International Conference on Bioenergy Utilization and Environment Protection

Dalian, China

24-26 September 2003

Dalian Bangchui Island Hotel

CONFERENCE PROCEEDINGS

The International Conference on Bioenergy Utilisation and Environment Protection was held in Dalian, P.R. China, from September 24 – 26, 2003. It was organized jointly by the Latin American Thematic Network on Bioenergy (LAMNET), the Center for Energy and Environment Protection (CEEP) of the Chinese Ministry of Agriculture and the China Association of Rural Energy Industry (CAREI).

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Updated information on this workshop is available at http://www.bioenergy-lamnet.org.

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“国际生物能利用技术与环境保护研讨会”暨
“第六届LAMNET（拉丁美洲生物能专家工作网）研讨会”
International Conference on Bioenergy
Utilisation and Environment Protection
&6th L A M N E T Project Workshops
中 国 大 连
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International Conference on Bioenergy Utilization and Environment Protection

OBJECTIVES

To promote the international cooperation and knowledge exchange in the field of bioenergy technology as well as to promote the development of commercial biomass energy utilization in China in order to achieve an improvement of the national and international environment and to guarantee sustainable rural development.

SUMMARY

With regards to the availability of biomass resources from both agriculture and forestry, China's potential for biomass development and utilization is among the largest in the world. During the past years China has already devoted large efforts to research and development in the field of renewable energies. Thereby, biomass is regarded as a key resource for renewable energy generation and fruitful achievements have been made in biomass energy utilization.

Due to increasing concern about the environment and the security of energy supply, biomass energy attracts interests from developing as well as from developed countries worldwide.

Consequently, the **International Workshop on Bioenergy Utilization and Environment Protection** will bring together for the first time 60 specialists in China from the academic, private, government and industrial sectors. An overview of the current conditions of biomass energy use in China and in the world will be presented, focusing on the availability of resources, bioenergy conversion technologies and the development of policies for the promotion and financing of bioenergy. The workshop will also arrange several technical visits to biomass and bioenergy applications in the region of Dalian.

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CONFERENCE PROGRAMME

TUESDAY 23th SEPTEMBER 2003

19:00 - 22:00 Conference Registration (Dalian Bangchui Island Hotel, Building No. 9)

WEDNESDAY 24th SEPTEMBER 2003

Inauguration Session

08:30 – 08:45	Conference Welcome Address Prof. Wang Mengjie, CAREI, China	14
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09:00 – 09:20	Inauguration Address Prof. Zhu Junsheng, Vice President of CAREI & CREIA	

Session 1: Strategy and Policy Issues on Biomass Energy Development and Utilisation
Moderators: Wang Mengjie, CAREI, and Rainer Janssen, WIP

09:20 – 09:40	Development and Utilisation of Biomass Energy and Related Supporting Policies in China Prof. Gu Shuhua, Tsinghua University, China	19
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11:30 – 11:50	Combustion and Gasification with TPS Technology Mr. Tord Fjällström, Energidalen, Sweden	49
11:50 – 12:10	Implementation of Sugar Cane Bioenergy Projects in the Cuban Sugar Cane Agroindustry Dr. Paulino Lopez, Ministry of Sugar, Cuba	52

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13:00 – 14:30	Lunch Break (Building No. 9, Floor 1)	

Session 2: Biomass Technology Applications and Their Market Penetration Potential

Moderators: Li Jingming, Ministry of Agriculture, China and Tord Fjällström, Energidalen

THURSDAY 25th SEPTEMBER 2003

Session 3: Innovative Bioenergy Technologies: Research and Application
Moderators: Yao Xiangjun, CAREI & CEEP and Giuliano Grassi, EUBIA

Session 4: Economics and Bioenergy Project Financing

Moderators: Denis Tomlinson, Illovo Sugar Ltd. / Dr. Liu Wenqiang, State Committee of Development and Reform

Session 5: Biomass Resources and Agriculture

Moderators: Dr. Peter Grimm, WIP / Prof. Sun Minghu, Dalian Academy of Environment Science

FRIDAY 26th SEPTEMBER 2003

Technical field visit to Lü Shun (08:00 – 15:00) 131

- Gasification and gas supply stations fuelled with agricultural residues
- Organic municipal waste treatment and organic fertilizer production plant

18:00 Farewell Dinner

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CONFERENCE INAUGURATION

International Conference on Bioenergy Utilization and Environment Protection
6th LAMNET Workshop – Dalian, China 2003

CONFERENCE KEY NOTE SPEECH

Addressed by Prof. Hong Fuzeng
Vice President of September 3rd Society &
Former Vice Minister of Chinese Ministry of Agriculture

Ladies and Gentlemen, dear Guests,

I am pleased to be invited to participate in this **International Conference on Bioenergy Utilisation and Environment Protection & 6th LAMNET Project Workshop** and I would like to congratulate its successful opening and wish fruitful results from this conference. On behalf of the September 3rd Society, I also would like to express my warm welcome to all the experts and guests coming from far away.

Currently, with globalization and integrated development of economics, the question is how to realise the economic increase in accordance with the principal of sustainable development. How to develop economics and society and how to ensure economic as well as human resources development and environment protection. This is the common mission and the key subject that each country is facing today. The utilization of biomass is not only a source of vitality in the energy sector, but also an important field to set up circular economy models and realise sustainable development. Hence, I believe that the subject of this conference is significant with respect to the elaboration of advanced visions.

All the participants here are experts, researchers in this specific field. My work is related to this field for over a half century, however, I am personally not specialized in biomass. I can only share with you here some personal viewpoints for your consideration.

Firstly, China is a developing country, and also a country in the process of shifting from a planning economic system to a socialized marketing economic system in terms of economics. China is transforming from roughness to intensiveness in terms of management approach, from traditional backwardness to modern approaches in terms of science and technology, and from a closed and ancient oriental state to an open state of learning jointly with developing fine traditions in terms of culture. Indeed, China is in progress in recent years. As is well known, China suffered from SARS in the passed half year, but the GDP increase still reached around 8%, which resulted partially from the adoption of new technologies and the attribution of importance to energy conservation in production.

However, the past 25 years, during an opening to the outside world and many reforms, environmental protection environmental protection has not been given sufficient attention in many places. Some problems like irrational use of resources and environment pollution expressively occurred in some economic well-developed regions. Among them, large unclean energy consumption is one of the most important factors. Since the mid 80's, the state and governments have started to develop demonstration plants on solar, wind, and biomass energy utilization, and until now certain achievements have been made. In the early 90's, China was the first state to work out an "Agenda for the 21st Century" and listed sustainable development as a priority.

Secondly, to increase the contribution of biomass in the overall energy utilization structure is the assured choice of China. China is still a developing country with high energy consumption of unit production and with low energy use efficiency. The increasing energy demand with economic development, population increase, and the increasing need of people for better lifes requests us not only to put more emphasis on domestic energy exploitation and energy conservation with supplementary import, but also to explore a new potential energy source - biomass. The Chinese government is advocating a coordinative inter-active development between urban and rural areas. Interactive with respect to different regions, economic and social issues, international and national players as well as with respect to human beings and nature. To develop biomass energy resource is an absolutely necessary linkage, especially to China. Until now, China is still a country with a majority population living in rural areas and engaged in agricultural production. On the one hand there is an increasing demand for energy due to the improvement of people's living standard in rural regions. On the other hand, the rural area is also a production base for energy sources. To develop biomass is necessary and of high importance for China.

Thirdly, development and utilization of biogas is one of the most popular and effective biomass energy sources in China in recent days. Biogas technology has a long history in China. Some experts here have had discussions on this topic. I personally believe biogas technology is one of the biomass technologies that can be easily accepted by farmers because of its relatively low cost and high economic, social and ecological benefits. However, its popularization is not very fast due to some restrictions. E.g., in northern China the popularization of biogas technology started in the 50's of the last century, but the development speed is slow because there is little gas production with long winter seasons and cold climate. Until the 80's, a model that combines greenhouses for vegetable production, pig sty, toilet, and biogas digesters in one system was developed. This so-called "four-in-one" model leads biogas technology popularization into a new time. In the new century, the state has launched a program titled ***better-off engineering with eco-garden*** in order to develop biomass energy and improve farmers' lives. It integrates biogas production with sanitation, waste treatment and prevention of pollution, provides fuels for cooking and lighting. This program reduces the over-cutting of forestry, resulting in protection of vegetation, and it reduces disposal and direct combustion of crop residues in fields, resulting in improvement of air quality. The model adoption increases income of farmers, for it combines the development of garden economics with structure adjustment of crop plantation and animal husbandry. It becomes an effective systematic approach to promote the integrated development of rural civilization. The living quality and civilization of farmers with biogas systems is obviously improved. Thereby, the state is continuing to increase the input to develop the biogas systems gradually nationwide. It might become an effective and practical approach to construct the rural 'better-off' society in China.

Fourthly, biomass development and utilization has a prospective future, but needs wide cooperation among scientists. Taking biogas as an example, its dissemination still focuses on domestic application. Its large-scale development in farm households needs more advanced and quality-stable equipment as well as improved energy production and utilization technologies. To include biogas into overall energy planning of the state and the connection of biogas power generation with the grid may take a long way to go. In addition, introducing ethanol from sweet sorghum for ethanol-gasoline blends as well as gasification of crop residues requests great technical effort and cooperation among domestic and international scientists. To hold fora like this is beneficial to promote biomass utilization and development.

Now, I would like to propose a suggestion here. I suggest a to hold a senior consultation forum in Cangxi County of Sichuan Province in March of next year in order to promote biogas development in terms of technical and theoretical innovations, to summarize the experiences for a popularizing of improved engineering within the eco-garden concept, and study its comprehensive functions on coordinative development of economics, society, and environment. Integrated future development of biomass taking biogas as the focus will be the major subject of the consultation forum. All the experts and foreign friends here will be warmly welcome to present at the proposed forum.

Ladies and gentlemen, biomass utilization and development has a great potential for future utilisation. Taking this opportunity, I wish you great achievements in your working field and a fruitful conference. I hope that all the experts can work hard hand-in-hand to protect our earth, to promote the civilization of human beings, and to contribute to a future better life.

Thank you.

CONFERENCE INAUGURATION

International Conference on Bioenergy Utilization and Environment Protection
6th LAMNET Workshop – Dalian, China 2003

China Association of Rural Energy Industry - CAREI

Prof. Wang Mengjie
Vice President of China Association of Rural Energy Industry - CAREI

Biomass Resources in China and Its Current Status of Utilization

1. Consumption status of biomass resources in China

The population in rural China in 2001 reached 933.829 million, with 341.210 million in Eastern China, 311.667 million in the middle region and 280.951 million in Western China.

In 2001, total civil energy consumption in rural areas was 370.13 M tce, from which 182.12 M tce was from biomass resources, and 188.914 M tce was from fossil fuel energy. The energy consumption per capita is 0.396 tce, and the figures for the east, middle and west part of China are respectively 0.379 tce (0.152 tce from biomass), 0.452 tce (0.226 tce from biomass), and 0.356 tce (0.213 tce from biomass).

2. Status of biomass resources in China

1) Agricultural straw resources amount to 604 Mt, from which 15% has been used for composting and fostering the fields, the rest of 513 Mt has mainly been utilized for cooking and heating of rural households (280-300 Mt), apart from producing feed as well as industrial and construction materials. With economic growth and rise of living standard in rural areas, straws are left and burned in some regions causing environmental pollution and serious social harm.
2) Core wood: 160 Mt (90 Mtce)
3) Livestock waste: 1.67 billion tons
4) Industrial organic waste water and residue: 20.6 billion tons
5) Municipal solid waste: 110 M tons
6) Bagasse resource: 15.4 Mt (2.5 Mt is used for paper making)
7) Finally, resources of aquatic lives and oil plants are abundant

3. Status of biomass utilization in China

1) Anaerobic technology

From the 70's, the household biogas ponds using human and livestock waste as raw material in rural areas have been improved gradually. The utilization rate has been raised and the total number reached about 10 million ponds.

The biogas plants using industrial organic waste water and residues as raw material have abated pollution and generated energy, which attracted investments from the industry. There are more than 300 plants at present, treating waste water and residues of industries such as alcohol, starch, sugar, medicine and monosodium glutamate. There are over 600 plants using livestock waste as raw material. The fermentation capacity is 0.639 M M^3 and annual biogas production amounts to 200 M M^3.

2) Direct burning

Direct burning is the major use of biomass to acquire energy for living and industrial production, especially for farmers in the middle and western part of China. The thermal efficiency is very low, namely 10-20%.

3) Gasification technology

The main methods adopted are pyrogenation gasification and carbonization, using straws as raw material and producing low-grade gas serving as rural living fuel. There are more than 700 plants developed so far. However, some of them have stopped production due to technology, equipment and management problems.

Power generation through fluidised bed gasification using wood chips has been developed. There are more than 10 stations adopting this technology and the largest one has a capacity of 5MW.

4) Biomass compaction and moulding

Compaction and moulding biomass using straws, rice husks and wood chips as raw materials. The development of this technology is limited due to high energy consumption during the process. Therefore, it is applied only in a few charcoal plants.

5) Biomass liquefaction

Producing ethanol by using agricultural residues is currently in the research stage.

6) Bio-diesel oil

Production of bio-diesel oil by hydrolyzing waste oil and oil residues. The commercialisation of this technology has been developed by several enterprises.

7) Bagasse power generation

Bagasse is utilized in sugar factories to generate power and for co-generation. Large-scale sugar factories in China have their own power stations which are operated seasonally. Today, components of the equipment is old and has low efficiency. Therefore, reconstruction is urgently required.

8) Ethanol as oil substitution

   The country has established bases in Jilin province and Nanyang (Henan province) for the production of ethanol by processing dated grain. With respect to ethanol production from sorghum, issues such as better breed of sorghum, straw juice extraction and fermentation have been solved. At the moment, pilot plants for the commercialisation of this technology are being implemented.

4. Prospectives of biomass utilization

China has a vast territory, complicated terrains, various climates and rich biomass resources. Energy consumption of farmers in rural areas heavily depends on biomass, especially in the middle and western regions. With rapid economic growth, living standard improvements, increase of fossil fuel consumption and reduction of biomass, it is of urgent need to develop high-efficiency biomass technology. It is expected that China can cooperate with advanced countries in developing biomass resources and mitigate environmental pressure caused by fossil fuel consumption.

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Latin America Thematic Network on Bioenergy - LAMNET

Dr. Rainer Janssen
Co-ordinator Latin America Thematic Network on Bioenergy - LAMNET

Latin America Thematic Network on Bioenergy – LAMNET

The project 'Latin America Thematic Network on Bioenergy – LAMNET' is engaged in setting-up a trans-national forum for the promotion of the sustainable use of biomass in Latin America, Europe, China and Africa. Currently, the global network LAMNET consists of 48 institutions (Knowledge Centres and SMEs) from 24 countries worldwide, thereby involving a large number of members with excellent expertise in the field of biomass.

LAMNET supports the elaboration of recommendations for the development and implementation of policy options for the promotion of biomass and bioenergy as well as the identification of commercially available and reliable biomass technologies worldwide.

The web site of this global network on bioenergy was established early in 2002 under www.bioenergy-lamnet.org. It provides detailed information on the objectives, activities and scientific publications of this trans-national forum as well as the contact details of all network members. Further dissemination activities of the LAMNET project include the publication of a periodic newsletter (2 issues per year), a project database providing information on the energy demand and the energy resources in Latin America and other selected emerging economies as well as the organisation of several bioenergy workshops.

LAMNET project workshops organised in 2002 include a Conference Related Event on the occasion of the 12th European Conference and Technology Exhibition on Biomass for Energy, Industry and Climate Protection in Amsterdam on 19 June 2002, a workshop on 'Biomass, Rural Energy and the Environment' in Durban organised one week prior to the WSSD in Johannesburg (August 2002) as a joint event of the three Thematic Networks CARENSA, SPARKNET and LAMNET and a workshop on 'Bioenergy Policies and Innovative Bioenergy Technologies' in São Paulo and Brasilia, 2-4 December 2002.

With respect to bioenergy technologies and systems it is the main objective of the LAMNET project to identify currently available, efficient, cost-competitive and reliable bioenergy technologies which provide opportunities for the conversion of biomass to energy services in Latin America, Europe, Africa and China. Relevant technologies and systems are selected on the basis of maturity of the technology, cost-effectiveness, simplicity of maintenance, social acceptability and the impact on development. Moreover, opportunities for international co-operation, technology transfer and joint-ventures in the field of bioenergy technologies are identified and promoted by the LAMNET network.

Finally, the analysis of the current energy policy framework and support for the elaboration of policy options for the promotion of the sustainable use of biomass follows three main lines within the framework of this global network on bioenergy:

- Involvement in major international events and initiatives focussing on Renewable Energies and Sustainable Development

- Monitoring of the national/regional policy frameworks and the elaboration of advice and recommendations for the development and implementation of policy options for the promotion of bioenergy in close cooperation with the national network members

- Active networking with other organisations, institutions and multilateral initiatives engaged in the field of Renewable Energies and Sustainable Development

SESSION 1: STRATEGIES AND POLICIES

International Conference on Bioenergy Utilization and Environment Protection
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Development and Utilisation of Biomass Energy and Related Supporting Policies in China

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1. Abundant and Various Biomass Energy Resources in China

Biomass resources which can be used as energy amount to 300 M Tce annually

- Among the annual production of 700 million tons of straw/stalk, 45%, or about 315 M tons (170 M Tce), can be used as energy fuel;
- The annual reasonable used amount of forestry energy is about 160 million tons, equal to 90 million Tce;
- Annual charge of industrial waste water in the whole country is about 23 billion tons, containing more than 5 million tons of BOD. By utilizing this, 9 billion m3 of biogas (about 8 million Tce) may be produced;
- Every year, 900 million tons of poultry and livestock excrement can be collected, equal to 160 million tons of dry materials.
  - 10 billion m3 of biogas (8 million Tce) can be produced in large and medium-size biogas plants
  - 5 billion m3 of biogas (4 million Tce) can be produced in household biogas digesters
- Annual volume of garbage disposal in cities is 180 million tons, from which 18 million Tce of energy can be generated;
- 10 million Tce of energy can be obtained from other resources (pasturage, energy corps, alga, waste water, etc.)

Impact factors of biomass energy development

- Biomass resources are renewable, their amount may vary from time to time;
- Biomass resources are usually used for multiple purpose
- Utilization of biomass energy has closed ties with environmental protection, e.g., returning fields to forestry;
- The level of conversion technology of the biomass energy determines that of the biomass energy utilization .

2. At present, the amount of developed biomass energy in China is about 258 million Tce, mostly used in traditional ways

Annual utilization amount of biomass energy in rural areas amounts to 255 million Tce

- Straw 330 million tons (141 million Tce)
- Firewood 200 million tons (114 million Tce)
- Key Technologies
  Stoves 189 million
  including 47 million improved stoves and 19 million energy conservation Kang; 2.45 million improved stoves and 0.79 coal-saving Kang are popularized every year

Annual amount of biomass energy developed by new technologies

- Family-sized Biogas Digesters
  Family number 10.23 million
  Annual increment 1.78 million
  Total Output 3.7 billion m^3 / 3 million Tce
- Large and Medium-size Biogas Plant
  Pool volume / number 765.1 thousand m^3 / 1570
  agriculture 425.1 thousand m^3 / 1351
  industry 340.0 thousand m^3 / 209
- Annual Biogas Production: 184 million m^3 / 0.15 million Tce
- Gasification
  Number of gas station 488
  Family number 0.105 million
  Volume of biogas 152 million m^3 / 24,000 Tce
  Utilized Straws 100,000 tons
- Carbonization
  Output 3,600 tons
  Utilized Straws 9,300 tons
- Briquette
  Output 300 tons
  Utilized Straws 400 tons

Biomass only occupies a small percentage in the utilization of renewable energy

- Amount : less than solar energy and small hydro power 28,000 MW small hydro power has been developed, equal to 33 million Tce per year;

  Over 3.3 million Tce of solar heat and PV has been developed.
- Speed: Lower than that of small hydro power, solar energy and wind energy

3. Future Biomass Conversion Technologies with Great Potentials

- Biomass is one of the safest and most stable renewable energies, which can be converted to different kinds of energy products.

- Power generation fueled by gasified biomass
  - -- the technology is matured
  - -- from the viewpoints of environment, safety and utilization mode, power generation and heating fueled by gasified biomass should be encouraged
  - -- main barriers: connection to the grid, electricity price
- Liquefied Biomass Fuel
  - -- Liquid fuels such as ethanol and cracked oil are not only clean, but also a strategic measure to reduce our dependence on petroleum so as to guarantee the energy supply safety in China.
  - -- At present, many countries are paying close attention to the technologies which using lignocelluloses (such as sawdust) to produce liquid fuels.

    Biomass cracking and liquefaction

    Producing ethanol by hydrolyzing and ferment
  - -- MOST is supporting biogas cracking technologies to produce liquid fuels. Current pilot-scale experiment system can produce 600 tons of ethanol and 400 tons of cracked oil annually.
- From Biomass to Hydrogen
  - -- There's no CO_2 emissions if we produce hydrogen by renewable energies
  - -- Bio-technologies (alga and bacteria) are focused by the whole world
  - -- MOST has finished the research of producing hydrogen by biomass. A demonstration system using biomass to produce and metal to store hydrogen has been established, which can produce 1,200 m3 hydrogen every day.

4. Supporting Policies

- Due to the higher cost, renewable energies cannot be developed through market competition
  - -- Related technologies is still under development. It needs large amount of investment and 20~30 years of time.
  - -- The scale is too small, and an mature biomass industry has not been formed
  - -- Supporting policies are quite necessary
- There are already some local and regional policies, but supporting laws at macro level are absent
  - -- State support to the development of technology, Protective policies
  - -- Investment subsidies, tax deductions, and waive of customs
- Environment and Resources Committee of China Parliament has made a plan to constitute *Law on Promoting Renewable Energies*
  - -- Establishment of the "National Target Systems" by legal files
  - -- Establishment and distribution of incumbency for the renewable portfolio system
  - -- Green certification, a combination of the government action and the market operation, will be a valuable securities, which can embody the environmental benefits, and can be traded and cashed in the market
  - -- Priority to enter the grid and production permission system, Public bidding
  - -- Promise to subscribe by free will (government purchase, volunteer subscribe)
  - -- Increase investment to support the research, demonstration and development of technologies

SESSION 1: STRATEGIES AND POLICIES

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Policies for the Promotion of New and Renewable Energies

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ABSTRACT

New and renewable sources of energy have been considered as an alternative to conventional sources for thirty years. In the last ten years concern with global pollution has been considered as one more positive factor in favor of their use. Even so, their participation in the world primary energy matrix is still quite modest (less than 2%). Such small participation is quite often justified by lack of commercial competitiveness requiring further technological improvement to overcome such barrier. However, several studies have shown that, presently, there are technologies for the use of new and renewable sources that make them economically competitive with conventional sources. Even in this circumstance, new and renewables occupy a market share much below their economic potential. Barriers other than explain this technological and economic. Also, when economic barriers are present it is necessary to provide incentives since through large-scale use, frequently, it is possible to reduce costs. With so many barriers to overcome it is imperative to create a portfolio of policies to foster the use of new and renewable energy sources. This paper discusses several categories of policies providing examples of policy tools (actions) already implemented or being proposed in some countries to promote alternative sources of energy. Some of the policy tools are designed to improve technology, others to face lack of economic competitiveness with conventional sources, but several are designed to change human habits and promote market transformation. These changes are difficult to perform and can be even harder to implement when there are market forces induced by the present economic power of fossil fuels user's and producers. A large portfolio of policy tools is presented and it is expected that decision-makers interested in a larger market share for new and renewable sources will be able to select the most appropriate ones for their countries.

I. INTRODUCTION

Almost all commercial energy used in the world is derived from fossil fuels. Coal, oil and natural gas represent around 90% of the energy supply, while hydro and nuclear electricity represent 5% of the commercial energy supply. The new and renewable sources (modern biomass, solar, wind, geothermal, and small hydro) represent a little over 2%, and from this total 1.7% are due to modern and sustainable uses of biomass (see Figure 1)

It is worthwhile to remember that new and renewable sources became to be considered as potential contributors to the energy matrix at almost 30 years ago with the oil crisis of 1973 and 1979. During these 30 years their contribution, in absolute value, looks impressive (see Table 1 and Table 2), but on relative basis, increased modestly from zero to 2%. Several barriers prevent their expansion.

- **Economic/financial barrier**. A major constraint for many biomass schemes is the relatively high cost per unit of output, because of the small-scale nature of most biomass energy-based projects, high capital and initial investment, high costs of raw material, low cost of competitive fuel, etc. Biomass schemes have to compete with scarce resources and it is a major difficulty to find adequate funding, but even more, that the financial community understands what is being proposed. It is well documented that many biomass schemes, although technically well prepared and costed, often overlook the financial implications. All these factors have combined in discouraging potential financial bankers and investors in biomass energy projects.

- **Institutional and legislative:** Bureaucratic obstacles can be a major problem, because the generally poor understanding such bureaucrats have about biomass, in particular those in the conventional energy institutions, owing to the different nature in which they operate. Integrating new energy sources into the existing energy systems has always required a long time span. Until quite recently almost all major energy suppliers were state monopolies or large private corporations, which have made it very difficult for small independent energy producers to enter the market. This situation is changing rapidly where the energy sector is open to competition. The regulatory and legal framework, whether at national, regional or local levels, can often be a barrier, as in most cases legislation deals with conventional (fossil or nuclear based) energy sources and is often behind with regard to other sources. This vacuum creates confusion, delays, etc., when it comes to planning permission. Thus it is important that there is legislative support to ensure that small independent producers have access to the national grid, or integration with other provincial or local lines, etc.

- **Environmental:** All biomass energy schemes have environmental costs and benefits that need to be quantified and compared with non-biomass ones. Public perception of biomass schemes is important and their views on possible disruption to habitats, ecosystems, conservation areas, visual effects, etc., must be taken into consideration. This has been notoriously lacking in many cases.

- **Socio-political:** Social acceptability and participation are important elements for the success of any modern biomass energy scheme. It is also important that biomass energy schemes do receive political support, to understand the policy implications and to have access to decision-makers, so that they understand the problems, what is being proposed and that issues of competence are well understood. The experience from Austria, Brazil, Sweden, and Denmark, for example, shows that these elements must combine for successful implementation. However, similar policies are still lacking in many countries (World Energy Commission 2000 Report).

Considering such large number of barriers it is clear that expansion of new and renewable sources of energy requires appropriated policies to succeed. The high cost for their production is a serious issue that can be mitigated through significant investments in R&D and “learning by doing”. But even when technology and cost are not any more barriers, renewable sources of energy still face other kind of barriers. In a recent study 68 countries (G-8, 2001) identified some of the market forces stimulating and restraining the growth of New and Renewable (see Column 1 and 3, Table 3). It is worthwhile to observe the large number of policies suggested by 68 countries study to influence such forces (Column 2, Table 3). In this paper we will provide several examples of policies tools that are being applied or are suggested in the literature to overcome these barriers, while also helping to overcome economic and socio-political barriers.

There is no "silver bullet" for overcoming the barriers to a more sustainable energy future. Many policy initiatives are needed to increase the availability and deployment of energy efficiency and renewable energy technologies. These policies can be grouped into the following 12 categories (Geller, 2002):

- research, development, and demonstration
- financing
- financial incentives
- pricing
- voluntary agreements
- regulations
- information dissemination and training
- procurement
- market reforms
- market obligations
- capacity building
- planning techniques

II. POLICIES and POLICY TOOLS

1. Research, development, and demonstration

Expand government-funded research, development and demonstration (RD&D) on clean energy technologies in order to reduce their cost and improve their performance. Also, expand RD&D on behavioral and implementation-related issues. Foster collaboration between research institutes and the private sector, and combine RD&D with market development efforts.

Examples of policy tools

1.1 Biomass Research and Development Initiative is a multi-agency effort to coordinate and accelerate all USA Federal bio-based products and bioenergy research and development, as outlined in the Biomass Research and Development Act of 2000 and Executive Order 13134.

Recommendations:

- Fully fund the Biomass Research and Development initiative at its authorized level of \$49 million a year, as authorized in the Biomass Research and Development Act.
- Extend the initiative from 2005 to 2010, conducting a review in 2005 to determine which areas of research have proved the most promising.
- Give priority funding in awarding competitive research grants to projects for the commercialization of cellulosic ethanol and the development of energy crops (Ames and Wermer, 2001).

1.2 Utilities Compulsory Investment in Energy Efficiency and R&D - Starting in 1998, the federal regulatory agency for the electric sector in Brazil (ANEEL) began requiring utilities in Brazil to invest at least one percent of their revenues in energy efficiency programs. But only one quarter of the one percent must be spent on efforts that help consumers to use electricity more efficiently. In 2000, the requirement was changed with half of the one percent devoted to an R&D fund, but the minimum amount for consumer-oriented efficiency programs was maintained (Jannuzzi 2001).

1.3 Japan – Importance of R&D to stimulate the learning effect

In June 1998, with PV generation costs three times as high as conventional electricity, Japan set a target of 5000 MWp of newly installed PV capacity by 2010, and established an R&D Programme, - Development of Technology for Practical Application of PV Power Generation Systems- to drive down PV costs thereby helping to insure that the target will be met.

To date the R&D programme has been very successful, with approximately 200 MW of PV installed in the first 18 months. Over ten thousand residential systems have been installed annually as a result of the subsidies. The programme has achieved economies of scale and as a result, significant price reductions: it reduced costs of installed residential PV systems from US\$30 in 1993 to US\$8 per peak Watt in 1998 (G-8, 2001).

2. Financing

Provide financial services to increase the adoption of renewable energy measures. Financing at low interest should reward superior performance; e.g., pay for renewable energy production. Also, financing at low interest should diminish or phase out as markets for renewable energy measures expand.

Examples of policy tools:

2.1 Rural Business-Cooperative Service – RBS in United States provides financial and technical assistance to establish and sustain agricultural cooperatives.

Recommendations:

- The mission of RBS should explicitly state that farmer-owned cooperatives are a crucial component of renewable energy development.
- Provide grants and loan guarantees to establish cooperatives or expand existing cooperatives to undertake wind, biopower, biofuel, and bioproduct development projects. Give priority funding to proposals that aim to produce several marketable products in the same integrated facility, such as a biorefinery (Ames and Wermer, 2001).

2.2 Commodity Credit Corporation Bioenergy Program – CCC is the financing organization for USDA's commodity programs and several conservation programs. The Bioenergy Program provides partial compensation to producers of ethanol and biodiesel for the purchase of commodities to expand existing production (cellulosic energy crops are considered eligible commodities)(Ames and Wermer, 2001).

2.3 Transmission – Facilitate financing for Rural Electrification Cooperatives (RECs) to improve the carrying capacity, reduce line loss and increase the overall efficiency of their existing transmission/distribution networks. In many places, a major barrier to the large-scale development of rural renewable energy resources (especially wind and biomass) is the lack of transmission capacity. Development of rural renewable energy resources is critical to U.S. energy supply, greenhouse gas mitigation, air and water protection and increased farm income and rural economic development. Therefore, it is critical that lack of transmission capacity in the grids owned by RECs not be the downfall of renewable energy development.

Recommendation:

- Provide loan guarantees or other appropriate financing assistance for on-farm renewable energy systems, including wind turbines, solar panels and anaerobic digestion systems (Ames and Wermer, 2001).

2.4 Bangladesh- seeds funding for solar home systems

In 1998 the Global Environment Facility (GEF) provided funding to an organisation in Bangladesh, Grameen Shakti, which enabled them to offer improved credit terms, increasing the payment period for solar home systems from one to three years. This had a significant effect on demand. Between 1997 and 1999, Grameen Shakti sold 1500 systems Solar Home Systems and installed 2000 to 2500 systems in the year 2000. Grameen Shakti found that after a "critical mass" of installations, for example 100 systems, the process of building customer confidence and demand became less time consuming, as people bought systems on the recommendations of other customers. Grameen Shakti believes that after three to four years of this profitable growth they will be able to obtain financing from commercial banks. This project has shown that the use of GEF financing to support a "high risk" project, unable to obtain commercial financing on its own, can result in significant growth and provide the means by which an organisation can obtain commercial financing (G-8, 2001).

3. Financial Incentives

Provide financial incentives to increase the adoption of renewable energy measures. Financial incentives should reward superior performance; e.g., pay for renewable energy production. Also, incentives should diminish or phase out as markets for energy efficiency and renewable energy measures expand and their costs drop.

Examples of policy tools:

3.1 In USA the idea is to provide "private use" relief for tax-exempt bonds of state and locally owned electric utilities and eliminates tax impediments faced by rural electric cooperatives that inhibit full participation in emerging competitive markets.

- Allow enhanced accelerated depreciation for property used in the transmission or generation of electricity.

- Encourage Federal Electricity Regulatory Commission of USA (FERC) to ensure adequate investment returns that will attract the necessary capital investment in the electric transmission system (Ames and Wermer, 2001).

3.2 Conservation Reserve Program - CRP is the largest of the Farm Bill conservation programs for United States, with a current enrollment cap of 36.4 million acres (equivalent in size to the state of Iowa). Its mission is to preserve land vital for soil conservation, water quality protection, and wildlife habitat. It is recommendable to add renewable energy production to those goals.

Recommendations:

- Permit the growing of biomass crops, and the harvesting of biomass, for the production of biopower, biofuels, and biobased products, on CRP lands with an appropriate reduction in rental payments. The rental reduction should not be so high as to cancel any incentive for a farmer to undertake a biomass project.

- Allow wind turbines to be sited on CRP lands, where ecologically and economically appropriate.

Give a higher priority in awarding Environmental Quality Incentives Program (EQIP) contracts to producers who propose to convert animal waste operations over to anaerobic digestion systems for the capture and burning of biogas to produce heat and electricity (Ames and Wermer, 2001).

3.3 Greening the Energy Sector Portfolio of Multilateral Banks: the case of ASTAE

The Asia Alternative Energy Programme (ASTAE) was established by the World Bank in 1992. The goal of ASTAE was to mainstream sustainable energy in Asia by ‘greening’ World Bank lending to the power sector in this region. The programme has been so successful that the target of increasing the share of alternative energy in its Asian power sector loan portfolio to 10 percent has now been met and exceeded. In the financial year of 1999 the share was as high as 46.3%. As of June 2000, 38 projects were either in the pipeline, approved or completed and it is projected that the implementation of these projects will avoid around 1GW of conventional capacity (G-8, 2001).

4. Pricing

Reform energy prices. Eliminate subsidies for fossil fuels and enact taxes based on their environmental and social costs. Use some of the tax revenue to support energy efficiency and renewable energy initiatives in order maximize the energy, environmental, and economic benefits.

Examples of policy tools:

4.1 Ethanol Small Producer Tax Credit – In the United States it is recommendable to expand this credit to include farmer-owned cooperatives. We also recommend allowing all producers with annual production capacity up to 60 million gallons to qualify (currently the limit is 30 million gallons) (Ames and Wermer, 2001).

4.2 “Green technologies are on the verge of becoming one of the next waves in the knowledge economy revolution. I believe the role of Government is to accelerate the development and take up of these new technologies until self-sustaining markets take over.

The Government's programme for incentivate renewables will create a new market worth over £500 million through the Renewables Obligation, Climate Change Levy exemptions and the Non Fossil Fuel Obligation. We have already announced £100 million to support offshore wind and energy crops. Today I can announce a further £100 million .... This new money will help us to promote solar PV, give a boost to offshore wind, kick start energy crops, and bring on stream other new generation technologies. This investment in renewable energy technology is a major down-payment in our future, and will help open up huge commercial opportunities for Britain." (Blair, 2001).

5. Voluntary Agreement

Adopt voluntary agreements between governments and the private sector in situations where regulations or market obligations cannot be enacted or enforced. Complement voluntary agreements with financial incentives, technical assistance where needed, and the threat of taxes or regulations should the private sector not meet their commitments

Example of policy tool:

5.1 The Netherlands tax incentives for green investments

The Green Fund System (GFS) was introduced in the Netherlands in 1992, as a co-operative activity between the government and the financial sector. It combines a tax incentive, a framework for designation of green projects and the active involvement of the financial sector. The basic principle behind the system is that the general public receives tax advantages for investments in 'Green Funds'. The Green Funds provide soft loans with low interest rates to green projects. Initially, only projects in the Netherlands were eligible for funding, but in 1995 the scope was extended to projects in developing countries and economies in transition.

The enthusiasm of the public has contributed to the success of the Green Funds system. The Green Fund System has successfully set up a self supporting market development programme for green projects, which is based on existing financing infrastructures and encourages the active support of the financial sector and general public (G-8, 2001).

6. Regulation

Enact regulations or market obligations to stimulate widespread adoption of energy efficiency improvements or renewable energy sources. Make sure these regulations or obligations are technically and economically feasible, enforce them, and update them periodically. Also, structure emissions cap and trading schemes so that they encourage and provide credit for emissions reductions from end-use efficiency improvements and renewable energy technologies.

Example of policy tool

6.1 Harnessing the bagasse resource would require a fully operational legislative environment for Independent Power Production (IPP) in USA. Legislation allowing for IPP exists; thus concrete steps toward implementing the long-term expectation amongst policymakers of private ownership of everything but the grid have been taken. However, the policy framework for operationalizing independent power production is not entirely in place.

Rural Utilities Service – RUS provides grants, loans, and technical assistance to rural electric and water utilities in USA. The following recommendations will likely entail amending the Rural Electrification Act of 1936.

Recommendations:

- **Net Metering:** Rural Electric Cooperatives (RECs) should provide net metering services to their customers (potential small residential generators) to encourage the production and use of renewable energy sources for on-farm use by their members. In essence, net metering allows the electric meter to run backwards as electricity produced by the customer is fed back into the system. In this way, customers already connected to the coops distribution lines can feed into the coops system any excess power they may generate. Thereby customers pay for the net amount of power they consume. Customers should receive a fair price on power they contribute to the system. Over 40 states have already passed various versions of net metering legislation, and bills have been introduced in the House and Senate regarding net metering. Because RECs serve so much of rural America, this is an important way in which RECs can benefit their members and improve the reliability and capacity of their systems.

- **Standardized Interconnection:** Rural Electric Co-ops should provide interconnection to their distribution systems at a fair and non-discriminatory price for their member/customers who want to generate power from renewable energy sources for their own .on farm. Use but also be able to sell excess power back to the coop. Such renewable resources would include solar, wind, and anaerobic digestion systems. Some states have enacted their own legislation, and bills have been introduced in the Senate (e.g., S. 933), but if farmers are going to be allowed/encouraged to develop their on farm renewable energy resources, then it is important that RECs provide this service to their members. Too many times utilities (of all kinds) have thwarted development of on site renewable energy by not allowing interconnection or by charging exorbitant fees (Ames and Wermer, 2001)..

6.2 Tax treatment and duties for imported biofuels

This issue is being discussed in many fora (Faaij et al, 2002). Very few of the new and renewable energy sources have the potential to be traded in significant amount. Wind, solar, small hydro sources are potential sources of electricity and such form of energy is essentially consumed in the producing site or nearby. Biomass, which can be used as a source of biofuel, heat, electricity or a combination of them, has some potential to be consumed in different regions than the one it is produced. In particular, biofuels are probably, the most feasible form of biomass that can be transported over large distances and still be economically competitive with conventional liquid fuels. Tropical countries with abundance of rainfall have a significant advantage as producers of biofuels (Moreira, 2002) and are potential exporters. Unfortunately, many developed countries with much less opportunities to produce them due their temperate climate impose trade barriers to protect their farmers. In a global economy such attitude is becoming susceptible to criticism. One possible way for the removal of trade barriers is to require fair use of commercial practices promoted by the World Trade Organisation through enforcement of policies designed by WTO it should be possible to open developed country’s market to biofuel produced in tropical countries.

6.3 Adopt Minimum Efficiency Standards for New Thermal Power Plants

Brazil has sought for some time to increase electricity supplies from thermal power plants, but Brazil lacks high-quality coal reserves and development of natural gas was quite limited until recently. The increased supply of natural gas has sparked great interest in the construction of natural gas-fired power plants. Utilities or private developers proposed many projects in recent years.

The great majority of the gas-fired power plants proposed or under construction is simple cycle plants, meaning efficiencies of 30-35 percent rather than 50-60 percent achieved by state-of-the-art combined-cycle plants. Private investors prefer simple cycle plants because of the lower investment costs, shorter construction time, and greater flexibility to respond to varying load conditions. In the future, some of these plants may be converted to combined-cycle operation.

Minimum efficiency standards could be adopted for all new gas-fired power plants that enter into operation in Brazil. Also, plants built as simple cycle gas turbines could be required to add steam turbines and operate as combined cycle plants if they are used more than a nominal amount. This policy would require all gas-fired power plants used over 500 hours per year to meet or exceed an efficiency level of 55 percent. This requirement also would narrow the difference in capital cost between electricity only and CHP plants, thereby helping to stimulate investment in CHP systems (Szklo and Geller, 2003).

6.4 Adopt Minimum Fuel Economy or CO_2 Emissions Standards for New Passenger Vehicles

There are no fuel efficiency standards for new cars or light trucks in Brazil. Vehicle manufacturers receive some tax incentives for producing vehicles with engines one liter or smaller in volumetric capacity. But the fuel efficiency of Brazilian cars and light trucks is still relatively low. In 1998, the average fuel economy of all passenger cars in circulation in Brazil was about 23.5 mpg or 10 kilomters per liter (km/l), while the average fuel economy of all new passenger cars sold that year in the country was about 26 mpg (11 km/l) (Azuaga 2000).

Passenger vehicles sold in Brazil are relatively inefficient because of the outdated technology employed in one-liter Brazilian engines. Most of these engines are derived from 1.6 liter-engines used to equip older models. But vehicle production by the multinational auto manufacturers is rapidly growing in Brazil. As production expands, it would be reasonable to insist that new vehicles include a variety of fuel-efficient technologies.

This policy calls for adopting passenger vehicle fuel efficiency standards in Brazil. These standards could be expressed in terms of either an increase in fuel economy (the approach followed in the United States) or a reduction in CO_2 emissions per kilometer traveled (as is the case in Europe). The advantage of a CO_2 emission standard in Brazil is that auto manufacturers could opt either to raise fuel efficiency or produce and sell more ethanol (and other cleaner fuelled) vehicles. If a CO_2 emission standard were adopted, manufacturers most likely would comply through some combination of efficiency improvement and fuel shifting (Szklo and Geller, 2003).

7. Information dissemination, and training

Disseminate information and provide training to increase awareness and improve know-how with respect to renewable energy options. Combine these efforts where possible with incentives, voluntary agreements, or regulations in order to increase their impact.

Example of policy tool:

7.1 RETScreen: a tool for market coherence

RETScreen is a global decision support and capacity building tool for assessing potential renewable energy projects developed by the Energy Diversification Research Laboratory of Canada. The tool evaluates the energy production, life cycle costs and greenhouse gas emission reductions for renewable energy projects at any geographic location around the world.

The tool enables planners and decision-makers to routinely consider renewable energy technology projects at the critically important initial planning stage. The tool has been used widely to date for example for: preliminary feasibility studies, project lender due-diligence, market studies, policy analysis, information dissemination, training, sales of products and/or services, project development and management, product development and research and development (G-8, 2001).

8. Procurement

Use bulk procurement to help commercialize and establish initial markets for innovative clean energy technologies. Governments should purchase energy-efficient products, renewable energy devices, or “green power” for their own use, as well as sponsor and help organize bulk purchases by a wide range of public and private entities.

Examples of policy tools:

8.1 Establish Federal Purchasing Programs - Executive Order 13134 and the Agricultural Risk Protection Act of 2000 set the goal of tripling the use of biofuels and bio-based products in the United States by 2010. We recommend establishing a purchasing requirement for all federal government agencies and contractors that sets increasing percentages for purchase of biofuels and bio-based products consistent with the above goals. We also recommend a Federal Renewable Portfolio Standard requiring agencies to purchase no less than 10 percent non-hydro renewable power by 2010, and 15 percent by 2015 (Ames and Wermer, 2001).

8.2 PROINFA – a Brazilian Federal Program foresee raising the share of renewable energy power generation by adding 3,300 MW installed capacity of wind, small hydro and biomass based electricity generation, offering long-term contracts with special conditions through ELETROBRAS the holding of the public electricity utilities, lower transmission costs, and lower interest rates from the local development banks. While the program is very indicative of a positive approach of the federal government, the “special conditions” were only precisely defined by the end of December 2002, although there is already some concern with the process designed for collection of funds that will support the programs. Several possible projects are in the pipeline; many of them have received approval of ANEEL, while others have construction licences issued by state authorities. Nevertheless, the initial call for project qualification to the program will occur by the middle of 2003, if time schedule set by the law will not be postponed.

8.3 PV Market Transformation Initiative in India

The PV market in India was approximately 10 MWp/year in 1997. Government PV purchasing and subsidy programmes have played a significant role in supporting the development of an Indian PV industry. However the market is characterised by:

- an unacceptably high incidence of system failure in the field
- inadequate marketing, distribution, customer support and after-sales service attributable to private sector markets being suppressed by subsidy programmes.
- general lack of consumer awareness of PV technology and its benefits.
- dependence on end-user subsidy.
- underdeveloped availability of consumer finance which is crucial to make solar home systems affordable.

The PVMTI programme aims to build up financing, distribution and service capability. This will be achieved through the provision of finance for sustainable and replicable commercial PV business models, the financing of business plans with commercial loans at below-market terms or with partial guarantees or equity instruments, and the provision of technical assistance to PV businesses on planning, financing operations and technology (G-8, 2001).

9. Market Reforms

Aim to transform markets. Integrate policies into market transformation strategies, addressing the range of barriers that are present in a particular locale. Make the policies strong enough to remove or overcome these barriers. And allow them to evolve over time as some barriers are removed and others come to the forefront.

Examples of policy tools:

9.1 PROALCOOL Program in Brazil – This program was introduced in 1975 with the purpose to diversify the sources of liquid fuels. To guarantee commercial space for ethanol, which at that time had a price above US$0.60/liter, the government created a fund with resources collected from tax on conventional gasoline (Moreira and Goldemberg, 1999).

9.2 Fuel Diversity and Supply - No individual fuel is capable of providing the energy to meet all of our nation’s electricity demands. Rather, a diversity of supply options is key to affordable and reliable electricity. Policymakers and regulators need to work together to reconcile conflicting energy, environmental, and other public policy goals in order to capitalize on our nation’s abundant natural resources and address challenges that now limit the development and viability of numerous fuel sources (Ames and Wermer, 2001).

9.3 Equipment Testing for Biofuels - Many gasoline and diesel engine manufacturers will not certify their engines to run on higher blends of ethanol and biodiesel. USDA and the Environmental Protection Agency should provide research grants to test biofuels in higher concentrations in farm equipment, construction equipment, diesel generators, and other applications. USDA should work in collaboration with equipment manufacturers to certify their engines to run on biofuels, and promote their use to consumers (Ames and Wermer, 2001).

9.4 Establishment of Independent Power Suppliers in Brazil – The reform of the Electric Sector in Brazil unbundled the sector into generation, transmission, and distribution assets. This model introduces competition among generators, maintains a neutral common carrier managed by the ONS and allows free consumers and producers, including IPPs, ready access to the grid. Privatizing distribution companies first was viewed as a crucial step not only in selling off the gencos but also in making IPP projects viable. Since the distribution companies would be the buyers of the energy sold by the gencos and new IPP producers, the credit risk to new investors would be reduced if the distribution companies were already financially sound and under private ownership. This policy was very relevant for the significant increase in the number of sugarcane mills interested in sales of co-produced surplus electricity to the grid, as shown in Figure 2.

9.5 Sri Lanka: the importance of IPP regulation

In Sri Lanka, the World Bank/GEF Energy Services Delivery project was started in 1997 with the aim of promoting the provision of grid electricity by private-sector power developers. The project had the effect of opening up the market to third party mini-hydro developers. More than 21 MW of small hydro has been financed by independent-power-producers (IPPs) as a result of the project. Also regulatory frameworks for IPPs were developed, including standardised “non-negotiable” power-purchase tariffs and contracts (Power Purchase

Agreements -PPAs). This project provided sufficient incentive for the national utility to adopt IPP frameworks and agree to PPAs, which together with demonstration of the technology through previous mini-hydro installations and new incentives for developers (such as import duty waivers and income tax concessions) succeeded in stimulating the market (G-8, 2001).

10. Market Obligation

Enact regulations or market obligations to stimulate widespread adoption of renewable energy sources. Make sure these regulations or obligations are technically and economically feasible, enforce them, and update them periodically. Also, structure emissions cap and trading schemes so that they encourage and provide credit for emissions reductions from end-use efficiency improvements and renewable energy technologies.

Examples of policy tools:

10.1 In September 2001, the European Union (EU) adopted the Directive on the promotion of electricity produced from renewable energy sources in the internal electricity market. According to this Directive, EU member states shall have their own national indicative targets (of renewables) at 12% share of gross national energy consumption by 2010 and 22.1% share of electricity generation by 2020" (Goldemberg, 2002).

10.2 The Brazilian Energy Initiative - A meeting of the Ministers of Environment, from Latin American and Caribbean Countries, which met in São Paulo in May 2002 prior to PrepCom IV, adopted as a resolution the Brazilian proposal drafted as:

- Increase in the region the use of renewable energy to 10% as a share of total by 2010" (Draft of the Final Report of the 7th Meeting of the Intersessional Committee of the Forum of Ministers of Environment of Latin America and the Caribbean)

The Brazilian proposal allows trading of "new renewable energy" certificates among countries.

Other proposals were presented in Bali:

- Diversify energy supply by developing cleaner, more efficient and innovative fossil fuel technologies, and promote the increase of the share of non- hydro renewable energy sources to at least 5% of total primary energy supply by 2010"(Switzerland).

- Diversify energy supply by developing cleaner, more efficient and innovative fossil fuel technologies, and promote the increase of the share of new renewable energy sources by at least 2% with the objective of increasing the global share to at least 15% of total primary energy supply by 2010. To achieve this all countries should adopt and implement ambitious national goals. For industrialized countries, these goals should aim at an increase of the share of renewable energy sources on total primary energy supply by, at as least, 2 percentage points by 2010 relative to 2000". (European Union)

They were all consolidated in a bracketed text PrepCom IV in Bali and included in the Chairman's Report (June 2002), which means it will be the object of further negotiations before or/at WSSD in Johannesburg.

[[Diversify energy supply by developing cleaner, more efficient and innovative fossil fuel technologies, and promote the] increase of the share of [non-hydro]/[new] renewable energy sources [by at least 2%]/[with the objective of increasing the global share to at least 15% of total primary energy supply by 2010.] [To achieve this all countries should adopt and implement ambitious national goals.][For industrialized countries, these goals should aim at an increase in the share of renewable energy sources of total primary energy supply by at least 2 percentage points of total energy supply by 2010 relative to 2000.]/[to at least 5% of total primary energy supply][by 2010].] at the goal level by 2010. To achieve this, all countries should adopt and implement specific national goals;]]

Recent discussions between Brazil and Sweden led to the following formulation for a target *: increase the share of modern renewable energy in the world's energy supply by 10% by 2012 (Goldemberg, 2002).

10.3 Renewable Portfolio Standard - Establish a national Renewable Portfolio Standard that will require 20 percent of power generated in the United States by the year 2020 to be derived from non-hydro renewable energy sources. This ensures a market for renewable power, critical to the development and use of renewable energy across the country and on America's farms (Ames and Wermer, 2001).

10.4 Texas Portfolio Standards

Under the Renewables Portfolio Standard (RPS) in Texas retail electricity suppliers have a requirement to include a specified percentage of renewables in their generation portfolio. The policy is backed up by annual renewable energy generation targets. Texas has set targets increasing to 2,880MW of renewables to be installed by 2009; this includes the addition of 2000MW from new renewable generating projects. Wind energy is currently dominating the new installed capacity of renewables with supply costs of around 3 cents/kWh (which includes a 1.7-cent/kWh federal production tax credit).

Projections show that the first year target of 400MW of new capacity to be installed during 2002 and 2003 will be exceeded significantly. The key factors considered to be contributing to the success of the policy are clear renewable energy targets, clear renewable resource eligibility requirements, stringent non compliance penalties, a Tradable Renewable Energy Certificate system that encourages flexibility and minimises costs, and a dedicated regulatory commission that fully involved numerous stakeholders during the detailed design of the policy.

A major lesson from Texas is that, while the RPS is new and relatively untested as a policy tool, it has the potential to cost-effectively support the establishment of a robust renewable energy market G-8, 2001).

10.5 Renewable Fuels Standard - Establish a national Renewable Fuels Standard (RFS) that would require an increasing percentage of transportation fuel sold in the United States to be renewable biofuels, such as ethanol and biodiesel. The RFS should contain a credit trading system to allow refiners, blenders, and retailers to buy and sell credits from each other to meet their content goals. The RFS should also contain an incentive to expand the production of cellulosic ethanol (Ames and Wermer, 2001).

10.6 Proposal to Foster Use of Sugarcane Residues - A combination of policies could facilitate higher efficiency bagasse cogeneration in Brazil as well as encourage use of leaves and tops for energy production, where appropriate. Some of these policies are similar to those needed to stimulate CHP with natural gas:

1) Require utilities to purchase excess power from sugar mills at avoided generation, transmission, and distribution costs via long-term contracts;
2) Require utilities to interconnect CHP systems to the power grid without excessive delay or unreasonable technical requirements;
3) Continue to develop and demonstrate more efficient technologies such as bagasse gasification and combined cycle power generation in sugar mills (Szklo and Geller, 2003).

10.7 Green electricity in Italy - In 1999 Italy introduced a quota system that obliges each power supplier from 2002 on, to feed electricity from renewable energy sources (2% of the non renewable electricity generated or imported in the previous year) into the Electrical National System. Suppliers can meet this obligation by building their own RE-plants or by buying certificates. This "Compulsory Renewable System" (CRS) follows defined rules regarding certificate issuing and trading.

The Italian government considers separate trading of green certificates and electricity to be one of the best options to promote renewable sources inside the European common market. The Italian government strongly advocates a common market, where all participants share similar rules and where green certificates are not merely a proof of origin, but a title per se, which can be sold separately (G-8, 2001).

10.8 German Renewable Energy Law

The German Renewable Energy Law was passed in 2000, in order to establish a framework for doubling the market share of renewable energy sources by 2010. The law sets specific maximum payback prices for each individual renewable energy technology, based on their annually decreasing real cost. The aim of the tariffs is to initiate a self-sustaining market for renewables and create a critical mass through a large-scale market introduction programme, whilst not imposing any additional burden on the taxpayer. A key lesson learned is that a law which takes into account learning curves for renewable energy technologies through decreasing feed-in tariffs is appropriate, particularly in a deregulated market. It has led to the largest installed wind energy capacity in the world (G-8, 2001).

10.9 Morocco: Rural Electrification Programme

Morocco has set up a rural electrification programme with the aim of increasing rural electrification from 20% in 1995 to 80% by 2006. The electricity utility ONE has assessed the areas where grid connection is the best option through the use of economic criteria. A cost per household for the grid connection of each village is calculated. The households which exceed the economic limit for grid connection are then identified as potential candidates for off-grid electrification. In these rural locations it is more economic to install solar home systems than to provide a connection to the grid (G-8, 2001).

11. Capacity Building

Build capacity to implement effective energy efficiency and renewable energy policies and programs in all countries. Also, train and support the businesses that will manufacture, market, install, and service clean energy technologies.

Examples of policy tools:

11.1 Agricultural Research Service - ARS is USDA's primary scientific research agency. The **Bioenergy and Energy Alternatives program** does research in the areas of ethanol, biodiesel, energy alternatives for rural practices, and energy crops.

Recommendations:

- Increase funding within the **Bioenergy and Energy Alternatives program** for the development of biofuels and energy crops.

- Expand the mission of the **Cooperative State Research, Education, and Extension Service (CSREES)** to promote the development of renewable energy resources on America's farmland.

- Provide funding to CSREES to provide education and technical assistance to farmers and farmer-owned co-ops for the development and marketing of renewable energy resources, including biomass, wind, solar, and geothermal. The CSREES should also conduct outreach to the general public on the societal benefits of developing these resources.

- Stipulate that the CSREES should work in close collaboration with the Regional Biomass Programs, sponsored by the Department of Energy. Together, the organizations should provide assistance to farmers for growing, handling, and processing energy crops and waste streams for the production of biopower, biofuels, and biobased products. Where possible, the two organizations should share resources, staff, and expertise (Ames and Wermer, 2001).

11.2 Guidelines for national renewable energy plans in developing countries (NREL/TCAPP, 2001).

Developed countries should facilitate preparation and implementation of renewable energy development plans, especially where such plans and planning activities:

- Drive the budgeting and policy decisions in developing countries so that the plan recommendations translate into real commitments for action at national and local levels.
- Integrate renewable energy strategies and initiatives with national and local economic, poverty alleviation, health, environmental, and other development programs
- Engage the business and finance community in structuring and implementing initiatives to ensure that they build sustainable markets and accelerate renewable energy investment
- Provide a vehicle for co-ordinating and focusing bilateral and multilateral donor support for renewable energy programs in developing countries
- Engage and build support from all key stakeholders in the country, including national and local government agencies, community groups, technical institutions, businesses and finance organisations, and other key stakeholders.

12. Planning Techniques

Carry out both integrated energy resource planning and integrated transportation and land use planning in order to guide investments to options that minimize overall societal costs (including environmental costs). Energy and transportation plans should contain concrete goals, actions for achieving the goals, and monitoring and evaluation procedures.

Examples of policy tools:

12.1 Local use in developing countries vs. export. Exporting country has the choice of exporting biofuels or CO2 credits. A sensitivity analysis would be needed to show at which levels of CO2 prices and biofuels prices which option would be best. Fossil reference systems can make a difference (coal vs. oil vs. gas) (Schalamadinger, 2002)

12.2 From the view of industrialized Countries technology export opportunities should be considered (e.g., processing and end use of biofuels) Security of fuel supply issues to be considered (Schalamadinger, 2002).

12.3 Biofuels import could alleviate concerns of wood industries regarding biomass energy use (competitive use of their resource). Could be important to get wood industries involved. Effects of biofuels trade on future power plant / refinery siting in Europe (Schalamadinger, 2002).

12.4 National Plan in China

China Renewable Energy Plan – The Government of China has developed 5 year plans to accelerate renewable energy development through market based policy instruments. In addition the Government will introduce a range of fiscal measures, such as VAT and income tax reduction, interest rate subsidies and government subsidies, to pay for part of the additional financial costs of new renewable energy capacity (G-8, 2001).

Currently the government is considering:

- To create a Mandated Market Share for renewable energy in the form of a legal requirement that a specified share of electricity comes from renewable energy.

- To introduce an instrument, such as trading, to share the incremental cost and benefits among the regions in China

III CONCLUSIONS

As has been pointed out by IPCC (Moomaw et al, 2001) in the short term (2010 – 2020) there is no shortage of technologies to abate Greenhouse Gas Emissions. Some of the technologies are already cost-effective and others can be used if carbon emission has costs up to US$100/tC. Even so, market potential for them is presently small and probably will continue to grow slowly. The market potential is well below the economic market potential, which is lower than the socio-economic market potential. The IPCC document concludes that lack of policies is the major obstacle for pushing up market potential to the level of the economic and socio-economic potential.

In this paper we try to classify policies in different categories and provide examples of practical policy tools (actions) already taken or being suggested to implement such policies. Examples were extracted from the literature and the list is far from complete, since we investigate a limited number of actions proposed in a limited number of countries. Nevertheless, the purpose of this document is to give insight to police makers about several possible policy tools that can be proposed to foster policies to foster the use and production of renewable sources of energy.

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Table 1
Renewable Energy Markets in Developing Countries

Application	Indicators of Existing Major Markets
1. Rural residential and community lighting, TV, radio, and telecomm	11 million households receive lighting from biogas 950,000 households with solar home systems (out of 300-500 million households not connected to electric grid) 170,000 household-scale wind-power generators 25,000 PV-powered cellular and satellite phones (serving a rural community)
2. Rural small industry, agriculture, and other productive uses	10,000 PV or wind-powered water pumps (out of 10 million off-grid water pumps total, mostly diesel powered) 100 PV-powered drinking water purifiers/pumps 40 MWp PV for off-grid industrial and telecommunications needs
3. Village-scale mini-grids	5,000 small hydro mini-grids (relative to 100,000 diesel-powered mini-grids) 200 solar or wind hybrid village mini-grids (with diesel)
4. Rural residential and commercial cooking	250 million more-efficient biomass stoves (out of [#] households that use biomass for cooking) 7000 solar cookers 20000 households cook with biogas fuel
5. Residential/ commercial heating	110,000 homes with solar hot water systems 8700 MWth geothermal direct heat production
6. Grid-based bulk power markets	55,000 MW installed capacity producing 200,000 GWh/year (mostly biomass and small hydro)[1]
7. Transport fuels	15 billion liters/year ethanol vehicle fuel produced from biomass 180 million people live in countries mandating mixing of ethanol with gasoline

[1] Some of this capacity serves small village mini-grids rather than central power grids

Table 2 – Renewable Electricity Grid-Based Generation Capacity Installed as of 2000 (Megawatts)

Technology	All countries	Developing countries
Wind power	18,000	1,700
Small hydropower	36,000	19,000
Biomass power	38,000	30,000
Geothermal power	8,500	3,900
Solar thermal power	350	0
Total renewable power capacity	100,000	55,000
Large hydropower	680,000	260,000
Total world electric power capacity	3,400,000	1,500,000

SOURCE: Martinot et al, 2002

<table>
<tr><th colspan="4">Table 3: Market Forces</th></tr>
<tr><th>Forces stimulating RE</th><th colspan="2">G8 vehicles to influence forces</th><th>Forces restraining RE</th></tr>
<tr><td>Aspirations to eradicate poverty</td><td rowspan="4">National RE plans</td><td>Co-operation with DC’s through ODA**/IFIs***</td><td>Lack of awareness of RE options/ benefits in DC’s, IFI’s & lack of co-ordination</td></tr>
<tr><td>Aspirations to improve local/global environment</td><td>Climate change & other environment policies: taxation, incentives and fiscal measures, carbon trading CDM,</td><td>Vested interests and subsidies for conventional energy, ignorance</td></tr>
<tr><td>Aspirations to diversify for energy security</td><td>RE portfolio</td><td>Vested interests in conventional energy, ignorance</td></tr>
<tr><td>Energy market liberalisation</td><td>Green certificates; Distributed generation policy; Renewable portfolio standards</td><td>Decrease ODA/IFI support for energy projects</td></tr>
<tr><td>Cost reductions for RE technology</td><td colspan="2">R&D policies, public-private-partnership</td><td>Lack of awareness / trust / familiarity with RE technology, other barriers to RE project development; apparent cost competition</td></tr>
<tr><td>Increased FDI* / trade promotion
Increased role of private sector</td><td colspan="2">ECA****, public-private-partnership, tax and other incentives, risk mitigation, global corporate initiative</td><td>Vested interests in conventional energy and export credit support
Decreased role of government</td></tr>
<tr><td>Global integration of markets</td><td colspan="2">Coherent action, policy co-ordination, information exchange, ECA reform</td><td>Market immaturity</td></tr>
</table>

*	FDI	= Foreign Direct Investment
**	ODA	= Overseas Development Assistance
***	IFI	= International Financing Institution
****	ECA	= Economic Commercial Agreement

FIGURE 1

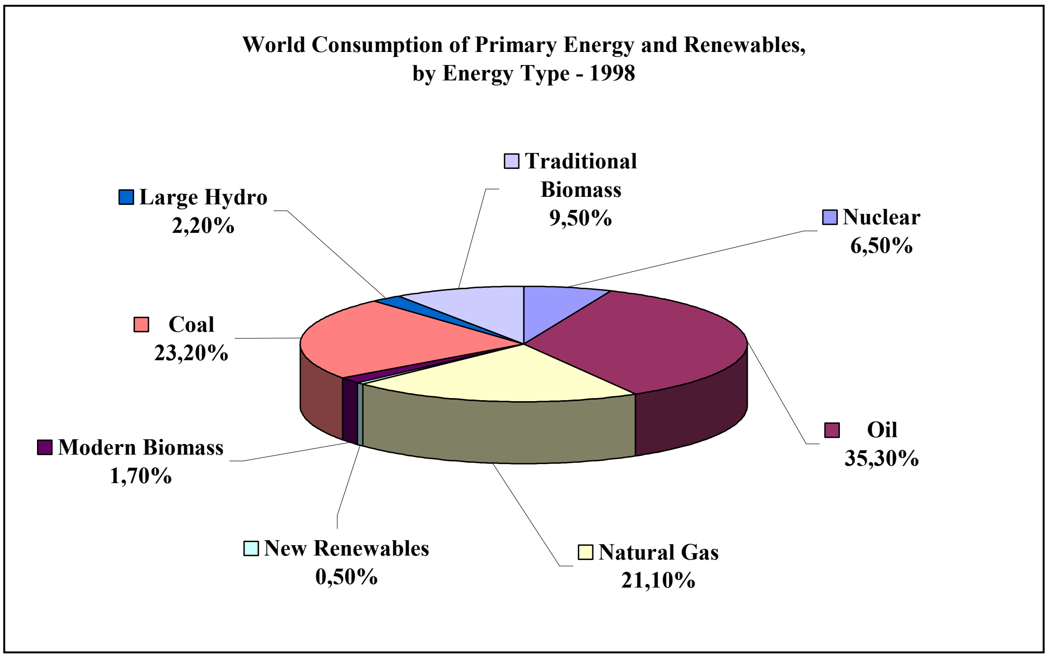
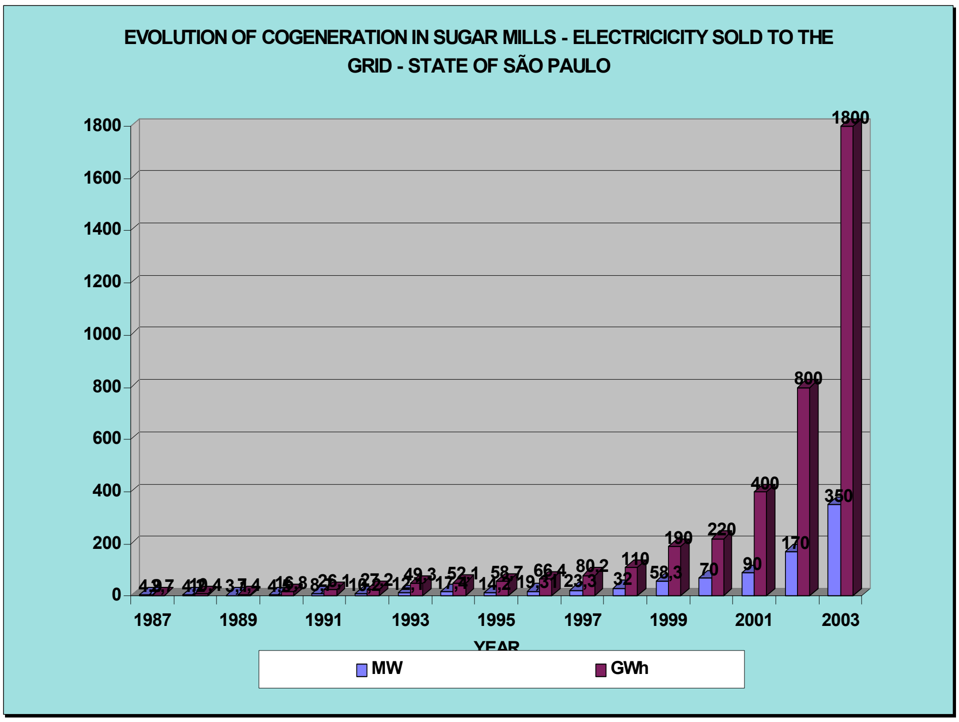


Figure 2

Evolution of Electricity Generated in Sugar Mills



SESSION 1: STRATEGIES AND POLICIES

International Conference on Bioenergy Utilization and Environment Protection
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Bioenergy Strategy in RSA and Southern Africa

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ILLOVO GROUP PROFILE

Illovo Sugar is listed on the JSE Securities Exchange South Africa and is a leading, global, low-cost sugar producer and a significant manufacturer of high-value downstream products. The group has extensive agricultural and manufacturing operations in six African countries and also operates a beet sugar manufacturing plant in the United States. Downstream products include furfural, furfuryl alcohol, Crop Guard, diacetyl, acetoin, 2.3-Pentanedione, ethyl alcohol, lactulose and syrup.

Approximately 5.8 million tons of sugar cane is produced on agricultural estates in South Africa, Malawi, Zambia, Swaziland, Tanzania and Mozambique. Sugar cane cultivation in Africa benefits from good growing conditions and is further enhanced by full-scale irrigation applied to the majority of the crop, resulting in above-average cane yields and high sucrose content. Group sugar production of approximately 2.3 million tons derives from South Africa at 1.3. million tons, Malawi 260 000 tons, Zambia 230 000 tons, Swaziland 215 000 tons, Tanzania 95 000 tons, Mozambique 50 000 tons and the United States 170 000 tons.

Independent international surveys consistently indicate that cane sugar production costs in Malawi, Zambia, South Africa and Swaziland are amongst the lowest in the world, whilst the production costs of Monitor Sugar, which produces sugar from beet, are also amongst the lowest in the United States.

The group is a major supplier of sugar to Southern African consumer and industrial markets particularly in South Africa, Malawi, Zambia, Swaziland, Tanzania and Mozambique. In Malawi, Illovo is the country's sole sugar producer whilst in Zambia and South Africa, the group manufactures 99% and 47% respectively of all locally produced sugar. Illovo has significant access to preferential markets in Europe and the United States while Southern Africa operations outside South Africa also have access to the South Africa Customs Union market in terms of the Southern African Development Community (SADC) Sugar Protocol on Trade. Sugar in consumer packs is also supplied into other regional markets within Africa. The group, through the South African, Swaziland and Mozambique industries, also exports sugar into the world free market. Sugar produced at Monitor in the United States is sold in the local US market.

The majority of downstream products are sold internationally into high-value, niche markets. Furfural and its derivates, including Crop Guard, are made at the Sezela mill complex on the south coast of KwaZulu-Natal whilst high quality ethyl alcohol, from which various grades of alcohol are made, is produced at the Merebank plant near Durban and at the Glendale distillery on the north coast. Lactulose is manufactured at Merebank whilst syrup and speciality sugars are produced in South Africa and Zambia. In Malawi, speciality sugars are produced primarily for preferential markets in Europe. Betaine is produced at the Monitor Sugar plant in the United States.

The Illovo group, throughout its African operations, provides considerable support for Black small-scale farmers in order to promote agricultural and economic development. The group also continues to focus attention on medium-scale farmers, the majority of whom are Black, and there are various programmes to assist local entrepreneurs to purchase their own farms and to build up their cane growing operations. Total cane supplies from both small and medium-scale growers amounts to more than two million tons annually. In addition, the group has a procurement policy which promotes and supports the development of small to medium-sized businesses to supply goods and services to these growers and to the group. Social investment programmes are undertaken in every country of operation, having been adapted to local conditions and requirements.

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Rural Renewable Energy Development in China

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Aims of Rural Energy Development in China

- **Problems and pressure China has been confronted with:** Population, development of TVE, higher energy demand and lower efficient utilization;
- **The need of political and state security:** China has signed international conventions such as Rio Declaration and Climatic Change Protocol and made clear to the international community its commitments and responsibilities to ensure energy security;
- **The need of social and economic sustainable development:** It is closely relevant to poverty alleviation, health, education and gender issues.
- **The need of resource and environmental protection:** It contributes to GHG emission reduction for regional and global environment protection.
- **The function of Ministry of Agriculture** is to improve agricultural productivity and to promote the sustainable development of agriculture and rural economy as well as to increase farmers' real income.

History of Rural Energy Development in China

The First Phase: before 1980s

- The traditional way of energy utilization was inefficient, less than 10%. There were many areas lack of fuel wood for 3 to 4 months every year;
- Deforestation was prevalent and soil erosion had become quite serious;
- Rural energy products such as wood-saving stoves had been popularized in 729 counties and household biogas in 101 counties.
- It was a supporting project to meet farmers' basic energy and life needs.

The Second Phase: in 1990s

- "Four-in-one" model had been popularized in north China and "pigs-biogas-fruits" model in south China;
- The integrated utilization had been encouraged and social, economic and environmental benefits been pursued;
- It had supported the general goal of increasing agricultural productivity and farmers' income.

The Third Phase: in the 21st Century

- "Biohousehold project" was initiated in 2000;
- Clean energy and energy efficiency technologies have been popularized and various resources integrated to achieve three goals: warm and clean household, highly efficient courtyard economy and green production;
- It supports the construction of Xiaokang society in rural China.

Rural Renewable Energy Opportunities for China

- Biomass – biogas, biomass gasification;
- Solar energy – water heater, solar cooker, solar house and solar home system (SHS);
- Micro-hydropower;
- improved stoves and Kang; and
- Small wind power.

Benefits of Rural Renewable Energy Development

- **Integrated utilization can directly increase farmers' income**
    - Integrated biogas utilization technologies: "Four-in-one" and "pigs-biogas-fruits" models have effectively increased outputs and improved products' quality ;
    - Agricultural and sideline product processing powered by "three small powers": rice milling, wheat grinding and wool cutting as well as lighting and cooking ;
    - Environmental protection can indirectly increase farmers' income: forest protection can reduce soil erosion and add to soil fertility, so that agricultural productivity and farmers' income can be maintained.
- **Rural renewable energy technologies can improve farmers' living standards**
    - Reduce in-door air pollution and negative impacts caused by illnesses such as eye and pulmonary disease;
    - Reduce energy costs: a new improved stove can save 35~50% firewood and costs can be recovered within 1 year;
    - Improve living standards: farmers can watch TV, listen to the radio and make their living rooms cleaner;
    - Free women from heavy work such as wood cutting, cooking and livestock raising and they can do housework or study in bright lights.
- **Improve environment and reduce the emission of greenhouse gas**
    - A 8m^3 biogas digester can annually save wood more than 2000kg, equivalent to the total wood production of 0.23 ha firewood forest or 0.4 ha timberland;
    - Compared with 1990, total CO_2 and CH_4 emission reduced in 2000, resulted from the extension of renewable energy products and technologies, mounted to 158,727,500 tons and 249,500 tons respectively. The biggest contributor was wood-saving stoves and the second contributor household biogas digesters.

Policy Framework in China

- Rural renewable energy development has been included in *China's 21 Century Agenda* and the *Fifteenth National Economy Development Plan* and *Program on Long-term Goals in 2010*;
- In 1995, the State Council approved *Report on the Development of New Energy and Renewable Energy*;
- In January 2002, the National Working Meeting on Agriculture stated that small infrastructure in rural areas should be strengthened and issues such as water-saving irrigation, human and livestock drinking water, biogas, water and electricity, roads and grassland fencing, shall be supported.
- On 11 April, 2002, the State Council issued *Some Suggestions on Further Improving the Policy of Returning Land for Farming to Forestry*. It was pointed out that in order to protect existing forests and vegetations and in order to strengthen environmental protection achievements, rural energy construction should be actively conducted during the implementation of policies on returning land for farming to forestry and protecting wild wood resource. Projects involving biogas, small hydropower, solar energy, wind energy and fuel wood forest shall be supported. Biogas digester should be built according to standards and industrialization shall be encouraged. The central government shall give some appropriate subsidy to rural energy development.
- On December 28, 2002, the National People's Congress revised the *Agricultural Law of People's Republic of China*. In Chapter 8, Agricultural resource and environment protection, it points out that the development of agriculture and rural economy must be based on reasonable utilization and protection of natural resources such as land, water, forest, grassland and wildlife, must be based on reasonable development and utilization of renewable energy and clean energy such as water energy, biogas, solar energy and wind energy. Ecological agriculture shall be developed and environment shall be protected and improved.
- In 2002, Ministry of Agriculture formulated the National Plan on Biogas Development in Rural China. It suggested that by the end of 2005, biogas technology shall be popularized to 20 million households and by the end of 2010, to 50 million households;
- Since 2001, with the support of national finance, the fund designated by Ministry of Agriculture to support biogas development has jumped from 100 million RMB Yuan to 350 million RMB Yuan. In 2003, the central government is going to support 1 billion RMB by the national debt for household biogas development.

Problems and Barriers

- Inadequate technical extension caused by factors such as short of qualified staff, poor and limited testing equipments.
- The significance and contributions of rural renewable energy technologies have not been fully recognized. They have effectively increased farmers' income and improved their living standards, but most social, environmental benefits and contributions to community development and to global climatic changes alleviations are external. It can not benefit farmers in terms of cash income;
- Insufficient investment. The majority of farmers in China can not afford the technologies and products.

Conclusions

- The general guideline of energy development is “centered on improving energy utilization efficiency and benefits”, renewable energy development and utilization shall be included in government’s long-term development goals;
- As an important part of energy construction, rural renewable energy development has become a major element for China’s rural social and economic sustainable development strategy;
- Rural China enjoys rich renewable energy resource and potential markets and users. It shall make considerable contribution to global GHG emission reduction.
- Ministry of Agriculture used to focus on energy efficiency and resource protection. Its attention has been shifted to poverty alleviation, heath and economic development. It has been realized that rural energy development must be integrated with the construction of small cities and towns and with environment protection and economic development. Rural energy development should attract communities and farmers’ participation.
- As a developing country, China has a large population living in remote and poverty-stricken areas and they are in urgent need of renewable energy technologies. Welcome international communities expand their cooperation with China in terms of capacity building, technical exchanges, pilot demonstration and research and development.

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Bioenergy Potential of Pine Tree Wood, Corn and Sorghum Residues to Generate Electricity using Gasification Technology in Mexico

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Abstract

According to the Mexican Energy Balance (2000), the internal consumption of bioenergy was 6.1% of the total energy demand, equivalent to 340.9 Petajoules. The biomass resource considered in the balance includes firewood and sugarcane baggasse only. Forestry and agricultural residues are not considered. Using official statistics on forestry residues, the energy potential of waste from sawmill operations was calculated in 4.8 Petajoules, and around 82.1 Petajoules from some agricultural residues. This work presents the results from a study aimed at evaluating the technical and economical feasibility of energy generation with gasification technology, identifying the Mexican regions with high production of forestry and agricultural residues.

SESSION 1: STRATEGIES AND POLICIES

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Combustion and Gasification of Biomass with TPS Technology

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History

TPS Termiska Processer AB originally was a division of the publicly-owned Studsvik group. In 1991, the Swedish State Power Board (Vattenfall) took over the ownership of Studsvik and as a result the Thermal Processes laboratory of Studsvik became a separate company in July 1992. It was named TPS Termiska Processer AB and was originally owned by Swedish producers of district heat and biomass fuel (51%), the employees of the company owning the remaining 49%.

In September 1999 there was a further change in ownership, and now the company is owned mainly by present and ex--employees and members of the board.

The company today offers product and services and performs research and development on gasification and combustion. The research is mainly based on experiments in the laboratories and on computerised flow simulation. The results are used to develop processes that are tested in pilot plant and exploited at commercial scale.

Over the last few years TPS has delivered an increasing number of services and products to district heat producers. Since incorporating CP Energi AB in the TPS group, the delivery of products by TPS has significantly increased.

Strategy

Studies, design and construction projects shall be based on TPSs knowledge of combustion and gasification processes.

TPS has performed and conducted research projects funded by the European Commission since 1992 and has good contact with research institutes. The knowledge and strategy of TPS are well suited to the aims of the European Commission to sharply increase the use of renewable fuel in the European energy system and to link technical research to large-scale pilot plant and demonstration projects.

TPS expects these aims of the European Commission as well as governmental support by member countries will greatly encourage commercial interest for the gasification technology of TPS. Experiences from the design and operation of the ARBRE plant is critical for the start-up and operation of new large-scale projects. Gasification of bagasse and cane trash could open a new and very large market for TPS technology.

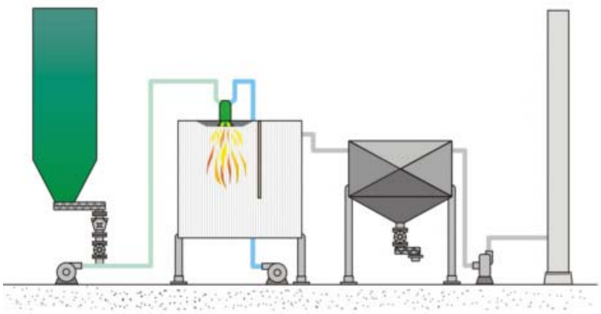
TPS Engineering

Fuel is converted to power and heat through a large number of fast and interacting reactions. The design of reactors involves an understanding of such complex processes. Our "toolbox" consists of a collection of models for simulating flow, chemical reactions and heat transfer. Guided by our models we test our ideas in our own laboratory and in full scale facilities. In cooperation with universities we constantly aim at improving our models. Together with industry we tailor models to be used as engineering tools.

Combustion

TPS has considerable theoretical and practical experience from most types of combustors. We offer optimisations, redesigns and retrofits of combustors. We offer a number of solutions to improve the performance of your combustor.

BioSwirl is a wood-fuelled combustor developed by TPS which is at the heart of a complete solution for district heat production. With BioSwirl, the conversion of your oil-fired boiler to pulverised wood combustion will benefit both the environment and the economy of the plant.



Schematic diagram of BioSwirl Technology

TPS is demonstrating modern combustion technology for refuse derived fuels. Sewage sludge, slaughterhouse waste or sorted industial waste can be combusted in a 9 MW fluidised bed that will be built in Kil, Sweden.
Methods for ash handling and flue gas cleaning will be demonstrated for heat production plants in the power range 5 to 30 MW.

Gasification

TPS has many years of experience with gasification of biomass and waste fuels. In the early to mid 1980s, pressurised technology was developed and tested at up to 30 bars in a 2.5 MW pilot plant at TPS.
In the mid 1980s, a 2 MW atmospheric circulating fluidised bed gasification (ACFBG) pilot plant was built at TPS, it being complemented by a patented hot gas conditioning unit (the so-called "tar cracker") in the late 1980s. Extensive fuel testing on biomass and waste fuels took place during the 1990s.

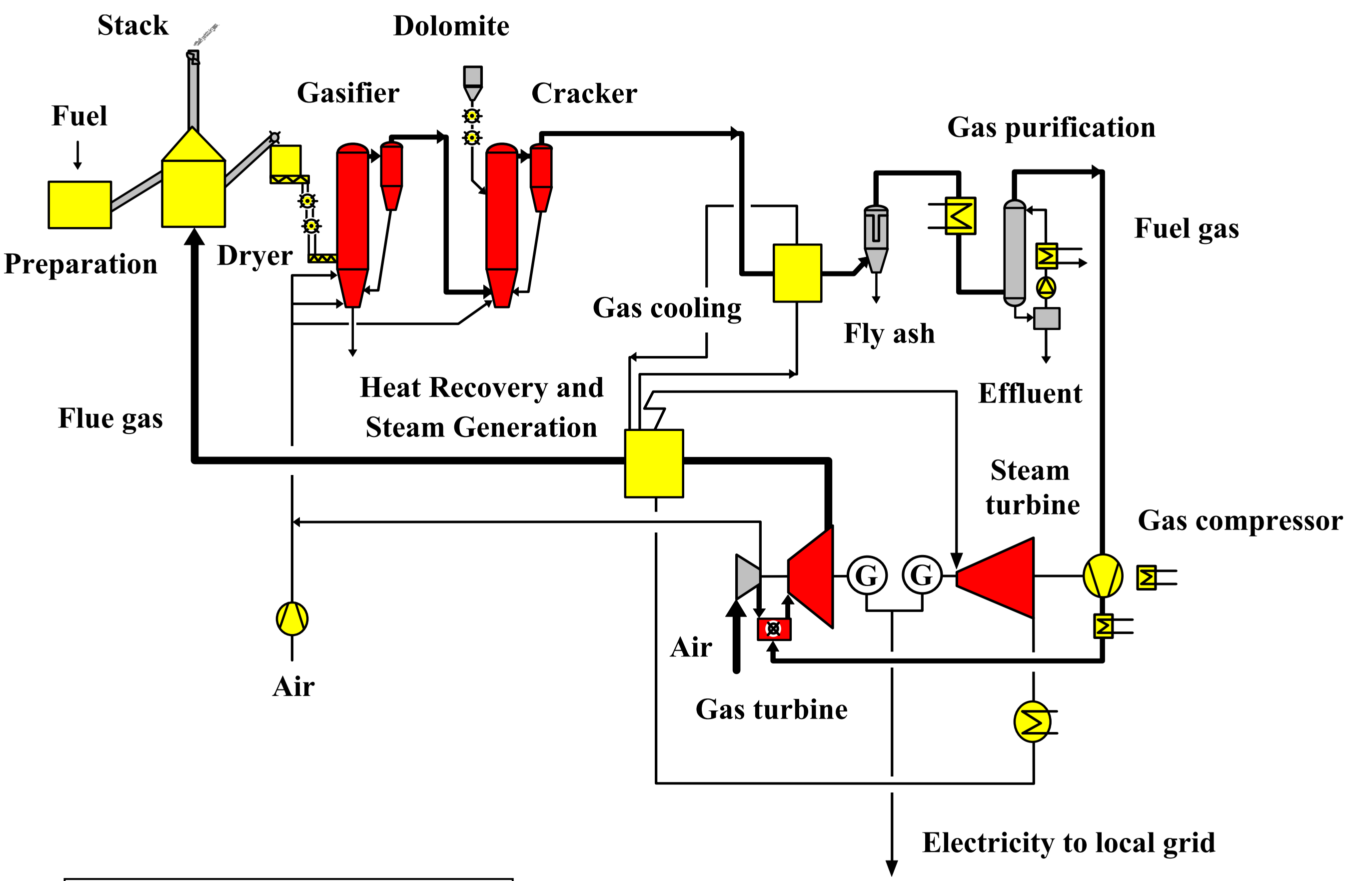
More recently, tests on bagasse and sugar cane trash have been completed. The TPS ACFBG technology can be applied to produce clean gas from biomass and waste. This clean gas can be utilised in a number of ways to produce for example heat, steam and/or power.

Typical applications are Fuelling lime- or cement kilns, Co-firing new or existing oil- or coal-fired boilers and Gas turbines.

Test results:

The operating temperature of the gasifier was kept below a threshold temperature and no agglomeration occurred. The high chemical reactivity of the organic part of the bagasse and cane trash results in a high carbon conversion to gas, above 95%. the carbon content of the bottom ash was low. The composition and heating value of the gas generated was typical for the pilot plant operating on a dry biomass fuel.
The main objective of the tests, to show that sugar cane bagasse and trash could be used as feedstock to the gasification process, was achieved.

TPS Atmospheric Gasification – ARBRE Combined-Cycle Plant



- Supplier: SEC, NL (TPS)
- Start up: Oktober 2001
- Fuel: Wood chips
- Fuel 25 MW
- Elect. gen. 8 MW
- Typhoon GT
- TIC: 30 M£
- EC support 35 %
- PPA: 105 £/MWh 2001

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Heat and Power Production Projects in the Cuban Sugar Cane Agroindustry 2004 - 2008

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Characterisation of Cuban Sugar Cane Agroindustry

SUGAR MILL	84
TOTAL INSTALLED CAPACITY	338 Mtcm/day
DAYS OF HARVEST	150 day
POWER CAPACITY	643 MW

BY – PRODUCTS PRODUCTION:

ALCOHOL, TORULA YEAST, PULP AND PAPER, DEXTRAN, PARTICLE AND FIBER BOARD, GLUCOSE - FRUCTOSE,

BIOGAS FROM:

ALCOHOL STILLAGE	16000 NM^3 / day
FILTER MUD & SUGAR PRODUCTION EFFLUENT	1500 NM^3 / day

Energetic Characteristics of the Sugar Production

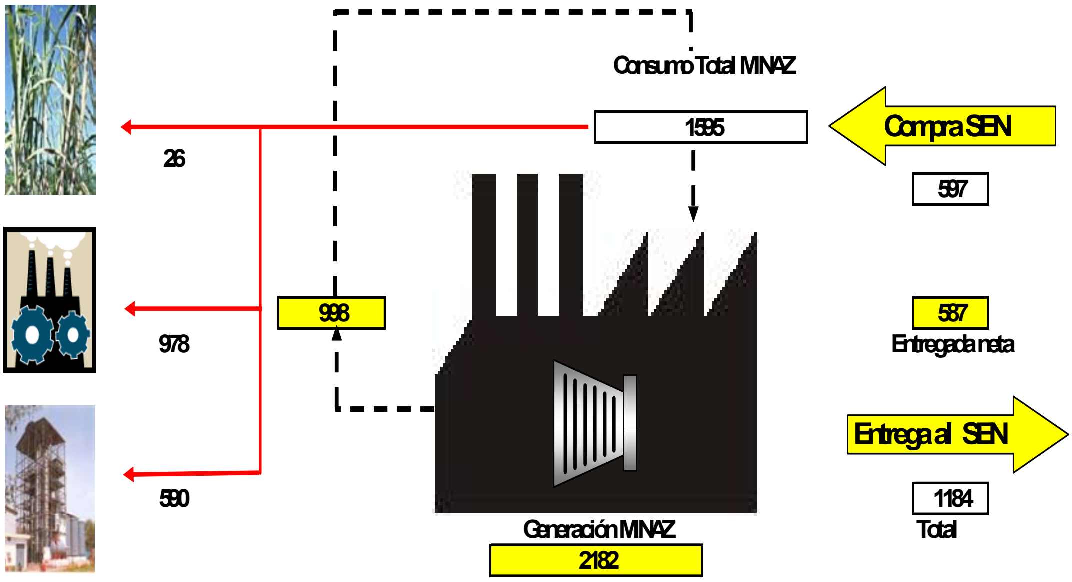
Fuel: 100% of bagasse is available and 5% of trash is available at cleaning stations

- 100% of the Heat Demand is satisfied (2500 Kcal/kg Raw Sugar)
- 100% of the Electricity Demand is satisfied (30 kW/h / tcm)

Main Targets

- Short Term: Electricity Co-generation = Demand of the Sector
- Medium Term: Electricity Co-generation > Demand of the Sector

Sugar Sector Electricity Balance



Line of Development

- Decrease the steam consumption to < 320 kg/tcm
- Increase the efficiency of steam boilers to 85-87%
- 7000 h/year co-generation in new installations with conventional technology
- Utilisation of advanced technology such as pyrolysis and biomass gasification

Projects Planned for 2004 – 2008

- Sugar Cane Biomass Power Plants
  - Power plant adjacent to existing sugar mill supplying heat and power for the production of sugar and by-products and for feeding into the grid
  - Operation of 7000 h/year on bagasse, trash and energetic cane biomass
  - Projects: Hector Molina (35 MW) and Melanio Hernandez (24 MW)
- Increasing installed power capacity of existing sugar mills with a new turbo-generator working 7000 h/year on bagasse and trash
  - Projects: Mario Muñoz (9MW), 30 Noviembre (9 MW), Batalla de las Guasimas (9 MW), Grito di Yara (9 MW), Majibacoa (9 MW), Argentina (5 MW), Colombia (7 MW), Agramonte (7 MW), Cespedes (6 MW)

SESSION 2: BIOMASS TECHNOLOGY AND MARKET

International Conference on Bioenergy Utilization and Environment Protection
6th LAMNET Workshop – Dalian, China 2003

Development of Biomass Conversion Technology and Industry in China – CAREI Annual Report 2002

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Nowadays, development and utilization of renewable energy resources promises good opportunities for China. The Chinese Ministry of Agriculture (MOA) is promoting the "energy agriculture" policy, which focuses on biomass resources development.

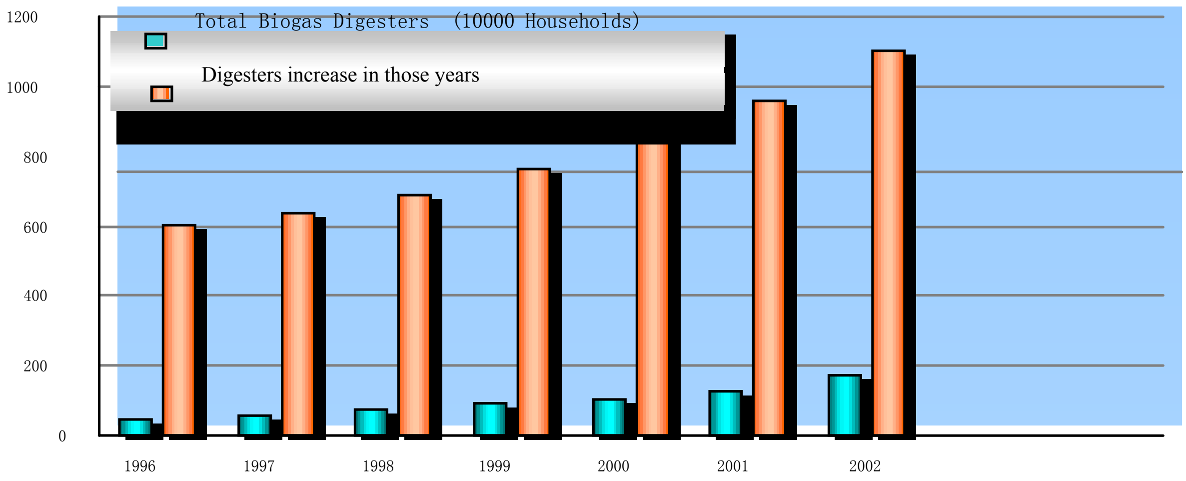
Biomass resources in China are characterized by a large variety, huge quantity and wide distribution. In terms of technological feasibility and economics, biomass that can be used for energy purposes is divided into 5 types: energy crops, agricultural straw, agricultural residues, forestry residues, human and livestock waste, industrial organic waste water and urban organic waste. In China, biomass is the major source of household fuel for rural people with a long history. With the urbanization of rural areas, intensification of agricultural production, and modernization of farmers' lives, because of its "renewability" and the development towards large-scale, efficient, and clean utilization technology, biomass must play an important role in meeting energy demand, environmental protection and sustainable development.

Presently, technologies on biomass conversion widely used in China include: biogas, straw gasification and central supply, gasification and electricity generation, direct combustion for heating, briquetting and bio-fuel.

1. Biogas industry plays an important role in rural energy and environment construction in China

1.1 Biogas industry is developing into a new stage

In 2002, the central government invested 410 million RMB Yuan in rural energy construction. Local investment in rural energy also increased. More than 10 provinces such as Hebei, Liaoning, Hunan, Guangxi, Hainan, and Yunan provided special fund for biogas utilisation. The total amount of local investment in small commonwealth projects was 180 million RMB Yuan. In 2002, 1.7 million households became new biogas users, and there were 11 million biogas digesters in China, constituting an increase by 45.4% since 1999 (see figure 1). In 2002, there were 1859 large- and medium-scale biogas plants with the purpose to treat wastes from large livestock farms, increasing by 500 compared to 2001. The total capacity was 870,000 m^3, with a production of 230 million m^3 biogas and treatment of 46.56 million tons of waste water per year. Approximately 15,000 biogas digesters for household waste water treatment were built in 2002 adding up to 111,000 in China. The total capacity was 4.34 million m^3, which treated 360 million tons of waste water per year.



1.2 New features and trends of biogas industry

Currently, biogas industry comprises of design and construction, biogas appliance production, supply, and operational service. The production capacity can meet the demand of construction of 300 large- and medium-scale biogas plants and 1.5 million biogas digesters and accessories.

- Strategy of “leading enterprises and brand products” has made good achievements.

The Jiangxi Provincial centre for Rural Energy and Environmental Protection Technology Development and its instrument factory increased their sales by 50% in 2002, and became the enterprise with widest market coverage in the field. The Beijing Hebaiyi Ecological Energy Science and Technology Development Company with its good performance concerning capital, technology, and management, was the only one named by the Ministry of Agriculture to have taken in tender enterprise for household biogas digester accessories. The largest gas apparatus enterprise in China, Zhongshan Huadi Gas Apparatus Company set up the Department of Biogas Apparatus Development. Because of its advantage in capital and technology, the company rapidly developed biogas stoves and accessories with good performance/price ratio.

- The product is up-graded and the quality improved

Based on its advantage in research, production, and technology, Luohe Yuli Instrument Company focussed on biogas barometers and developed a metal membrane barometer. Jiangxi Provincial centre for Rural Energy and Environmental Protection Technology Development produced erosion-proof biogas transmission components. Beijing Hebaiyi Ecological Energy Science and Technology Development Company developed adjustable cleaners that combine dehydrate, desulfate, pressure control and pressure display. Most of the enterprises that manufacture biogas stoves are paying attention to product quality, design of stove structure and improvement of product appearance.

- Improved techniques and engineering technology

Construction of household biogas digesters has been industrialized and commercialised. Research on large- and medium-scale biogas plant, equipment and post-treatment technology have made new achievements. Tsinghua University developed the 3-generation anaerobic fermentation techniques: ECSB and internal circulation reactors. ECSB has been practically used in China, and has reached a world leading level. The institute of Biogas Science of the Ministry of Agriculture, Shanghai Mingxing Energy Conservation and Environmental Protection Engineering Company, Hangzhou Energy and Environmental Engineering Company, Beijing Academy of Environmental Protection, Centre for Energy and Environmental Protection Technology Development of the Ministry of Agriculture, Department of Environmental Science and Engineering of Tsinghua University, and Beijing Meihuaboda Environmental Engineering Company are capable to design large- and medium-scale biogas plants. Besides, research and development of biogas generators also made good progress.

- Level and capability improvements for operational services

Government biddings and purchases have promoted the enterprise cooperation and industry developments, and therefore guarantee users' rights. Some strong enterprises catch the good opportunity to establish and perfect their own sale and operational service system while suppling biogas stoves into the market, which has dramatically improved the level of operational service. In the process of promoting industrialized management of household biogas digesters, some new management patterns such as township biogas associations were created.

- Improved systems of biogas industry standards

Improvement of the system of biogas standards has basically met the demand of development of biogas construction. Standards for Design, Construction, and Use of North Model of Household Rural Energy Engineering, Standards for Design, Construction, and Use of South Model of Household Rural Energy Engineering, and the National Standards for Household Biogas Stoves GB3606-83, which fully reflect up-grades of biogas stove technology, have been issued and implemented. Other relevant standards are to be issued soon. The institute of Biogas Science of Ministry of Agriculture and Centre for Biogas Product and Equipment Quality Test of Ministry of Agriculture have been working on the formulation, modification, and extension of biogas-related standards.

1.3 Planning of Biogas Construction Development provided good opportunities for biogas industry development

The 2003-2010 Biogas Construction Plan in Rural Areas of China, formulated by the Ministry of Agriculture, clearly stated that the government will actively promote the development of biogas industrialization, which provided excellent opportunities to industry development. According to the plan, 11 million household biogas digesters will be produced by the end of 2005, and then there will be a total of 20 million in China: one of every ten rural households will be a biogas user. In 2010, 50 million rural households (20% of the total) will use biogas as daily fuel. Meanwhile, the government will support the construction of large- and medium-scale biogas plants in "vegetable basket" livestock feeding base in suburbs of cities in East coastal areas and some other large and medium cities. 2500 biogas plants are to be constructed by 2005, which can supply biogas to 300,000 households; 5000 in 2006-2010, supplying 600,000 households. Implementation of such a great plan will strongly promote the progress of biogas technology and enable the biogas industry to improve further.

2. Biomass technology has made good progress

2.1 The Framework of standard systems has been established and relevant standards are gradually formulated

In this case biomass resources mainly refer to crop straw. Considering the current situation of biomass utilization in China, some of the biomass technology has not been technically mature enough to be widely applied. The technical limitation and management problems are too serious to realize a large scale application. Further experiments are necessary to decrease conversion costs and improve products' quality. At present, a framework of standardization systems has been established. Perfection of industrial standards ensures the further development of biomass utilization.

2.2 Diversified products variety and advanced technology

With the urbanization of rural areas, intensification of agricultural production, and modernization of farmers' lives, and because of its "renewability" and development towards large-scale, efficient and clean utilization technology, biomass must play an important role in meeting energy demand, environmental protection and sustainable development.

Currently, technologies on biomass conversion widely used in China include: biogas, straw gasification and central supply, gasification and electricity generation, direct combustion for heating, briquette for fuel and bio-fuel.

The existing village-level straw gasification and central supply plants can normally supply fuel gas to 100 - 1,000 households. The thermal conversion efficiency is more than 70%, the thermal value of fuel gas more than 4600kJ/Nm^3, and CO and O_2 content is less than 20% and 1%, respectively. Compared with old straw gasification systems, the new ones have a better performance, especially for carbonisation gasification systems, and operation is more steady. However, the problems of low thermal value and high tar treatment costs still exist.

China is researching and developing two types of biomass gasification systems for electricity generation: fixed bed gasification and electricity generation systems, and fluidized bed gasification and electricity generation systems.

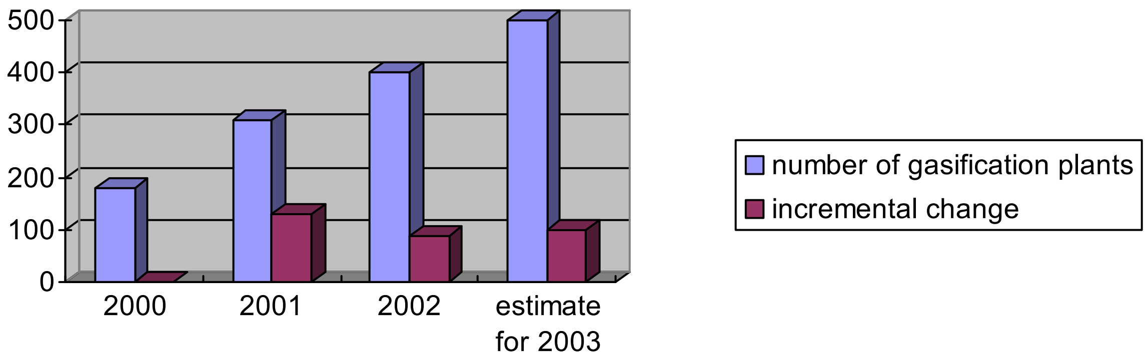
Biomass direct combustion is used for heating and drying. As an effective approach to consume large amounts of crop straw, this method has a promising prospect.

The prominent problem of biomass briquetting machines is that the press screw and sleeve do not have a sufficient life-time.

The technology of biological liquid fuel from biomass is now a research project funded by the State Planning Commission and Ministry of Science and Technology.

2.3 Industrialization process is seeking turning point

In recent years, industrialization of biomass conversion technology in China made good achievements, and a variety of enterprises and research organizations are able to conduct technology development, equipment production and plant construction. The involved fields are: biological liquid fuel from biomass, biomass gasification, biomass briquetting and fuel gas drying, biomass direct combustion boilers, etc. In particular, companies in the field of biomass gasification equipment production and technological service developed very fast, and industrialization and socialization of small-scale biomass boiler has achieved good progress.



Trend of Gasification Plant Development in China

By the end of 2002, there were more than 400 biomass gasification and central supply plants in China, which produced 150 million m^3 of fuel gas per year and involved equipment manufacturing output of 900 million RMB yuan. There are more than 40 companies and research institutions able to undertake the design and construction of crop straw gasification and central supply plants in China. There are 15 biomass gasification and electricity generation plants in operation. 5 organizations are able to design and construct biomass gasification and electricity generation plants. Among them, Guangzhou Energy Institute of the Chinese Academy of Science is the best.

Biological liquid fuel mainly refers to bio-ethanol. China has issued national standards: *Denaturalized Fuel Ethanol* and *Vehicle Ethanol Gasoline*. The State Planning Commission has approved 4 demonstration projects, in Heilongjiang Province (200,000 tons per year), Jilin Province (600,000 tons per year), Henan Province (300,000 tons per year), and Anhui Province (60,000 tons per year), respectively. These projects produce fuel ethanol from old grain and the petroleum industry uses the ethanol to produce vehicle ethanol gasoline for sale at local gas stations.

The Chinese Academy of Agriculture Engineering and Beijing Taitiandi Energy Technology Development Company are undertaking a National 863 Project “Fuel Ethanol from Sweat Sorghum”. The technology uses sweat sorghum as raw material and produces fuel ethanol through biological conversion technology. The project is established on the base of biomass conversion technology, agricultural residue recycling technology, and ETBE (non-pollution ethanol gasoline additive) conversion and synthesis technology. A straw briquetting machine developed by Henan Agriculture University has been manufactured in several scales. Beijing Laowan Biomas Science Company has developed efficient biomass grain fuel automatic combustors and a series of stoves, characterized by high efficiency and environmental protection.

The development of renewable energy technology and industry in China has made good achievements with the help of international organizations such as UNDP, FAO, UNIDO, ESCAP, WORLD BANK and in cooperation with other countries. We are willing to carry out better and more effective cooperation with Latin countries to serve the whole world.

SESSION 2: BIOMASS TECHNOLOGY AND MARKET

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Bio-diesel Production from African Palm in Colombia

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The Corporation for Biotechnology Industrial Development and Clean Production – CORPODIB – is a non-profit technological development center. CORPODIB has been developing alternative fuel programmes and projects such as vehicle natural gas and biofuels in Colombia: sugar cane bioalcohol for Colombian gasoline and African Palm biodiesel for Colombian Diesel (ACPM).

The Colombian Law 693 of September2001 demands the use of bioethanol mixed with gasoline from 2006. Currently, a new law is in process in the Republic Congress, which demands the use of biodiesel from vegetable Oils to be mixed with Colombian Diesel (ACPM).

Colombia has African Palm plantations of 170.000 hectares and produces 547.000 ton/year of palm oil, being the fourth world producer with 2% of the production, after Malaysia (52%), Indonesia (31%) and Nigeria (3%).

If biodiesel is produced from oil to be mixed at 10% with Colombian Diesel (ACPM), 100.000 additional hectares of African Palm are required to produce 300.000 tons/year of oil, which means a 55% increase of the national production and approximately 100.000 direct and indirect jobs generated.

The chemical reaction for the conversion of vegetable oil into bio-diesel is:

$$\text{Vegetable Oil} + \text{Ethanol} \xrightarrow{\text{Catalyzer}} \text{Biodiesel} + \text{Glycerin}$$

$$1\ \text{Ton} + 0.15\ \text{Ton} \xrightarrow{\text{KOH}} 1.05\ \text{Ton} + 0.1\ \text{Ton}$$

SESSION 2: BIOMASS TECHNOLOGY AND MARKET

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Prospects for Application of Biomass Pyrolysis Technology in China

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1.Preface

Biomass is a regenerative substance storing solar energy. All living creatures on earth rely on the transformation of biomass. Utilizing biomass as energy source has a long history. Starting from the recognition of fire, biomass has been utilized by human beings. 60 million years ago, a large amount of biomass was stored under the earth's surface, which underwent thermo-chemical changes and turned into coal, petroleum and natural gas. Therefore, the maximum amount of available coal, petroleum and natural gas can be calculated, and it will not be greater than the total amount of living creatures at that time. That is to say, coal, petroleum and natural gas are special substances that were formed once and they are not regenerative. However, living plants are a regenerative resource (animals being also a kind of biomass are not to be discussed here). So, biomass energy can be developed and utilized in a continuous way.

At present biomass energy is utilized in the following ways:

- Obtaining heat energy through direct combusting;
- Obtaining combustible gas through biomass fermentation;
- Obtaining combustible gas through biomass gasification;
- Obtaining combustible gas, charcoal, tar and other chemicals through biomass pyrolysis;
- Obtaining various chemical raw materials through biomass chemical conversion.

2. Comparison of biomass pyrolysis technology with other biomass energy converting technology

1) Direct combustion and densification of biomass

The direct use of biomass by human beings from ancient times until now has been by burning. This traditional way of using biomass has been gradually replaced by other forms of energy conversion, due to its low rate of heat utilization (less than 13%) and heavy pollution.

Biomass densification is a technology that has been developed in recent years replacing wood and coal. This technology applies mechanical force onto plant bodies transforming them into biomass blocks and bars of greater density after being crashed, dried and heated. The density of such blocks and bars is large, so it can be burned like wooden bars to overcome the disadvantages of burning loose materials.

The process of biomass densification consumes large amounts of energy, so that wooden chips, at the cost of RMB 60 yuan per ton, are transformed into artificial wooden bars of RMB 400 yuan per ton. In this case, direct burning becomes quite uneconomic. At present, most of densified biomass bars are used for the production of artificial charcoal through pyrolytic processing. As the current price of artificial charcoal in the market is between RMB 1,500 and 2,000 yuan per ton, this makes biomass densification processing possible.

2) Biomass fermenting, production of biogas

Under anaerobic conditions, biomass is transformed into a gas mainly containing methane and carbon dioxide (biogas). This is a biochemical process involving biological engineering.

Consuming far less energy is the greatest advantage of biological engineering which uses metabolic energy of germs in the production process. Biogas production is the lowest in energy consumption among various biomass energy conversion options. Biogas contains 50-70% methane and 30-50% carbon dioxide. Being a combustible gas of high quality and medium heat value (lower heat value usually greater than $20MJ/Nm^3$) it is particularly suitable as combustible gas for civil use.

The reason why biogas production can not be spread broadly in the countryside of China mainly lies in:

- In-sufficient sources of nitrogen in biogas production In the course of biogas production, C/N should not be greater than 25, but the C/N of dry stalks (harvested in autumn) is usually greater than 30, such as 87 for dry wheat straws, 67 for dry rice straws and 53 for corn stalks. They are main biomass in the countryside but can’t be used directly in fermenting processes. Biological engineering is applicable only in places where pigs and chicken are raised in a centralized way.

- Biogas-generating tanks for single households do not comply with modern modes of living in China and therefore provide no opportunity for future development. Especially for countries like China with large population and few land resources, garden type agriculture based on single households is by no means a long term policy.

- Biogas production by biological engineering has a great limitation in Northern China because it is low in production capacity and temperature has a great influence on it.

Although problems mentioned above exist, biogas production will not lose its significance for applications in the countryside for quite a long time, especially in areas backward in economy and dispersedly inhabited. It will have more value of application especially in places rich in nitrogen.

3) Biomass gasification

Under the condition that oxidizers are available, biomass undergoes oxidation. This reaction is called biomass gasification because it can oxidize biomass into gaseous substances. More combustible gases like carbon monoxide and hydrogen can be obtained only by controlling the course of oxidation leading to incomplete oxidation. This is the most important approach in biomass gasification.

According to the characteristics of oxidizers, there are the following ways of biomass gasification:

- Gasification using air as the oxidizer
  Incomplete burning of biomass using air as the oxidizer. The main reactions are:

$$C + O_2 \rightarrow CO_2 + Q$$

$$2C + O_2 \rightarrow 2CO + Q$$

Both reactions above are exothermic reaction and there are reduction reactions at the same time:

$$CO_2 + C \rightarrow CO_2 + Q$$

$$C + H_2O \rightarrow CO + H_2 + Q$$

Both reactions above are endothermic reaction.

From the reactions we can see that the produced gas mainly contains CO, a combustible composition (usually 18-23%), H_2 (usually 6-10%), and CO_2 (usually 8-10%). As inert gases exist, the contents of combustible gases are diluted so that the heat value of the gas becomes very low with a lower heat value usually between 3,500 and 5,500KJ/m^3 (some are called hot gas, namely, it has to be preheated for use before being combusted).

Air gas production is a relatively economical and simple way of conversion of biomass energy with the advantage of being fast in gas production, large in production volume and high in utilization rate of energy without any by-product. The biggest disadvantage is that the heat value of the gas produced is low which limits its application.

- Gasification using pure oxygen as oxidizer

The principle of reaction in this way of production is the same as that of air gas producers. As pure oxygen is used instead of air, this reduces the content of nitrogen in the gas so that the content of combustible components are increased. The content of CO is usually between 40 and 50% and the heat value is doubled compared with that of airgas (usually between 10 MJ/m^3). As the combustible gas contains too much CO, safety is particularly important in use.

- Gasification using water as oxidizer

Reactions involving vapour and carbon:

$$C + H_2O \rightarrow CO + H_2$$

Carbon monoxide and hydrogen are produced, both of which are combustible gases. As this water gas reaction is endothermic, preheating of biomass is needed and vapour should be led in for reaction after it being heated to a high temperature. This course preserves heat with reactions happening alternatively, nearly 50% biomass is consumed but less than 50% of charcoal generating water gas reaction is consumed. The lower heat value of water gas is usually between 10 and 12 MJ/m^3 and it is not suitable for civil use because it contains high amounts of CO. Water gas is mostly used in synthesizing ammonia as it is a good source of hydrogen.

4) Biomass Pyrolysis

Biomass is pyrolyzed under condition being free from air, namely destructive distillation of biomass. The resultants of biomass pyrolysis have three states: solid charcoal, liquid wood tar and pyroligneous liquor, combustible gas. According to the temperature in pyrolyzing, the process can be divided into pyrolyzing at low temperature (below 600°C), pyrolyzing at moderate temperature (600 to 900°C) and pyrolyzing at high temperature (above 900°C). Pyrolyzing at different temperatures may produce resultants with different content. The higher the temperature, the greater the amount of combustible gas and liquids, and the less the amount of solid charcoal.

Wood destructive distillation was very popular early in the century for the purpose of producing wood charcoal and ethylic acid for metallurgy, and tended to decline in the middle of the 20th century because of lack of wood and coal and the start of petroleum refining.

Generally, it is regarded that wood destructive distillation is very similar to coal destructive distillation. Herbaceous plants can't be distillated, i.e. the resultants from distillation of herbaceous plants is not the same as that from wood distillation. This point of view is challenged through research results obtained by the Dalian Environmental Science Design & Research Institute. The Institute has successfully made distillation and pyrolyzing tests with more than 20 kinds of biomass like wood chips, leafs, corn stalks, rice straws, soybean stalls, wild grasses, coconuts shells, yellowweed, bagasses, furfural residues, etc. and all resultants obtained from the tests were almost the same. This brings new life to wood destructive distillation, especially in the 21st century when coal and petroleum will come to an end. Then, biomass destructive distillation and the pyrolyzing industry will rise again.

Charcoal obtained from biomass pyrolysis is a kind of charcoal purer than coal coke in both block and powder form. Being low in ash content, good in reactivity and large in specific surface area, it is a high-quality reducer for nonferrous metallurgy, an absorptive agent for the environmental protection industry and a soil modifier for agriculture. It therefore has a broader application than coal coke.

Tar and pyroligneous liquor produced in pyrolysis is a liquid containing more than 200 components, like acetic acid, methanol, acetic aldehyde, acetone, ethyl acetate, etc.. Some components have a value as raw material in the chemical industry.

Resultants produced in biomass pyrolysis mainly contain: CO_2, CO, CH_4, C_2H_4, H_2, etc., with a lower heat value is between 15 and 20 MJ/m^3, therefore belonging to combustible gases of medium heat value. It is called wood gas because its compositions and heat value are similar to urban artificial gas. It is also a gas of high quality because it doesn't contain any sulphide and nitride, and can be used directly as civil combustible gas.

Contents of resultants produced in biomass pyrolysis at temperatures of 900°C:

Wood charcoal: 28 to 30%, wood tar: 5 to 10%, combustible gas: 30 to 35%, pyroligneous liquor: 30 to 35%.

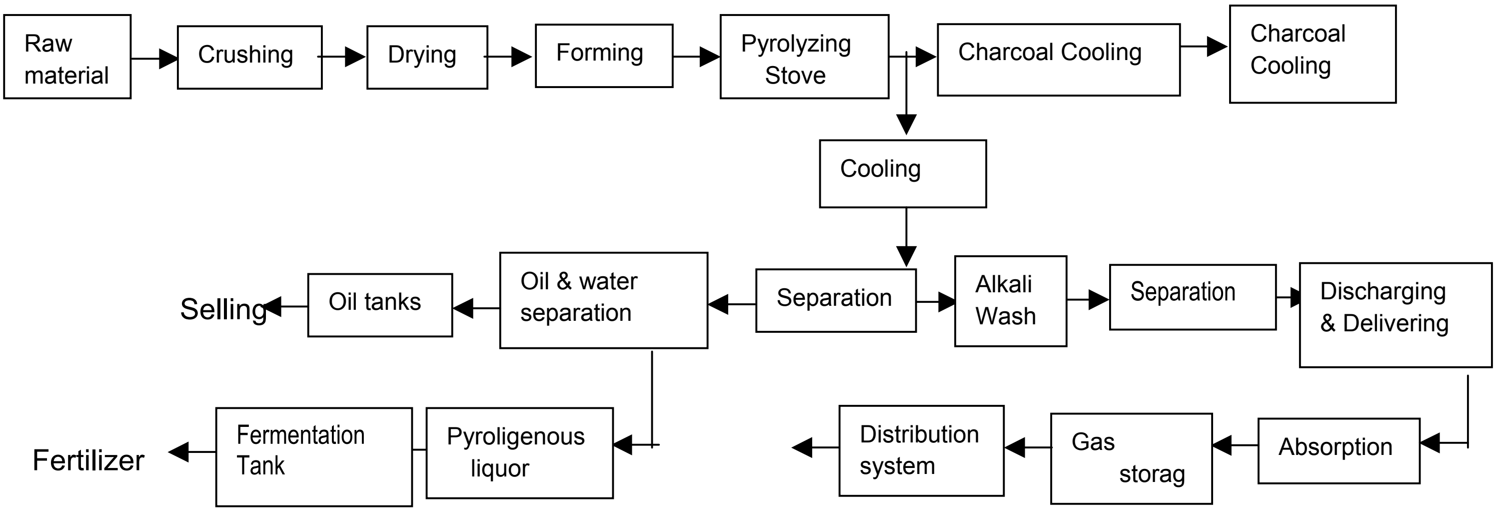
One of the features of biomass pyrolysis is the diversification of resultants. This is both an advantage and a disadvantage. If market are found for the main by-products, great economic benefits can be obtained. If only combustible gas without other by-products is to be used, economics are not favourable.

3. Engineering practice of biomass pyrolysis

A biomass pyrolysis plant had been built in 1995. The designed capacity of gas production was 1500m3/d. Three years later, the plant was moved and rebuilt with doubled capacity. This Sanjianpu Biomass Gas Plant is in operation for 4 years now.

It is the first social practice to use biomass pyrolyzing replacing artificial gas production by pyrolyzing coal to make a continuous supply of pipe gas to the peasants. All design codes, standards, management system and pricing use that of urban artificial gas.

1) Process Flow:



2) Standards for control of product quality

Standards should be in accordance with the technical requirements for artificial gas in Standard GB - 13612 - 92.

	Standard value	Actual value
Lower heat value(MJ/m^3) should be greater than	14.7	15 to 20
Foreign substance:		
Tar and dust (mg/m^3) should be less than	10	5 to 10
H2S (mg/m^3) should be less than	20	None
Ammonia (mg/m^3)should be less than	50	None
Naphthalene(mg/m^3)should be less than in winter	50	None
in summer	100	None
Oxygen content (V%) should be less than	1	0.8
CO content (V%) should be less than	10	10 to 15

3) Operating procedure and management systems of the Combustible Gas Plant

There are 20 items, such as "Technical Qualification Requirements for the Workers in Combustible Workshop", "Operating Procedure of Pyrolyzing Stove", "Management Rules on Users' Using Combustible Gas", "Fire Prevention Systems of the Combustible Gas Plant ", "Handing of Electricity Shutdown Incident ", "Handling of Water Supply Stop Incident", "Handling of Alkali Supply Stop Incident", etc.

4) Investment of the Combustible Gas Plant

Total investment according to the design was RMB 4.5 million yuan but actual investment is RMB 2.5 million yuan, including 0.9 million for the 1,000 m^3 gas storage tanks, 0.5 million for the main distribution system and branch distribution systems, 0.5 million for the pyrolyzing equipment, 0.5 million for purifying equipment and 0.1 million for others items.

It was planned to charge RMB 2,000 yuan per household as gas source fee, but the actually charged fee was 1,000 per household.

The pricing of combustible gas is RMB 1 yuan/m^3 in accordance with the price of urban gas. Average consumption by each household daily is about 1.3m^3, the same as the average consumption of Dalian inhabitants for many years, namely 2,093.5MJ per person each year.

Ex-factory price of charcoal is RMB 1,600 yuan/ton, and the actual selling price of tar is RMB 3,000 yuan/ton.

5) Economic benefits

Supply of gas for use by 1,000 households, we can have a profit of RMB 0.8 to million yuan each year.

4. Factors that currently limit the spread of biomass energy conversion technology in the countryside

It is clear that biomass energy has advantages in many aspects. Especially the engineering technology of biomass energy conversion by using stalks has advantages of obtaining raw materials locally, utilizing wastes, reducing pollution, increasing energy utilization, being convenient and clean. But why can biomass energy conversion not spread in the vast countryside of China. In the past eight years, several hundred of communities from countryside China contacted the Institute with the request to build gas supply projects in the countryside. But, only three became successful for the following reasons:

1) Limited by the economic situation in the countryside

The economy in the countryside of China is still backward. Food and clothing is still a problem in parts of the regions and the people are concerned with eating, dwelling and wearing in the first place. They are quite satisfied with having enough burning wood and therefore combustible gas is out of question. In places having better living conditions, electricity and tap water supply is starting to be taken into consideration without the intention to change the structure of fuels. In cities there are allowances for gas supply of governments, but who will offer allowance for gas supply in the countryside?

Besides, combustible gas at the price ranging from RMB 1 to 1.2 yuan/m^3 is still unaffordable due to bad economic conditions, and burning grasses and coal are much cheaper.

2) Limited by low living quality in the countryside

Due to the low living quality, the user value of combustible gas can not be fully evaluated. Standards like time saving, cleanliness, less pollution, less hard work, etc. are not included in the evaluation. In some places questions such as “ is gas cheaper than stalks?” is raised.

3) Limited by dispersed settlements in the countryside

Today, a vast majority of the population (more than 9 million) in the countryside lives in dispersed settlements. This courtyard style of living brings great difficulty to combustible gas projects and increases investment tremendously.

4) Limited by ideas

Only considering personal economic and short-term interests and disregarding general interests, long-term and environmental benefits. Unbalanced economic development and different views of households, some households are in favour and some against the use of combustible gas.

5. Biomass pyrolysis has a bright future in China's countryside

1) Economy in the countryside is developing very fast and peasants become richer every year. In China, there are nearly 1 million villages, of which 20 thousand villages will improve their standard of living in a way that they will require modern fuels in the near future. Especially in suburbs of big cities and in small towns, living conditions like in cities will be needed very soon due to the fast development of the economy. This will cause them to consider the opportunity of combustible gas.

2) The situation of dispersed settlements in the countryside of China will not last long. China has a relatively large population and little land, it is impossible for the households of courtyard style in the countryside which are disperse and occupy more land to exist for a long time. Households in the countryside of China must be placed in a centralized way in towns. According to the principal of being advantageous to both living conditions and production, it is preferable for size of future towns in the countryside of China being 1,000 to 2,000 households. This will provide advantageous environmental conditions for gas supply in a centralized way by pyrolyzing biomass.

3) Prices of coal and petroleum will rise significantly as estimated by experts. In 2010, the price of artificial gas will be above RMB 5 yuan/m^3, and crop stalks will more and more become discarded. At that time artificial wood gas using stalks as raw materials will be a cheap fuel of high quality and will be doubly welcome.

4) With the modernization of the large industry, new rural industries will come into being. Pyrolysis projects using stalks as raw materials will also require industrial systems to obtain materials locally, such as wood charcoal deep processing industry, tar processing industry, pyroligenous liquor extracting and processing industry. At that time biomass energy converting project will be spread everywhere in the countryside.

5) When a new pricing system is formed at a certain stage of economic development, there will be changes in prices of combustible gas, wood tar and powdered charcoal. At that time, it will be possible for powdered charcoal to be used on farmland (being confined by economic conditions it is impossible now in our country, but in Japan powdered charcoal are being used as soil modifier.)

6) At present peasants have built successively living areas with buildings similar to those in cities on the brink of big developed cities and imitate those living conditions, but they can't have gas supply like cities. Therefore, in these parts linking cities with countryside market, opportunities exist for gas supply projects using pyrolysis of biomass.

Above all, biomass pyrolyzing technology is a mature and excellent applied technology. It is a comprehensive utilization technology being advantageous to environment, society and economy. Though it is rather difficult to spread and popularise the biomass pyrolyzing technology at the moment, its application has a extraordinary bright future in an agricultural country such as China.

SESSION 2: BIOMASS TECHNOLOGY AND MARKET

International Conference on Bioenergy Utilization and Environment Protection
6th LAMNET Workshop – Dalian, China 2003

Innovative Ethanol Production and Gasification Technologies

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1. Desalination of seawater and extraction of fuel ethanol from waste fermented liquid biomass products

The desalination system is based on a patented technology and method to use a crystal hydrate to absorb pure H^2O from seawater. The technology gives the opportunity to use waste energy, renewable bioenergy or sun energy to operate a very simple and cost effective system to produce distillate water or drinking water. In small-scale applications (for household) the system operates with electricity.

Scientific tests has given the result that the same crystal hydrate, which is used in the desalinisation system, can be used for extraction of fuel ethanol from wine mash, fermented sugar juice or other fermented liquid products.

Gougel Industri AB (GIAB) develops the technology

2. Gasification processes, which convert biomass into absolute, clean syngas and utilize a catalytic process to convert the syngas to ethanol

The technology is based on a pyrolytic/gasification system developed by Studsvik AB and commercialised in USA (The THOR-process). One of the responsible persons behind the THOR-process is the inventor Rolf Hesböl.

Rolf Hesböl has now invented a filter that makes it possible to produce an absolute clean syngas, which is the prerequisite of producing ethanol

The technique that will be used allows it to be construct as a mobile production plant. The system can be transported from place to place by trucks and/or railway.
The plant is suggested for use in processing a wide variety of organic wastes for example straw from Corn or Sweet Sorghum. Also organic municipal waste can be used.

The total system is named Idnar Processing Facility (IPF) (Idnar is the name of Rolf Hesböl´s own company).

SESSION 2: BIOMASS TECHNOLOGY AND MARKET

International Conference on Bioenergy Utilization and Environment Protection
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A New Type of Straw Gasification-Heating Set

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1. Disadvantage of traditional biomass gasification-heating sets

As a method to utilize all kinds of biomass energy on a large scale, biomass gasification technology is today experiencing worldwide research activities and current applications include heating, electricity generation, centres for the supply of cooking gas as well as synthesizing chemical products.

'Biomass gasification-heating' denotes that biomass is converted into combustible gas through a gasifier and the produced gas is burned in order to provide heat energy.

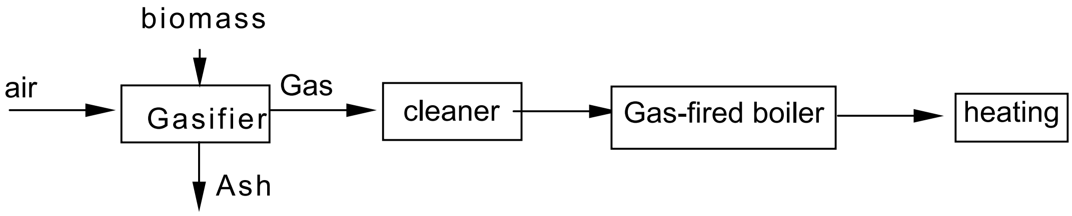

Figure 1: Technological process of biomass gasification-heating system

A number of studies on biomass gasification-heating have been performed during the past years in China. New practical biomass gasification-heating sets were developed for district heating or industry boilers and brought certain economical and social benefits. Figure 2 is a schematic diagram of a wood drying system by means of waste chip gasification. Figure 3 is a schematic diagram of a grain drying system by means of corncob gasification.

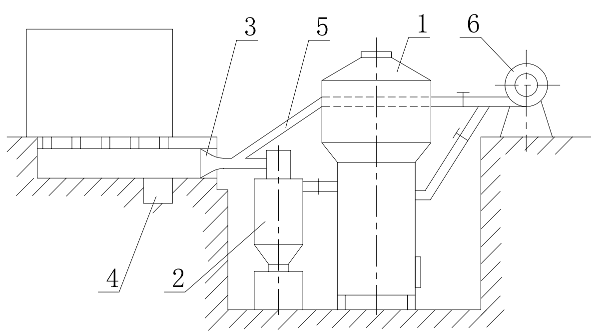

Figure2 Schematic diagram of wood drying system by means of biomass gasification
1.gasifier 2.cleaner 3.burner 4.dust drop chamber 5.duct of supplemental air 6.blower

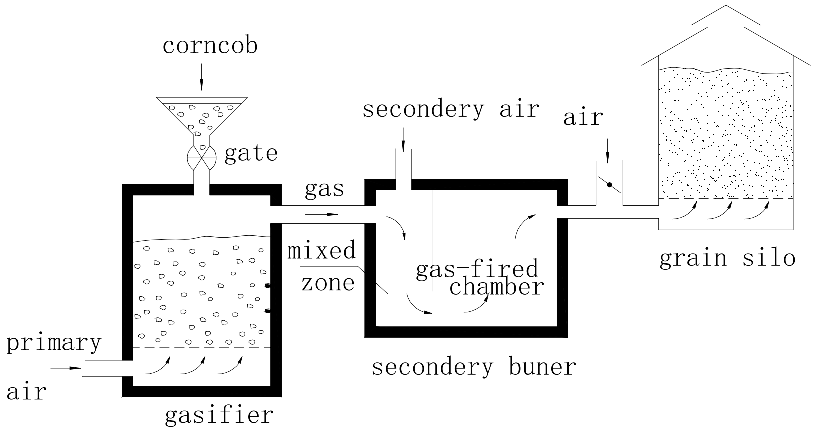

Figure3 Schematic diagram of grain drying system by means of biomass gasification

As shown in figure 2 and figure 3, every existent set of biomass gasification-heating is operated under positive pressure conditions. The raw material should have large stack density and low ash content such as wood, corncob etc. But these technologies are not suitable for straw gasification-heating systems, in which case benefits could be taken from the large yield and wide distribution of straw in China. The reason is that the gasifiers are always operated always under positive pressure and the raw material feeding is discontinuous, when straw is used as raw material. Thereby, the gasifier's status will rapidly undulate, leading to great operational difficulties and even failure of the gasifier.

The new straw gasification-heating set is realised as down-draft fixed bed gasifier with a rectangular gasifier cross-section. Under continuous feeding of the raw material and continuous removal of ashes, the system is operated under negative pressure conditions. Not only can this technology be applied for wood and corncob, but also for various straws. In addition, it also has such advantages as simple structure, easy operation, high heat efficiency and unpolluted exhaust.

2. Principle and work process of new type straw gasification-heating set

The new straw gasification-heating set mainly consists of a gasifier and a gas-fired boiler.

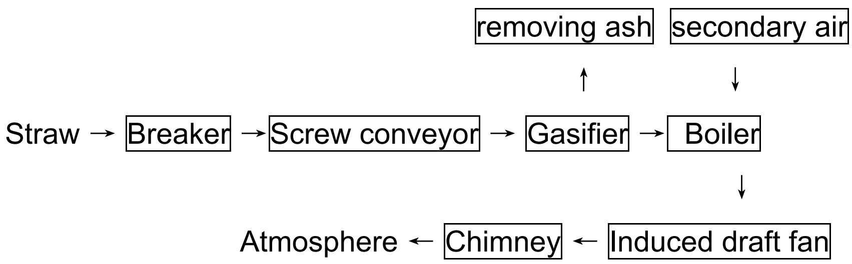

Figure 4 Principle diagram of new straw gasified-heating set

The broken straw is fed from top into the gasifier by a screw conveyer In the gasifier the oxidation and reduction reactions take place producing gas at high temperature. A screw remover is used to get rid of the ashes from gasifier during operation. The gasifier is isolated from the outside by a rotating valve, therefore the equipment can operate continuously for a long time, both for raw material with high ash content (such as rice husk and peanut shells) and for raw material with lower ash content such as wood and corncob.

The temperature of the gas is about 400°C and the gas contains impurities such as dust and tar. After dust removal, the gas is transferred to the combustion device, a boiler, in which the gas is mixed with secondary air and burns perfectly in a special designed burner.

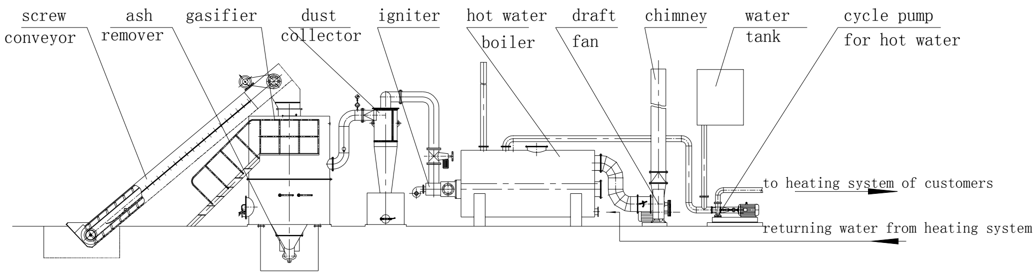

Figure 6 Technological process of heating system of hot water through straw gasification

As the gas is not cooled, the heat of the gas and the heat content of the tar leads to a higher heat efficiency of the system. The tar is cracked and combusted completely continuously by burning at a high temperature, so that the environment is not polluted by tar.

The flue gas generated in the combustion process at high temperatures is transferred to a heat exchanger inside the boiler, or is mixed directly with cool air for drying purposes. Then the flue gas is vented to the atmosphere via a chimney by induced draft ventilation.

3. Main characteristics

3.1 Working under negative pressure

The reason for operation under negative pressure is primarily to realise flexibility to various biomass sources, especially to all sorts of straw. Since the gasifier is designed as down-draft fixed bed which is working under negative pressure, the gasifier can be fed, observed and operated conveniently.

3.2 Rectangular cross-section of the gasifier

When used for biomass gasification-heating, a larger production capacity for the gasifier is required in order to meet the demand of technological heating. In traditional round-section-gasifiers, the air required for the gasification process will have difficulties to enter the centre of the gasifier, when its gas yield exceeds 600 m^3/h. This leads to an uneven flow and an uneven gasification process, reducing the efficiency of gasification and even causing failures of the system. The new design uses a rectangular cross-section of the gasifier, with holes for the circulation of air for the gasification process on the narrow sides of the gasifier. By restricting the width of the gasifier, air can enter into the centre of the gasifier, ensuring a stable biomass gasification.

3.3 Reliable gas burning equipment

The burner is another key part of the new system. The combustible gas and flue gas is introduced by a draft fan located behind the boiler. Therefore, the combustion of gas and the secondary air occurs under negative pressure. The burner is required to run steadily in a certain load range and at a variety of operation conditions affected by the heat value and the yield of the gas. After many test, we have designed a burning device (shown as figure 5) which has good burning characteristics and load adaptability.

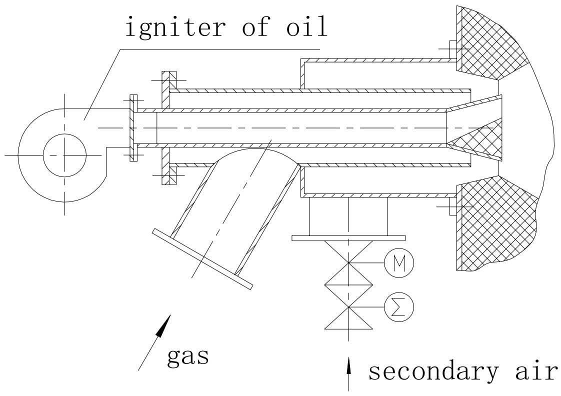

Figure5 Schematic diagram pof gas burner

3.4 Simple start process

This set is easy to start. If it has not been running for a longer time (cold condition), it can begin from a simple ignition of the gasifier and it will reach normal operation state in less than 15 minutes. If the set had run the day before (hot condition), it can directly enter into the starting program and reach normal operating conditions in 5 minutes.

3.5 Reliable method of automatic control

The set adopts a reliable method of automatic control, so that its adjustment of operational conditions is easy and simple. Automatic control includes:

- Definition of the thickness of ashes according to the flow resistance of the gasifier
- Adjustment of the rotary speed of the grid
- Control of the opening angle of the adjustable door of the draft fan (adjustment of the set load) according to the temperature signal of the heated medium (or steam pressure)
- Adjustment of secondary air according to the dynamic signal of flue gas composition detectors and gas burning temperature
- Ensuring optimal state of gas combustion and higher system heat efficiency
- Flameout alarm and pressure evacuation.

4. Testing result and practical operation

4.1 Testing result

Early in 2002, a gasification-heating set with 1.4 MW output was tested, with respect to thermal engineering and environmental protection. The result are as follows:

items	Heat output	Heat efficiency	Expenditure of rice hull	Expenditure of electricity	Dust contain of tail gas	Exhaust of SO2	Exhaust of NO2
results	1.4MW	75.5%	490kg/h	7.7kw/h	52mg/Nm3	36mg/ Nm3	294mg/ Nm3

As indicated in the table, the exhaust dust fully complies with the standard I category of China and the exhaust SO_2 is far lower than the standard I category.

4.2 Practical operation

In 2002, a 1.4MW straw gasification-heating set started practical operation. It was built in a modern agriculture demonstration development zone, using multiform raw material including rice husk, peanut shell, peel of sunflower, corncob, straw of corn etc. The total running time was 6 months. Compared with coal-firing, the running cost only corresponds to 55% of that for coal-fired boilers. Moreover, it did not lead to any environmental pollution or damage.

Photo of 1.4MW straw gasification-heating set

5. Conclusion

This technique provides a new way for the utilization of biomass by gasification. It belongs to pioneer technologies developed in China and it has obvious benefits with respect to environment, economy and substitution for energy. New straw gasification-heating sets with downdraft fixed bed operate under negative pressure and are adaptable to many kinds of raw material. It provides an effective, economic and environmentally-friendly method to utilize straw as energy source on a large scale. Particularly in northern areas of China it has obvious practical significance to use straw in great quantities and to reduce cost of heating in winter. This technology converts waste straw into useful commercial energy and increases the income of farmers. It plays an important role in raising the level of living in the countryside, improving the living environment and accelerating the development of small towns. Thus, this new technology is in accordance with the demands of country development in China.

SESSION 3: INNOVATIVE BIOENERGY TECHNOLOGIES

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Properties and Treatment of Gas-washes Wastewater from Biomass Gasifiers

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Abstract:

In this paper, the properties of the gas-washed wastewater from biomass gasifier is described, and treatment of this wastewater by a three-step method is investigated. The three-step method consist of physical precipitation, chemical coagulation and biodegradation.

Keywords: biomass gasification；gas-washed wastewater；wastewater properties ；water treatment

SESSION 3: INNOVATIVE BIOENERGY TECHNOLOGIES

International Conference on Bioenergy Utilization and Environment Protection
6th LAMNET Workshop – Dalian, China 2003

Pilot Plant for Ethanol Production from Sweet Sorghum

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Pilot Plant for Ethanol Production from Sweet Sorghum

Pilot Plant of Continuous Fermentation with Immobilised Yeast

SESSION 3: INNOVATIVE BIOENERGY TECHNOLOGIES

International Conference on Bioenergy Utilization and Environment Protection
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Synthesis of DME via Catalytic Conversion of Biomass

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Abstract

The utilization of biomass for Dimethyl ether production via gasification faces the problem of a large excess carbon in form of carbon dioxide in the produced synthesis gas. The stoichiometric adjustment can be accomplished either by adding hydrogen or by removing carbon in form of carbon dioxide. But hydrogen admixture to the syngas requires supplementary investments for an electrolysis unit. The removal of carbon dioxide, due to the extremely low carbon conversion efficiency of about 20% of the biomass carbon content, makes the DME production cost very high.

The novel stoichiometric adjustment concept was investigated by dry reforming carbon dioxide with methane. The addition of methane for reforming allows a nearly complete utilization of the carbon contained in the biomass. At 750°C, the CO_2 content of the gas stream was completely consumed via dry reforming reaction. This concept is an acceptable way for avoiding about 60% the carbon removing from the biomass and avoiding extreme high investment for electrolytic hydrogen.

1. Introduction

Renewable energy (e.g. solar, wind and biomass) could play a major role in reducing greenhouse gas emissions. Only biomass offers the possibility to produce liquid, carbon neutral, transportation fuels on foreseeable term [1,2]. This is particularly relevant since transport is responsible for a large part of global CO_2 emissions.

Dimethyl ether (DME) is an important chemical for the production of gasoline, ethylene, aromatics and other chemicals. Its applications as a fuel or a fuel additive for vehicles and family cooking have been studied. It is reported that DME can be synthesized from H_2/CO in a single step. It is much more thermodynamically and economically favourable [3-5].

In contrast to gasification process for electricity production, the requirement for the syngas composition for the DME generation process is a high hydrogen content, because a main part of the biomass carbon is converted to CO_2 in the gasification step. In the produced gas of biomass air-steam gasification, there exists a lot of CO, CH_4 and other hydrocarbons that can be converted to hydrogen through steam reforming reaction (converts CH_4 with steam to CO and H_2) and water gas shift reaction (adjusts the H_2/CO ratio by converting CO with steam to H_2 and CO_2) [6]. Interestingly, optimum DME synthesis over Cu-ZnO/γ-Al_2O_3 catalysts requires about 5% CO_2 in the inlet gas. If the CO_2 content is lower or higher, the DME formation rate drops. Furthermore, the DME formation apparently does not occur if the synthesis gas is free of CO_2 and H_2O [6].

The present paper investigates DME generation concepts via synthesis gas production of biomass. As the biomass gasification processes generally lead to a synthesis gas with a carbon excess in form of carbon dioxide, The stoichiometric adjustment of raw synthesis gas was investigated by dry reforming carbon dioxide with methane. Different pathways for meeting the required stoichiometry for the DME synthesis are compared and analysed.

2.Experimental

2.1 Catalyst Preparation

The $Ni_{0.03}Mg_{0.97}O$ solid solution reforming catalyst was prepared by co-precipitating nickel acetate and magnesium nitrate aqueous solutions with potassium carbonate aqueous solution. After being filtered and washed with hot water, the precipitate was dried overnight at 393K and then calcined in air at 1223K for 10h in order to form a solid solution [7].

The DME synthesis catalyst was prepared by the conventional wet impregnation method with $Cu(NO_3)_2$, Mn $(NO_3)_2$, mixed aqueous solution taken in appropriate ratio (Cu/Mn). The support was γ-Al_2O_3, 20-40 mesh. Catalyst was dried at 120°C followed by calcinations in air steam for a certain time.

2.2 Catalytic reforming

Conversion of biomass to an H_2 and CO containing feed gas that is suited for DME synthesis takes place in pilot air-steam gasification units. The raw syngas from the gasifier was passed through the fluidized catalyst bed ($Ni_{0.03}Mg_{0.97}O$, 100ml) under a total pressure of 1MPa at a temperature of 750°C. The products were analyzed by gas chromatograph (Shimadzu GC-20B) with a thermal detector.

2.3 DME synthesis

DME synthesis reaction was carried out by using a high pressure reactor (i.d.=12mm) after introducing pre-treatment gas (H_2/N_2=5:95) at 300°C for 3h. The reactant gas was passed through the catalyst bed (2ml, 20-40 mesh) under a total pressure of 3.0-5.0 MPa and a spaced velocity of $1800h^{-1}$, at a temperature of 230-290°C. The products were analyzed by gas chromatograph (Shimadzu GC-2010) with a thermal detector, in which columns Porapak-Q was used to separate reaction products.

3.Results and Discussion

3.1 Concept of DME synthesis via catalytic biomass conversion

The biomass gasification processes generally lead to a synthesis gas with a carbon excess in form of carbon dioxide. The raw syngas needs to be cleaned and processed to make it suitable for DME synthesis. In the present paper, dry reforming was applied to manipulate the syngas composition prior to the DME synthesis reactor. The basic schematic view is shown in Fig.1.

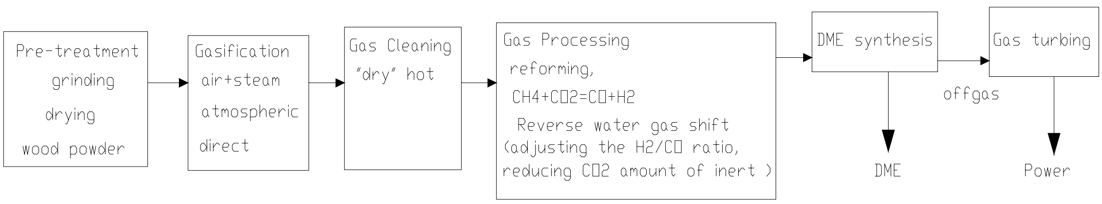

Fig.1. A basic schematic view of the key components for the conversion of biomass to DME combined with gas turbine (combined cycle) power generation.

The syngas produced by the gasification process contains condensable tars and particulates. A dry hot gas cleaning process was adopted because dry reforming reaction was carried out with high temperature (>700°C). A tar cracking reactor was designed to destroy condensable tars and filtrate particulates. The temperature of the cracking reactor was above 950°C with log combustion. Almost all the tars were destroyed and 80% of the particulates were filtrated. The dry reforming for gas composition adjustment was carried out in a fluidised bed reactor over $Ni_{0.03}Mg_{0.97}O$ catalyst at 750°C which avoided the reactor to be jammed by remaining particulates. The off gas from reforming reactor with stoichiometric composition was cleaned by wet cold cleaning processes to DME synthesis. Due to the high single-step CO conversion (>70%) of DME synthesis, the off gas from the DME synthesis reactor need not be recycled and could be used in a gas turbine for power generation.

3.2 Stoichiometric adjustment of synthesis gas

As shown in table 1, the raw syngas composition by biomass air-steam gasification (V1) is carbon dioxide rich gas which leads to low DME production. After dry reforming with methane by adding methane for CH_4/CO_2 ratio of 1, the stoichiometric synthesis gas composition was gained with H_2/CO ratio of 1.5 and content of CO_2 and CH_4 below 4 mol% because carbonic oxide rich synthesis gas is suitable for DME synthesis. Several authors [8] choose 10MW gasifier to meet the goal of decentralized fuel production from biomass with a capacity of <50 tons of methanol per day. Different ways of oxygen production for gasification and stoichiometric adjustment of the synthesis gas (V2, V3, V4) are shown in table 1.

Table 1. Different pathways for stoichiometric adjustment of synthesis gas

Name	V1	V2	V3	V4
Gasifier process type	Direct Air-steam Atmospheric	Direct Electrolysis-O_2 Atmospheric	Direct Electrolysis-O_2 Atmospheric	Direct PAS-O_2 Atmospheric
Composition of raw syngas (mol% dry)				
H_2	31.5	37.3	37.3	37.3
CO	14.8	15.8	15.8	15.8
CO_2	18.6	34.7	34.7	34.7
CH_4	5.4	11.4	11.4	11.4
N_2	21.3	0.3	0.3	0.3
Others	4.4	2.5	2.5	2.5
Adjusting process type	Dry reforming by adding methane, 750°C	Adding electrolysis-H_2	Adding electrolysis-H_2	
Removing percentage of total CO_2 (%)	0	61	0	95
Composition of synthesis gas (mol% dry)				
H_2	41.6	63.5	68.7	55.6
CO	27.8	13.6	7.8	23.6
CO_2	3.4	11.7	17.3	2.6
CH_4	2.7	9.8	5.6	17.0
N_2	19.1	0.2	0.15	0.5
Others	5.4	1.2	0.45	0.7
H_2/CO ratio	1.5	4.6	8.8	2.3

The H_2/CO ratio in the process of V2, V3 and V4 is 4.6, 8.8 and 2.3, respectively, which is preferable for the methanol synthesis requirements. But process V1 may be a best way of stoichiometric adjustment for DME synthesis requirement although the content of N_2 in the gas is relatively high which leads to higher synthesis pressure.

3.2 DME synthesis

DME synthesis reaction was carried out by using a high pressure reactor with model gas stream according to biomass gasification and dry reforming experiment results. As shown in table 2, the CO conversion and selectivity to DME in all products was increased by 39% and 49%, respectively, by stoichiometric adjustment through dry reforming. Compared to ideal gas composition, the 5MP synthesis pressure is needed for the high DME production due to the high content of N_2 in the biomass air-steam gasification syngas.

Table 2 DME synthesis of Different gas composition

	Composition						CO conversion	Selectivity to DME	
	H_2	CO	CO_2	N_2	CH_4	others		All products	Organic products
A 3MP	55.3	28.7	4.6	6.3	0	5.1	78.2	71.3	98.7
B 5MP	31.5	14.8	18.6	21.3	5.4	4.4	54.1	46.7	96.5
C 5MP	41.6	27.8	3.4	19.1	2.7	5.4	75.3	69.6	98.4

A-- ideal gas composition, B—biomass raw syngas, C—synthesis gas after dry reforming
DME synthesis condition: 260°C; 3-5MP

4.Conclusion

The utilization of biomass for Dimethyl ether production via gasification faces the problem of a large excess carbon in form of carbon dioxide in the produced synthesis gas. The stoichiometric adjustment can be accomplished by reforming with methane. The preferable ratio of CH_4/CO_2 is 1. At 750°C, the CO_2 content of the gas stream was completely consumed via dry reforming reaction. The CO conversion and selectivity to DME in all products has increased by 39% and 49%, respectively, by stoichiometric adjustment through dry reforming. This concept is an acceptable way for avoiding about 60% of the carbon removing from the biomass and avoiding extreme high investment for electrolytic hydrogen.

Acknowledgements
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SESSION 3: INNOVATIVE BIOENERGY TECHNOLOGIES

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Normal Temperature Briquetting Technology for Biomass with Original Moisture Content

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Abstract

Untreated biomass has low bulk density and high transportation cost. The existing biomass processing systems are normally complicated, expensive and space demanding. The new normal temperature briquetting technique developed for biomass with original moisture contents can simplify treatment process, reduce space required and lower transportation cost.

1 Introduction

A series of biomass briquetting systems have already been widely developed based on lignin plasticitation mechanism. These systems are normally complicated, space demanding and energy consuming. They are also very sensitive to biomass moisture content. The availability of these systems are limited by the radius of biomass transportation and the life of key abrasion-resistant components. Hence, the general cost of biomass utilization is high and the biomass application heavily rely on government subsidies. Biomass can only be market competitive after its running cost is comparable or even lower than that of coal.

2 Existing Biomass Briquetting Technique

2.1 Mechanism

Lignin and cellulose are the two major compounds of biomass. Lignin distributed among cellulose determines the structure strength of biomass. Lignin is a non-crystallized aromatic polymer with no fixed melting point. If heated to 200–300°C, lignin starts to be soft, melted and liquefied. If pressure is applied in this case, lignin will glue cellulose together, which is solidified and briquetted after cooling down.

2.2 Briquetting Process

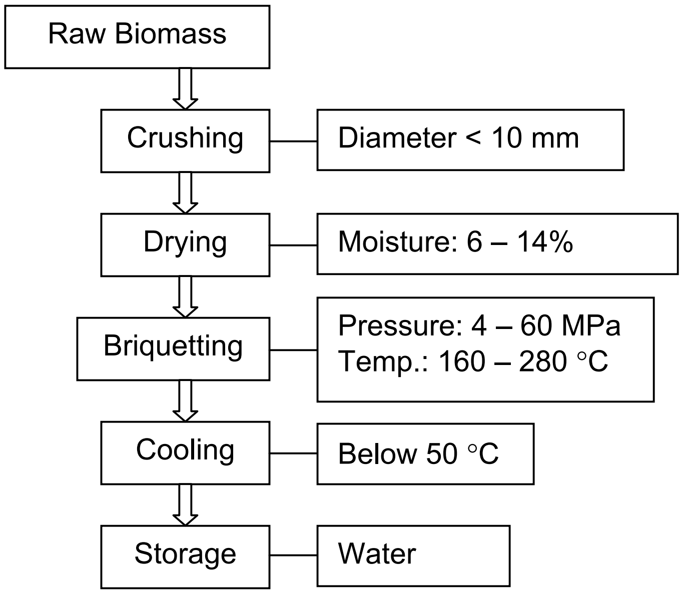


Figure 1. The Existing Biomass Briquetting Technique

2.3 Major Problems

The biomass briquetting systems based on lignin plasticitation mechanism requires high temperature of 160 – 280 °C. They generally have the following problems:

2.3.1 The moisture content of the raw material must be controlled within the range of 6 – 14% for a successful briquetting process. However, the moisture contents of original biomass is normally much higher than required. Energy must be applied for the drying and cooling procedures before and after the briquetting process respectively. The low moisture requirement not only increases the cost of biomass processing, but also limits the whole system to specific workshops.

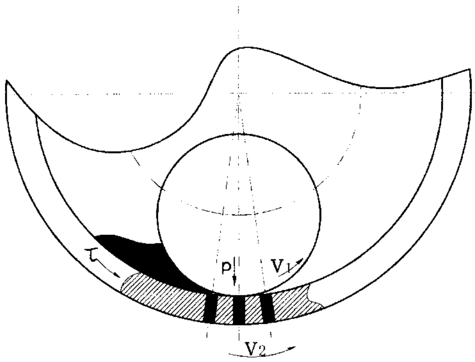
2.3.2 The compressing part must work under 160 – 280 °C. The abrasion of the device will be increased and the working lifetime will be reduced.

2.3.3 The whole system lost its mobility and is limited within the reasonable biomass transportation radius. It is difficult to scale-up to gain more economic benefits.

3 New Biomass Briquetting Technique

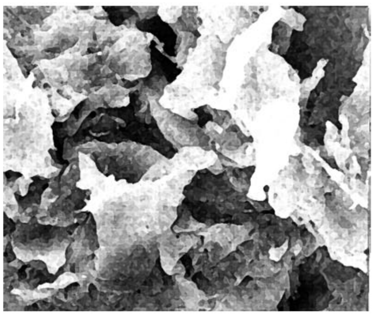
3.1 Mechanism

The characteristics of original biomass depends on the overall performance of its compounds. It has been verified that, although pure lignin does dissolve in water, it has the ability to absorb water. Lignin and water co-exist in original biomass. Biomass has low physical resistance. If a shear force is applied, the cellulose molecules in biomass will be disturbed, shifted and expressed as layers. With relatively small pressure, these layers will be embedded, folded and reformed into a new shape.



V_1 —— inner wheel speed P —— pressure
V_2 —— outer wheel speed τ —— shear force

Figure 2. Schematic Diagram of Briquetting Mechanism

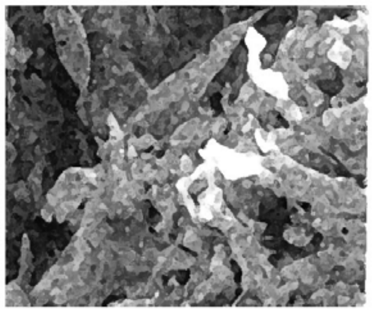


2000×Cross Section

1: Irregular layers formed after the process, layers embedded;

2: Spaces among layers are small as layer well folded;

3: Spaces among layers are well distributed.

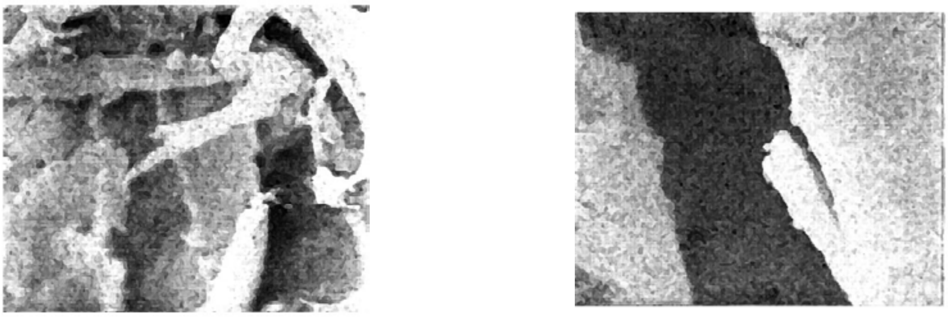


2000×Cross Section
Pingya, Nanjing

1: fibres from raw materials are obvious;

2: big gap can be found among fibres;

3: gaps have irregular orientation.



6000×Cross Section

1: Fibre-like material disappeared, layers cross linked;

2: layers' contacts and connections are irregular;

3: intervals among layers are unified

6000×Cross Section
Pingya, Nanjing

1: Parallel fibre remains without cross link;

2: Big gap among fibres;

3: The glue-effect of lignin may be suggested.

Figure 3. Comparison of Processed and Original Biomass

3.2 Briquetting Process

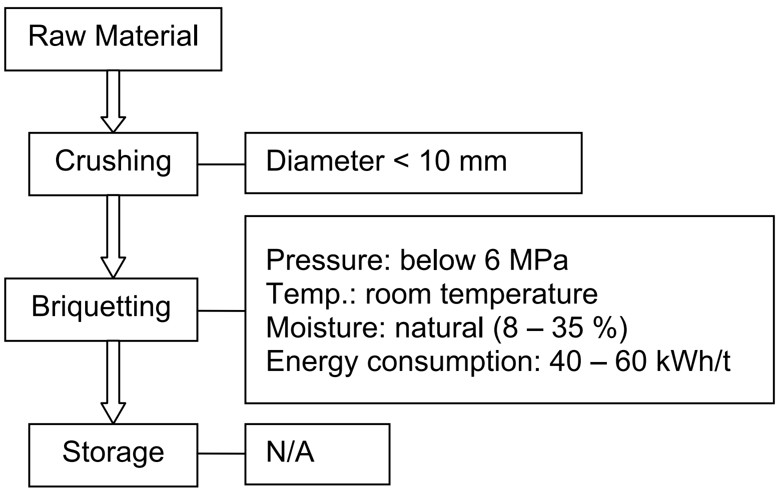


Figure 4. The New Biomass Briquetting Technique

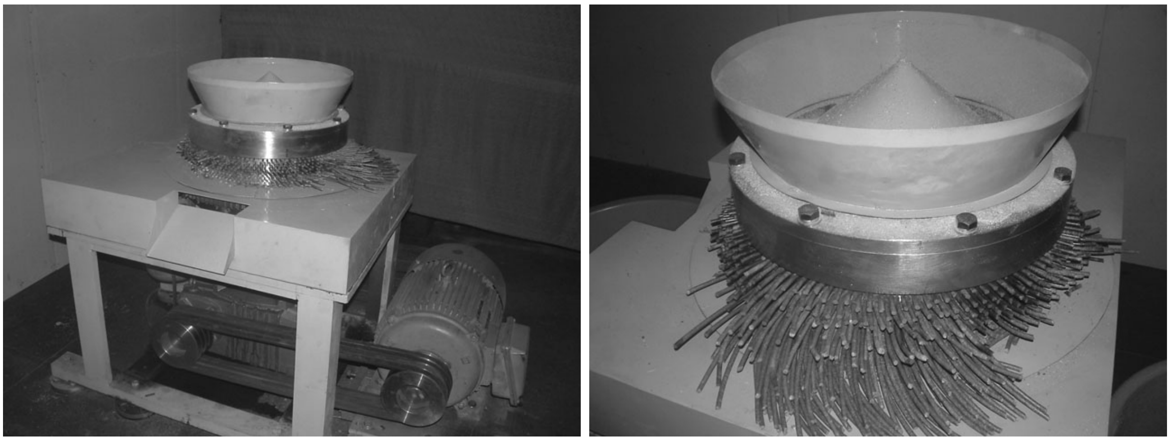


Figure 5 The Briquetting Device and Discharge Status

Figure 6 Raw Biomass Material and Briquettes

3.3 Major Parameters in Trial Test

Energy Consumption: 40 – 60 kWh/t
Density: $\geq$ 1.26
Moisture Contents: 8 – 35%
Particle Diameter: < 10 mm
Briquetting Pressure: < 6 MPa

3.4 Major Advantages of the New Briquetting Technique:

3.4.1 The electrical heating and temperature control are not required in the new briquetting system. The system complexity, the area requirement and energy consumption are greatly reduced.

3.4.2 The existing *Normal Pressure Briquetting* has been replaced by *Sheared Layer Embedding Briquetting*. The pressure required for the process is also reduced.

3.4.3 When briquetting under room temperature, there is no trouble caused by steam generated in the heat-up procedure. The technique is not sensitive to moisture content. The cost on drying and cooling systems can be saved.

3.4.4 Biomass is briquetted into pellet or stick shape under room temperature. There is no specific requirement on storage and transportation.

3.4.5 The whole system works under room temperature. The operation conditions, safety, reliability and maintenance are improved.

3.5 Current Status of Normal Temperature Briquetting Technique for Biomass with Original Moisture Content

3.5.1 The trial tests of normal temperature briquetting technique for biomass with original moisture content have been completed. The new briquetting mechanism has been verified.

3.5.2 The new briquetting process has been established via the trial tests:

Raw Material → Crushing → Natural Dry and Room Temperature Briquetting
→ Storage and Transportation

3.5.3 The prototype system revealing the new briquetting mechanism and technique has been developed.

3.5.4 18 patents have been declared nationally

3.5.5 2 patents have been declared internationally (PCT)

4 Conclusions

With the successful development of the new briquetting technique for raw biomass under room temperature, the space requirement, energy consumption, and running cost of biomass briquetting have been reduced significantly. With optimized system operation, small volume and low energy cost, this technique will make practical mobile biomass collecting and processing units. This will turn biomass into a promising alternative energy source for coal in the near future.

SESSION 3: INNOVATIVE BIOENERGY TECHNOLOGIES

International Conference on Bioenergy Utilization and Environment Protection
6^{th} LAMNET Workshop – Dalian, China 2003

Immobilised *Methanosarcina* and Strength Organic Wastewater Treatment

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Abstract

There are many shortcomings in anaerobic strength organic wastewater treatment with immobilized *Methanosarcina.* In this paper a new immobilization method is presented and strength organic wastewater is digested using immobilized *Methanosarcina*.

During the soybean cake wastewater treatment, the immobilized *Methanosarcina* can start-up an anaerobic digester quickly and efficiently. The COD of strength organic wastewater can be removed more satisfactorily with steady operation of the anaerobic reactor by immobilized *Methanosarcina* than with operation involving free cells.

The average COD load is 10.02 kg COD/m^3, being 1.88 times that of free cells. The average COD removal rate is 85.34%, which is 1.332 times that of free cells. The average gas production rate is 4.03 L/L.d and the highest gas production rate is 9.5 L/L.d. The methane content is 76-78%. The acetic acid content is below 0.2% and pH is in the range of 7.0-7.5.

Key words: immobilized *Methonasarcina,* strength organic wastewater, COD loading, gas production rate

SESSION 3: INNOVATIVE BIOENERGY TECHNOLOGIES

International Conference on Bioenergy Utilization and Environment Protection
6th LAMNET Workshop – Dalian, China 2003

Biomass Pyrolysis and its Potential for China

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Abstract

China has abundant resources of biomass characterised by agricultural wastes and residues distributed all over the country. To apply this kind of biomass on a large-scale, one appropriate technical route is to convert it into a liquid and to transport the bio-oil to a central site where it can be used as a feedstock for energy or chemicals. For both, economic perspectives and local biomass availability, it must be envisaged that the appropriate scale for a pyrolysis plant is to process approx. 1 to 2 tones of biomass per hour with a yield of bio-oil between 60~70 wt.% for different agricultural wastes and residues. In this paper a draft has been prepared for a tech-economic evaluation, from which it can be concluded that biomass pyrolysis has a good potential in China.

Keywords**:** Biomass; Pyrolysis; Bio-oil

1 Introduction

Biomass is the general terminology to describe all organic materials stemming from green plants that store solar energy in chemical bonds through photosynthesis. When the bonds among adjacent carbon, hydrogen and oxygen molecules are broken through digestion, combustion, or decomposition, these substances will release their stored chemic energy. Biomass has always been a major source of energy for mankind and is presently estimated to contribute to the order of 10-14% of the world's energy supply (Peter McKendry, 2002).

China has abundant biomass resources with an estimated annual amount of more than one billion tce (ton coal equivalent, or 25 EJ; Li Junfeng, 1997). The principal biomass resources are: (1) wastes and residues from agriculture and forest industries, (2) animal manure from medium and large-scale livestock farms, and (3) municipal solid waste. Among them, the wastes and residues from agriculture and forest industries whose annual productions are listed in Table 1 (Li Jingjing et al, 2001) are the primary biomass energy resource. From Table 1 it can be seen that biomass resource in China is characterised by wastes and residues from agricultural activities.

Table 1: Annual production of main biomass from agricultural and forestry in China

Biomass type	Straw	Wood residues	Rice husk	Bagasse	Total
Production (Mt)	655.9	110.6	42.1	21.2	829.8
Caloric value (GJ/t)	14.5	15.5	13.3	19.4	-
Energy value (EJ)	9.5	1.7	0.6	0.4	12.2

Table 2 summarises the energy consumption in China in 2000 (Eric D. Larson et al; 2003), from which it can be concluded that:

- The energy consumption in China is heavily dominated by coal, providing more than 60% of all consumed energy. This coal-based energy structure leads to high emissions of CO_2 and other pollutants in China.
- Biomass energy is the third important energy source, after coal and oil. Nevertheless, it only accounts for 10.8% of all consumed energy and only about 20% of available biomass resources are exploited. Therefore, biomass energy can play far more important role in the future energy consumption in China.

Table 2: Energy consumption of China in 2000

Energy source	Quantity (EJ)	Percentage
Coal	32.0	61.9
Oil	8.9	17.2
Natural gas	1.4	2.7
Hydro electricity	2.5	4.8
Nuclear electricity	0.3	0.6
Biomass energy	5.6	10.8
Other renewable energy	1.0	2.0
Total	51.7	100.0

2 Overview of biomass conversion

If biomass could be made available for energy use in order to replace fossil fuels, it often needs to be upgraded to overcome its disadvantages such as dispersed availability and low bulk density.

Combustion, gasification and pyrolysis are the main three thermo-chemical processes to convert biomass into heat or energy products. Combustion of biomass in air is used over a wide range of outputs to convert the chemical energy stored in biomass into heat, mechanical power or electricity using various items of process equipment, such as stoves, furnaces, boilers, steam turbines, turbo-generators. The scale of combustion plants ranges from very small-scale domestic stoves up to large-scale industrial plants. Co-combustion of biomass in coal-fired power plants is an attractive option because of its high conversion efficiency.

Gasification is the conversion of biomass into a combustible gas mixture by partial oxidation with air at high temperature. It is carried out typically at temperatures in the range 800-900ºC, producing gaseous products with a lower calorific value (about 4-6 MJ/Nm^3). The gas can be directly burnt in gas ovens or (after being cleaned) used as a fuel for gas engines. One of the most promising concepts is biomass integrated gasification/combined cycle, where gas turbines convert the gaseous fuel into electricity with a high overall efficiency.

Flash pyrolysis (or simplified as 'pyrolysis') is the conversion of biomass to a liquid (termed bio-oil), solid and gaseous fractions by rapidly heating biomass to about 500~600ºC in the absence of oxygen. Among the products, bio-oil is predominant with a yield between 60~70 wt.% for different biomass resources. As pyrolysis is a simple one-stage atmospheric process, it can be applied to convert biomass into bio-oil, which then can be used as feedstock for other processes such as combustion or gasification.

The main hurdles for large-scale implementation of biomass are the nature of biomass (non-uniform, low-energy density, large ash content), together with the usual inconsistency between the local availability of biomass and the demand for biomass related products (heat, electricity and chemicals). Usually, import/transport of fossil fuels is cheaper. Pyrolysis may be a process to overcome these hurdles. Biomass is transformed into a versatile liquid, easy to handle and to transport. In the present paper, the authors emphasise the pyrolysis technology that has been demonstrated on various resources by BTG (Biomass Technology Group B.V., Enschede, Netherlands), which can be applied in China to convert various agricultural wastes and residues into bio-oil. Bio-oil is a mixture of oxygenated organic compounds (~75%) and water (~25%). Research has shown that bio-oil has the following advantages:

- Bio-oils from different biomass resources are easily mixed, which makes them suitable for application at large-scales where bio-oils from various resources can be used.
- Bio-oil has a viscosity of approx. 40cP, which makes it suitable to be pumped and atomised.
- Bio-oil has a volumetric energy density of about 20 GJ/m^3 which is much higher than that of agricultural wastes and residues (about 2 GJ/m^3). Therefore, bio-oil is convenient and cheap to be transported and stored.
- The ash content contained in bio-oil is a factor of 100 lower than in biomass. The alkalis always present in biomass remain in the char product, which makes bio-oil suitable for applications requiring a low ash content of the input material.

In summary, combustion and gasification are economically and efficiently feasible only on a large scale. But, enormous logistic problems can be foreseen with respect to collecting, transporting, storing and handling for agricultural wastes and residues. If pyrolysis is applied to locally convert biomass into oil that is transported from various places to a central site and is used as the feedstock for combustion or gasification, the hurdles can be overcome in an easy and cheap way.

3 Application analysis of biomass pyrolysis in China

3.1 Moderate capacity of pyrolysis equipment and its capital cost

In this study, the analysis of biomass resources for pyrolysis is focused on agricultural wastes and residues such as rice husk and various straws. Rice husk is of no use in the present situation (or is combusted at low efficiencies) and is already available at the generally small rice plants. Various straws are left on the fields and usually burned out. In the east and middle of China, the estimated average farmland is 50 ha/km^2 and the average annual production of biomass is 10 ton/ha. Some of the agricultural wastes and residues are used for other purposes such as fertiliser, animal forage, raw material for paper, etc. It is supposed that 30% of all agricultural wastes and residues can be used as the feedstock for pyrolysis. Based on these deductions, the available amount of biomass for pyrolysis annually produced in an area with different radius is shown in Figure 1.

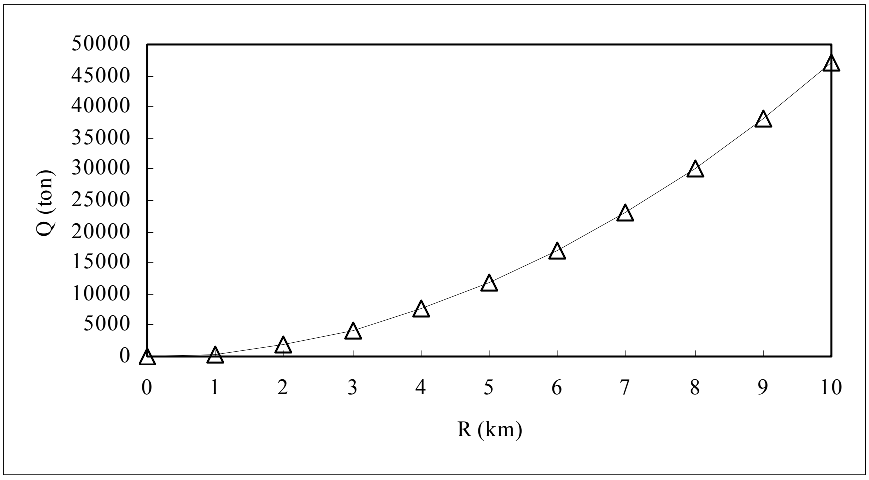

Figure 1 Available amount of biomass for pyrolysis versus collection radius

The primary principle to determine the moderate capacity of pyrolysis equipment is to decrease the production cost of bio-oil which mainly depend on the depreciation of the pyrolysis equipment and the transportation cost of biomass (see Table 4). In general, the higher the capacity of the pyrolysis equipment, the lower its capital cost of per unit and the lower its depreciation cost. But on the other hand, the area of biomass collection will be larger and the cost of biomass transportation will be higher. Considering the actual situation in Chinese rural areas, the feasible distance is 5 or 6 km for farmers to deliver biomass to pyrolysis plants at low price. Correspondingly, it is moderate for a set of pyrolysis equipment to process 1 to 2 ton biomass per hour, based on Fig. 1 (operation time: 24 hr per day and 300 days per year).

Table 3 gives the estimated capital cost of the pyrolysis equipment with a capacity of 2t biomass per hour. The total capital cost of 4,000,000¥ (note: 1¥ = 1Yuan RMB = 0.12US$) includes the capital cost of the additional equipment (dryers and shredders), but does not include the additional costs for licensing the technology.

Table 3 Capital costs of pyrolysis plants with a capacity of 2t biomass/hour

Cost factor	Capital cost (10^4¥)
Pyrolysis equipment	250
Equipment manufacture (material and labour)	150
Hand factor (control, software, etc.)	40
Infrastructure and installation	40
Others	20
Additional equipment	100
Shredder and dryer	40
Vessel for bio-oil storage	60
Unforeseen	20
Total	**370**

3.2 Production cost of bio-oil

Pyrolysis requires small (<10mm) and dry (<10wt% moisture) biomass feedstock, which demands most of agricultural wastes and residues have to be dried and shredded. The components of bio-oil production cost are all listed in Table 4 based on following supposition,

- The normal life-time of pyrolysis equipment is about 50,000 hours and its depreciation is 80 Yuan per hour.
- The caloric values of rice husk and wheat straw are 15MJ/kg and 17MJ/kg, and their bio-oil yields are 60% and 65%, respectively.
- Other suppositions are seen in Table 4.

Table 4 Production cost of bio-oil (¥/ton)

Cost factor	Rice husk	Wheat straw
Biomass price	150(¥/ton)×1.67(ton) = 251	170(¥/ton)×1.54(ton) =262
Pre-treatment	10(¥/ton)×1.67(ton) = 8.5	15(¥/ton)×1.54(ton) = 15.4
Depreciation	80(¥/h)×0.84(h) = 67.2	80(¥/h)×0.77(h) = 61.6
Maintenance	5% of depreciation = 3.4	5% of depreciation = 3.1
Labour cost	6×5(¥/h)×0.84(h) = 25.4	6×5(¥/h) ×0.77(h) = 22.7
Electric fee	0.50(¥/kWh)×40(kW)×0.84(h)=17	0.50(¥/kWh)×40(kW)×0.77(h)=15
Unforeseen	10% of total above = 37.3	10% of total above = 38.2
Total	410	420

3.3 Retail price of bio-oil

Bio-oil can be directly used as fuel in boilers to produce heat and steam. For this use, its retail price can be determined to be 850 ¥/ton based on following factors:

- The current market price of fuel oil in China is about 3000 ¥/ton. So, the equivalence price of bio-oil can be estimated to be 1140¥/ton as the caloric values of fuel oil and bio-oil are 42 MJ/kg and 16 MJ/kg, respectively.
- Considering that the users of bio-oil may need to modify their existing equipment, the selling price for bio-oil should be lower than the equivalence price. Therefore, a price of 1000¥/ton may be acceptable for them.
- Considering transportation costs and retailers profits, the retail price of bio-oil for pyrolysis plant can be determined to be 850 ¥/ton.

3.4 Anticipated profit for a pyrolysis plant

From the above analysis, it can be seen that the anticipated profit for a pyrolysis plant to produce and sell bio-oil is about 400 ¥/ton (see Table 5), which shows that biomass pyrolysis has a good potential in China.

Table 5 Anticipated profit for a pyrolysis plant (note: rice husk as feedstock)

Item	Anticipated profit
Annual production of bio-oil	1.2(t/h)×24(h/d)×300(d/y) = 8,640(t)
Annual total profit (no tax)	400 (¥/t)×8,640(t) = 3456000(¥) = 345.6($\times 10^4$ ¥)
Pay-back time for investment	0.9 (year)

4 Conclusions

- China has an enormous amount of biomass resources. Biomass consumption amounts to 10.8% of the total energy consumption and about 20% of available biomass resources are exploited. Therefore, biomass energy can play far more important role in the future energy consumption in China.
- Chinese biomass is characterised by agricultural wastes and residues. To apply these biomass resources, an appropriate technical route is to use pyrolysis to locally convert them into bio-oil, and to transport the oil to a central site where it can be used as feedstock for the production of heat-energy or chemicals in slightly adapted existing equipments.
- As a compromise between biomass availability and investment costs, the moderate capacity of biomass pyrolysis equipment is to process 2 tons of biomass per hour. This concept promises large profit for operators of pyrolysis plants.
- Biomass pyrolysis has a good chance of application in China, if this technology is mature and the route of application is correctly chosen.

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SESSION 3: INNOVATIVE BIOENERGY TECHNOLOGIES

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Bioenergy from Sugar Sorghum in Xinjiang

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Sugar sorghum is characterized by drought resistance, water-logging resistance, salt-alkali tolerance, rapid growth, high yield and wide range of uses. Sugar sorghum is a C_4 crop with high energy, low compensation level of carbon dioxide and high efficiency of photosynthesis. Especially in regions with distinct day-night temperature difference, and longer sunshine duration, sugar sorghum has large accumulative photosynthesis, low consumption of respiration, high accumulation of sugar and high potential for increasing the yield. According to the domestic and international experiences of production and processing sugar sorghum, and the climate condition and current research achievements in Xinjiang, it has become one of the main strategic measures for Xinjiang to vigorously develop the industry of sugar sorghum so as to adjust industrial structures, to optimise crops structure, to promote the industrialization of regenerative energy crops and to improve the living conditions of farmers.

1. The Advantages of Developing Sugar Sorghum Production in Xinjiang

1) Abundant resources of sunshine and heat

The basic climatic requirements for growing sugar sorghum is that the annual accumulated temperature above 10°C should reach 3000 to 4000°C. Annual accumulated temperatures above 10°C in Hotan Prefecture of southern Xinjiang, Tacheng Prefecture of northern Xinjiang, Turpan Prefecture of eastern Xinjiang and Kashgar Prefecture of western Xinjiang are 4443.9°C, 3081.0°C, 5443.2°C and 4271.9°C, respectively. Therefore, sugar sorghum can be grown in most places of Xinjiang. As the frost-free period can reach 160-240 days in the whole South Xinjiang and parts of North Xinjiang, especially in East Xinjiang, even the latest maturing variety of sugar sorghum can be mature. Annual radiation value in Xinjiang is 130-155 kcal/cm^2. The effective radiation energy for photosynthesis is decreasing from south to north of Xinjiang, generally 60 to 75 kcal/cm^2 per year, about 5 to 10 kcal/cm^2 per year more than that of East China, South China and the Middle & Lower Reaches of Yellow River. Xinjiang is one of the regions in China with the longest sunshine duration. Annual sunshine duration in Xinjiang can reach 2550 to 3500 hours and annual percentage of sunshine is 60 – 80 %. The abundant sunshine and heat resource in Xinjiang favours growing short-day plant, and it is also very good for the nutrition growth of sugar sorghum.

2) Plentiful water and land resource

Xinjiang is located in northwest of China, the central part of Eurasia. Total land area of Xinjiang is 1660.4 thousand square kilometers, about 2.419 billion mu (1 ha = 15 mu), accounting for one sixth of China’s total territory. Xinjiang has small population and large land area and the land resource in Xinjiang is very rich. The land area suitable to cultivation accounts for 7.8 percent of the total area of useable wasteland.

Xinjiang is far from the ocean, where the climate is arid and annual rainfall is very low with only about 150 millimeters. However, Xinjiang has much snow in high mountain areas and surface run-off as well as underground run-off, which has high potential to be exploited. The development of oasis agriculture in Xinjiang is mainly dependent on irrigation, which is suitable to grow many kinds of crops.

2. The foundation of research achievements for developing sugar sorghum in Xinjiang

1) Richness of sugar sorghum varieties

The Xinjiang Academy of Agricultural Sciences (XAAS) has 12 local sugar sorghum varieties, 3 new varieties with intellectual property, 50 hopeful and reserve strains and 15 good varieties introduced from domestic and international sources. According to different uses of sugar sorghum, efforts should be made to introduce domestic and international excellent varieties of sorghum, suitable to Xinjiang's condition, so as to accelerate the industrialization course of sugar sorghum.

2) Maturing cultivation techniques for growing sugar sorghum

The cultivation techniques for growing sugar sorghum have been maturing in Xinjiang and China. The relevant research organizations and production enterprises have accumulated and summarized the successful production experiences in terms of sowing pattern, planting density, disease and pest control, irrigation and fertilizer management and machinery harvest. These techniques are reliable technological supports for Xinjiang producing sugar sorghum in large area by machinery.

3) Powerful research ability of sci-tech

XAAS and other research organizations can provide technological support to develop sugar sorghum industry in Xinjiang. XAAS has rich experiences and powerful research ability in breeding, judging technique of introduction and cultivation technique. The institute of Turpan of XAAS has been engaging in research of sugar sorghum for more than 30 years, and already bred 5 sorghum varieties and 3 sugar sorghum varieties. Now, the extension area of sugar sorghum is more than 150 thousand mu.

4) Good foundation for technological cooperation

The Institute of Botany of China Academy of Sciences (CAS), and Beijing Green Energy Institute of Cash Crop have already made many advanced achievements in the research field of sugar sorghum, which is leading in the world. They have already bred many new varieties, and summarized a set of cultivation techniques, and applied a compound feed patent of sugar sorghum straw powder and published book and thesis collection on sugar sorghum. Moreover, they have already established a social system of technological service. XAAS already established a good cooperative relationship with the Beijing Green Energy Institute of Cash Crop in introducing excellent varieties and the patent achievement of processing techniques.

5) Comparison of component analysis and feeding experiment between sugar sorghum and maize

The comparative results of active component analysis between sugar sorghum and maize show that:

a) In all the eleven indicators analysed, seven indicators of sugar sorghum are better than those of maize, while other 4 indicators of maize are better than those of sugar sorghum;

b) In all the 9 kinds of active microelements analysed, sugar sorghum has higher content than maize in 5 kinds of microelements, while maize has higher content in other 4 kinds;

c) In all the 17 kinds of active components of amino acid analysed, sugar sorghum has the same content as maize in 3 kinds, and other 12 indicators of maize are better than sugar sorghum.

A feeding experiment was conducted in 2002 in Manasi County. Sugar sorghum harvested with a plant area of 133 hectares can be used to feed 1333 cows in one year. While normal silage maize with the same plant area can only be used to feed 1000 cows in one year. The demonstration and extension results have shown that sugar sorghum in Xinjiang has many advantages, such as good quality, higher content of sugar, good palatability, high nutrition value, strong adaptability and easy management. All these prove that extension of sugar sorghum in Xinjiang has a fine prospect.

6) The implementation plan

An implementation plan has been made according to the research report on industrialization of sugar sorghum in south Xinjiang. The plan stressed that the industrialization must be driven by the leading dragonhead enterprise and animal husbandry industry. In the next 3 years, follow targets will be achieved:

a) Excellent varieties of sugar sorghum will be vigorously extended, and the extension area will be expanded to 1200 thousand mu;

b) Through researching on cultivation technique of higher yield, the new rules of cultivation technique of yield 10 ton/mu will be summarized and designed;

c) The production output of silage feed will reach 2500 thousand tons, the production of straw powder will reach 600 thousand tons and the production of compound feed will reach 3000 thousand tons;

d) The production output of white spirit over 55-degree will reach 96 thousand tons and accordingly the production of ethyl alcohol will reach 48 thousand tons.

Furthermore, following targets will be achieved before 2010:
The plant area of sugar sorghum is expected to expand to 2000 thousand mu, 3 processing factories are to be established, which can annually produce 900 thousand tons of straw powder and process 4500 thousand tons of compound feed;

To meet the rapidly growing demand of feed in South Xinjiang, the annual production of silage feed will reach 4000 thousand tons, and an enterprise will be established to annually produce 300 thousand tons of fuel ethyl. According to the developing plan above-mentioned, the plant area of sugar sorghum must reach 2000 thousand mu at least, so as to meet the material demand from industrialization.

XAAS has already done much research on sugar sorghum for developing industrialization of sugar sorghum, and already laid a solid foundation for promoting the development of sugar sorghum industry.

3. Benefit analysis of sugar sorghum in Xinjiang

1) Benefit analysis of silage sugar sorghum

A sample analysis was conducted in Manasi County, where the frost-free period is 157 days and annual accumulated temperature above 10°C is 3563.9°C. In 2001, the demonstration area was 15 mu and the experiment results shown that the plant height is 3.8 to 4.0 meters, and average biological mass production is 6.9 ton/mu. In 2002, the demonstration area was expanded to 2000 mu and the plant number is 10600, the average stem height is 3.76 meters, stem diameter is 3.89 centimeters, average sugar content is 16.1 percent, and the yield is 5000 to 8850 kg/mu. If calculated with 7000kg/mu of the average yield and 0.105 yuan/kg of the straw price, the net benefit will reach 485 yuan/mu after a deduction of 250 yuan/mu of all production cost, i.e. seeds, fertilizer, irrigation, machinery and tax. Because the average yield of sugar sorghum is more than 7 ton/mu, production of sugar sorghum with 3 mu can meet the feed demand of two cows in one year. Clearly, production of sugar sorghum can provide sufficient and good quality silage feed for developing animal husbandry.

2) Benefit analysis of producing compound feed of straw powder

If the yield of fresh silage is 7.5 tons /mu, and the purchase price of factory is 0.12 yuan/kg, then following benefits can be obtained:

Farmer's benefits: farmer can gain 900 yuan /mu from selling fresh silage, and gain net benefit of 600 yuan/mu after deduction of the production cost of 300 yuan/mu.

Factory's benefit: supposed that 100 kg straw can be processed into 28 kg powder, then the powder output will be 2.1tons/mu and the price of powder is 1 yuan/kg. Therefore, factory can gain benefit of 2100 yuan/mu and gain net benefit of 850 yuan/mu after deduction of material cost of 900 yuan/mu and other cost of 350 yuan/mu, including depreciation, labour, water and electricity, coal, tax and management fee.

Then, the total net benefit of farmer and factory will be 1450 yuan/mu. If we consider the factory can further produce white spirit and ethyl alcohol with sugar sorghum, the benefit will be much larger.

3) The economic analysis of sugar sorghum and maize

It is planned to expand the accumulated plant area of sugar sorghum to 1200 thousand mu in 3 years.

Sugar sorghum of 500 thousand mu will serve as silage feed and the farmers can gain 300 million yuan;

Sugar sorghum of 500 thousand mu will serve as compound feed of straw powder and farmers and factories can benefit 725 million yuan;

Sugar sorghum of 200 thousand mu will serve as ethyl alcohol and the net benefit will be 360 million yuan;

The total benefit of sugar sorghum with a plant area of 1200 thousand mu, will be 13850 million yuan.

In 2001, the plant area of maize in Xinjiang was 6154.5 thousand mu, the total production is 2938 thousand tons, and average yield is 477 kg/mu. The production value of maize will be 477 yuan/mu, if the maize price is 1 yuan/kg. The net benefit will be 297 yuan/mu after deduct the production cost of 150 yuan/mu. Thus, the total net benefit of maize with plant area of 1200 thousand mu, will be 35.64 million yuan. Accordingly, the benefit of sugar sorghum is 2.88 times the benefit of maize.

The analysis results clearly show that the incremental benefit will increase by 102.86 million yuan if the crop structure is adjusted the sugar sorghum material is further processed. Obviously, the development of sugar sorghum industry will bring huge economic benefit and it should be vigorously promoted in Xinjiang.

Development of sugar sorghum industry not only can bring economic benefit, but also huge ecological and social benefit. Burning of fuel alcohol only produces little waste gas, non-poisonous and with little smell, so as to greatly reduce air pollution. Fuel ethyl also can replace part of gasoline when gasoline is mixed with a certain amount of fuel ethyl, which will have no influence on car performance, but will benefit environmental protection. Therefore, development prospects of sugar sorghum in Xinjiang is very hopeful, also it is a necessary shortcut for Xinjiang's farmers to alleviate poverty and to improve their living conditions.

SESSION 3: INNOVATIVE BIOENERGY TECHNOLOGIES

International Conference on Bioenergy Utilization and Environment Protection
6th LAMNET Workshop – Dalian, China 2003

From Energy Cropping to Pellet Appliances: A Three Year Co-operation between Sweden and China

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Three Year Cooperation Project between Sweden and China - Project Overview

- Started in 2000
- Financed by Beijing Laowan Bioenergy Technology Cooperation
- Focussed on agriculture, environment and energy issues in arid and semi-arid regions in northern China
- Aimed at the development of a full bioenergy production chain

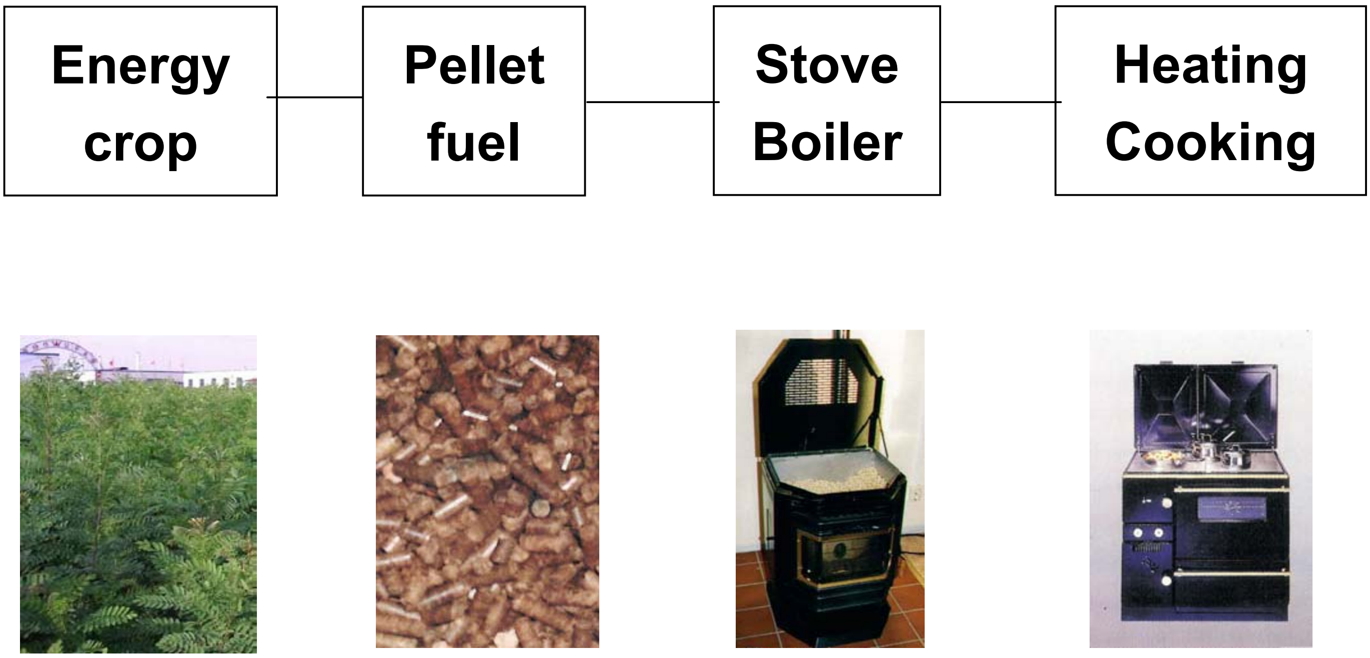

Figure: Bioenergy Production Chain

SESSION 4: FINANCING

International Conference on Bioenergy Utilization and Environment Protection
6th LAMNET Workshop – Dalian, China 2003

Financing Large-scale Bio-ethanol Projects in China and Italy

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ABSTRACT:

The ECHI-T project aims at elaborating a technical, economical and financial feasibility study on integrated bio-energy/bio-ethanol/DDG (Distillers' Dried Grains) production from Sweet Sorghum able to attract private capital investors for its positive economics. The main goal of the project is the definition of a possible plant configuration for each of the three selected sites (one in Italy and two in P.R.China). The analysis covers the complete biomass chain, from the production of the resource, to the reception of the biomass at the plant gate, to the supply of products and their potential market. The project intends to demonstrate that Sweet Sorghum is a very promising energy crop from both the economic as well as the environmental point of view, with high yields of grains, sugar and bagasse. In fact, it can be processed into various high value added commodities, such as bio-ethanol, DDG, electricity/heat, charcoal, hydrogen, activated coal, methanol, pulp for paper, with an overall positive economic performance and energy input/output ratio.

A selection of these possible processing steps has been made to draw a configuration in Basilicata region (Southern Italy), Dongying City (Shandong Province, China) and Huhhot City (Inner Mongolia, China). For each of the three configurations a preliminary technical, economical, environmental and financial feasibility study have been performed. This paper deals with the description of the three sites and with the main technical results of this project.
Keywords: bio-energy strategy, bio-ethanol, innovative concepts

1 INTRODUCTION

Bio-energy can offer a significant contribution to the future challenge of a more sustainable energy mix and in the medium-term also to the fulfillment of the Kyoto commitments that the EU is determined to implement. There is wide consensus that bio-energy has the possibility to provide a significant renewable and sustainable contribution to the EU energy scenarios, with its present estimated potential of ~200 MTOE/year (probably ~400 MTOE/year on the longer term). At present, the heat-market is the most developed one, but mainly in the Northern-Central Europe. Large possibilities exist for biomass resources (in particular energy crops) to penetrate the power generation and the transport markets: however, the demonstration of the economic viability of this new activity is essential for its large deployment. This project aims at demonstrating the feasibility of Sweet Sorghum cultivation for renewable and sustainable production of transport fuel (bio-ethanol, and - in case - hydrogen and methanol), energy (electricity and heat) and other products (as animal feed, pulp for paper, charcoal, activated coal) with commercially available technologies.

In fact, integrated Sweet Sorghum complexes can contribute to the following EU policy needs and goals:

- Renewable energy production at competitive cost, both in the transport market (bio-ethanol from Sweet Sorghum sugar juice and grains) as well as in the electricity and heat market (from Sweet Sorghum bagasse), contributing to achieve the EU Kyoto goals for greenhouse gas emission reduction.
- Diversification of energy supply, with the non-fossil resource Sweet Sorghum produced at competitive cost, thereby reducing the dependency on non-EU (fossil) energy resources. Sweet Sorghum may be grown competitively within the EU.
- Vegetal protein production. Possibility of a significant co-production (approx. 1.5 t/ha) of vegetal proteins (DDGs), today of great interest for the EC due to the BSE problem.
- New permanent job creation in both the agricultural as well as in the industrial sectors.
- Innovation and development of advanced technologies. Processing of Sweet Sorghum can be done with existing, commercially available technologies, but the application of these technologies to Sweet Sorghum crop is very innovative. Furthermore, the integrated processing of an energy crop into several high added value products (as chemicals) has not been implemented yet. Should the Sweet Sorghum complexes be implemented, these would be the first of that kind.

The project contributes to the achievement of both European and Chinese policy measures that aim at increasing the share of (bio-)ethanol as fuel in the transport sector:

- The European Union [1] aims at replacing 20% of the fossil energy in the transport sector by 2020 with renewable fuels.
- The proposal for a Directive of the European Parliament and of the Council on the promotion of the use of biofuels for transport. The proposal, currently under discussion, recommends that 2 % of the gasoline and diesel fuels used in the transport sector should be replaced with biofuels by 2005. This amount should increase with 0.75 % each year and reach 5.75 % in 2010.
- China has recently (May 2001) set up a national standard for (bio-)ethanol fuel, aiming at the widespread use of (bio-)ethanol in the transport sector in 3 provinces (Henan, Heilongjiang, Jilin) in a pilot-project phase. The final goal is to achieve a share of 25-30 % of ethanol cars in 2-3 years. The two Chinese oil companies involved in the project (Kenli Oil Company in Dongying and PetroChina in Huhhot) indicated that their interest in bio-ethanol from Sweet Sorghum stems from this Chinese national policy plan.

Finally, the ECHI-T project also aims at establishing a more active co-operation between EU and P.R.China since it could be of mutual benefit:

- Sweet Sorghum is a well known Chinese crop in China, that has extensive experience in Sweet Sorghum development, cultivation and use. China's know-how could be successfully transferred to the EU for in-Europe cultivation, and seed supplied to EU during th the start-up phase.
- Europe has suitable and valuable commercial technologies for Sweet Sorghum processing, potential financial resources (if the project is economically viable) and potential interest on the implementation of complexes based on Sweet Sorghum. EU technologies could be exported to the Chinese market.

The implementation of a large industrial bio-energy complex in China, as the one under assessment in the ECHI-T project, could be beneficial for Europe to verify the viability of these types of schemes in a different context. Moreover, the various mechanisms for carbon trading (as the Joint Implementation) could be implemented in a common EU-China project.

2 SHORT DESCRIPTION OF THE THREE SITES

2.1 Basilicata Region, Italy (Pisticci)

The Basilicata region, located in the Southern part of Italy, is mainly characterised by hilly areas (up to 2000 meters above the sea level), with two accesses to the sea (Ionio and Tirreno Seas).

The area (Bradano-Metaponto) which has been studied for the project consists of 5 separate zones situated in the valleys of two rivers. The total extension of the region is approximately 22,250 ha: the whole area is managed by the Consorzio di Bonifica di Bradano e Metaponto (CBBM). Within this land, 7000 ha were selected for the project, located near the Municipality of Pisticci, where the industrial complex could be located. These fields are mainly valley floor areas on alluvial soil, having a good or high degree of fertility and equipped with irrigation infrastructures (a pipeline for pressure irrigation system is available). The industrial area near Pisticci (Val Basento district), managed by the "Consorzio per lo Sviluppo Industriale della Provincia di Matera" (Syndicate for the industrial development of the province of Matera, CSIPM, also known as ASI, Area Sviluppo Industriale – Industrial Development Area), extends for a total of 300 ha.

2.2 Shandong Province, P.R.China (Dongying City)

The Dongying City, in the Shandong Province, is located on the coast of Bohai Sea (118° 07'-110° 10' east longitude; 37°20'-38°10' north latitude) with 350 kilometers of coastal line: it is the bridge linking the northeastern and mid-China economic regions. It is 400 kilometers, 300 kilometers and 250 kilometers away from several large municipalities as Beijing, Tianjin, Qingdao and Jinan respectively. Dongying is well equipped with infrastructures, as highways, electric grids, power stations, etc.: Dongying covers an area of 790,000 hectare. The Delta of the Yellow River passes through the Shandong Province, flowing into the sea from Dongying, with a cross-section of approximately 128 kilometers.

Dongying is the production base of the second largest oil field in China with annual production of 30 million tons of crude oil and 23 billion m^3 of natural gas per year. The Kenli Petrol Chemical Plant has been selected as the partner factory for large-scale production of bio-ethanol from Sweet Sorghum. The Kenli Petrol Chemical Plant is a large state-owned enterprise. The refinery plant covers an area of 60 hectares. Since 1999, Kenli has carried out the feasibility and planning study on the production of 30,000 tons of bio-ethanol and 10,000 tons of ethyl acetate, which has been listed as a Provincial-planned Project. At present, the Kenli target for bioethanol is 100,000 t/year. According to Kenli original plan, corn and dried sweet potato will be used as raw materials to produce ethanol: however, as the use of Sweet Sorghum is expected to be more convenient than conventional crops.

The land in Dongying - Shandong Province is suitable for Sweet Sorghum cultivation: today, a total area of 800 ha is already cultivated with this crop, mainly used as forage for cow and cattle. The potential plantation area reaches 60,000 ha. Several cultivars (as "M81-e", "Tianza No.2" and "Tianza No.3") have already been tested in Dongying, and results were very positive in terms of adaptability and productivity of these hybrids.

2.3 Inner Mongolia, P.R.China (Huhhot)

The Hueahote district (also called Huhhot) lies in the Inner Mongolia region (i.e. the P.R.China region close to the border of Mongolia), at approximately 40° North Latitude, W-NW from Beijing. It belongs to a middle-warm semi-dry zone: the average elevation is around 800-1,100 meters above the sea level.

Inner Mongolia Autonomous Region is the main animal husbandry zone in the P.R.China, with high demands for grass-feeds. However, specific regulations had to be issued in this region for environmental protection: the risk of desertification due to cattle breeding restricts the use of natural vegetation as feed or fuel. Therefore, a large market exists for animal feed products and domestic heating, that could be addressed by the ECHIT project.

The PetroChina oil refinery, located 9 km from Huhhot City and covering an industrial area of 130 ha, has been selected for the ECHIT project in Inner Mongolia. Today the PetroChina refinery processes. The target amount of ethanol for PetroChina Company is 100,000 t /y.

The low temperature typical of winter time offer unique on-field storage conditions for sweet sorghum stems stalks) in Inner Mongolia. In fact, since the temperature falls below zero at the harvesting season (end of October) cut stems will not deteriorate if left on the fields, and the stem-processing phase can therefore be completed by the subsequent April. Harvested stems can therefore be stored on the fields for a period of approximately 5 months. The quality and the fertility of the soil in this region are very good. Inner Mongolia has already developed Sweet Sorghum cultivation for food-ethanol (wine) production. The Sweet Sorghum wine is distilled and produced in Tuoketuo County, 70 km far from Huhhot.

3 SWEET SORGHUM CULTIVATION

The cultivation of Sweet Sorghum has been studied and planned for the different sites in Italy and China. 7,000 ha, 19,000 ha and 20,000 ha have been considered in Basilicata, Shandong Province and Inner Mongolia respectively. In the case of Inner Mongolia, a cluster scheme based on 10 similar unit of 2,000 ha each has been adopted.The existing rural structure and the logistic prerequisites in Huhhot did not seem suitable for a single large scale, centrally organised cultivation, plantation, and processing scheme. A decentralised structure based on 10 similar clusters has therefore been proposed for Inner Mongolia, more suitable for projects focused on the rural development issue.

Various cultivars have been selected for each site of the project. Irrigation demand and strategies have been elaborated by means of the [2] CROPWAT program by FAO and the associated CLIMWAT database.

With regards to the harvesting and processing time, different strategies have been elaborated for the Basilicata and Shandong regions (on one side) and the Inner Mongolia region (on the other side). In fact, the particular climate in Inner Mongolia allows a 5 months cane processing time (to squeeze the juice and produce the pellets), while in the other two regions this processing time is reduced to two months. However, in the case of Dongying, by mean of a careful selection of crop hybrids having different Growing Degree Days (GDDs) it is possible to obtain a 4 month harvesting time. Nevertheless, this approach requires irrigation, and a more detailed experimental work is necessary to assess the productivity, yields and elaborate a suitable price strategy for the farmers.

As far as regards the crop rotation, a two year rotation has been chosen, as its sustainability has already been demonstrated and is already carried out in China with wheat.

4 THE THREE INTEGRATED COMPLEXES: MAIN PRODUCTS

According to the scheme described in figure 1, various levels of integration are possible:

1st level: production of bio-ethanol/DDG/CO_2/bagasse pellets for sale

2nd level: production of bioethanol/DDG/ CO_2/heat&power/bagasse pellets for sale

3rd level: production of bioethanol/DDG/ CO_2/heat&power/pulp for paper

4th level: production of bioethanol/DDG/ CO_2/heat&power/pulp for paper, activated coal

5th level: production bioethanol/DDG/ CO_2/heat&power/pulp for paper, activated coal/hydrogen (syngas)/bio-methanol (or bio- Fischer-Trops gasoil)

The analysis of the possible schemes compared to local conditions and collected data, led to the conclusions that - at the present moment - the 2nd level of integration is the most suitable approach for the actual situation in the selected sites (with CO_2 recovery considered in Dongying only). Cogeneration from bagasse is not considered in Inner Mongolia.

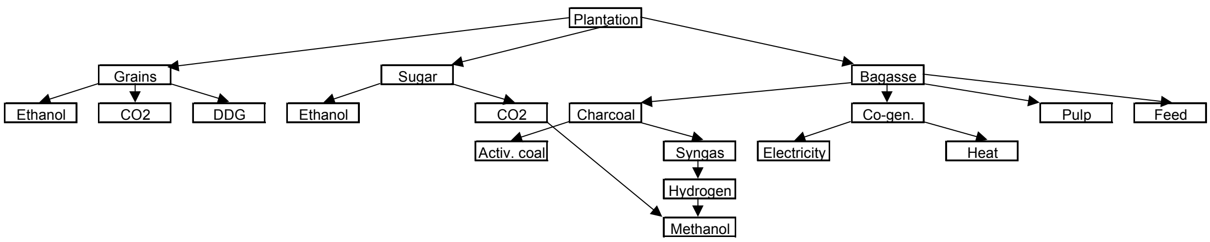
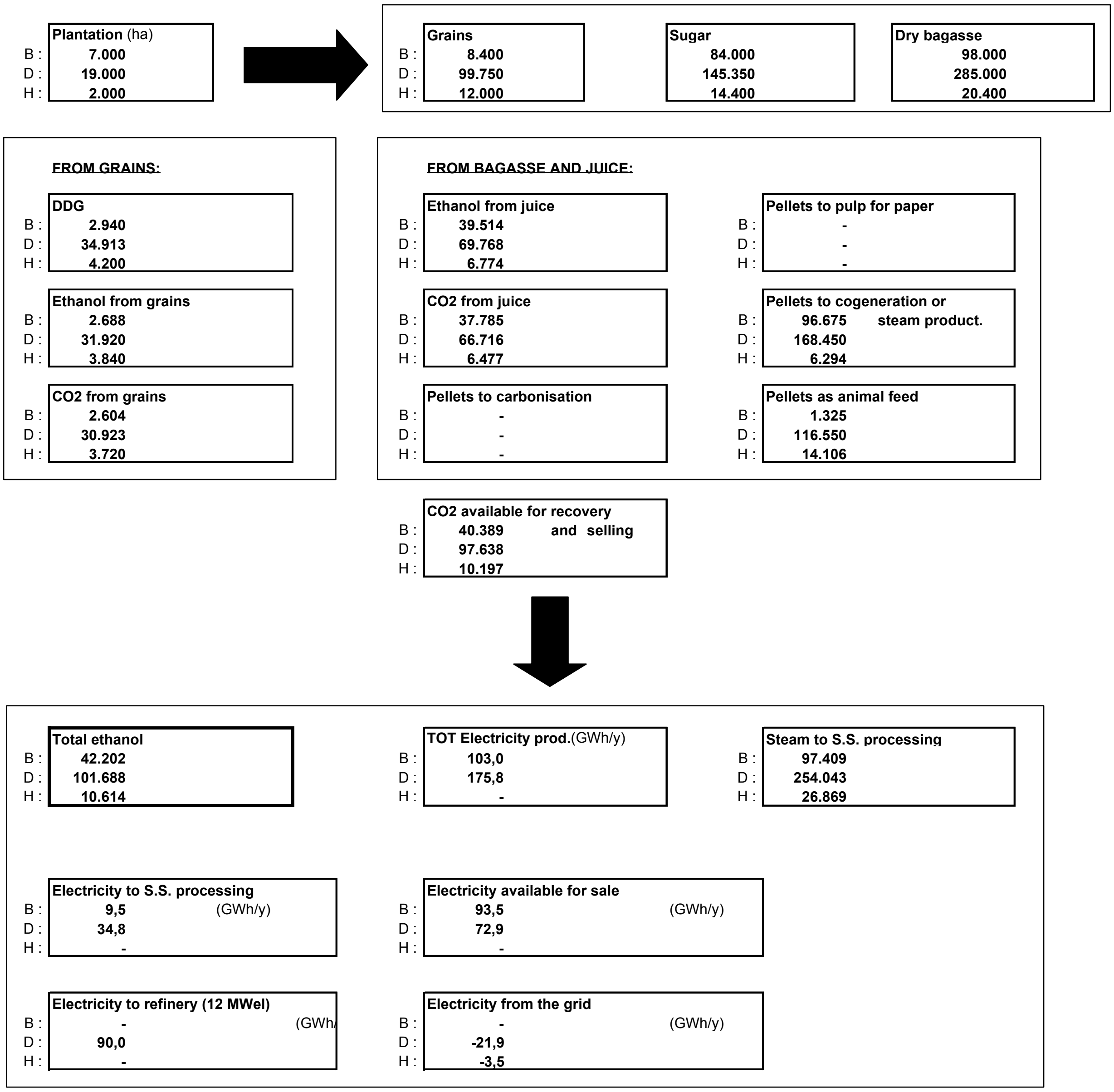


Figure 1: Sketch of the possible conversion paths in the Sweet Sorghum Integrated complex.

The expected productions in each of the three sites are presented in figure 2. The scheme shows how Sweet Sorghum provides sufficient feedstock to produce the requested amount of bioethanol plus some high value additional products as bagasse pellets (animal feed) and electricity. In the case of Dongying, 12 MWel are produced all year round from bagasse for use in the refinery: moreover, given the amounts of CO_2 generated from juice and grain fermentation, in this site CO_2 recovery for various application (as beverages, etc.) can be considered.

SCHEDULE OF QUANTITIES PRODUCED IN THE THREE SITES (in **t/year** unless stated otherwise)

B=Basilicata D=Dongying H=Huhhot



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ACKNOWLEDGEMENTS

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SESSION 4: FINANCING

International Conference on Bioenergy Utilization and Environment Protection
6th LAMNET Workshop – Dalian, China 2003

Regulatory Framework of Bioenergy Financing and the Clean Development Mechanism (CDM)

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Kyoto Protocol – Flexibility Mechanisms

Through these mechanisms the global economic efficiency of reducing emissions is increased while global greenhouse gas emissions are reduced and thus the overall 5 % reduction target is met.

The Kyoto Protocol establishes three "mechanisms" for obtaining these credits:

- International Emission Trading (IET)
- Joint Implementation (JI)
- Clean Development Mechanisms (CDM)

Clean Development Mechanisms

- A Clean Development Mechanism will provide credit to Annex 1 countries for financing emissions-reducing or emissions-avoiding projects in Non-Annex 1 countries.
- The difference between emissions with the project and emissions as they would have been without the project (baseline emissions) constitute potential Certified Emission Reductions (CERs) under the CDM.

Main Actors in the Project Approval

1) CDM Executive Board (EB)

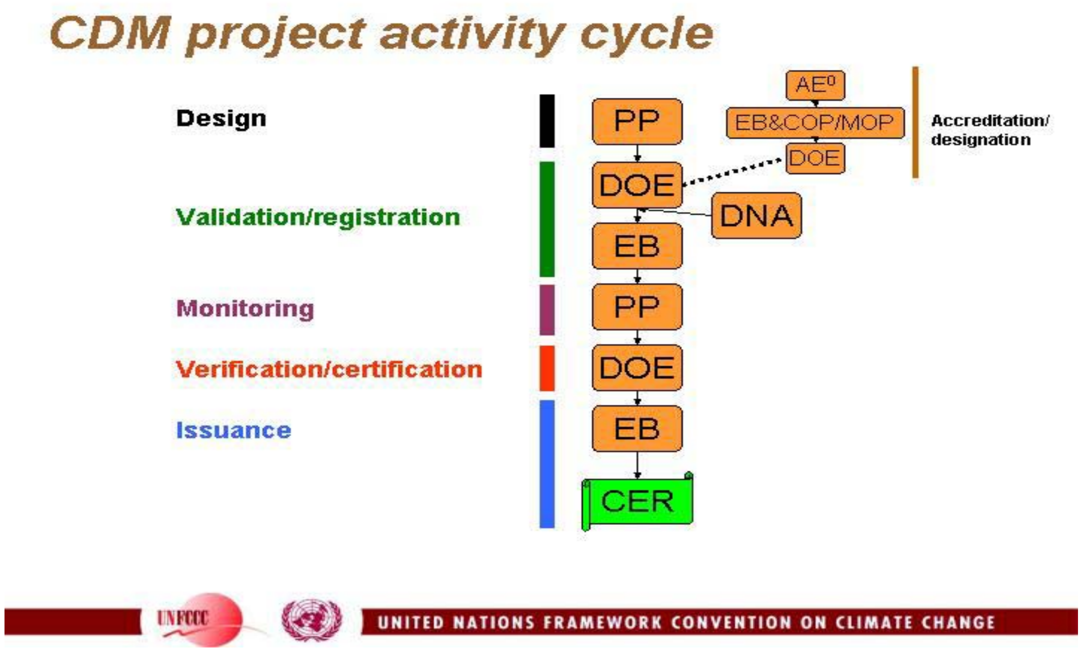
- The CDM is supervised by an Executive Board (EB), which itself operates under the authority of the Parties
- The EB is composed of 10 members, including one representative from each of the five official UN region (Africa, Asia, Latin America and the Caribbean, Central and Eastern Europe, and OECD), one from the small island developing states and two each from Annex I and non-Annex I Parties

2) Designated Operational Entities (DOE)

- The Designated Operational Entities (DOE) are independent organizations accredited by the EB that will validate proposed CDM projects, verify the resulting emission reductions, and certify these emission reductions as CERs.

3) Designated National Authority (DNA)

- All countries wishing to participate in the CDM must designate a National CDM Authority (DNA) to evaluate and approve the projects, serve as a point of contact and determine the national criteria for project approval.



Designing a CDM Project

- In order to qualify under the CDM procedure, a project needs to demonstrate a measurable and long-term ability to reduce emissions, and forecast reductions that would be additional to any that would otherwise occur (baseline emissions).
- The most important issues to be addressed when designing a CDM project are the additionality criterion, the baseline methodologies and the monitoring plan

Additionality

- Reductions need to be "additional to any that would otherwise occur" (Kyoto Protocol)
- Little further guidance from the Marrakech Accord
- Environmental additionality must be proved
- Requirements for proving additionality currently tends to vary between buyers (environmental additionality vs. financial additionality)
- Making the case for additionality is like going to court (the validator being the judge)
- Main questions to be addressed:
  - What are the barriers to implementation ?
  - How does the technology compare to other practices in the sector or country ?
  - Is the project financially viable without the revenue from carbon credits ?
  - Is there a requirement to implement the project anyway based on policy or regulatory framework ?

Baseline Methodologies

- A baseline methodology shall be established on a project specific basis
- Project proponents may use methodologies previously approved by the CDM Executive Board (the so-called precedent approach) or a new methodology that must be authorized and registered by the CDM Executive Board
- Baseline methodologies are being developed based on the three approaches in the Marrakech Accord:
    - existing current or historical emissions;
    - emissions from a technology that represents an economically attractive investment; or,
    - the average emissions of similar project activities undertaken in the previous five years under similar circumstances and whose performance is among the top 20 % of their category.

Monitoring Plan

- CDM projects must also have a monitoring plan to collect accurate emissions data.
- The monitoring plan, which constitutes the basis of future verification, should provide confidence that the emission reductions and other project objectives are being achieved and should be able to monitor the risks inherent to baseline and project emissions.

Latest Developments on Baseline and Monitoring Methodologies

- Deep concerns were being expressed as during its meeting of 7-8 June 2003 the EB refused to approve all of the first 14 CDM project baseline and monitoring methodologies submitted to the EB
- However, the EB finally approved, during its meeting of 28-29 July 2003, the first two CDM project baseline and monitoring methodologies
- These two projects are :
    - Salvador da Bahia Landfill Gas project (Brazil)
    - HFC Decomposition Project in Ulsan (South Korea)

Validation and Registration

- The DOE will review the project design document (PDD) and, after public comment, decide whether or not it should be validated
- If validated, the DOE will forward it to the EB for formal registration in accordance with the CDM's criteria

Monitoring

- Once the project is operational, participants prepare a monitoring report, including an estimate of CERs generated, and submit it for verification by the DOE.

Verification and Certification

- Verification is the independent ex-post determination by the DOE of the monitored reductions in emissions.
- The DOE must make sure that the CERs have resulted according to the guidelines and conditions agreed upon in the initial validation of the project.
- The DOE will, following a detailed review, produce a verification report and then certify the amount of CERs generated by the CDM project.
- Certification is the written assurance that a project achieved the reductions as verified.

Issuance

- The certification report also constitutes a request for issuance of CERs.
- Unless a project participant or three EB members request a review within 15 days, the EB will allow the issuance of the CERs.

Advantages of the CDM compared to the other Flexibility Mechanisms

Whereas Joint Implementation and International Emissions Trading merely shift around the pieces of the Annex 1 countries' overall 5 % target, the CDM is project based and involves emissions in non-Annex 1 countries (which do not have targets). This in effect increases the overall emission cap.

Entry into force of the Kyoto Protocol

- The Protocol will only become legally binding when at least 55 countries, including developed countries accounting for at least 55 % of developed countries' 1990 CO**2** emissions, have ratified it.
- Ratification of the Protocol by the Russian Federation is the only obstacle in the way of its entry into force
- Latest news concerning Russia's ratification

EU ETS Directive

- The EU has decided to implement a EU-wide trading system at the company level - the EU Emission Trading Scheme (EU ETS)
- The carbon credits traded under the EU ETS are EU Allowance Units (EAUs)
- The first trading period is set from 2005 to 2007 (also known as the « pre-Kyoto period »)

EU Linking Directive

- The Commission adopted on 23 July 2003 a draft directive (the « Linking Directive ») aiming to link the CDM and JI Kyoto Flexibility Mechanisms to the EU ETS starting from 2008.
- If the Linking Directive is adopted by the EU Parliament and the Council, it will become an amendment to the EU ETS Directive

Benefits from the Linking Directive

- The Linking Directive gives CERs a legislative basis (even prior to Kyoto Protocole's entry into force)
- Strong incentive for European countries to invest in CDM projects as it gives them more flexibility in meeting their commitments and lower their costs
- CERs will be fully convertible in EAUs (1 CER= 1 EAU)
- No cap has been set. However, If credits converted for use in the EU ETS reach 6% of total allowances allocated by Member States for 2008-2012, a review will be triggered and a quantitative limit could be the result

CDM Funding Sources

- The main sources of financing for CDM projects are :
  - Companies covered by the EU ETS looking to meet their commitment at lower costs
  - 2.Carbon Funds (i.e. Prototype Carbon Fund, Community Development Carbon Fund, Clean Tech Fund, GG-CAP)
  - 3.Government initiatives (i.e. Dutch CERUPT)
  - 4.Public Private Partnerships (i.e. Danish CDM)

- These sources of financing can be further classified based on :
  - type of financing (debt finance, private equity, funds investing in publicly traded companies,etc.)
  - technology type (energy efficiency, renewable energy, etc.)
  - geographical focus (global, regional, developing countries, etc.)

- **New Fund: Community Development Carbon Fund**
  - operational since 15 July 2003
  - involve private and public participants (i.e. Italy, the Netherlands, Nippon Oil (Japan), BASF (Germany))
  - Budget : USD 100 M
  - eligibility criteria : "small scale CDM project activities", improvements to the material welfare of the local communities involved
  - potential project: Mongolia: modernisation of 40 baseload boilers in 40 district coal burning heating plants, Kenya : switching from fuel oils to biomass fuels for tea drinking

- **New Fund: Clean Tech Fund**
  - not yet operational
  - venture capital fund
  - Budget : USD 100 – 150 M
  - Geographical focus: Brazil, Mexico, Argentina, Chile
  - potential projects: waste recycling, renewable energy technologies

General benefits from CDM for the Host Country

- Attract capital for projects that assist in the shift to a more prosperous but less carbon-intensive economy ;
- Encourage and permit the active participation of both private and public sectors ;
- Provide a tool of technology transfer, if investment is channeled into projects that replace old and inefficient fossil fuel technology, or create new industries in environmentally sustainable technologies ; and,
- Help define investment priorities in projects that meet sustainable development goals.

Sustainable Development Benefits from CDM for the Host Country

- Transfer of technology and financial resources;
- Sustainable ways of energy production;
- Increasing energy efficiency and conservation;
- Poverty alleviation through income and employment generation; and
- Local environmental side benefits

SESSION 4: FINANCING

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Circular Economy Model - Taking Fuel Ethanol and Bio-gas as its core

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Circular economy is a new concept which started more than ten years ago. It is the abbreviation of the closed material circular economy. Essentially, it is a kind of zoological economy and it requires people to use ecological rules but not mechanistic rules to instruct human economic activities. Since the industrial Revolution in 1712, people have developed in such a traditional way:

mass-exploiting resources → producing mass → consuming mass → Producing mass waste.

Its characteristics are high exploitation, low utilization and high discharge and it is a kind of one-way-flow linear economy. It uses resources carelessly and it achieves increase in quantity through changing resources into waste continuously. This economic model has lasted for about 300 years. In the late 20th century, resource shortage and environment pollution, the two major obstacles, appeared and became a great threat to human life and development.

On the opposite, circular economy proposes a kind of economic development pattern, which is in harmony with the environment. It demands organizing economic activities into a feedback flow 'resources — products — renewable resources'. Its characteristics are low exploitation, high utilization and low discharge. All the materials and resources will be used reasonably and continuously in the economy circulation in order to reduce the impact produced by economic activities to the lowest degree. In this way, we can save a lot of natural resources for our descendants. At the same time, we can reduce the discharge of waste and lighten the burden on environment. That is to say, circular economy is realized by continuous circulation of materials, which is also called sustainable development. For a producing enterprise, circular economy is realized by the continuous circulation of its products. Circular economy provides a strategic canonical form of theory to change traditional economy into sustainable economy and eliminates the long-lasting and acute conflict between environment and development.

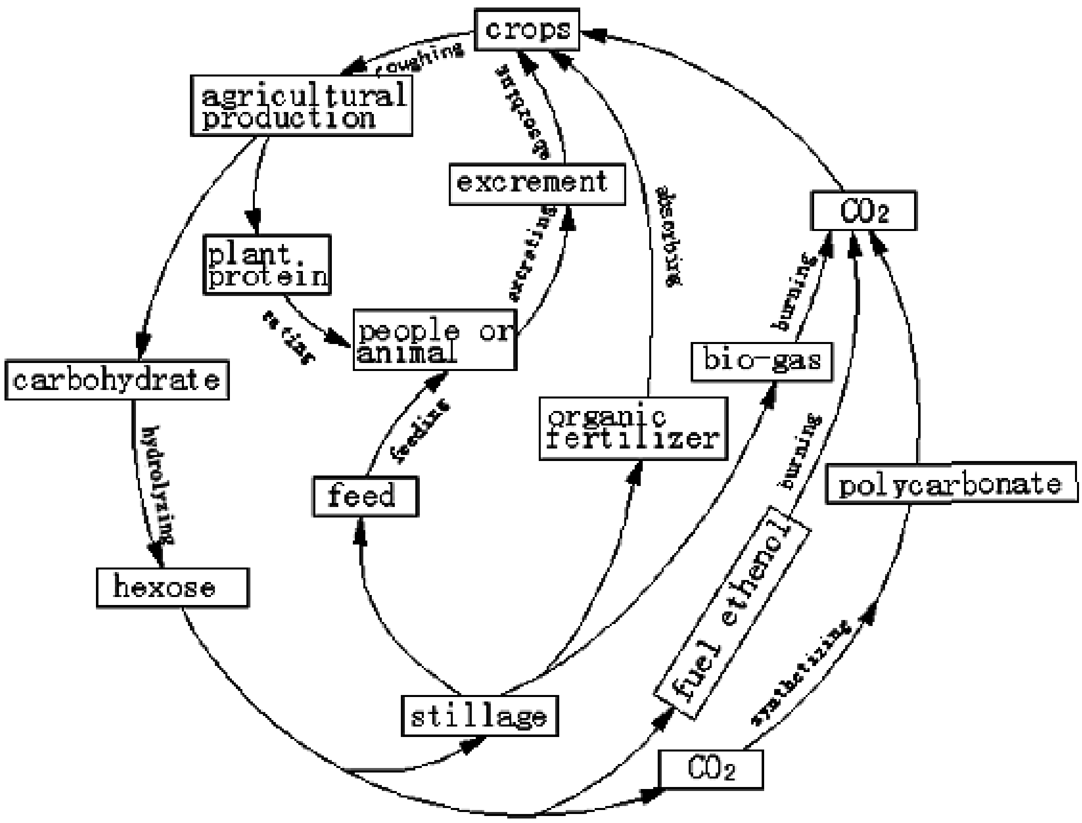
In the late 1990s the primary resources of energy were in shortage and oil price rose quickly. Human living environment suffered serious destruction from industrial waste. Meanwhile, China's grain production experiences continuous and substantial growth. Due to its over-production the government has to pay a lot of money for storage and deposition. The yield has increased but the farmers' income did not increase. As a result, their production initiative is greatly frustrated.

Henan Tianguan Group is a large enterprise for grain processing. Through internal and external market research, we think that in order to realize the development of national economy and sustainable development of the enterprise, we must choose the way of sustainable development and make a plan for the exploitation of fuel ethanol. This project can solve the three central issues: surplus of grain, oil shortage and environment deterioration.

This project gains high attention of the national officials and govenrment departments. With support of officials on different levels, the 200,000 tons per year fuel ethanol plant rebuilding project of Tianguan was completed and put into production in April 2001. A new 300,000 tons per year fuel ethanol project was started in November 2002. Tianguan takes the comprehensive processing of grain and bio-energy as the cut-in point and realizes sustainable development of the enterprise, striding toward the realization of a circular economy.

In the early 1990s, facing fierce competition in the markets, we initiated the strategy of 'alcohol production as a base, deep processing of alcohol as a guideline and comprehensive utilization as well as comprehensive development as the two wings (one base and two wings)'. We carry out clean production, exploit deep processing and comprehensively utilize products, such as acetic acid, ethyl acetate, carbon dioxide, bio-gas and feed and we proceed the way of sustainable development. These items free the enterprise from difficulties in the weak periods of the ethanol market and enable the company to face the fierce competition. Based on the deep processing and comprehensive utilization we realize plural product patterns led by alcohol and clean production models of producing alcohol from sweet potatoes. The exploitation of fuel ethanol combines the development of the enterprise with grain transformation and makes the enterprise stride forward to a higher level and a broader field. It raises the strategy of 'one base and two wings' to the green concept and sustainable development strategy in the best harmony with nature, society and economy. It forms sustainable development and good circulation of production, environmental protection and reuse of resources.

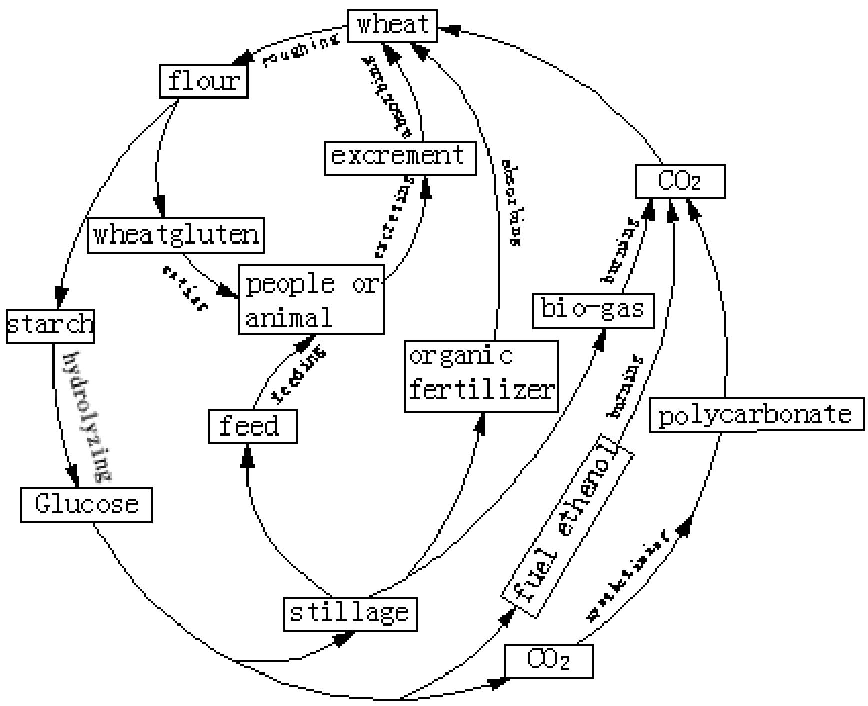
The circular economy product model proposed by Tianguan group is shown in the following picture.



Circulation diagram for sustainable development by the Tianguan Group

From the above scheme, we can see clearly that the discharge of one step is the raw material of the next step. No waste is produced in the whole course and zero discharge is realized. Resources are utilized effectively and the natural environment is protected to the highest degree. We realize the best combination of economic, social and environmental interests. The circular reuse and the utilization of waste products are necessary conditions for the realisation of a circular economy.

Fuel ethanol is a new industry which is in accordance with the state industrial policies and helps to solve the three central issues — resources shortage, comparative surplus of grain and environment deterioration. Through appropriate design, its production course is in line with the requirements of a sustainable circular economy. Besides the main product (fuel ethanol), by-products such as wheat bran, wheat gluten, bio-gas, CO_2, etc. add high economic interests to the enterprise.



Circulation diagram for the production of fuel ethanol from wheat by the Tianguan Group

From the picture we can see clearly that wheat is transformed to flour and bran by milling. Through extraction, we can get wheat gluten and starch, which raise the economic value of wheat. After gluten and bran are used as food for people and animals, the excrement are used as fertilizer for wheat or other plants. (For large breeding farms, the mud after the bio-gas fermentation can be used as fertilizer.) During the whole course, no industrial waste is discharged and no harm is done to the environment. After extracting wheat gluten the remaining starch mash is transformed to glucose by hydrolysis. Through fermentation of *saccharomyces cererisiae* glucose can be converted into ethanol and carbon dioxide. Through purifying and dehydrating, fuel ethanol is gained which can be used as transport fuel for vehicles. After burning, fuel ethanol is transformed into carbon dioxide and water returning to nature and are used again in photosynthesis by wheat or other plants. The purified and compressed carbon dioxide from fermentation can be used in the beverage industry and in other industries. It can also be used for the production of polycarbonate together with propylene oxide.

After fuel ethanol is produced, the stillage contains much organic material, which will cause great pollution to environment if discharged. Of course, controlling pollution requires large investment, but we realize its urgency and necessity. Looking at the strategic height of sustainable development, we invest money and accelerate the speed of pollution research. After continuous experiments and studies, we found the best solution — producing bio-gas by stillage.

First, the stillage is separated into filter cake and filtrate. The filter cake can be converted into DDG protein feed by drying. The filtrate is transformed into bio-gas by anaerobic fermentation. After filtering the fermentation mash, we get a filter cake, which can be used as organic fertilizer and its filtrate contains only little organic material. It can be used as process-water after aerobic fermentation. After burning, bio-gas changes into carbon dioxide and water, which will be used in photosynthesis. Organic fertilizer can be produced from the residue (without the micro-organism fermentation). Finally, all of the products become nutrition for wheat or other plants, and we realize a complete circulation of material under natural conditions. During the course of controlling pollution, we realize the secondary exploitation of all products, leading to significant economic gains. It proves that our way of controlling pollution is reasonable, effective and we can make sustainable development possible.

In the whole course, fuel ethanol and bio-gas are the main products and there is no waste discharged. We realize circulation under natural conditions and also realize the 'resources → products → resources reproduction' circulation flow model of material that is proposed by circular economy.

The proposal of the above model clarifies the concepts of circular economy and sustainable development. Of course, it may not be so simply and perfect in practice. However, it clarifies the development scheme of our enterprise and proposes an aim. We believe that Tianguan Group will be the model of circular economy in practice.

Brief introduction of Tianguan Group

Henan Tianguan Group is a large state-owned enterprise reorganized by some companies with the former Nanyang alcohol factory as its core. It is one of the 520 key enterprises in China and is one of the 50 key enterprises in Henan. It is the first enterprise, which has passed the ISO 9002 attestation and it is the only one that has post-doctorate working stations in China's alcohol industry. Tianguan has more than 5000 employees, more than 900 technicians and 12.8 billion yuan assets. There are 12 productive enterprises, 6 subsidiary companies and 1 institute of the Henan province under the supervision of the group. It has the largest fuel ethanol production line in China, which is 200,000 ton/year, the largest xanthan gum production line and bio-gas projects in China. Its products involve organic chemistry, fine chemistry, biochemistry, distilled liquor, industrial gases and electric power. The main products are food-grade ethanol, fuel ethanol, distilled spirits, beer, acetic acid, and xanthan gum, DDG feed, wheat gluten, bio-gas and more than 40 other products. The total production per year is 500,000 tons with 1 billion yuan sales income and 100 million yuan of tax and profits. At present, the 300,000 ton/year fuel ethanol project sustained by the state is under construction. After it is put into production, the total production will be more than one million ton and the sales income will achieve 2.38 billion yuan and the tax and profits will be 2,800 million yuan.

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Liquid Fuel Production Through Biomass Pyrolysis and Ethanol Fermentation Technology

SESSION 5: BIOMASS RESOURCES

International Conference on Bioenergy Utilization and Environment Protection
6th LAMNET Workshop – Dalian, China 2003

Sweet Sorghum – An Important Energy Crop for China

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Sweet Sorghum belongs to the C_4 crops. It has a very high photosynthetic efficiency and it grows quickly. The cultivar Wray grows by an average of as high as 12 cm/day in Beijing. This rate of growth is surprising indeed. It is worthy of the glorious name of “a high-energy crop”. China has a large population and we need high-energy crops.

2. The security of energy has been faced with challenge.

China has become an oil net-importing country since 1993. In 2000, China imported 70.27 million t of oil from abroad, which accounts for 36% of the total volume processed in China. The estimated world reserves of oil can only be recovered for about 40 years. Using the recovering rate of the year 2000 as reference, the estimated reserves of oil in China can only be recovered for about 17 years.

3. The pollution is a serious threat.

At present, the amount of carbon emitted by burning mineral fuel has reached 60 hundred million t in the whole world each year, leading to the appearance of the Green-house Effect and Acid Rain. The pollution is a serious threat. The Chinese Society of Medical Sciences made an investigation on 11,348 Students in a school in Shenzhen City in October to December 2001. It shows that the lead content in the bodies of 65% of the students has surpassed the secure level approved by the World Health Organization. In Beijing, for 20% of the children, the content of lead in their bodies surpassed the approved level. In Taiyuan, the surpassing rate is 64%. An investigation made in Guangzhou, shows that the lead content in 83% of the children’s bodies surpassed the approved secure level.

4. Sweet sorghum is an important Energy Crop.

At present, not one individual technique can be used for meeting the demand of energy in the world. Sugarcane is used to produce alcohol in Brazil. However, in China, the tropical area is limited, and the average yield of sugarcane in China is not very high, it is only equal to that of the world average yield. However, the yield of grain sorghum is 285% of the average yield of the world. The biological characteristics of grain sorghum and sweet sorghum are similar. The experiments show that most areas of China are adapted to grow sweet sorghum. Sweet sorghum can be harvested 1-3 times per year, while sugarcane just one time. Sugarcane is propagated using the stems and it needs 4500-6000 kg/ha of stem sown, while sweet sorghum is sown with seeds, 4-8 kg/ha of seeds being sufficient. The quantity of water needed by sweet sorghum is only 1/3 of that needed by sugarcane. The tolerance of sweet sorghum towards droughts, waterlogging and salt-alkali is much higher than that of sugarcane. In 1999, the average sugar output of sugar crops was 349 kg/mu in China, giving an alcohol yield of 203 l/mu. The average yield of maize is 330 kg/mu, giving an alcohol yield of 133 l/mu.

The average yield of grain of sweet sorghum is 100-500 kg/mu, the yield of stalk is 4000-7000 kg/mu. If to calculate as the yield of grain 200 kg/mu and stalk 4,000 kg/mu, the alcohol yield would be 351 l/mu, which is equivalent to 173% of that of sugar crops and 264% of maize in 1999.

5. We have the elements for the development of sweet sorghum.

I am engaged in the research of sweet sorghum 29 years. Many germplasm have been collected or introduced. Some books on sweet sorghum were published. The FAO of the UN pays great attention to the development of sweet sorghum, supporting the organisation of The First National Sweet Sorghum Conference and the First International Sweet Sorghum Conference in 1995 and 1997, respectively and supporting International Sweet Sorghum Trials in Asia. Some new cultivars with high sugar content high seed yield and high stalk yield have been bred. The foundation for developing sweet sorghum has been set up.

6. Adjusting the structure of agriculture, Growing 10 million ha sweet sorghum to produce alcohol 56 billion l for ensuring the security of energy in China.

In 2001, the harvested area of maize was 24.282 ha (3.64 亿亩) in China. The total yield was 114.088 million t (the average yield was 313 kg/mu). 68% of the produced maize (2.47 hundred million mu) was used as feed for livestock.

If 3.33 million ha (0.5 亿亩) from the area growing maize or from the useable land for agricultural production (there are 35.35 million ha in China in 2001) are used to grow new sweet sorghum cultivars, and new technologies are used, then the yield will be 4.1 times of that of maize. The total output yield of feed sweet sorghum will be more than that of the maize yield produced from 13.355 million ha and the heat energy of the new product will be higher than that of maize, paddy or dry powder of potato.

The remaining 10.015 million ha (1.5 亿亩) will be used to grow sweet sorghum for the production of bio-fuel. The yield of sweet sorghum is 4,000-8,000 kg of stalk and 100-500 kg of grain. Assuming a yield of 4,000 kg of stalk and 200 kg of grain, then the output of alcohol will be 5603 l/ha, and then the 10.015 million ha of sweet sorghum can produce 56.2 billon litres of alcohol. This amount is about 170% of the total world alcohol production, and it is sufficient for China’s future needs.

In this case, it will not only ensure security of energy supply but also reduce the released carbon (in CO_2 form) and will save the expenditure used for purchasing oil. In addition, it will increase the chance of obtaining employment, accelerate urbanization of village, and help to improve the living standards of farmers by initiating new aspects of agricultural and rural work in China.

SESSION 5: BIOMASS RESOURCES

International Conference on Bioenergy Utilization and Environment Protection
6th LAMNET Workshop – Dalian, China 2003

Innovative Transportation Fuels

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Future alternative fuels should offer the possibilities to be used as the current fuels within the existing infrastructure, to contribute to the reduction of greenhouse gases, to promote the development of new technologies of the recent combustion systems and energy generation (i.e. fuel cells), to be affordable, sustainable and they should be renewable. Moreover, they have to ensure a safe supply within the regional and global markets.

Biomass can be considered as the best option and it has the largest potential, which meets these requirements and could insure fuel supply in the future. Plant oils, bio diesel, biogas and ethanol have been successfully introduced and are already in use. Innovative synthetic fuels are related to aspects and the new developments in conversion technologies of lignocellulosic to fuels: Gasification, pyrolysis and upgrading to gasoline, diesel and hydrogen, methanol, DME as well as the possibilities of their generation from biomass.

Fuels derived from biomass are not only potentially renewable, but they are also sufficiently similar in origin to fossil fuels in order to provide direct substitution opportunities. They can be converted into a wide variety of energy carriers (biogas, biodiesel, ethanol, methanol, DME, diesel, gasoline, hydrogen) as of recent fossil fuels through conversion technologies, and thus have the potential to be significant new sources of energy for the 21st century (Fig. 1).

The input/output energy balance ratio may reach up to 1:25. The CO_2 mitigation potential of energy crops as energy sources is considerably large. Data related to global conversion of solar energy to biomass are summarised in table 1 and the possible contribution of biomass in future global energy supply is given in table 2.

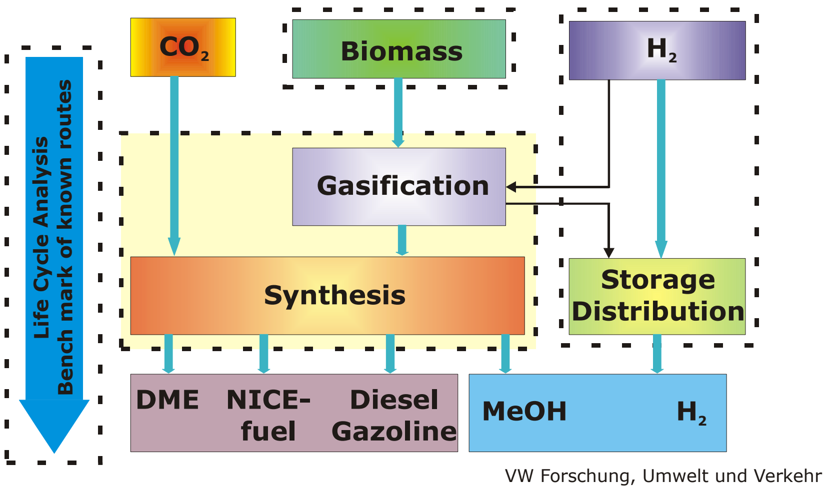

Figure 1: Pathways to Renewable Fuels (from plant to tank)

1000 kWh is 3.6 GJ and 1 ha is 10 000 m², so the total annual energy is	36 000 GJ
One third of this delivered during the growing period	12 000 GJ
20% of which reaches the growing leaves	2 400 GJ
After a further loss of about 20% by reflection	2 000 GJ
50% of this is photosynthetically active radiation	1 000 GJ
30% of which is converted into stored energy	300 GJ
But 40% is consumed in sustaining the plant, leaving	180 GJ
Corresponds to	10 t ha^{-1} y^{-1} GJ

Table 1: Conversion of Solar Energy (Annual Energy Delivered by Solar Radiation is 1000 kWh m^{-2} y^{-1}. ha^{-1})

Scenario	**Year of Scenario**		
	2025	2050	2100
IEA (1998)	60*	--	--
IIASA/WEC (1998)	82**59***	153** 97***	316** 245***
Shell (1996)	85	200-220	--
IPCC (1996)	72	280	320
Greenpeace (1993)	114	181	--
Johansson *et al* (1993)	145	206	--
WEC (1993)	59	94-157	132-215
Dessus *et al* (1992)	135	--	--
Lashof and Tirpak (1991)	130	215	--

* *2020 (Total primary energy supply)*
** *Scenario A3 (High growth – biomass and nuclear)*
*** *Scenario C1 (ecologically driven - large renewables, no nuclear)* **Source: Hall (1999)**

Table 2: The role of modernized biomass in the future global energy use (Present biomass energy use is about 55 EJ/year)

Biomass can be considered as a source for carbon and hydrogen (table 3). The possible outcome of oil from biomass depends on the productivity of energy plants and up to 9000 l oil through modern conversion technologies from one hectare could be achieved (table 4).

Fuel	*Ratio of atoms*			*% by weight*		
	C	H	O	C	H	O
Coal	1	1	<0.1	85	6	9
Oil	1	2	0	85	15	0
Methane	1	4	0	75	25	0
Wood	1	1.5	0.7	49	6	45

Table 3: Proportions of carbon, hydrogen and oxygen in fuels

Biomass Yield ($t\ ha^{-1}.\ y^{-1}.\ kg^{-1}$)	Energy content *($MJ\ .\ kg^{-1}$)*	*eta Conversion Efficiency*	*Fuel Yield ($t.\ ha^{-1}.\ y^{-1}$)*	*Fuel Yield ($l.\ ha^{-1}.\ y^{-1}$)*
10	*17,5*	*0,48*	*1,9*	*2448 (3000)*
20	*17,5*	*0,48*	*3,8*	*4895 (6000)*
30	*17,5*	*0,48*	*5,7*	*7343 (9000)*

Table 4: Fuel yields from biomass

More than 100 plant species have been identified for different region of the world to serve as biomass sources for biofuels. A summery of energy plant species which could be grown under various climatic conditions have been documented in the tables 5-7.

Table 5: Representative energy plant species for different climate (temperate climate)

- Cordgrass (*Spartina spp.)*
- Fibre sorghum *(Sorghum bicolor)*
- Giant knotweed (*Polygonum sachalinensis)*
- Hemp (*Cannabis sativa)*
- Kenaf (*Hibiscus cannabinus)*
- Linseed (*Linum usitatissimum)*
- Miscanthus *(Miscanthus x giganteus)*
- Poplar *(Populus spp.)*
- Rape *(Brassica napus)*
- Reed Canary Grass (Phalaris arundinacea*.)*
- Rosin weed *(Silphium perfoliatum)*
- Safflower (*Carthamus tinctorius)*
- Soy bean (*Glycine max)*
- Sugar beet (*Beta vulgaris)*
- Sunflower (*Helianthus annuus)*
- Switchgrass *(Panicum virgatum)*
- Topinambur *(Helianthus tuberosus)*
- Willow *(Salix spp.)*

Table 6: Representative energy plant species for different climate (aride and semiaride climate)

- Argan tree (*Argania spinosa)*
- Broom (Ginestra) *(Spartium junceum)*
- Cardoon (*Cynara cardunculus)*
- Date palm (*Phoenix dactylifera)*
- Eucalyptus (*Eucalyptus spp.)*
- Giant reed (*Arundo donax)*
- Groundnut *(Arachis hypogaea)*
- Jojoba *(Simmondsia chinensis)*
- Olive (Olea europaea*.)*
- Poplar *(Populus spp.)*
- Rape (*Brassica napus)*
- Safflower (*Carthamus tinctorius)*
- Salicornia (*Salicornia bigelovii)*
- Sesbania (*Sesbania spp.)*
- Soybean *(Glycine max)*
- Sweet sorghum *(Sorghum bicolor)*

Table 7: Representative energy plant species for different climate (aride and semiaride climate)

- Aleman Grass (*Echinochloa polystachya)*
- Babassu palm *(Orbignya oleifera)*
- Bamboo (*Bambusa spp.)*
- Banana (*Musa x paradisiaca)*
- Black locust (*Robinia pseudoacacia)*
- Brown beetle gras (*Leptochloa fusca)*
- Cassava *(Manihot esculenta)*
- Castor oil plant *(Ricinus communis)*
- Coconut palm (*Cocos nucifera)*
- Eucalyptus *(Eucalyptus spp.)*
- Jatropha (*Jatropha curcas.)*
- Jute *(Crocorus spp.)*
- Leucaena (*Leucaena leucoceohala)*
- Neem tree (*Azadirachta indica)*
- Oil palm (*Elaeis guineensis)*
- Papaya (*Carica papaya.)*
- Rubber tree *(Acacia senegal)*
- Sisal *(Agave sisalana)*
- Sorghum *(Sorghum bicolor)*
- Soybean *(Glycine max)*
- *Sugar cane (Saccharum officinarum)*

Figure 2 shows the energy plantation of the Federal Agricultural Research Centre (FAL) which represents the "Oilfields of the 21st century.

Figure 2: A VW car fuelled with "SunFuel" from biomass on the energy plantation of FAL.

Summery and Perspectives

- Annual primary biomass production: 220 billion DM, 4,500 EJ = 10 times of world primary energy consumption.
- Biomass used for food: 800 millions DM = 0.4% of primary biomass production.
- Annual food production corresponds to 140% of the needs of world population.
- Biomass currently supplies 14% of the worldwide energy consumption. The level varies from 90% in countries such Nepal, 45% in India, 28% in China and Brazil with conversion efficiency of less than 10%. The potential of improving is efficiency through novel technologies is very high.
- Large areas of surplus of agricultural in USA, EU, East Europe and former soviet countries and could become significant biomass producing areas (> 200 millions ha).
- Microalgae have the potential to achieve a greater level of photosynthetic efficiency than most other forms of plant life. If laboratory production can be effectively scaled up to commercial quantities levels of up to 200 mt/ha/yr may be obtained.
- The efficiency of photosynthetic is less than 1%. An increase in this efficiency (through genetic engineering) would have spectacular effects in biomass productivity: successful transformation of C_4-mechanism (from maize) to C_3-crops (rice). New achievement in accelerating cell division opens opportunities to speed up the growing seasons, resulting in several harvests per year and an overall increase in biomass.
- Developments in car technologies is leading to significant reduction in fuel consumption, i.e. less areas will be needed for more cars.

Conclusion

Of all options, biomass represents the largest and most sustainable alternative to substitute fossil transport fuels as "Win-Win" strategy.

Reference

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SESSION 5: BIOMASS RESOURCES

International Conference on Bioenergy Utilization and Environment Protection
6th LAMNET Workshop – Dalian, China 2003

Potential of Giant Grass *Triarrhena lutarioriparia* to grow in cold, dry and saline conditions as Energy source

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Abstract: Giant grass *Triarrhena lutarioriparia* (a special type of *Miscanthus sacharilorus*) is originally a subtropical plant growing in humid condition or even in water in regions of about 28-29° N. latitude, with yields from 20-40 t (dm) /ha in its natural vegetation. To our great surprise we found that this plant can also be grown in cold and dry regions and even in saline soils, though the plant has adapted to moderately acid soils in its long growing history in the subtropical lake area. Experimental cultivation has been successfully conducted in Yuncheng (35.02° N. lat), Dongying (37.27° N. lat), Beijing (39.55° N. lat) and Braunschweig (52.16° N. lat). The results show that the yield of this plant can be over 20 t (dm) /ha in Yuncheng and in Beijing without problem. The yield of the plant in saline soils in Dongying is lower, but still to be observed in the next years. The materials used for these experiments were from the natural vegetation of the plant in 1994-95. We believe the plant have adjusted its adaptability to new conditions step by step in the process of transplantation, because it is very elastic to the growing conditions and therefore has a very strong viability. This plant is a very good choice to produce bio-energy materials in various regions with diverse conditions.

Other giant grasses such as *Arundo donax* are also taken into test to compare their adaptabilities to adverse conditions. The result showed that *A. donax* was somewhat frost-sensitive in the first growing year. Further it would grow better.

Keywords: Giant grass, *Miscanthus*, Bio-energy, renewable materials, biomass

1. Introduction

Miscanthus is a group of well known energy plants which produce large amounts of biomass in humid and warm or moderate climate conditions. The widely cultivated species *M. x giganteus* is actually a hybrid plant derived probably from *M. sinensis* and *M. sacchariflorus* (Greef & Deuter 1993). The latter is recently classified as 2 species: *Triarrhena sacchariflora* and *T. lutarioriparia* (Liu 1997). *T. sacchariflora* is a relatively small plant distributed in northern regions, while *T. lutarioriparia* is the one which grows normally in the South. But in fact, the species *T. lutarioriparia* itself consists of various types with different plant heights, culm thickness and growing densities. Many types of this species show a wide range of adaptability to their growing conditions. This means that they could also have high productivity in regions with conditions far different from their original growing sites (Xi 2000). Based on this knowledge the author began to collect natural resources of this plant species and to transplant them in different places with cold and dry climate and even with saline soils, in order to examine their productivities and related cultural properties. It is believed that this plant, the real “China reed”, will be developed to a new crop which is useful for energy supplying, for landscape and soil conservation, for gardening and for environment protection both in southern and in northern regions.

A. donax is another important giant grass species and should be taken into test as a comparison.

2. Materials and Methods

Since 1994 the author has collected a series of *T. lutarioriparia* strains for test transplantation and cultivation. Among them 2 strains were intensively observed in Yuncheng China (35.02° N. lat) and 1 strain were tested in Braunschweig Germany (52.16° N. lat). All the results are positive to persuade people that the 2 strains, Monan-Lingdi and Hanshou, can grow and overwinter in dry, cold climate (-14-21℃) and even in a little alkaline soil condition (pH 8.1).

Since 2002 the author have taken the above 2 strains for more test-cultivation in the North both in Beijing (39.55° N. lat) and in Dongying (37.27° N. lat). The climate in Beijing is more extreme than in Yuncheng, i.e. similarly dry in Spring and Summer but more cold in Winter. The lowest temperature in the Winter 2002-2003 was under -16℃. The soils in the test field in Beijing has a pH-value of about 7.7. The climate condition in Dongying (lowest temperature in the Winter 2002-2003 was under -19℃) is more extreme than in Beijing, and the soils in Dongying are heavily saline. The site for growing Hanshou-Strain of *T. lutarioriparia* has a soil salt content of about 1%. The pH-value of the soils is about 8.5. Despite of these adverse conditions, the tested plant strains Monan-Lingdi and Hanshou grew very well in Beijing, and the strain Hanshou withstood the saline problem and established its vegetation indomitably in Dongying.

Together with *T. lutarioriparia* some other giant grass species have also been taken into the examination. All the cultivation tests were made without irrigation and fertilization. For planting materials all the plants were taken from Yuncheng test-field as rhizomes which were than buried in new test-fields in Beijing and in Dongying within 1 week after the rhizomes were dug out. The burying time was 27th April, 2002. The burying depth was about 20 cm.

In 8-13th November 2002 the same rhizome materials of the above plants were buried in Beijing test-field to see the effect of Autumn-transplantation.

3. Results and Discussion

(1) The cultivation test in Beijing

All transplanted plant species or strains grew very well in the first year. The *T. lutarioriparia* strains sprouted panicles between 10-20th September. By 23th October both the *T. lutarioriparia* strains grew to 250 cm (Tab.1). On 23th October an early frost (-2℃) came suddenly and all the plants were frozen to die and to keep a green-dry status. The rhizomes of this species overwintered under ground safely and showed new sprouts by the end of the next March.

In 2003 the strains of *T. lutarioriparia* are growing stronger than the last year. On 11th September their max height is about 3 meter. At the same time, they have increased their culm numbers greatly. The final biomass yield are estimated as not less than 20 t/ha.

Tab.1 The plant height of various species or strains of giant grasses in the first year of transplantation (cm)

Time / Species or Strains	02.05.09	02.07.11	02.08.29	02.10.23
T. l. Hanshou	20	180	195	250
T. l. Monan-Lingdi	18	180	190	250
Miscanthus x giganteus	10	130	160	200
Arundo donax	20	195	300	350

Miscanthus x giganteus can also establish its vegetation in drought climate conditions in Beijing, though it grew a little smaller than the above 2 strains of *T. lutarioriparia*. To overwinter was also no problem for *M. x giganteus*.

Arundo donax showed a still better growth in the first vegetation period and got a height to 3.5 meter, higher than other plant species or strains. It sprouted panicles also in the middle of September. But anyway, as far as to the overwinter problem, it showed an unfortunate result. The plant was heavily frozen to die on 23th October. Its rhizome had also entirely died out and could not get any sprout in the next Spring.

It is interesting that the in November buried rhizomes of *Arundo donax* overwinterd and grew out its sprouts in April. By September they grow to about 2.5 meter. This result can give explanation to the death of rhizomes of *Arundo donax* in October: The plant showed weakness to a sudden frost. It is probably that the frost effect could transmit from the culms to their rhizomes. More details should be further investigated.

The Autumn-buried rhizomes of *T. lutarioriparia* have also overwintered alive and sprouted in April 2003. But the plants are growing weakly. Till the Beginning of September the plant height was not over 1.5 meter, and without tillering.

From the above results we can conclude that the tested strains of *T. lutarioriparia* can grow well in Beijing, and their plantation time should be in spring.
The rhizomes of *Arundo donax* must be well protected in winter between 20th October and 20th February. The cultivation methods should be further investigated.

(2) The cultivation test in Dongying

The same plant materials of various species and strains mentioned above were also transplanted in saline field in Dongying. Most of the rhizomes sprouted out in 5-10 days after the burying. But they grew or only kept alive with difficulty due to the saline soils. By 2th October only a part of plants of Hanshou strain stood growing with a max height of 1.5 meter.
In 2003 the alive Hanshou strain of *T. lutarioriparia* sprouted out again in the saline soils in Dongying. It is growing stronger than the last year. By 1th September its max height is near to 1.8 meter.

It is commonly known that *T. lutarioriparia* is a plant adapted to warm and humid climate, growing in light acidic soils. But the above experiments show that this plant has not only a wide range of adaptability to their growing conditions, but also a possibility to widen their distribution or change their habitat step by step. The experimental materials were collected from the natural vegetation and thereafter cultivated by the author in the North for near to 10 years. They have build up their new properties and adapted to their new environment gradually? For this question some comparison experiments and long time observations are necessary.

4. Conclusion

Some ecological strains of *T. lutarioriparia* have an wide and quite elastic adaptability to their growing conditions. Therefore they are easy to be transplanted and bred to a new crop in other places. Due to their high biomass productivity they have quite bright prospects to be grown as a type of energy plants not only in the South, but also in the North.

A. donax is another potential giant grass species which can be used as energy plant, but it is somewhat sensitive to sudden frost in the north.

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SESSION 5: BIOMASS RESOURCES

International Conference on Bioenergy Utilization and Environment Protection
6th LAMNET Workshop – Dalian, China 2003

Large-scale Industry Utilization is an Essential Approach for Resolving Stalks

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1. Preface

In recent years, it has become a great social problem to burn stalks in grain production districts. It pollutes environment, threatens plane take-off and landing, and influences car traffic. Because this situation is getting worse, country leaders, ministries and commissions put emphasis on this topic and issued a ban on burning stalks. National administration departments on the one side increase technology investment for research on comprehensive stalk utilization and on demonstration engineering activities for the utilization of stalks. On the other side, they adopt manage means to burning stalks and severly execute the law. These measures show a large effect, but burning stalks is still a serious problem. With the developing of country economy and the improvement of farmers living standard, waste stalks are abundant in many districts of China.

It should be considered strategically to resolve the problem of stalk utilization and to eliminate pollution connected with the burning of stalks.

2. Characteristics of burning stalks

Through the production of food and stalks, grain provides the basis for living of many people in China. In the past, natural economy was the main economical factor in China. Every house was a life and production unit. Economy was not developed, and the living standard was low. Stalk was one of the valuable products of farmhouses. Stalk could be used as fuel for cooking and heating the houses and as raw materials to produce cushions, bars and to cover houses. It could feed flocks and herds. Since reform and opening, the country economy has experienced great changes. Farmers who changed their traditional life style became richer. Tile house were built instead of clay houses. Coal, LPG and electricity and used as energy source and machines replace cattle. Therefore, stalks become waste in some developed districts of China, especially in grain producing districts. So, the problem of stalk burning appeared. The characteristics of stalk burning are the following:

1) According to statistical data of the year 2000, annual production of crop stalk in China is 0.648 billion tons. Corn, wheat and rice are primary comprising 80 percent of the total. Stalk is still used as fertilizer, feed, industry material and planting material, but 45.7 percent of the total stalk is regarded as waste. The quantity of used stalks decreases every year, while waste stalk increases.

2) The largest quantity of stalk per year is 0.185 billion tons in East of China. Additionally, there are 0.147 billion tons in South of China, 0.1 billion tons in Northeast, 0.091 billion tons in North of China, 0.079 billion tons in the Southwest and 0.046 billion tons in Northwest. Provinces producing large quantities of stalks are ShanDong, HeNan, SiChuan, HeBei, HeiLongjiang, JiangSu, JiLin, AnHui, HuBei and HuNan. As in some provinces grain is produced in 2 or 3 harvests per year, stalks are being burned to ensure quick disposal in order not to influence the following harvest.

3) Stalks are burned between harvest time and the next seed time. Time is short and the quantity of stalks is large, so that some places have to dispose stalks within several days.

4) Economy is developed and farmers living standard has improved in some places, so that farmers rather buy LPG than collect stalks for cooking and heating purposes.

5) Disposing stalks is serious in united city-country districts and country layout zones. In these districts farmers strive for the same living conditions as people in the cities.

3. Actuality and problems of utilizing stalks

Stalk is a good available material according to its property and It is widely utilized. It is fuel, feed, fertilizer, base material and raw material.

Stalk is a high-grade feed. With the increased production of meat and milk, waste has continuously increases. Today, stalk waste is 27 percent of the total.

A small amount of stalk is used as base material to breed esculent fungal or earthworm and non-soil plants.

About 3 percents of the stalk is used to make paper, shade bar, table box, packing board, sound insulation board, heat preservation material, artificial charcoal and furfural material.

The use of stalks as fertilizer is 15 percent of the total. In the past, fertilizer has been made from stalks by fermentation, but now stalks are spread in the field after crushing. But this method causes problems as China has more people than fields.

The primary purpose of stalk is the production of fuel. Involved departments attempt to adopt this conversion technique for bioenergy to improve the quality of fuel and to enhance enthusiasm to use stalks as fuel. We have build several hundreds of demonstration stations for stalk gasification. The technology routes are of three kinds:

- air-oxidation - gasification
- carbonisation - pyrogenation
- gasification for the generation of electricity.

The technique of stalk gasification is a promising conversion option for bioenergy. But it has some problems:

1) Stalk gasification is determined by the economical development of a city, the financial income and culture. These conditions are not adequate in rural areas.

2) Farmers are short of enthusiasm. They care for house, electricity, water, television, telephone, vehicle and fuel. It is not advisable to depend national allowance on constructing gas pipelines.

3) On account of limited finance and allowance, the investment of stalk gasification system is lower and hidden quality troubles are few. Some departments work out lower department standard and local standard, so stations of stalk gasification didn't run stably and continuously.

4) Stalk gasification improves the rate of energy utilization and decreases the quantity of stalks as fuel in rural area.

5) Concerning departments promote the route of oxidation-gasification of stalk, which produces low heat value and high impurity gas, which does not reach the standard of national fuel gas. The equipment is simple and crude while opearting with no economical benefit.

We have more than 700 of these little gasification stations, which cost 0.3 billion yuan, and face termination of operation.

In summary, we have not resolved the social problem of surplus stalks, which pollutes the environment.

4. Development of a great industry system for the utilisation of stalks

Agricultural production schemes with families as basic units will not resolve the surplus stalk problem. It is considered as macroscopic strategic and great resource utilization problem, which can only be solved in a great-industry system. The technology level for the development of a great-industry system is sufficient today and economic benefits will be considerable after development of suitable markets. The following projects are envisaged:

1) Construction of large production plants for organic fertilizer production

This is a mature technology to crush and ferment stalks to produce organic fertilizer. If we build organic fertilizer plants, which produce 0.1 to 0.15 million tons of fertilizer from stalks every year in surplus stalks district, we can dispose large amounts of stalks and get considerable economic benefit.

2) Construction of large plants for stalk charcoal production

The technology of stalk pyrogenation is the same as for wood pyrogenation. If we build stalk charcoal plants, which produce 0.1 to 0.5 million tons of charcoal in surplus stalks district, we can dispose 0.35 to 1.65 million tons of stalks every year. The plants can produce 0.03 to 0.12 billion cubic meters of gas for the supply of small and medium-size cities and 0.03 to 0.15 million tons of gum. It is a project of great economic benefit.

3) Popularisation of the technology mixing stalk powdery-charcoal into fertilizer

Japan uses a technology that mixes stalk powdery-charcoal into fertilizer for many years. The Chinese Agriculture department should promote this technique and develop supporting policies. This would decrease the quantity of fertilizer consumption and increase the production of crops.

4) Construction of large electricity generation plants using stalks as feedstock

The technology of generating electricity by using smashed or lumpish stalks is mature. If we build stalks electricity generation plants, which produces 0.2 million kW of electricity in surplus stalks district, we can dispose 1.8 million tons of stalks every year, and can get considerable economic benefit. The quantity of generating electricity from surplus stalks is three times the quantity of generating electricity of the Yangtze Gorges, while the investment is lower.

5) Development of utilization techniques for stalks similar to coal

After crushing granules of stalk can be mixed with coal. Mixing of 10 percent stalks powder with coal causes no obvious changes and will increase the production of gas.

6) Wood replacement

Artificial coal made from stalk or straw is a good example for wood replacement. The performance of artificial wood made from sunflower straw is same as that of hard-wood. Fibreboards or thick boards made from stalk powder are is same as the ones made from wood chips.

Artificial wood sticks are easy to transport after crushing under high pressure. They can be used as fuel in the great-industry.

As soon as large-scale utilization of stalks is being developed, collection and transportation of stalks will become more professional. The transportation radius of coal, which is larger than the transportation radius of stalks, is more than 800 kilometres. Therefore, air pollution will also be reduced due to the smaller transportation radius of stalks.

5.Conclusion

In summary, it is not difficult to solve the problem of burning stalks with the help of mature technologies. The key to resolve burning stalks completely is the development and utilisation of stalk resources, to build designed and industrialized production projects in great-industry systems.

CLOSING AND FAREWELL

International Conference on Bioenergy Utilization and Environment Protection
6th LAMNET Workshop – Dalian, China 2003

Conference Closing Address

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Ladies and Gentlemen, dear Auditorium,

As you might see I changed my dress to a more formal one in order to underline the high value which I account to this LAMNET Conference and Workshop.

It was a pleasure for WIP as the coordinator of the project and the local organizers to welcome 54 Chinese delegates and 19 colleagues from abroad, 6 coming from the Latin America, 1 from South Africa and another 12 coming from Europe.

Today the value of the conference was supported by three presentations of high-level politicians and decision makers. President Prof. Hong, who is Member of the Standing Committee of Chinese People’s Political Consultative Conference and Vice-Chairman of Central Committee of September 3rd Society, Vice-Director Mr. Tang of the Dalian Municipal Rural Economy Development Bureau and Director Mr. Zhao, Head of the China Social Economic Investigation and Research Center.

During the two-day sessions we heard many very interesting inputs on economical, political and technical issues for biomass for energy. It was pointed out and underlined by the discussion contributions that biomass is not only for food but also for energy and chemicals.

Which area of arable land was formerly utilized for transportation can be shown by some data which were published some weeks ago in a speech of the States Minister Mr. Miller for the Free State of Bavaria.

In statistics of 1914, just 100 years ago, in Southern Germany animal husbandry of farmers included 261 thousand oxen and 675 thousand cows. All of them were used for transportation – oxen and cows for example – to pull ploughs and carriages. Each of these animals was fed on approximately 1.5 ha of arable land. Accounting only half of this area to transportation with oxen and cows – because of their double utilization for meat and milk – approximately 25% of the total arable land in Bavaria was used to produced fuel for transportation. And the EU is discussing to attribute approximately 15% to this issue.

It was also pointed out that biomass is a renewable energy which is sustainable and environmentally friendly when handled correctly with regards to production, provision and transformation and that it is a storable energy source. That is to say that biomass is the best means to support the other renewable energy sources such as hydropower, photovoltaic and wind.

In order to summarize we can state that biomass for energy will help:

- to increase farmers income and living standard,
- to create new employment,
- to keep investments in the country,
- to compete against export of money for the import of oil,
- to reduce desertification as well as soil erosion,
- and last but not least to protect the environment of this single globe for the future coming generations.

Finally, I thank very much Prof. Wang MengJie, Ms. Yao XiangJun and all those who supported in organizing this Conference and also all the translators as I can imagine which efforts they have made.

Big hands and many thanks

TECHNICAL TOUR

International Conference on Bioenergy Utilization and Environment Protection
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Technical Tour to Lü Shun – 26 September 2003

Organic Municipal Waste Treatment – Organic Fertiliser Production

Gasification Demonstration Plant fuelled with Agricultural Residues

Within the framework of the International Conference on Bioenergy Utilization and Environment Protection - 6th LAMNET Workshop - in Dalian, a technical tour was organised by the China Association of Rural Energy Industry (CAREI) in co-operation with the Dalian Academy of Environment Sciences and the LAMNET project.

About 40 conference participants took part in the trip which included guided tours visiting an organic municipal waste treatment facility for the production of organic fertiliser and a gasification demonstration plant, both located in the vicinity of the coastal city Lü Shun, approximately 25 km west from Dalian.

Fig. 1: Participants of the Technical Tour visiting biomass technology applications in the city of Lü Shun

The organic fertiliser production plant (Fig. 2) is a demonstration installation operated by the Dalian Environment Protection Agency with a daily throughput of 5 tons during 8 hours of operation. The plant uses chicken manure as feed material, and in general the technology is well suited for all sorts of animal manure, such as chicken, sheep, pig and cattle manure. The benefits of this kind of waste treatment plants is two-fold, namely the avoidance of environmental impact such as bad odour and the production of a useful and valuable commodity.

The moisture content of the input manure is 70-80% whereas the output material has a moisture content of 50%. No specific drying process is required, but the moisture content of the output fertiliser is further reduced by mixing it with about 30% of straw or wood chips. This output material is stored in a large hall for about 10 days (Fig. 3), whereby it is rotated several times to ensure complete oxygenation. After this storage time the fertiliser has a nutrient content of about 7% and it can be sold on the local market. Thereby, this biomass application combines the benefit of sensible municipal waste treatment for environment protection with the benefit of the production of an income generating commodity offering a new market opportunity in China.

Fig. 2: Organic fertiliser production equipment

Fig. 3: Storage of organic fertiliser

The second biomass installation visited during the technical tour was a gasification demonstration plant located in the Sanjianbu township of the city of Lü Shun (Fig. 4). Information on the technical details and the operation performance of this pilot plant were presented by Prof. Nan Fang from the Dalian Environmental Science Design & Research Institute of the Dalian Academy of Environment Sciences.

Fig. 4: Pilot gasification plant fuelled with agricultural residues

This demonstration plant, which was put in operation 4 years ago, has been developed for the thermal conversion of a variety of biomass residues into bio-gas through incomplete combustion due to insufficient supply of oxygen during the combustion process. The capacity of the installation under full-load operation is sufficient to supply 5000 households in the vicinity of the plant with bio-gas for cooking and heating. Currently, the produced bio-gas is limited to the supply of 430 households due to low availability of straw feedstock in the region. Therefore, today raw material for the operation of this pilot gasification equipment has to be transported over a long distance from the north-eastern part of China.

For the gasification process biomass feedstock is used in form of straw briquettes (Fig. 5). Per day 15 tons of straw are processed producing 4.500 cubic metres of bio-gas with a heating value of 4000 kJ/m^3. The bio-gas is then cleaned using a multi-step cleaning process (Fig. 6). The filtered bio-gas impurities amount to about 24 kg of tar for 1 ton of processed straw. Additionally, 330 kg of charcoal (see Fig. 5) are produced in the gasification process of 1 ton of straw briquettes. This charcoal can be directly used for heating or alternatively for water purification after a further refinement process. The cleaned bio-gas with a composition of 20-28% CH_4, 10% CO, 10-18% H_2, 3% C_2H_2 and about 40% CO_2 is supplied via a pipeline system to households and restaurants in the neighbourhood of the demonstration plant.

Fig. 5: Straw briquette feedstock

Fig. 6: Multi-step gas cleaning system

After the visit to the gasification plant the group was welcomed by inhabitants of the neighbourhood who demonstrated the bio-gas burning cooking stoves in their kitchens (Fig. 7). The participants of the technical tour were deeply impressed by this successful bioenergy application with the potential to contribute to the sustainable future energy supply for rural regions in China.

Fig. 7: Bio-gas burning cooking stove in operation

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