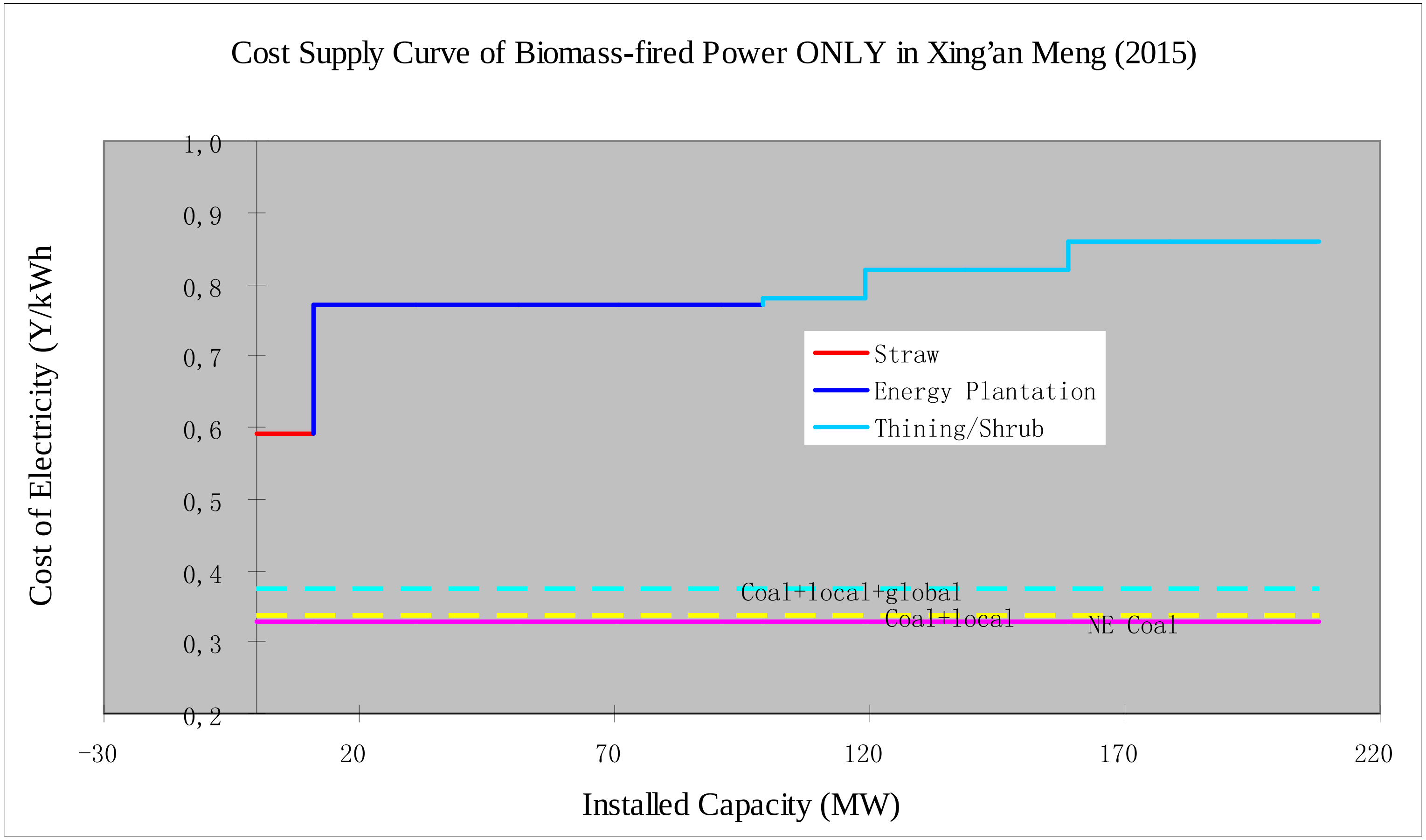
Number	City	Present heating system						
		Citizen	Heated area (million m^2)	Central heating plant %	Small boiler stations %	Stoves (%)	Development in heated area % per year	Capacity of new biomass Boiler MW
1	Wuchagou	4664	0.179	–––	8.4	91.6	8	13.1
2	Mingshuihe	3286	0.132	–––	7.6	92.4	6	7.3
3	Erti	3596	0.133	–––	6.0	94.0	6	4.4
4	Suolun	3172	0.125	–––	8.0	92.0	6	4.2
5	Haorensumu	3092	0.085	–––	8.2	91.8	4	2.0
6	Chaersen	4051	0.135	–––	7.4	92.6	6	4.5
7	Ergetu	4121	0.129	–––	9.3	90.7	6	4.3
8	Dayouzhai	5071	0.195	–––	7.7	92.3	8	8.6
9	Halahei	5074	0.195	–––	5.7	94.3	8	8.6
10	Guiliuhe	4521	0.161	–––	8.1	91.9	7	6.2
11	Weidong	3614	0.121	–––	7.0	93.0	5	3.4
12	Gaoliban	4761	0.156	–––	5.8	94.2	6	5.2
13	Tuliemaodu	3247	0.108	–––	12.1	87.9	5	3.1
14	Tuliemaodu	3540	0.138	–––	7.2	92.8	5	3.9
15	Mengen	4932	0.198	–––	10.1	89.9	8	8.8
16	Bayangaole	5463	0.169	–––	8.9	91.1	7	6.5
17	Xinlin	4738	0.158	–––	13.9	86.1	7	6.2
18	Huerle	3638	0.128	–––	7.8	92.2	6	4.3
19	Liuhu	3805	0.123	–––	13.8	86.2	6	4.2
20	Duerji	3402	0.1	–––	10.0	90.0	5	2.9

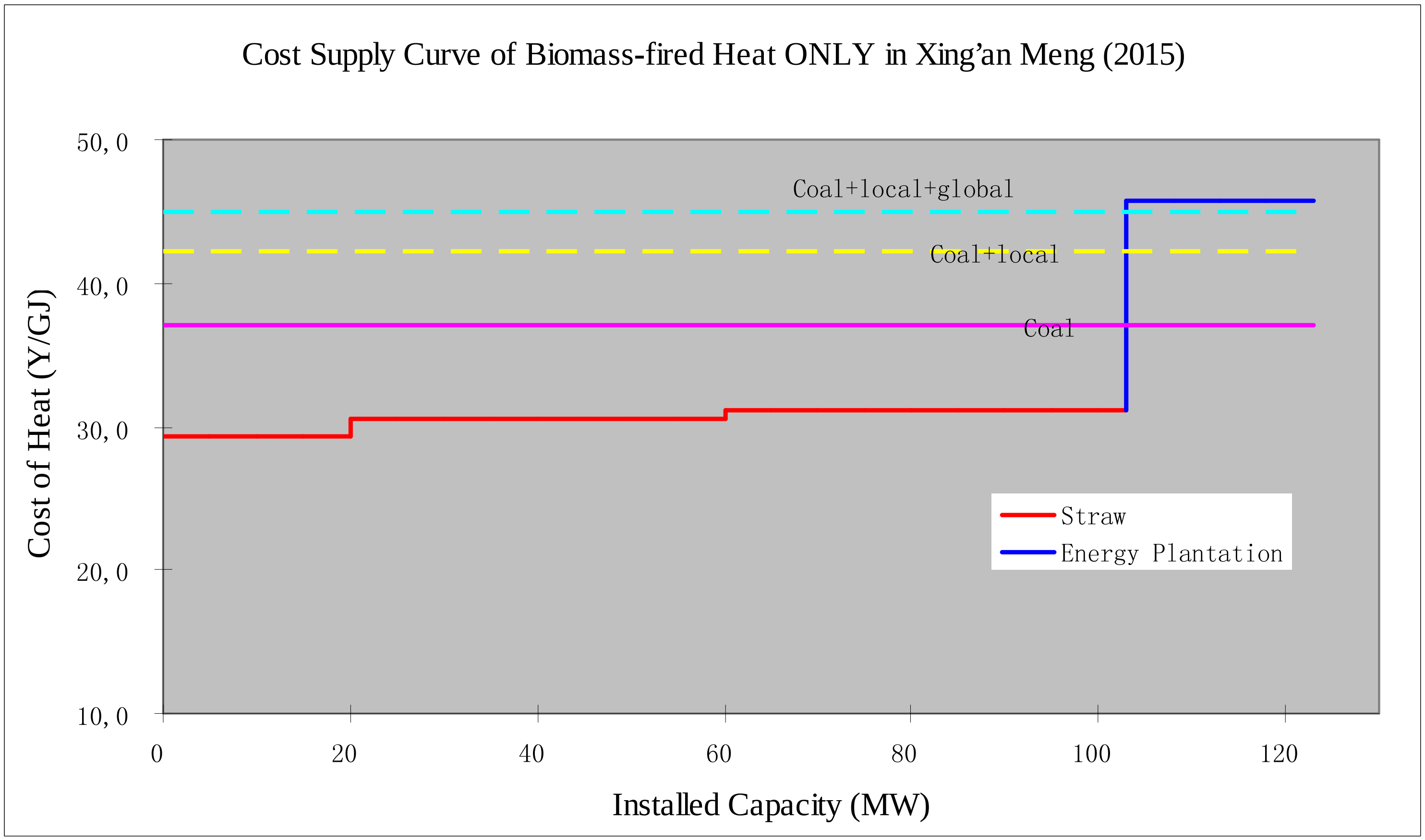
Other Cities With A Population Between 2000-3000 - Table three

Number	City	Present heating system						
		Citizen	Heated area (m^2)	Central heating plant %	Small boiler stations %	Stoves%	Development in heated area % per year	Capacity of new biomass Boiler MW
1	Julihen Town	2300	37,000	----	14.3	85.7	3	0.8
2	Bailang Town	2536	41,000	----	27.7	72.3	3	1.5
3	Shumuhao	2715	43,000	----	14.5	85.5	3	0.9
4	Alideer	2896	46,000	----	16.2	83.8	3	1.0
5	Guji	2985	48,000	----	11.8	88.2	3	1.0
6	Balagedai	2235	36,000	----	16.8	83.2	3	0.8
7	Haoyao	2673	43,000	----	8.8	91.2	3	0.9
8	Barentaiben	2000	32,000	----	10.5	89.5	3	0.6
9	Bayannaoer	2384	38,000	----	7.9	92.1	3	0.8
10	Xinjiamu	2567	41,000	----	11.0	89.0	3	0.8
11	Bazhalage	2015	32,000	----	19.8	80.2	3	0.7
12	Barenzhelimu	2402	38,000	----	13.7	86.3	3	0.8
13	Budunhua Pasture	2739	44,000	----	18.8	81.2	3	0.9
14	Budunhua Copper Mine	2187	35,000	----	27.9	72.1	3	0.8
15	Zhuole	2469	40,000	----	15.2	84.8	3	0.8
16	Xiaochengzi	2190	35,000	----	17.1	82.9	3	0.7
17	Erlongshan	2506	40,000	----	14.0	86.0	3	0.8
18	Badai	2655	42,000	----	15.2	84.8	3	0.9
19	Nuwenmuren	2167	35,000	----	19.5	80.5	3	0.7
20	Handahan	2745	44,000	----	10.2	89.8	3	0.9
21	Bayanzhalaga	2883	46,000	----	8.1	91.9	3	0.9
22	Tumuji	2731	44,000	----	17.2	82.8	3	0.8
23	Aladaertu	2766	44,000	----	10.2	89.8	3	0.9
24	Baoligenhua	2388	38,000	----	9.8	90.2	3	0.8
25	Bayanwulan	2346	38,000	----	10.0	90.0	3	0.8
26	Badaerhu	2942	47,000	----	12.7	87.3	3	1.0
27	Aerbengele	2433	39,000	----	11.6	88.4	3	0.8
28	Yongan	2563	41,000	----	18.3	81.7	3	0.9
29	Halaqing	2361	38,000	----	15.9	84.1	3	0.8

ANNEX 2 – Cost Supply Curves




Cost Supply Curve of Biomass-fired Power ONLY in Xing'an Meng (2015)
Cost of Electricity (Y/kWh)
1, 0
0, 9
0, 8
0, 7
0, 6
0, 5
0, 4
0, 3
0, 2
-30
20
70
120
170
220
Installed Capacity (MW)
Straw
Energy Plantation
Thining/Shrub
Coal+local+global
Coal+local
NE Coal


Cost Supply Curve of Biomass-fired Heat ONLY in Xing'an Meng (2015)
Cost of Heat (Y/GJ)
50, 0
40, 0
30, 0
20, 0
10, 0
0
20
40
60
80
100
120
Installed Capacity (MW)
Coal+local+global
Coal+local
Coal
Straw
Energy Plantation