Insight: state-of-the-art of biomass gasification in China

Li Chen

S3D – Waste & Sustainable Development Solutions, Nantes, France
www.sol3d.com
S3D

- Activities: Consulting, R&D, industrialisation

- Wastes:
  - Animal by-products (fat)
  - Biodegradable wastes
  - Lignocellulosic wastes

- Processes
  - Valorfat® CHP patented system (50KWe – 2 MWe)
  - Biomethanation
  - Gasification
  - Pressure swing adsorption for CO₂ separation and storage
State-of-the-art of biomass gasification in China

- Context
  - Energy structure in China
  - Biomass resources in China
  - Update of Chinese renewable policy
- Manufacturers and case studies
  - Fuel gas stations
  - Power plants
- Environmental impacts
- Prospects
Energy structure evolution

- Economic development
  1979: GDP = 400 billions of CNY
  2009: GDP = 34 000 billions of CNY (= 4 000 billions of EUR)

- Primary energy production and consumption

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total primary energy</td>
<td>457</td>
<td>436</td>
<td>1623</td>
<td>1720</td>
</tr>
<tr>
<td>Oil</td>
<td>113</td>
<td>94</td>
<td>202</td>
<td>357</td>
</tr>
<tr>
<td>Dry natural gas</td>
<td>15</td>
<td>15</td>
<td>46</td>
<td>44</td>
</tr>
<tr>
<td>Primary coal</td>
<td>312</td>
<td>310</td>
<td>1270</td>
<td>1218</td>
</tr>
</tbody>
</table>

In 2005, China imported 97 Million TOE of primary energy.
Energy mix

- 2006 Share of non-fossil energy = 7%

Total Energy consumption in China (by type)

Source: EIA international energy annual 2006
Biomass resources

- Main feedstocks for gasification:
  Agricultural residues, forestry residues

  - Agricultural residues:
    Rice + wheat + corn residues represent 80% of total available amount
    Energy potential = total amount - collection loss - paper making industry – forage
    Value estimated for 2010 = 781 - 117 - 21 - 271
      = 373 Mt
      = 127 MTOE

  - Forestry residues:
    Energy potential = firewood + Logging and timber processing
    Value estimated for 2007 = 48 + 77
      = 125 Mt
      = 48 MTOE
Biomass resources

- Geographical distribution of agriculture and forestry in China

Agricultural distribution, China, 1986  Forestry distribution, China, 2006
Update of energy policy

- Reduction of the energy intensity (EI) of GDP by 20% between 2006 and 2010.
- Increase of the share of non-fossil energy to 15% in energy mix by 2020 (compared to 2006 = 7%).

In 2005, electricity bonus for biomass gasification power plant = 3 cEUR/KWe. (fossil or hydro electricity price = 2 – 6 cEUR/KWe)

From July, 2010, electricity grid price of biomass gasification power plant > 8 cEUR/KWe
Main characteristics of gasification plants in China

- Oxidation agent: Air
- Main gasifier type (total manufacturers > 100)
  - Downdraft fixed-bed gasifier
  - Circulating fluidized-bed gasifier
- Usual gas treatment facilities
  - Cyclones
  - Scrubbers
- Gasification plants
  - Fuel gas stations (up to 2007, number of stations ~ 600)
  - Power plants (up to 2008, ~ 40 installations & 60 MWe)
Fuel gas stations

- One village (100 ~ 500 households) = one fuel gas station
  
  \(1 \text{ household needs } 5 \text{ Nm}^3 \text{ cooking gas/day}\)

- Distribution zone diameter < 1 Km

- Gasifier type: downdraft fixed-bed

- Feedstocks: agricultural residues

- Feedstock consumption: 1 kg for 2Nm\(^3\) fuel gas

<table>
<thead>
<tr>
<th>Main manufacturers</th>
<th>No. of Stations (up to 2007)</th>
</tr>
</thead>
<tbody>
<tr>
<td>JiNan BaiChuanTongChuang Co. Ltd. (<a href="http://www.sdbctc.cn/">http://www.sdbctc.cn/</a>)</td>
<td>~ 210</td>
</tr>
<tr>
<td>HeFei TianYan Co.Ltd. (<a href="http://www.tianyancn.com/">http://www.tianyancn.com/</a>)</td>
<td>~ 170</td>
</tr>
<tr>
<td>ShenYang BeiLong Co. Ltd. (<a href="http://www.sinobaron.com/">http://www.sinobaron.com/</a>)</td>
<td>~ 80</td>
</tr>
<tr>
<td>Liaoning Institute of energy resource (<a href="http://www.lnsnys.com/">http://www.lnsnys.com/</a>)</td>
<td>~ 15</td>
</tr>
</tbody>
</table>
Fuel gas stations

- Technical specification and acceptance of standard for straw gasification system of central gas supply
  - Gasification efficiency > 70%
  - Fuel gas heating value > 4600 kJ/Nm³
  - Before entering gas storage tank,
    - T < 35° C
    - CO%v <20%; O₂%v <1%; tar% < 50mg/Nm³; particles < 50mg/Nm³; H₂S%<20 mg/Nm³
    - Noise < 80db
  - Gas storage tank design (Volume = 0.4 ~ 0.6 total gas daily production)
  - Pipeline design (High Density Polyethylene + steel)
  - End user’s gas burner efficiency > 55%
  ......
BaiChuanTongChuang fuel gas station

- Traditional system

1. Feeder
2. Gasifier
3. Water scrubber
4. Filter
5. Separator
6. Venturi scrubber
7. Blower
8. Tar collection tank
9. Water sealing tank
10. Gas tank
11. Flame arrester
12. Pipe net

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BaiChuanTongChuang fuel gas station

- New system (invented in 2008)

Solvent: Wood vinegar (Pyroligneous acid)


12.
BaiChuanTongChuang fuel gas station

- **Specifications**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas production capacity</td>
<td>400 – 900 Nm³.h⁻¹</td>
</tr>
<tr>
<td>Gas heating value</td>
<td>&gt; 5000 kJ.Nm⁻³</td>
</tr>
<tr>
<td>Gasification efficiency</td>
<td>&gt; 78%</td>
</tr>
<tr>
<td>Tar concentration</td>
<td>&lt; 10 mg.Nm⁻³</td>
</tr>
<tr>
<td>H₂S concentration</td>
<td>&lt; 10 mg.Nm⁻³</td>
</tr>
</tbody>
</table>

- **Gas composition**

<table>
<thead>
<tr>
<th>Gas</th>
<th>Vol%</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂</td>
<td>9-12</td>
</tr>
<tr>
<td>CO</td>
<td>18-23</td>
</tr>
<tr>
<td>CH₄</td>
<td>1-2</td>
</tr>
<tr>
<td>CO₂</td>
<td>11 – 14</td>
</tr>
<tr>
<td>N₂</td>
<td>rest</td>
</tr>
</tbody>
</table>
Liaoning Institute of Energy Resource


<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas production capacity</td>
<td>200 – 1000 Nm³.h⁻¹</td>
</tr>
<tr>
<td>Gas heating value</td>
<td>4200 – 5500 kJ.Nm⁻³</td>
</tr>
<tr>
<td>Gasification efficiency</td>
<td>68 -72%</td>
</tr>
<tr>
<td>Tar concentration</td>
<td>&lt; 20 mg.Nm⁻³</td>
</tr>
</tbody>
</table>
Liaoning Institute of Energy Resource
Fuel gas station

- Main technical parameters (obtained based on a synthesis of 10 downdraft fixed-bed gasifier systems)
  - Total energy efficiency = 20% ~ 35%
  - Feedstocks size before entering in gasifier: 5~30 mm
  - Tar concentration at the outlet of gasifier: 25~100 mg/Nm³
  - Tar elimination methods:
    - 50% wet treatment (water scrubbers)
    - 10% dry treatment (packed-bed filter)
    - 10% combination of wet and dry treatments
    - 10% catalytic treatment
  - Tar concentration before end user’s gas burner: < 15 mg/Nm³
  - Tar recovery situation?
    - Natural stacking
    - Direct landfill without safe disposal
Fuel gas station

- Economic analysis (for a village of 100 households)
  - Investment per household = 220 EUR
  - Fuel gas cost = 2 cEUR/Nm³ = 0.3 cEUR/MJ, LPG = 1 cEUR/MJ)

- Government objective of total fuel gas station in 2010 = 5000, but in reality, <1000, obstacles?
  - Short life (40% of stations have a life < 10 years)
  - Real capacity < 50% of designed capacity (fuel supply, gas storage tank sizing, etc.)
  - Gas quality (tar concentration) & Waste water treatments
  - Carbon-rich ash discharging
  - Workers not qualified
Gasification power plants

- Main gasifier type:
  - downdraft fixed-bed (generally <400KWe); fluidised-bed (400 – 6000 KWe)
- Feedstocks: agricultural residues, forestry residues
- Main manufacturers

<table>
<thead>
<tr>
<th>Manufacturers</th>
<th>Capacity (KWe)</th>
<th>Total installed capacity up to 2005 (MWe)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guangzhou Institute of Energy Conversion (<a href="http://www.giec.ac.cn/">http://www.giec.ac.cn/</a>)</td>
<td>200 - 6000</td>
<td>21.3</td>
</tr>
<tr>
<td>HeFei TianYan Co.Ltd. (<a href="http://www.tianyancn.com/">http://www.tianyancn.com/</a>)</td>
<td>100 – 1000</td>
<td>6.8</td>
</tr>
<tr>
<td>ChongQing FengYu Coop. (<a href="http://www.fengyugroup.com">http://www.fengyugroup.com</a>)</td>
<td>200 – 1200</td>
<td>7.6</td>
</tr>
<tr>
<td>(0.8 in China, 3 in Kenya)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WuXi HuGuang industry furnace co.Ltd (<a href="http://www.wxhuguang.com/">http://www.wxhuguang.com/</a>)</td>
<td>400 – 2000</td>
<td></td>
</tr>
</tbody>
</table>
GIEC – 5.5 MWe biomass gasification plant

- Feedstocks: rice husk (75%)+sawdust(20%)+straw(5%)
- Gasifier type: circulating fluidised bed
- Main gas treatment: water washing
- Power production system
  - 10 Gas engines (400KWe each)
  - 1 steam turbine (1500 KWe)
GIEC – 5.5 MWe biomass gasification plant

Parameters:
- Temp of preheating air: 250 °C
- Exhaust temp of gas engine: 500 °C
- Temp in outlet of tar cracker: 850 °C
- Tar content in raw gas: <250mg/m³
- Power ratio of engines to turbine: >3:1
- Fuel percents of gas burner: <10%
- Power output of system: >3000kW
- Gasifier efficiency: >78%
- Gas engine efficiency: 26.6-29%
- Overall efficiency: 25-28%
GIEC – 5.5 MWe biomass gasification power plant

This plant was working from 09/2005 to 06/2007

- Economic analysis
  - Investment = 770 EUR/KWe
  - Feedstock cost = 33 EUR/T Too high (estimated < 20 EUR/T)
  - Electricity production cost = 6cEUR/KWe
  - Electricity grid price = 5cEUR/KWe

feedstock cost represents 65% of total electricity production cost
GIEC – 1MWe gasification power plant (timber factory)


Power production: 6 Gas IC engines (200 KWe each)
GIEC – 1MWe gasification power plant
(SanYa timber factory)
GIEC – 1MWe gasification power plant

- Factory background
  - Timber processing waste: 100 T/day
    - 35T wood powder + 10T leftover material + 10T sieving waste + 45T all kinds of bark
  - Required power: 5MWe

- Specifications
  - Feed rate for gasifier: 1.5 T/h (~ 30 T/day)

<table>
<thead>
<tr>
<th>Producer gas composition</th>
<th>Vol%</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂</td>
<td>7</td>
</tr>
<tr>
<td>CO</td>
<td>20</td>
</tr>
<tr>
<td>CH₄</td>
<td>5</td>
</tr>
<tr>
<td>CO₂</td>
<td>9</td>
</tr>
<tr>
<td>N₂</td>
<td>rest</td>
</tr>
</tbody>
</table>

Manufacturers and case studies
GIEC – 1MWe gasification power plant (timber factory)

- Designed running hours = 24h/d * 300 days/y
- Real capacity = 70% of designed capacity
- Worker number: 30 (salary/p/y = 1000 ~ 2000 EUR)

Economical analysis

- Investment = 550 EUR/KWe
- Maintenance cost = 30 kEUR/y (15 kEUR for generators)
- Feedstock cost = 6 EUR/T
- Electricity price = 6 cEUR/KWe
- Gross profit = 250 kEUR/y
Specifications for GIEC CFB gasifier power system

- **Technical parameters**
  - Fuel types: sawdust, rice husk, crop straw
  - System efficiency: 16~21%
  - Feedstock consumption:
    - Wood wastes: 1.2~1.8 kg/kWh electricity
    - Rice husk: 1.8~2.5 kg/kWh electricity
  - Designed operation time: 6500~7000 hours/year
  - Wastewater treatment:

```
<table>
<thead>
<tr>
<th>Waste water COD (mg/m³)</th>
<th>3000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice husk ash</td>
<td></td>
</tr>
<tr>
<td>Aeration</td>
<td>1500</td>
</tr>
<tr>
<td>Precipitation</td>
<td>1000</td>
</tr>
<tr>
<td>Biological treatment</td>
<td>150</td>
</tr>
<tr>
<td>COD (mg/m³)</td>
<td></td>
</tr>
<tr>
<td>Filteration</td>
<td>1500</td>
</tr>
<tr>
<td>Aeration</td>
<td>1000</td>
</tr>
<tr>
<td>Precipitation</td>
<td>150</td>
</tr>
<tr>
<td>Biological treatment</td>
<td>150</td>
</tr>
</tbody>
</table>
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HeFei TianYan – Fixed bed gasifier power plant
100 -- 400 KWe
HeFei TianYan – Fixed bed gasifier power plant

100 KWe, Italy

200 KWe, Japan

400 KWe, China
Other gasifier manufacturers (export)

- ChongQing FengYu Coop. ([http://www.fengyugroup.com](http://www.fengyugroup.com))
  - Fluidised bed gasifier power plant
Other gasifier manufacturers (export)

- ChongQing FengYu Coop.
Other gasifier manufacturers (export)

- WuXi HuGuang industry furnace co.ltd (http://www.wxhuguang.com/)
  - Fluidised bed gasifier power plant
Other gasifier manufacturers (export)

- WuXi HuGuang industry furnace co.ltd

1 MWe, China
GaoYou 5 MWe gasification plant – Heat, Electricity, Gas

- Feedstock: straw briquette
- Updraft fixed bed gasifier + gas turbine
- Gas treatment: water scrubbers + electrostatic tar precipitators
- Gas heating value: 7000 MJ/m³
- Plant efficiency: 25%

Explored by:
Gaoyou Linyuan Technology Co., LTD
College of resources and environmental engineering, ECUST
SGHI, Shenyang, China

Supported by:
NEA
ERI, NDRC
CRESP programme
GaoYou straw gasification plant: Gas-Heat-Electricity
Environmental impact

- No (or almost no) net CO$_2$ emission
- Lack of emission and pollutant controls
  - Gas emission control? (NO$_x$, SO$_2$, dioxin, etc...)
- No law for exhaust gas from biomass gasification power plant (only existing law concerns gas emission of MSW incineration published in 2002).
  - Solid residues (carbon-rich ash) discharging or valorisation?
  - Waste water treatment
  - Tar (recovered from waste water treatment) discharging or valorisation?
Prospects

- **Policy**
  - Investment subvention
  - Biomass resource management and collecting (fuel supply handbook)
  - Grid price warranty and purchase obligation

- **Technical aspects**
  - Monitoring programs on the performance of biomass gasifier plants
  - New technologies development & importation
  - Automation

- **Environmental aspects**
  - Standards, certification system
  - Control of pollution emissions (gas, liquid, solid)
A special thanks to Mr. Harrie Knoef of BTG Netherland for his review and constructive suggestions.

Vielen Dank
Thank you
Merci
谢谢

If you have any questions, please contact:
chen@sol3d.com
# Appendix 1

**GB 18485-2001 Standard for pollution control on the MSW incineration**

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Specification</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smoke</td>
<td>mg/Nm³</td>
<td>Average value</td>
<td>80</td>
</tr>
<tr>
<td>Smoke intensity</td>
<td>Lingeman blackness</td>
<td>Max value</td>
<td>1</td>
</tr>
<tr>
<td>CO</td>
<td>mg/Nm³</td>
<td>Average value per hour</td>
<td>150</td>
</tr>
<tr>
<td>NOx</td>
<td>mg/Nm³</td>
<td>Average value per hour</td>
<td>400</td>
</tr>
<tr>
<td>SO₂</td>
<td>mg/Nm³</td>
<td>Average value per hour</td>
<td>260</td>
</tr>
<tr>
<td>HCl</td>
<td>mg/Nm³</td>
<td>Average value per hour</td>
<td>75</td>
</tr>
<tr>
<td>Hg</td>
<td>mg/Nm³</td>
<td>Average value</td>
<td>0.2</td>
</tr>
<tr>
<td>Cd</td>
<td>mg/Nm³</td>
<td>Average value</td>
<td>0.1</td>
</tr>
<tr>
<td>Zn</td>
<td>mg/Nm³</td>
<td>Average value</td>
<td>1.6</td>
</tr>
<tr>
<td>Dioxin</td>
<td>ng TEQ/Nm³</td>
<td>Average value</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Appendix 2

- Pilot plants for DME production via gasification
  (Guangzhou Institute of Energy Conversion + Liaoning Institute of Energy Resource)

100 T/y, ShanDong, China, 2007
1000 T/y, GuangZhou, China, 2009