Research on the Strategy of Technological Innovation and Development of Biomass Energy Industry in China

Professor. Tao Zheng
Guangzhou Institute of Energy Conversion
Chinese Academy of Science
Content

I. Background

II. Current Status

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IV. Policy Suggestions
In view of the urgent needs of the development of China's renewable energy industry, the national and international policy environment, the economic and the social environment are discussed, and the position and orientation of the technological development are clarified.
1.1 Strategic significance of developing biomass energy industry

The demand of renewable energy is increasing with the gradual depletion of fossil fuels and the serious environmental pollution.

Biomass, as the only renewable carbon source on earth, is the only renewable resource that can be directly converted into gas, liquid, solid and other forms of energy.

At present, the world is investing heavily on technologies utilizing biomass energy, to solve the resource, environmental and economic issues faced by mankind.

China is rich in biomass resources. The importance in developing biomass energy industry lies in promoting the sustainable development of rural society and economy, improving the ecological environment and alleviating the energy shortage.
(1) Developing biomass energy industry is an important measure for the rural development and ‘new countryside construction’ in China

- Increase farmers' income
- Improve rural environment
- Promote agricultural production
- Promote urbanization
(2) Developing biomass energy industry is an important measure to speed up China's ecological environment protection and cope with climate change.

- Reduce the use of fossil fuels;
- Reduce the pollution by agricultural wastes (soil, water and air);
- Reduce greenhouse gas emissions
- Improve air quality
- Improve the ecological environment (planting energy plants)
Fossil fuels are still the main source of energy consumption in China.

In 2017, China's total energy consumption was about 4.5 billion tons of standard coal, net oil imports amounted to 420 million tons, and oil imports dependence rose to 69% while natural gas imports dependence is 39%.

Partial replacement of fossil fuel consumption;
Optimize the structure of energy consumption;

(3) Developing biomass energy industry is an important measure to improve the energy structure and safeguard national energy security.
The development of biomass energy technology and industry are closely related to the status of global economic development, science and technology development, policy and social environment.
The main factor for the rapid development of biomass energy industry in recent years lies in the existing policies that promotes biomass energy utilization.

Judging from the history of its development, the pertinent policies, regulations and provisions of the biomass energy industry have strengthened and promoted the rapid development of the biomass energy industry.
## The policy environment for biomass energy industry development

<table>
<thead>
<tr>
<th>Country</th>
<th>Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>US</strong></td>
<td>2020 : biofuel 136 billion liter</td>
</tr>
<tr>
<td><strong>EU</strong></td>
<td>2020 : 20% renewable energy, 10% renewable for transportation</td>
</tr>
</tbody>
</table>
| **Germany** | 2020 : renewable energy usage 18%; renewable energy power generation 35%; heat from renewable energy 14%; biofuel 12%  
2030 : renewable energy usage 30%; renewable energy power generation 50%; |
| **England** | 2020 : renewable energy usage 15%; renewable energy power generation 15%; |
| **Sweden** | 2020 : renewable energy usage 50% |
| **Japan**  | 2020 : renewable energy usage 6%; biofuel replacing gasoline 3% |
| **Brazil** | 2020 : renewable energy power generation 16% |
## The policy environment for biomass energy industry development

<table>
<thead>
<tr>
<th>Country</th>
<th>Relevant policy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>US</strong></td>
<td>Bio jet fuel for all air force in 2011; the navy use 50% biofuel; renewable portfolio standard; Financial support for large biofuel manufacturing facilities</td>
</tr>
<tr>
<td><strong>EU</strong></td>
<td>Renewable Energy Certificate (REC); European Union Emissions Trading Scheme (EU-ETS)</td>
</tr>
<tr>
<td><strong>Germany</strong></td>
<td>Renewable energy fixed electricity generation tariff policy (EEG-2017); renewable energy regulations</td>
</tr>
<tr>
<td><strong>England</strong></td>
<td>Renewable energy fixed electricity generation tariff policy since 2013</td>
</tr>
<tr>
<td><strong>Sweden</strong></td>
<td>RPS; REC</td>
</tr>
<tr>
<td><strong>Japan</strong></td>
<td>Renewable energy fixed electricity generation tariff policy; green power certificate</td>
</tr>
<tr>
<td><strong>Brazil</strong></td>
<td>PROINFA, 2002</td>
</tr>
</tbody>
</table>
The policy environment for biomass energy industry development

2013
“20 in 10”: Gasoline consumption in the next 10 years will be reduced by 20%, about 35 billion gallons / year.
- 15% vehicles use alternative fuels (AFS)
- 5% use higher standard fuel (CAF)

2017
The Energy independence and Security Act
- Biofuels for transportation reach 36 billion gallons/year

2022
- Annual production of 21 billion gallons of high quality biofuels (cellulose derived ethanol reaches more than 16 billion gallons)

2030
“30 in 30”
- Replacing fossil fuel consumption by 30%
- The annual output of biomass fuel is 60 billion gallons.

Example 1: Bio-fuel Plan in the US
The policy environment for biomass energy industry development

Example 2 - EU biofuel program (2030)

Mass production of second generation biofuels

2050

Deploy the second generation biofuels to demonstrate the concept of bio refining. Continuous development and improvement of lignocellulosic fuels and integrated bio-refinery processes for energy crops and sustainable agricultural development

2020

Upgrade existing technologies to develop second generation biofuels (lignocellulosic materials) and bio-refinery. Establishment of the second generation fuel demonstration plant

2010
The policy environment for biomass energy industry development

The biofuel supply is projected to increase 13 times from 2010 to 2050.
The policy environment for biomass energy industry development

Technology roadmap of biomass liquid fuels in China

<table>
<thead>
<tr>
<th>2008</th>
<th>2020</th>
<th>2035</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio-liquid fuel technology</td>
<td>Gasification, cracking, catalysis, hydrolysis, synthesis and enzyme technology</td>
<td>Bio gasoline, biodiesel</td>
<td>Large scale commercial application of bio-liquid fuel technology</td>
</tr>
<tr>
<td>Biomass breeding &amp; cultivation technology</td>
<td>Selection, genetic modification, breeding of energy crops;</td>
<td>Trial cultivation of energy crops, aquatic biomass and microalgae</td>
<td>Scaled production of energy crops, aquatic biomass and microalgae</td>
</tr>
<tr>
<td>Advanced biomass industry technology</td>
<td>Environmental impact of energy crops</td>
<td>Liquid fuel &amp; chemical production from cellulose</td>
<td>Demons tration plant</td>
</tr>
<tr>
<td></td>
<td>Aquatic biomass genetic engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Oil-rich microalgae genetic engineering</td>
<td></td>
<td>Scaled commercialization</td>
</tr>
<tr>
<td></td>
<td>Study on the biochemical &amp; thermo chemical reactions of cellulose</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biochemical &amp; thermo chemical reactions of microalgae, aquatic &amp; industrial crops; biomass based materials; bio-bionics</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Biomass based materials, liquid fuel &amp; chemical production technology; Biomimetic energy conversion technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Raw materials for industrial applications</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Industrial demonstration</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Commercialization to replace fossil fuels</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fundamental study</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Technology breakthrough</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>Matured technology</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Commercialization</td>
<td></td>
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</tr>
</tbody>
</table>
At present, the world is in a critical stage of social and economic development and reform. Under the pressure of economic development, energy shortage and environmental pollution, all countries are seeking social and economic transformation, promoting the development of strategic industries, and integrating biomass energy industry with other industries has become the new focal point.
The unbalanced development of biomass energy industry in the world is mainly restricted by the economic development level of each country.

Through subsidies and tax reduction to promote the biomass energy industry, one can promote development of new energy industry in the future.
In the critical moment of the 21st century, biotechnology and information technology have become the core competitiveness to promote the development of the world economy.

The function of various technology to biomass energy industry:

Modern agricultural technology: a strong resource guarantee;

Biotechnology: the key link in the preparation of biomass energy and biomass-based materials.

Modern industrial equipment manufacturing technology: a strong equipment guarantee

Information technology: a catalyst for rapid development
1.3 Meaning and orientation of technological innovation in biomass energy industry

1. Meaning:

Biomass energy industry is a complex system engineering. The science and technology innovation cover the whole industrial chain, includes raw materials, conversion technology and products.

Biomass raw materials: organic wastes & new energy biomass raw materials;

Technology: physical, thermochemical and biochemical conversion;

Energy products: liquid fuels (fuel ethanol, biobutanol, biodiesel, etc.), gas fuels, solid fuels and biomass power generation.
Biomass energy utilization technology
— complex, interdisciplinary

**Raw material**
- Oil
- Starch/sugar
- Waste/poultry/manure
- Cellulose

**Pre-treatment**
- Separation/extraction
- Collection/separation
- Purification/refinement
- Pre-treatment

**Conversion**
- Esterification
- Fermentation
- Anaerobic Digestion
- Compression
- Fermentation
- Catalytic reform
- Gasification/pyrolysis
- Combustion

**Purification**
- Separation/purification
- Distillation/purification
- Purification
- Refinement
- Syntesis
- Purification

**Product**
- Liquid fuel
- Gas fuel
- Solid fuel
- Chemicals
- Heat/electricity

**Resource**
- Germplasm integration innovation
- Energy enrichment/storage
- Scale cultivation
- Biomass resource
### 2. Orientation:

**Biomass industry** = energy industry + rural economy

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Serving goals</th>
<th>Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dispersed raw materials</td>
<td>Rural and urbanization construction</td>
<td>Adjust measures to local conditions; moderate scale</td>
</tr>
<tr>
<td>Renewable</td>
<td>Ecological environment, energy conservation, emission reduction</td>
<td>Low consumption conversion technology, green application</td>
</tr>
<tr>
<td>Energy</td>
<td>Optimize energy structure</td>
<td>Supplement conventional energy</td>
</tr>
</tbody>
</table>

Biomass industry = energy industry + rural economy
**Zone I:** R&D urgently needed

**Zone II:** high subsidies required

**Zone III:** less subsidies for industry

**Zone IV:** New modes of utilization to be explored

- Bio-hydrogen
- Energy algae utilization
- Gasification/synthesis
- Cellulose-ethanol
- Phyto-diesel
- Starch derived ethanol
- Waste oil diesel
- Combustion power generation
- Power generation
- Pyrolysis liquefaction
- Biogas utilization
- Densification
- Industrial demonstration
- Break even point
- Energy plants selection;
- Energy algae R&D;
- Lipid microbes;
- Biomass Briquette Fuel Utilization;
- Cellulose butanol ethanol;
- Microbial fuel cell;
- Microbial synthesis;
- Biogas utilization;
- Catalytic alkane production;
- Synthesis of alcohol ether;
- Heavy oil production via pyrolysis;
- Hydrogen production via gasification;
- Biodiesel;
- Oil replacement by gas;
- Power generation via gasification & combustion;
- Land resource Cultivation;
- Seed resource;
- Bio-conversion;
- Gasification synthesis;
- Direct pyrolysis;
- Catalytic liquefaction;
- Direct combustion;
- Municipal waste.
II. Current Status

This chapter presents the status quo at home and abroad, development trends, opportunities, challenges, innovation needs and policy of the biomass energy technology.
2.1. Current situation and trend of technology development in biomass energy industry

After decades of R & D, considerable progress has been made in the collection technology of biomass raw materials, various energy conversion technologies and the application of biomass products.

Liquid fuel technology is still at the stage of technological research.

Biogas, Biomass Briquette Fuel, and biomass power generation have entered the stage of industrialization and application.
‘The national medium to long term development plan for science & technology’ and ‘medium to long term development plan for renewable energy’ - China
The gap between the current status & goals

<table>
<thead>
<tr>
<th>Types</th>
<th>Capacity</th>
<th>Production</th>
<th>Coal equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas</td>
<td></td>
<td>21.3 B m³</td>
<td>15.19 Mt</td>
</tr>
<tr>
<td>Bioethanol</td>
<td>3.2 Mt</td>
<td>2.54 Mt</td>
<td>2.54 Mt</td>
</tr>
<tr>
<td>Biodiesel</td>
<td>3.5 Mt</td>
<td>0.8 Mt</td>
<td>1.14 Mt</td>
</tr>
<tr>
<td>Biomass Briquette</td>
<td>15 Mt</td>
<td>10 Mt</td>
<td>5 Mt</td>
</tr>
</tbody>
</table>

Challenge: technology breakthrough & industry development!
Current status

Biogas — household

- **Raw material**: livestock manure, crop straws
- **Technology**: AD, biogas plant
- **Application**: 52 million households 21.3 billion m$^3$ biogas, saving 28 billion RMB/yr till 2016.
Current status

**Biogas — centralized plant, power generation**

- **Raw materials:** livestock manure, waste water, municipal waste, straws, etc.
- **Technology:** AD with mixed feed, high concentration AD, two phase AD, heat and power cogeneration
- **Application:** 4700+ large and medium-sized biogas plants utilizing livestock manure and poultry breeding wastes; 1600+ biogas plants utilizing industrial organic wastes; annual output of 4 billion m$^3$ of biogas.

The largest livestock and poultry waste biogas project produces 20,000 cubic meters of gas per day (installed capacity of 3 MW), the largest industrial organic waste (brewery's grains) biogas project produces 500,000 cubic meters per day.
Current status

Biogas — vehicle & canning

- Raw materials: industrial organic waste, urban living organic waste, food waste, sewage sludge, and mixed raw materials.
- Technology: AD with mixed feed, high concentration AD, biogas purification.
- Application: Wuming Anning Starch Co., Ltd., Zhenyuan Group and PetroChina Group have constructed automotive biogas projects in Wuming, Anyang and Haikou with capacities of 40,000, 10,000, 10,000 cubic meters per day respectively.
## Current status

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Raw material</th>
<th>Power (MW)or automotive gas (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shandong Minhe husbandry</td>
<td>Penglai, Shandong</td>
<td>Chicken manure</td>
<td>3</td>
</tr>
<tr>
<td>Deqingyuan Peking</td>
<td>Yanqing, Beijing</td>
<td>Chicken manure</td>
<td>2</td>
</tr>
<tr>
<td>COFCO Dongtai farm</td>
<td>Dongtai, Jiangsu</td>
<td>Pig manure</td>
<td>1.8</td>
</tr>
<tr>
<td>Haifeng Farm Jiangsu</td>
<td>Dafeng, Jiangsu</td>
<td>Cow manure</td>
<td>1</td>
</tr>
<tr>
<td>Mengniu Group of Inner Mongolia</td>
<td>Helin, Inner Mongolia</td>
<td>Cow manure</td>
<td>1.26</td>
</tr>
<tr>
<td>Guangxi Anning starch factory (Phase I)</td>
<td>Wuming, Guangxi</td>
<td>Cassava alcohol and starch waste liquid</td>
<td>15000</td>
</tr>
<tr>
<td>Guangxi Anning starch factory (Phase II)</td>
<td>Wuming, Guangxi</td>
<td>Cassava residue</td>
<td>60000</td>
</tr>
<tr>
<td>Shandong Minhe Husbandry (Phase II)</td>
<td>Penglai, Shandong</td>
<td>Chicken manure etc.</td>
<td>60000</td>
</tr>
</tbody>
</table>
Current status

Ethanol/butanol fuel — process

Sugar → Pre-treatment → Yeast Fermentation → Purification

Starch → Saccharification → Yeast Fermentation

Cellulose → Pre-treatment → Thermochemical conversion

Ethanol production from biomass

Power

Biofuel

Syngas
Current status

Bioethanol / biobutanol - non-grain biofuel

- **Raw materials:** cassava, sweet potato, sweet sorghum, Jerusalem artichoke, duckweed, etc.
- **Technology:** high concentration mash fermentation technology, viscosity reduction technology, etc.
- **Application:** the capacity reached 3.2 Mt in 2016.

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Raw material</th>
<th>Capacity kt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tianguan fuel ethanol Co., Ltd.</td>
<td>Nanyang, Henan</td>
<td>Tubers</td>
<td>100</td>
</tr>
<tr>
<td>COFCO</td>
<td>Beihai, Guangxi</td>
<td>Cassava</td>
<td>200</td>
</tr>
<tr>
<td>Sichuan Yinshan Hongzhan Industry Co., Ltd.</td>
<td>Zizhong, Sichuan</td>
<td>Sweet potato</td>
<td>10</td>
</tr>
<tr>
<td>Hubei jinlongquan Beer Group Co., Ltd.</td>
<td>Jinmen, Hubei</td>
<td>Sweet potato</td>
<td>100</td>
</tr>
<tr>
<td>Sinopec Jiangxi Yu Fan alcohol Co., Ltd.</td>
<td>Dongxiang, Jiangxi</td>
<td>Cassava</td>
<td>100</td>
</tr>
<tr>
<td>Jilin Sanhua Group</td>
<td>Songyuan, Jilin</td>
<td>Sweet potato</td>
<td>300</td>
</tr>
</tbody>
</table>
**Current status**

**Bioethanol / biobutanol - cellulose**

- **Raw material**: crop straws, forestry waste, etc.
- **Technology**: pre-treatment, cellulase selection & breeding, CBP, co-fermentation of pentose and hexose;
- **Application**: cellulose derived ethanol production reach 3.5 Mt in 2016.

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Raw material</th>
<th>Capacity kt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Songyuan Lai Wo Chemical Co., Ltd.</td>
<td>Jilin</td>
<td>Straw</td>
<td>50</td>
</tr>
<tr>
<td>Shandong Longli Biotechnology Co., Ltd.</td>
<td>Yucheng, Shandong</td>
<td>Corn</td>
<td>100</td>
</tr>
<tr>
<td>Tianguan fuel ethanol Co., Ltd.</td>
<td>Nanyang, Shandong</td>
<td>Straw</td>
<td>50</td>
</tr>
<tr>
<td>Shandong ZS Biotechnology Co., Ltd.</td>
<td>Dongping, Shandong</td>
<td>Straw</td>
<td>30</td>
</tr>
<tr>
<td>Anhui Fengyaun Group</td>
<td>Benbu, Anhui</td>
<td>Corn</td>
<td>30</td>
</tr>
<tr>
<td>Shanghai Tian Zhi Guan renewable energy Co., Ltd.</td>
<td>Shanghai</td>
<td>Rice husk</td>
<td>6</td>
</tr>
<tr>
<td>COFCO biochemical energy (Zhaodong) Co., Ltd.</td>
<td>Heilongjiang</td>
<td>Straw</td>
<td>5</td>
</tr>
</tbody>
</table>
Current status

Biodiesel — process

Microalgae
Oil-producing Yeast
Oil-producing Plant
Waste oil/lipid

Solid catalyst
Lipase gene engineering bacteria

Biodiesel pour point depressant
Hydrodeoxygenation and hydroisomerization
Aviation fuel

Raw material → Technology → Product → Refinement

Biodiesel industry chain
Biodiesel

Raw materials - crop species:
- Soybean oil and rapeseed oil. (raw materials used abroad)
- Waste oil. Gutter oil, hogwash oil, acidified oil, frying oil (raw material at this stage)
- Plant species. Jatropha curcas, Pistacia chinensis Bunge, Xanthoceras sorbifolia Bunge.
- Oil producing microalgae. (future raw materials)

Technology
- Chemical method. Liquid acid and alkali, few cases using solid acid. The mainstream technology of industrial production.
- Biological enzymatic method and supercritical fluid method. No commercial application yet.

Application
- By the end of 2010, the production capacity was about 1 million tons and the output was about 300-500 kt.
Current status

50kt/yr biodiesel project in Xiamen

10kt/yr biodiesel plant model
Biodiesel — market not fully developed yet

- 129 companies in 22 provinces (Fujian, Jiangsu, Shandong)
- 2 foreign companies, the rest are medium to small sized companies
- Actual production is 370 kt/yr, the majority of which are exported

The Diesel Engine Blending Biodiesel (BD100) Standard came into effect on May 1, 2007, and revised in 2015.
Current status

Biomass power generation
– direct combustion (mainstream technology)

- Raw materials: straw, wood, etc.
- Technology: biomass is directly burned in vibrating furnace or fluidized bed boiler, steam turbine power generation.
- Application: by 2010, China has built a capacity of about 2000MW.

The 1st domestic demonstration plant for straw burning power generation - Hebei Jinzhou straw thermal power plant
Current status

Biomass power generation

- Raw materials: straw, wood, etc.
- Technology: biomass & coal co-combustion, steam turbines power generation.
- Few Application: Shandong Shiliquan Power Plant, (capacity: 140 MW); Jiangsu Xiexin Company, 2 x15MW generator.
Current status

Biomass power generation

- Gasification power generation (distributed generation technology in the future)

➢ Raw materials: straw, wood, rice husk, bagasse, etc.
➢ Technology: biomass pyrolysis gasification, gas internal combustion engine or gas turbine power generation.
➢ Application: by 2010, China has built a capacity of about 40MW.
## Current status

### Biomass power generation

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Raw material</th>
<th>Capacity (MW)</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hebei Jian Dao biological Power Generation Co., Ltd.</td>
<td>Jinzhou, Hebei</td>
<td>Cornstalk, straw and fruit tree branches</td>
<td>25</td>
<td>Direct combustion</td>
</tr>
<tr>
<td>National energy bioelectricity Co., Ltd.</td>
<td>Shanxian, Shandong</td>
<td>Cotton stalks, branches, etc.</td>
<td>25</td>
<td>Direct combustion</td>
</tr>
<tr>
<td>National energy bioelectricity Co., Ltd.</td>
<td>Sheyang, Jiangsu</td>
<td>Cotton stalks</td>
<td>50</td>
<td>Direct combustion</td>
</tr>
<tr>
<td>Guoxin Huaian Biomass Power Generation Co., Ltd.</td>
<td>Huaian, Jiangsu</td>
<td>Rice straw and wheat straw</td>
<td>30</td>
<td>Direct combustion</td>
</tr>
<tr>
<td>Wuhan Katie electric Ltd</td>
<td>Nanping, Fujian</td>
<td>Chicken manure and chaff</td>
<td>45</td>
<td>Direct combustion</td>
</tr>
<tr>
<td>National Electric Technology and environmental protection group</td>
<td>Dezhou, Shandong</td>
<td>Corn stalks, cotton stalks, branches, etc.</td>
<td>25</td>
<td>Direct combustion</td>
</tr>
<tr>
<td>Company</td>
<td>Location</td>
<td>Raw material</td>
<td>Capacity (MW)</td>
<td>Remark</td>
</tr>
<tr>
<td>-------------------------------------------------------</td>
<td>------------------------</td>
<td>------------------------</td>
<td>---------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Huadian Power International Corp</td>
<td>Zaozhuang, Shandong</td>
<td>Coal + rice straw</td>
<td>140</td>
<td>Mixed combustion</td>
</tr>
<tr>
<td>Wuxi special energy technology Co., Ltd</td>
<td>Wuxi, Jiangsu</td>
<td>Rice husk</td>
<td>0.4</td>
<td>Gasification</td>
</tr>
<tr>
<td>Lin Yuan Technology Development Co., Ltd.</td>
<td>Gaoyou, Jiangsu</td>
<td>RDF from rice straw</td>
<td>4</td>
<td>Gasification</td>
</tr>
<tr>
<td>Hefei Tian Yan Green Energy Development Co., Ltd.</td>
<td>Wangjiang, Anhui</td>
<td>Rice husk</td>
<td>0.4</td>
<td>Gasification</td>
</tr>
<tr>
<td>GIEC, CAS</td>
<td>Xinghua, Jiangsu</td>
<td>Rice husk, wood</td>
<td>5.5</td>
<td>Gasification</td>
</tr>
<tr>
<td>Wo Jia Energy Development Co., Ltd.</td>
<td>Tongyu, Jilin</td>
<td>Rice husk</td>
<td>2</td>
<td>Gasification</td>
</tr>
<tr>
<td>Mengniu biomass energy Co., Ltd</td>
<td>Hehuhaote, Inner Mongolia</td>
<td>Biogas from cow manure</td>
<td>1.36</td>
<td>Biogas</td>
</tr>
<tr>
<td>Veolia environment Limited</td>
<td>Changping, Beijing</td>
<td>Landfill gas</td>
<td>2.7</td>
<td>Biogas</td>
</tr>
<tr>
<td>Fuzhou Hong Miao Ling Waste Incineration Power Generation Co., Ltd</td>
<td>Fuzhou, Fujian</td>
<td>Municipal waste</td>
<td>24</td>
<td>Waste</td>
</tr>
<tr>
<td>Chengdu West renewable energy Co., Ltd</td>
<td>Luodai, Sichuan</td>
<td>Municipal waste</td>
<td>24</td>
<td>Waste</td>
</tr>
</tbody>
</table>
Biomass briquette fuel

Granular
- **Raw material**: forestry waste
- **Technology**: ring die extrusion technology
- **Application**: the annual capacity reaches 900kt

Block
- **Raw materials**: crop stalks, etc.
- **Technology**: piston hydraulic forming, flat die extrusion molding.
- **Application**: annual capacity of 700 kt.

Rod like
- **Raw materials**: forestry processing residues, etc.
- **Technology**: spiral extrusion molding
- **Application**: annual capacity of 200 kt
Service life of vulnerable parts: > 500h
Energy consumption: < 70kwh
Good product rate: > 95%
Production cost: < 270 RMB/t.
Molding fuel density: > 1.0t/m3
Production scale: >10000 tons
# Biomass briquette fuel

- **Raw materials:** straw, forestry waste, etc.
- **Technology:** ring molding technology, flat die pressing block molding technology;
- **Application:** biomass solid briquette production capacity was 15 Mt in 2016.

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Raw material</th>
<th>Capacity (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guangzhou Disen Thermal Energy Technology Co., Ltd</td>
<td>Guangdong</td>
<td>Sawdust, straw</td>
<td>130</td>
</tr>
<tr>
<td>Beijing Olympic New Energy Co., Ltd.</td>
<td>Henan; Beijing</td>
<td>Straw</td>
<td>90</td>
</tr>
<tr>
<td>Heilongjiang Sheng Yan new energy Co., Ltd.</td>
<td>Heilongjiang</td>
<td>Straw</td>
<td>80</td>
</tr>
<tr>
<td>Henan Sanli new energy Co., Ltd.</td>
<td>Henan</td>
<td>Straw</td>
<td>50</td>
</tr>
<tr>
<td>Beijing Sheng Chang green energy Co., Ltd.</td>
<td>Beijing</td>
<td>Sawdust, straw</td>
<td>50</td>
</tr>
<tr>
<td>Liaoning Sen Neng renewable energy company</td>
<td>Liaoning</td>
<td>Sawdust, straw</td>
<td>40</td>
</tr>
<tr>
<td>Dongguan Baifa New Energy Company</td>
<td>Guangdong</td>
<td>Sawdust</td>
<td>40</td>
</tr>
</tbody>
</table>
Bio-oil

- **Raw materials:** agricultural and forestry waste, etc.
- **Technology:** vacuum cracking, rapid pyrolysis, flash pyrolysis and microwave pyrolysis.
- **Product upgrading technology:** hydrodeoxygenation, steam catalytic cracking, emulsification, steam reforming.
Current status

Bio – oil — application & demonstration

3 million ton/year – scale demonstration plant

USTC 500kg/h bio oil production plant

Fluidized bed reactor for fast biomass pyrolysis in Shanghai Jiao Tong University

Demonstration of biomass pyrolysis and liquefaction at Shandong University of Technology
Current status

Alcohol ether fuel via gasification synthesis

- Raw materials: straw and other agricultural and forestry wastes
- Technology: oxygen enriched steam gasification, tar catalytic reforming and purification, one-step synthesis.
- Application: the demonstration of 1000 ton alcohol ether fuel production was completed in 2010.
Current status

Catalytic process for the synthesis of alkane fuel in aqueous phase

- **Cellulose**
  - Pre-hydrolysis with dilute acid
  - Subcritical hydrolysis pretreatment with CO₂

- **Pentose**

- **Cellulose + lignin**

- **Bio-gasoline/biodiesel**

- **Bio-alkane**

- **Residue**

- **Sugar**

- **Diacid/enzyme**

- **Bio gasoline**
  - Phase separation
  - Water-soluble intermediate

- **Aviation fuel**

- **Waste**

- **H₂**

- **Deoxygenating**

- **Catalytic hydrogenation**

- **Dehydration, hydrogenation, isomerization**

- **Tail gas reforming**

- **Aldol condensation**

- **Chain growth**

- **HMF, furfural**

- **Catalytic dehydration**

Current status
Catalytic process for the synthesis of alkane fuel in aqueous phase

Bio-gasoline

- **Raw materials:** lignocellulosic biomass
- **Technology:** catalytic hydrogenation and isomerization in aqueous phase
- **Application:** the pilot scale of 100t bio gasoline was completed in 2010.

Aviation fuel

- **Raw materials:** lignocellulosic biomass
- **Technology:** catalytic condensation, hydrogenation and isomerization in aqueous phase
- **Application:** an 1000 ton scale pilot plant was built in 2014.
Microalgae

- Microalgae bioenergy: autotrophic, heterotrophic and concurrent culture

- Other oil-producing microorganisms—yeast: oil-producing yeast can transform glucose, xylose and arabinose into oil simultaneously. The oil content of the yeast exceeds 55% of its dry weight.
# Current status

## Microalgae

<table>
<thead>
<tr>
<th>Key technology</th>
<th>Objectives</th>
<th>State of the art</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screening and cultivation</td>
<td>High oil content, fast growth, high CO2 and high temperature resistance, and easy to be genetically engineered.</td>
<td>Chlorella, Pseudochlorophyll, Diatom, Dunaliella salina, the highest oil content of Chlorella can reach more than 50%, genetic engineering research is in the initial stage.</td>
</tr>
<tr>
<td>Photo bioreactor</td>
<td>Light transmission, mass, momentum and heat transfer, clean, low cost</td>
<td>Track tank, vertical column, flat plate, closed tube photo bioreactor</td>
</tr>
<tr>
<td>Biomass harvesting &amp; extraction</td>
<td>Low cost</td>
<td>Centrifugation, filtration, flocculation, ultrasound</td>
</tr>
<tr>
<td>Biomass processing and conversion</td>
<td>Highly efficient conversion energy and value added products</td>
<td>one-step method, enzymatic conversion process, extraction of pigment and auxin</td>
</tr>
</tbody>
</table>
Current status

Microalgae

Plate reactor @ Qingdao Energy Research Institute

Track tank reactor @ New daze

Column reactor @ GIEC

No commercialization of microalgae biodiesel yet, companies focusing on R&D

Shenzhen Zhaokai bioengineering research and Development Center Co., Ltd.
Current status

In comparison with developed countries in Europe:

- **In terms of technology**, low bio-gas production efficiency, lag in bio-gas purification and distribution technology, and bio-gas utilization mode is simple.
- **In terms of engineering equipment**, there are some problems, such as low overall efficiency, poor matching, long-term stability, lack of complete engineering equipment design and manufacturing standards.
- **In terms of commercialization**, biogas engineering demonstration projects have not played the leading role, and are lack of a distinctive, well arranged and coherent system and industry chains.
2.2. Opportunity and challenge of biomass energy industry

1. Opportunity

➢ The energy demand is growing rapidly due to the economic growth, industrialization and urbanization in China.
➢ As the most serious air pollution in the world is caused by the burning of fossil energy, replacing fossil energy with biomass energy is much more environmental friendly.
➢ Countries all over the world, especially developed countries, are investing heavily on the promotion of scientific and technological progress and innovation, making it their national strategies;
➢ The objectives of biomass energy industry have been clearly stated in several national strategic plans issued by the state council: the Outline of the National Medium and Long-term Science and Technology Development Plan (2006-2020), the National Science and Technology Development Plan during the 13th Five-Year Plan, the National Energy Science and Technology 13th Five-Year Plan (2016-2020) and the Renewable Energy 13th Five-Year Plan.
2.2. Opportunity and challenge of biomass energy industry

2. Challenges

(1) Raw material bottlenecks.
(2) Key technologies need breakthroughs.
(3) The user market needs to be trained.
(4) Financing channels are not smooth.
(5) Lack of funds in R&D
(6) Immature market environment and lack of policy support.
(7) Standard specifications are to be improved.
2.3. Demand for scientific and technological innovation in biomass energy industry

1. diversified supply of raw materials
2. modern biotechnology
3. highly efficient pretreatment technology with low energy consumption
4. clean, efficient, low-cost and stable conversion technology.
5. system integration and eco-industrial chain construction technology
2.4. Policy demand of biomass energy industry

1. Improve the policy system and the operability of the policy.
2. Introduce subsidy rules to stimulate the development of biomass energy industry.
3. Tax reduction, encourage enterprises to actively join the biomass energy business.
4. Increase investment in R&D to tackle key technological problems.
5. Improve on the talent security policy, attract and cultivate talents.
III. Main tasks

The chapter points out the direction of biomass energy technology innovation, the future plan of the biomass energy industry, clarifies the main tasks and development priorities of scientific and technological innovation, and recommends a business model suitable for local biomass industry.
In view of the development status of biomass energy technology at home and abroad, one should consider comprehensively the industry chain of biomass energy, design systematically the development route of biomass energy technology and industry, and deploy the integrated projects.

### Approaches:

- Diversification of resources
- Highly efficient conversion technology
- Integrated equipment system
- Highly value added end products
- Coproduction of diverse products
- Regionalized industrial plan & layout
3.2. Goals

Objectives during the 13th Five-Year Plan period,

- Fundamental & systematic theories for the catalytic preparation of high-quality liquid fuels from biomass-based;
- Improvement on the energy content & quality of raw materials through genetic modification;
- Breakthroughs in new biomass resources, high-efficiency and low-cost conversion technologies, advanced equipment, and high-quality biofuel products;
- New biomass species;
- New microbials for biomass energy;
- A series of advanced technologies and core technologies for biomass raw material pretreatment and conversion, with corresponding equipment and integrated systems;
- Demonstration plants that shows unique technical, regional and product characteristics;
- Compilation of technical standards for different systems;
- A sound integrated technical system for biomass energy utilization;
- Innovation platforms including key laboratories, engineering centers, industrial technology alliances, etc.
- Effective research teams
3.3. Key R&D tasks
3.3. Key R&D tasks

1. Highly efficient production and utilization of biogas

- Fundamental research on hydrogen and methane production with anaerobic microorganism in AD
- Research on key pretreatment technology and equipment of biogas applications
- Innovative process and reactor design for high concentration and high efficiency AD
- Purification, transportation technology and vehicle gas application technology
- Research and development on biogas equipment manufacturing
2. Advanced technology for bio-liquid fuel production

- Fundamental research to fully utilize all composition from biomass
- Key core technologies of bio-liquid fuels (cellulosic ethanol, non-grain ethanol, biodiesel, bio-fuel, synthetic fuel)
- Key technologies for pretreatment of cellulose materials with high efficiency and low cost
- New microbials and technology, metabolic regulation for cellulosic ethanol and butanol production
- Key technologies for cogeneration of energy and chemicals from lignocellulosic resources
- Green technology for biodiesel production
- Whole set of integrated pyrolysis equipment for bio-oil production from biomass
3.3. Key R&D tasks

3. Breeding and utilization of energy microalgae
   - Energy microalgae breeding system, large-scale cultivation, bioreactor design, oil extraction and transesterification Technology
   - Breeding microalgae in wastewater, biodiesel production technology from microalgae.

4. Standardized equipment for briquette fuel production
   - New equipment with high efficiency and low cost for briquette fuel production
   - Production and demonstration suitable for various regions and climate
   - Anti-slagging equipment suitable for briquette fuel combustion
5. Cultivation and efficient conversion of cellulosic biomass

- Breeding and cultivation technology for new species of non grain energy plants;
- High efficiency and low cost pretreatment technology including enzymatic and radiative depolymerization.
- Microbials and conversion technology for simultaneous hydrolysis and ethanol production
- New technology of bio-liquid fuel (Gasoline, Diesel Oil and Fuel Oil) production by thermochemical conversion of catalysis
- New pretreatment and fermentation technology for biogas production
3.3. Key R&D tasks

6. Crops with high energy content, and high quality fuels

- Cultivate species with high content of cellulose, oil, sugar and starch, etc.
- Catalyst and process for aviation and vehicle fuel production, including benchtop and pilot test
- Characterization and application of the biomass based aviation fuel and vehicle fuels

7. Power generation technology

- Technology to inhibit metal corrosion due to the straw ash
- Power generation technology with mixed coal and biomass
- Equipment and system for heat and power cogeneration from biomass pyrolysis gasification
3.4. Key Scientific & Technological Projects

1. $10^{10}$ m$^3$ biogas projects

- Traditional raw materials and new biomass resources (high cellulose content, high oil content, high sugar content, high starch content and other biomass resources) for biogas production,
- Study the fundamental mechanism of hydrogen and methane production system by anaerobic microorganisms,
- Integrated technology: pretreatment of mixed multi-component raw materials, high concentration AD, pyrolysis and gasification, heat and power cogeneration, biogas purification for automotive and pipeline gas,
- The total capacity of 50 billion cubic meters per year,
- Showcase and promotion of new commercial mode via demonstration plant
2. $10^7$ tons bio-liquid fuel projects

✓ Study the fundamental mechanism of efficient conversion technology

✓ Highly efficient and low cost technology for compound enzyme production

✓ Technology for various product: cellulosic ethanol, non-grain fuel ethanol, biodiesel, biofuels, gasoline, aviation fuels, synthetic fuels

✓ New microbials for cellulosic ethanol/butanol

✓ Demonstration plant with capacity 10 Mt/yr

✓ Explore new commercial mode
3.4. Key Scientific & Technological Projects

3. $10^7$ kW power generation projects
✓ Theoretical study on clean, efficient biomass-based power generation technology
✓ Breakthroughs in core problems
✓ Appropriate, diversified, flexible and stable power generation technology and industry
✓ Demonstration plant with suitable sizes

Key projects:
(1) $10^5$ kW power generation projects with direct combustion
(2) $10^6$ kW power generation projects with mixed combustion
(3) Distributed $10^6$ kW power generation projects with gasification technology
3.4. Key Scientific & Technological Projects

4. 10^7 tons biomass derived chemicals and materials production projects

- Functionalization and microstructural interpretation of biomass based materials
- Key technologies of biological and chemical conversion
- Establish the theoretical system and process of starch-based materials
- Continuous polymerization process
- The theory and technological process of bio-based thermosetting resin synthesis, microporous structure control, surface modification and hybridization of complex elements
- Technology for wood-plastic composites
- The separation and purification technology of high-purity lignin and its oxidative degradation products
- The biosynthetic route of bio-based isoprene, and other important biomaterials
- The production scale reaches 60 million tons per year,
- Form and promote a new business model
IV. Policy Suggestions

By considering the raw materials of biomass energy industry, the frontier R&D and technological innovation, technology integration demonstration, enterprise innovation, commercial mode, national policies and scientific & technological programs, international collaboration, intellectual property protection, etc. a list of feasible strategic recommendations are put forward.
4.1. Policy suggestions

1. Science and technology support policy
   (1) Encourage fundamental research and discipline construction.
   (2) Focus on frontier technology development and technological innovation.
   (3) Nurturing the technological innovation capability of the biomass industry.

2. Finance and taxation policy
   (1) Improve and strengthen the implementation of existing policies.
   (2) Formulate new industrial policies in the right time.
   (3) Encourage capital investment from society.
4.2. Implementation plans

1. Administrative organization construction
2. Deploy research projects
   (1) fundamental research
   (2) innovative technology research
   (3) industrialization demonstration research
   (4) commercialization of technology
3. Research platform
   (1) Key Laboratory Construction
   (2) Engineering Research and Development Center
   (3) strategic alliance
4. Research team building
5. International cooperation
4.2. Implementation plans

- **Innovation and progress of technology:**
  Frontier technology, key technology, integrated system;
  Synergistic innovation among production, teaching and research;
  Construction of technology system

- **Exploration and practice of industry development**
  Division and cooperation of the whole industry chain,
  Effective integration of technology and finance.

- **Attention and support from society:**
  governments’ attention—project, grant, policy
  society’s support——industry, finance
4.3. Guarantee Measures

（1）Organizational guarantee.
The Ministry of Science and Technology shall direct and coordinate the scientific and technological work of biomass energy industry, organize and set up a leading group with other relevant departments to manage and promote the biomass energy industry.

（2）Technological guarantee.
Form an expert team including technical experts, entrepreneurs and policy planning experts, relying on scientific research institutes, universities and large enterprises, to lay a solid foundation for science and technology innovation and to enhance the vitality of industry.
4.3. Guarantee Measures

（3）Policy guarantee.

Improve relevant policies and regulations for the development of the biomass industry by referring to international policies, balance the subsidy standards for renewable energy and biomass energy, implement investment subsidies and tax deduction policies, and formulate action plans to promote the rapid development of biomass energy.

（4）Input guarantee.

Direct the funding from the relevant state science and technology plans (973, 863, support plans, etc.) more on biomass energy science and technology; guide the industrial sectors to invest in biomass industry; attract investment from non-governmental, social and foreign capital into the biomass energy industry in various ways, so as to promote the financing and industrialization of biomass energy projects.
Thank You!