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

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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 CO_2 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

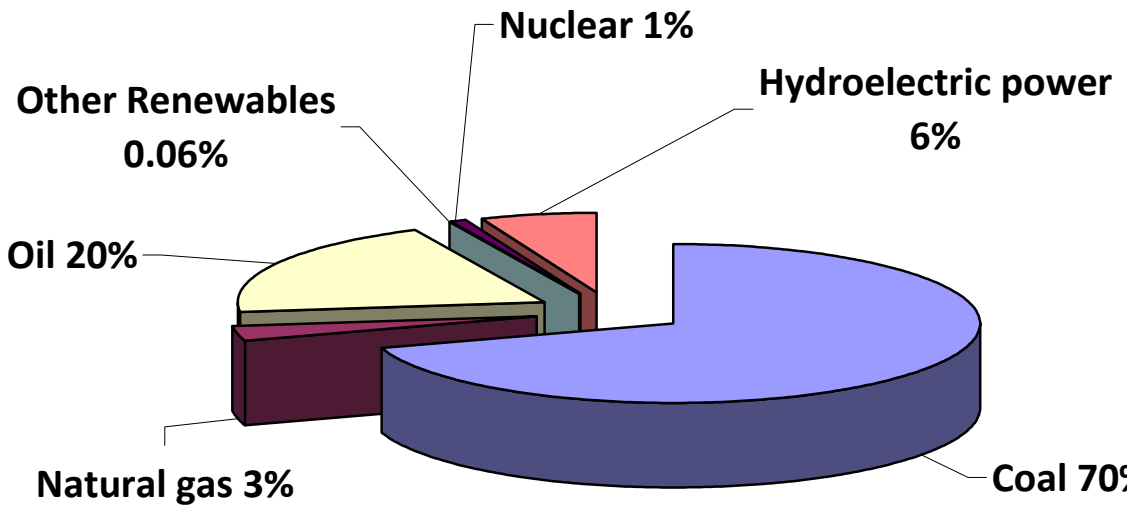
2009: GDP = 34 000 billions of CNY (= 4 000 billions of EUR)

- Primary energy production and consumption

	1980		2005	
MTOE	**Production**	**Consumption**	**Production**	**Consumption**
Total primary energy	**457**	**436**	**1623**	**1720**
Oil	**113**	**94**	**202**	**357**
Dry natural gas	**15**	**15**	**46**	**44**
Primary coal	**312**	**310**	**1270**	**1218**

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

Energy mix



Source: EIA international energy annual 2006

Total Energy consumption in China (by type)

- **2006 Share of non-fossil energy = 7%**

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

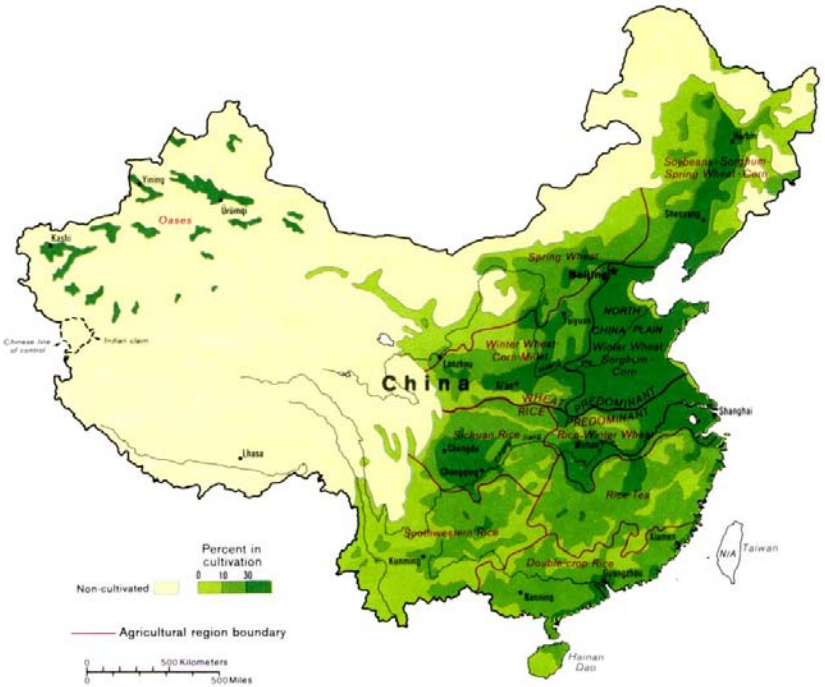
- Forestry residues:

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%).
- Publication of " China Renewable Energy Law" in 2006.

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 household needs 5 Nm^3 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

Main manufacturers	No. of Stations (up to 2007)
JiNan BaiChuanTongChuang Co. Ltd. (http://www.sdbctc.cn/)	~ 210
HeFei TianYan Co.Ltd. (http://www.tianyancn.com/)	~ 170
ShenYang BeiLong Co. Ltd. (http://www.sinobaron.com/)	~ 80
Liaoning Institute of energy resource (http://www.lnsnys.com/)	~ 15

Fuel gas stations

- Standard published in 2001: NY/T 443-2001

Technical specification and acceptance of standard for straw gasification system of central gas supply

- Gasification efficiency > 70%
- Fuel gas heating value > 4600 kJ/Nm^3
- Before entering gas storage tank,
  - T < 35° C
  - CO%v <20%; O_2%v <1%; tar% < 50mg/Nm^3; particles < 50mg/Nm^3; H_2S%<20 mg/Nm^3
  - 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%

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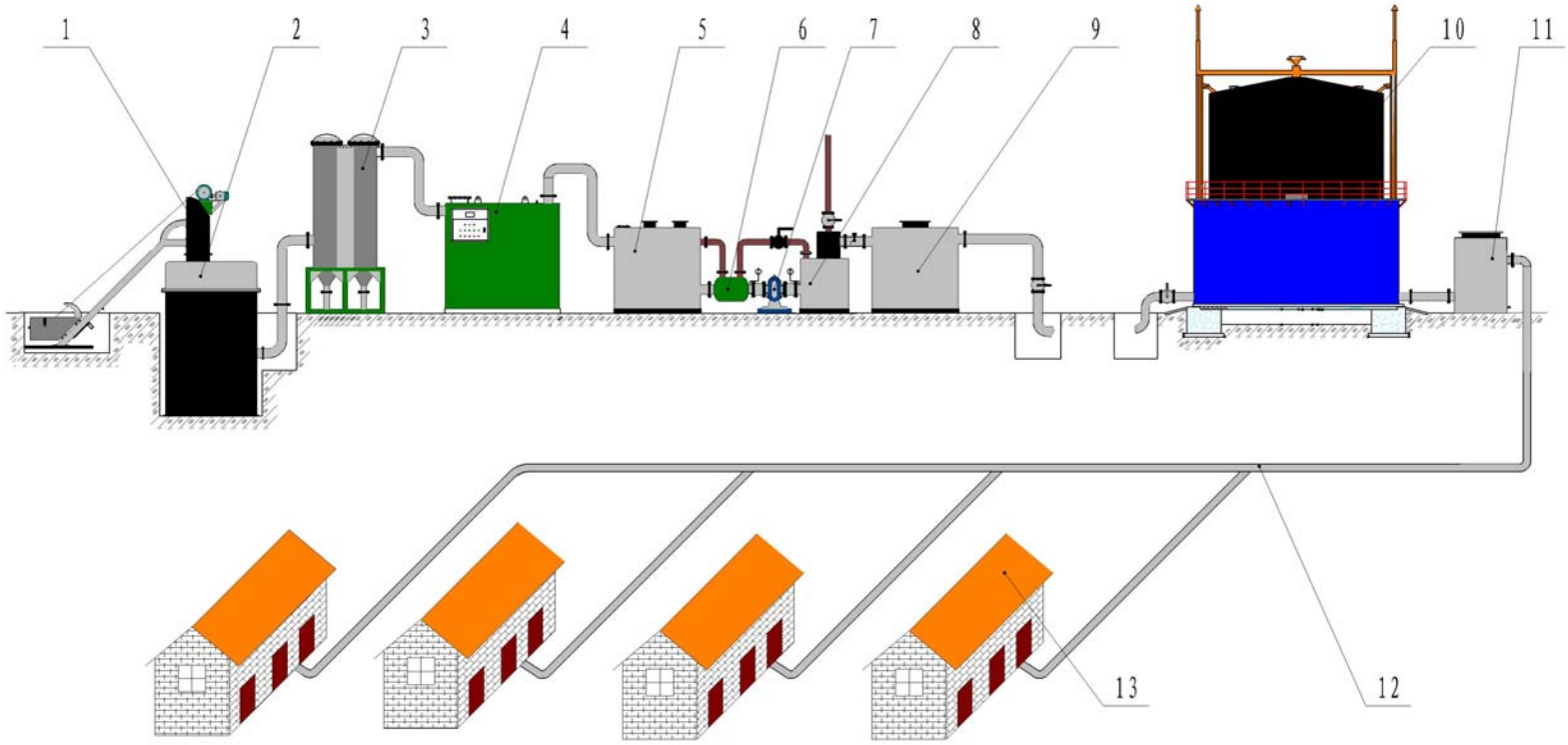
BaiChuanTongChuang fuel gas station

- Traditional system



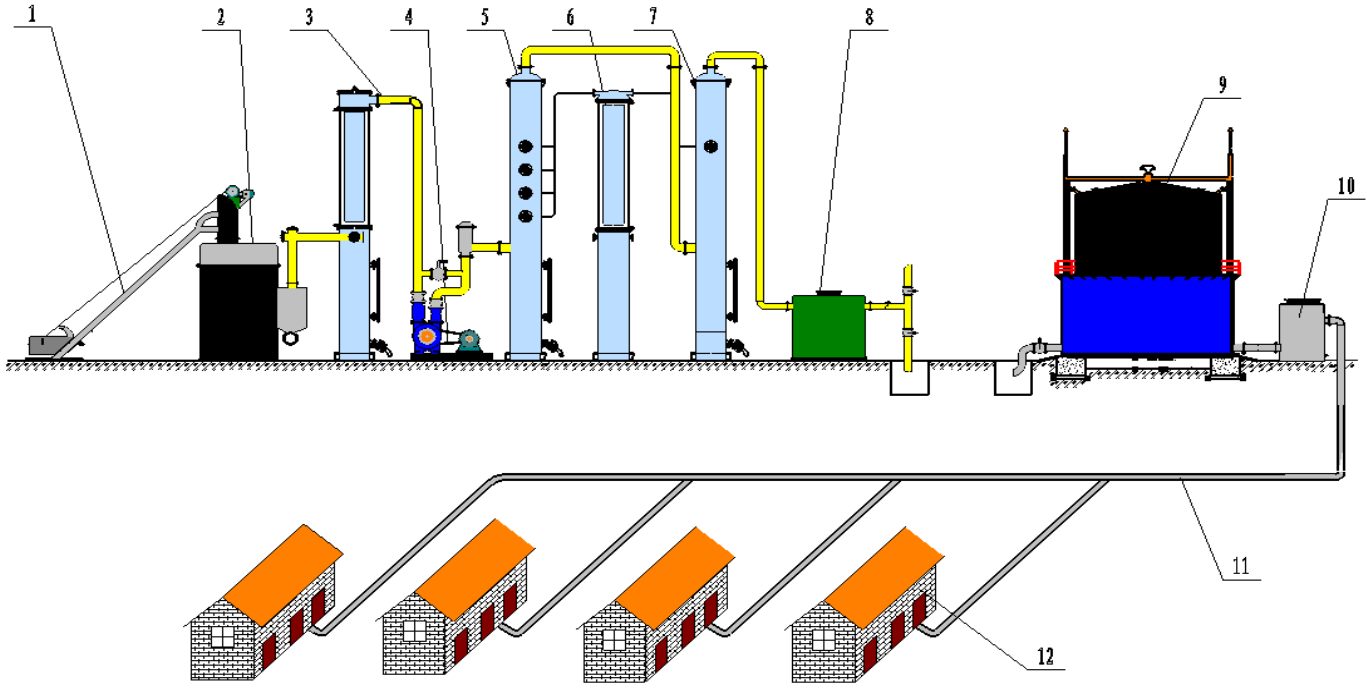
1. Feeder 2. Gasifier 3. Water scrubber 4. Filter 5. Separator 6. Venturi scrubber 7. Blower

8. Tar collection tank 9. Water sealing tank 10. Gas tank 11. Flame arrester 12. Pipe net

BaiChuanTongChuang fuel gas station

- New system (invented in 2008)

Solvent: Wood vinegar (Pyroligneous acid)



1. Feeder 2. Gasifier 3. Condenser 4. Vacuum pump 5. Absorber 6. Separator

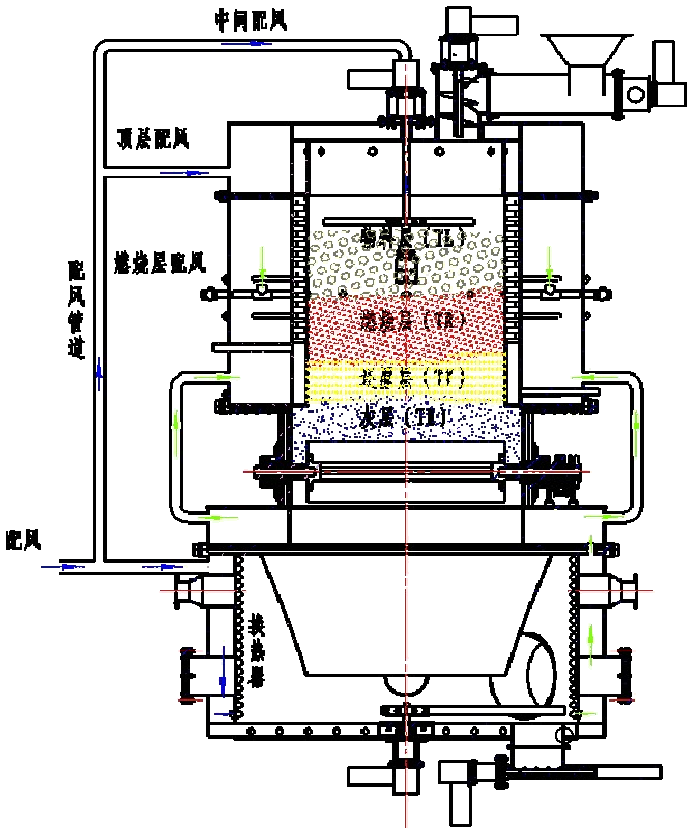
7. Absorber 8. Sealing tank 9. Gas tank 10. Flame arrester 11. Pipe net

BaiChuanTongChuang fuel gas station

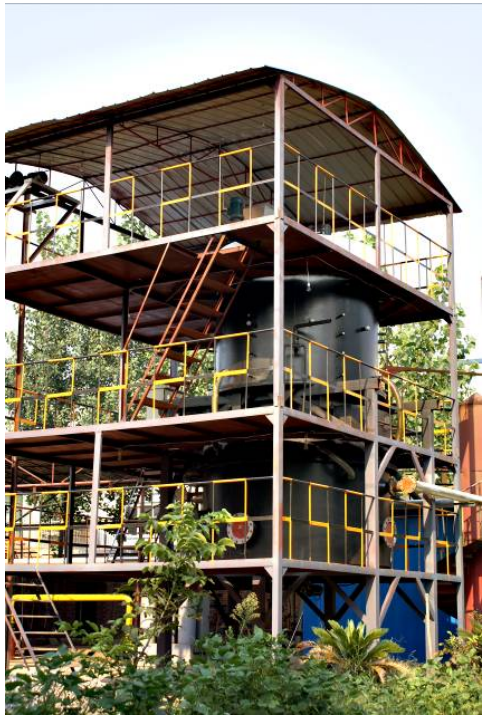
Specifications

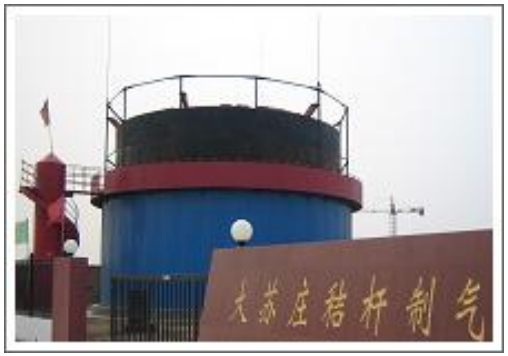
Gas production capacity	400 – 900 $Nm^3.h^{-1}$
Gas heating value	> 5000 $kJ.Nm^{-3}$
Gasification efficiency	> 78%
Tar concentration	< 10 $mg.Nm^{-3}$
H_2S concentration	< 10 $mg.Nm^{-3}$

Gas composition	Vol%
H_2	9-12
CO	18-23
CH_4	1-2
CO_2	11 – 14
N_2	rest

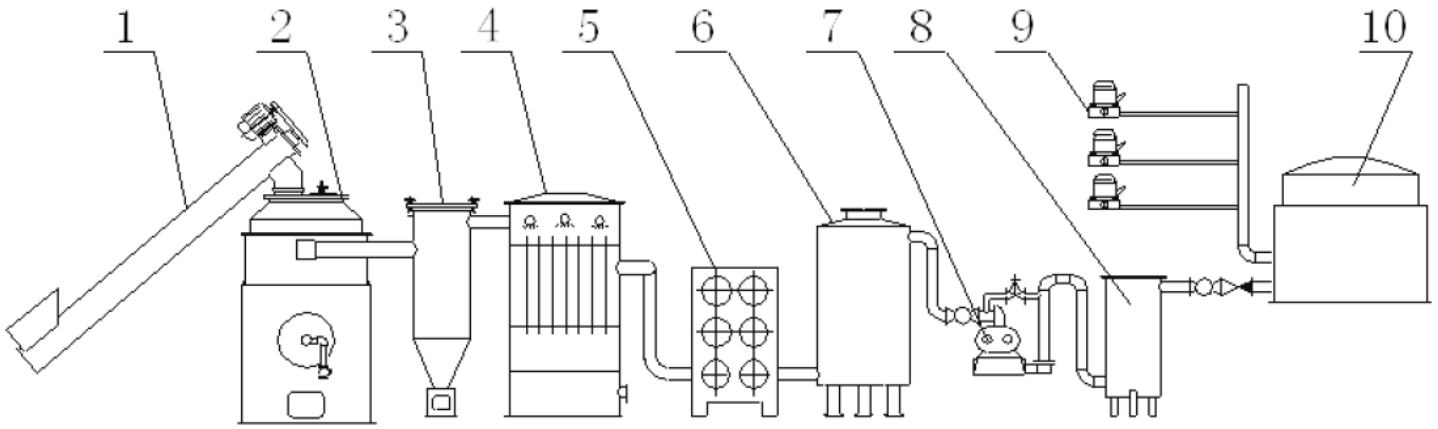


BaiChuanTongChuang fuel gas station





Liaoning Institute of Energy Resource



1. Feeder 2. Gasifier 3. Cyclone 4. Scrubber 5. Water seperator

6. Filter 7. Blower 8. Water sealing tank 9. End-user 10 Gas tank

Gas production capacity	200 – 1000 $Nm^3.h^{-1}$
Gas heating value	4200 – 5500 $kJ.Nm^{-3}$
Gasification efficiency	68 -72%
Tar concentration	< 20 $mg.Nm^{-3}$

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/Nm^3
  - 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/Nm^3
  - 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/Nm^3 = 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)

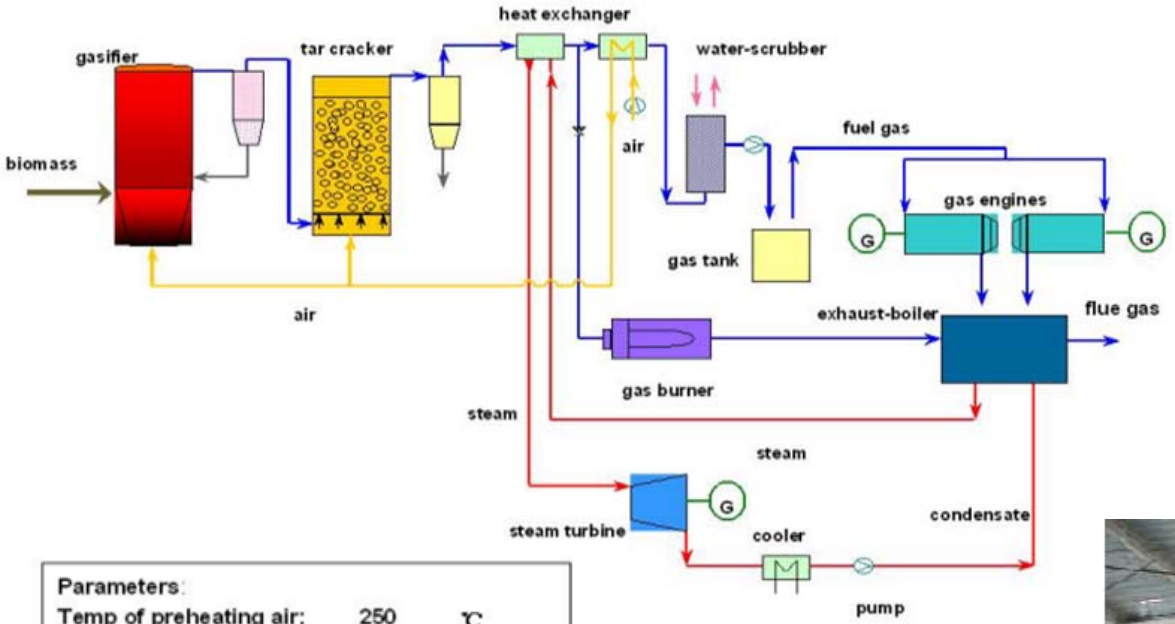
- Feedstocks: agricultural residues, forestry residues
- Main manufacturers

Manufacturers	Capacity (KWe)	Total installed capacity up to 2005 (MWe)
Guangzhou Institute of Energy Conversion (http://www.giec.ac.cn/)	200 - 6000	21.3
HeFei TianYan Co.Ltd. (http://www.tianyancn.com/)	100 – 1000	6.8
ChongQing FengYu Coop. (http://www.fengyugroup.com)	200 – 1200	7.6 (0.8 in China, 3 in Kenya)
WuXi HuGuang industry furnace co.Ltd (http://www.wxhuguang.com/)	400 – 2000	

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	℃
Exhaust temp of gas engine:	500	℃
Temp in outlet of tar cracker:	850	℃
Tar content in raw gas:	<250mg/m^3	
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%	

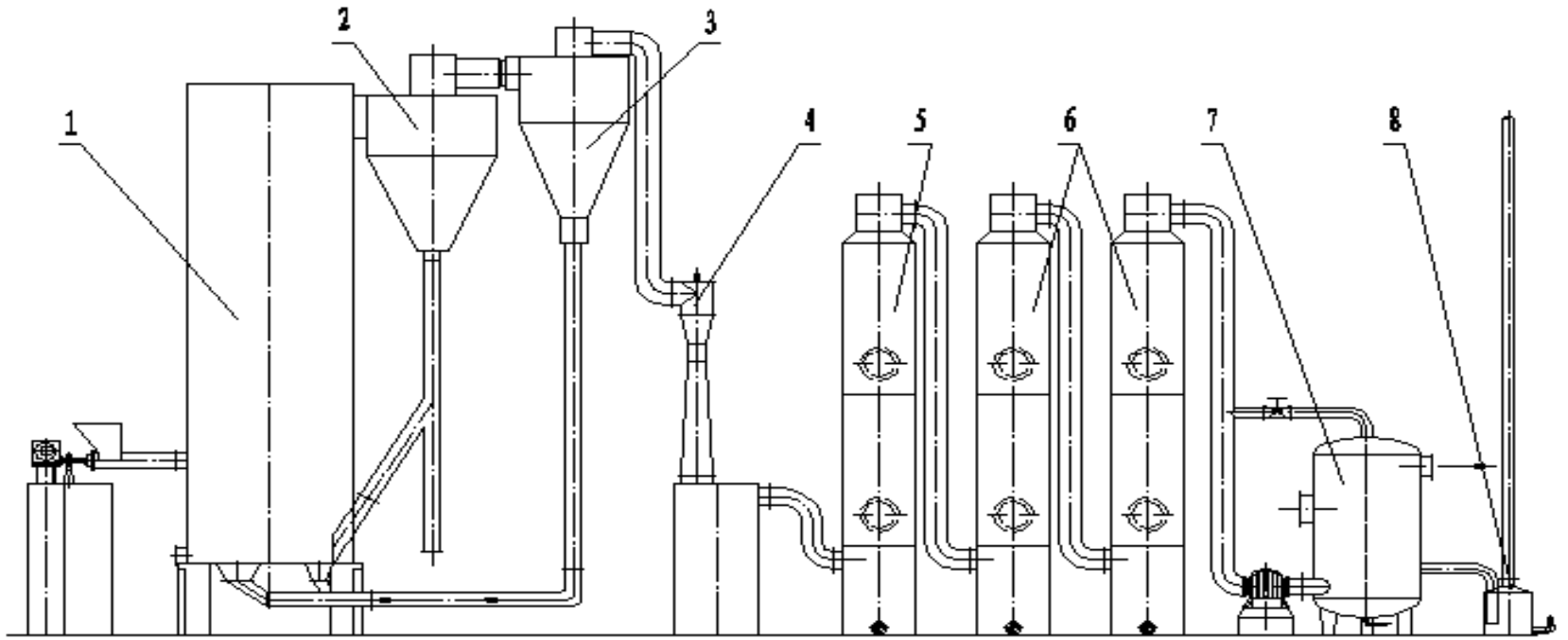
GIEC – 5.5 MWe biomass gasification power plant

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)



1. CFB Gasifier 2 &3. Cyclones 4. Venturi scrubber
5 & 6. Water scrubbers 7. Gas tank 8. Water sealing

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 + 10Tsieving waste + 45T all kinds of bark

  - Required power: 5MWe
- Specifications
  - Feed rate for gasifier: 1.5 T/h (~ 30 T/day)

Producer gas composition	Vol%
H_2	7
CO	20
CH_4	5
CO_2	9
N_2	rest

GIEC – 1MWe gasification power plant (timber factory)

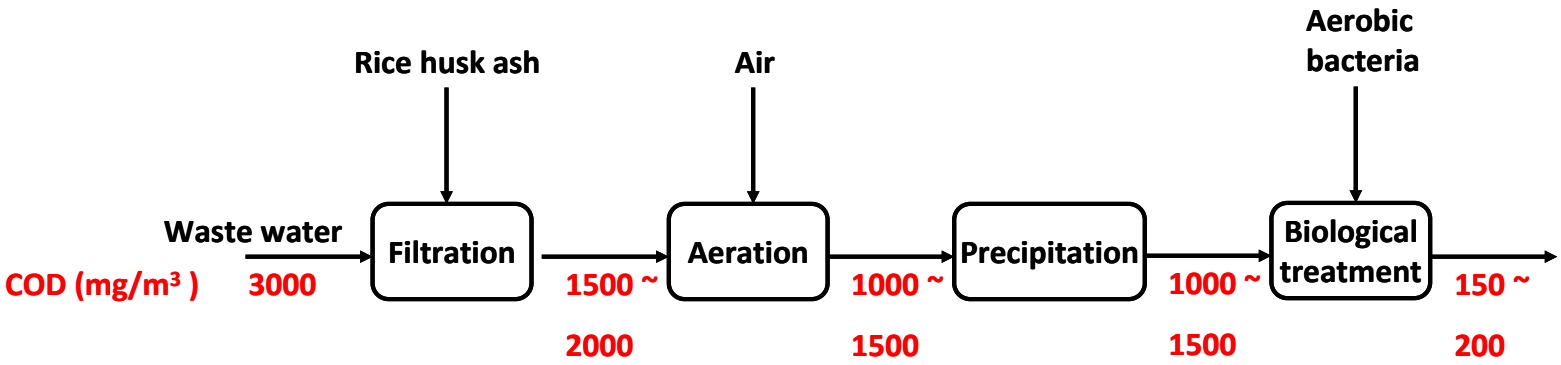
- Designed running hours = 24h/d * 300 days/y
- Real capacity = 70% of designed capacity
- Worker number: 30 (salary/p/y = 1000 ~ 2000 EUR)

Economical analysis

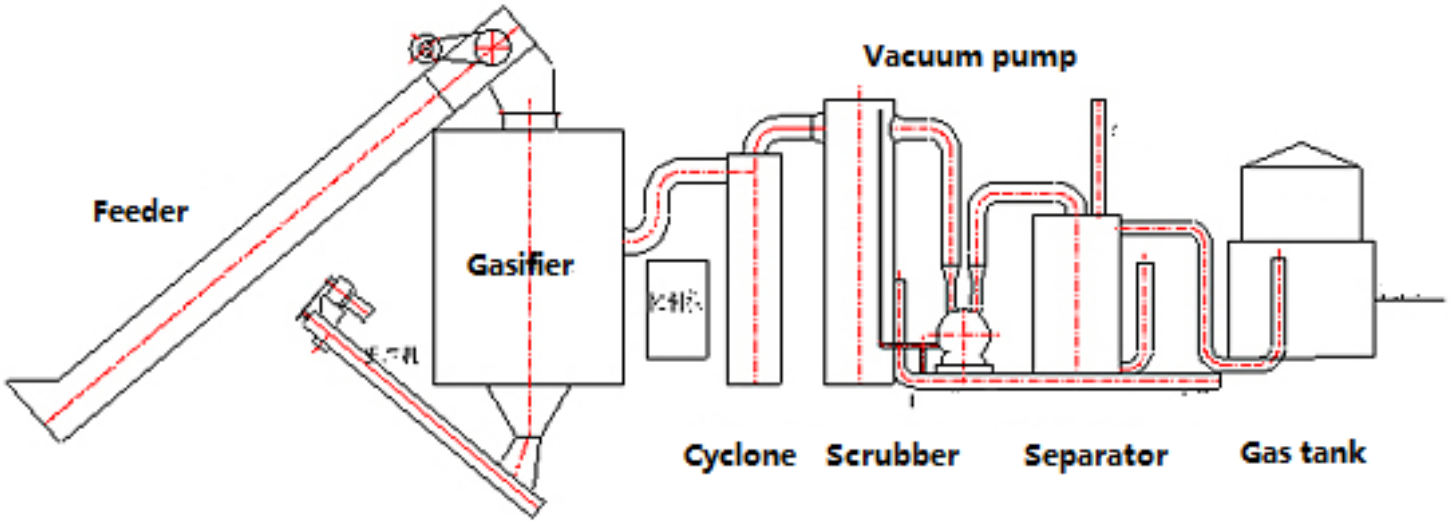
- Investment = 550 EUR/KWe
- Maintenance cost = 30 kEUR/y (15 kEUR for generators)
- Feedstock cost = 6 EUR/T
- Electricity price = 6 cEUR/KWe
- Gross profit = 250 kEUR/y

Specifications for GIEC CFB gasifier power system

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



HeFei TianYan – Fixed bed gasifier power plant 100 -- 400 KWe



HeFei TianYan – Fixed bed gasifier power plant

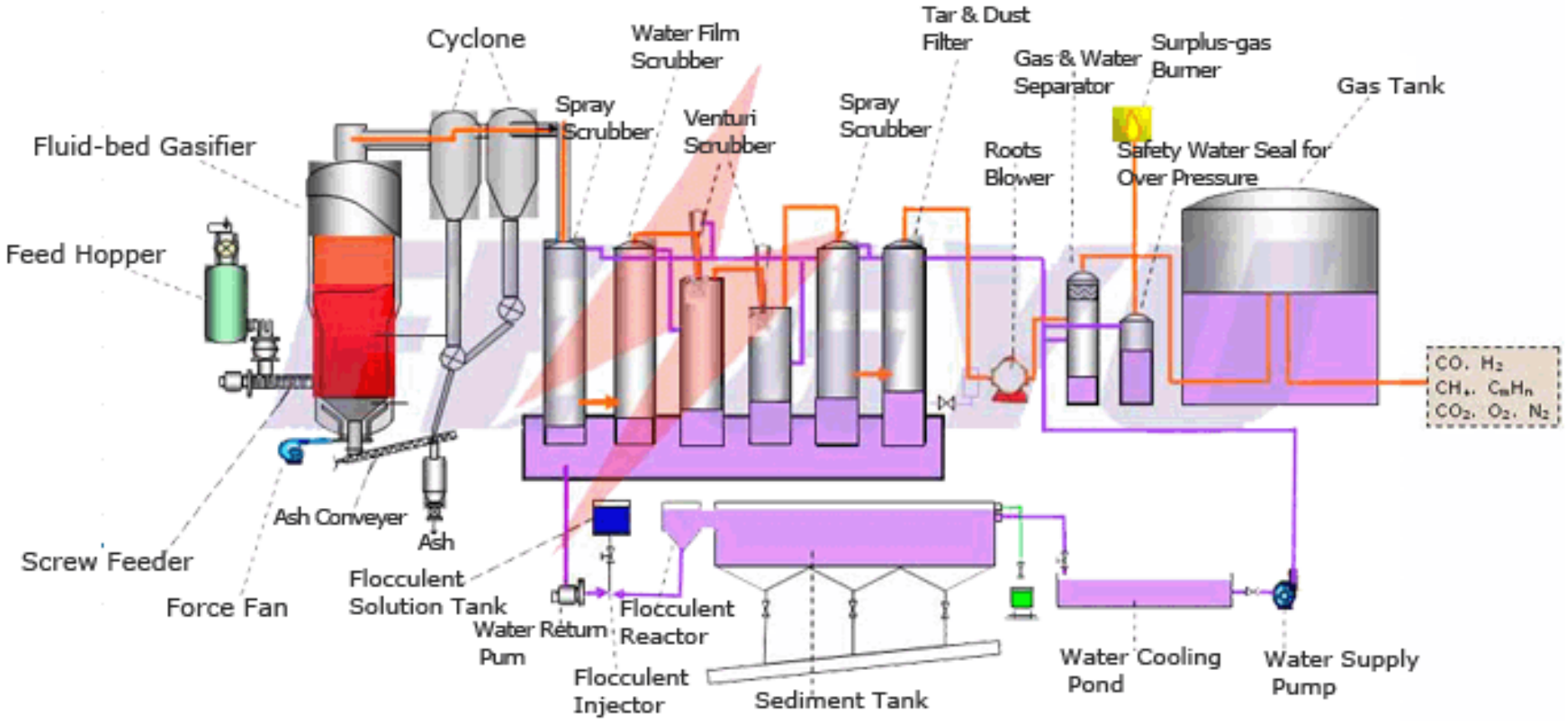
100 KWe, Italy

200 KWe, Japan

400 KWe, China

Other gasifier manufacturers (export)

- ChongQing FengYu Coop. (http://www.fengyugroup.com)
  - Fluidised bed gasifier power plant



Other gasifier manufacturers (export)

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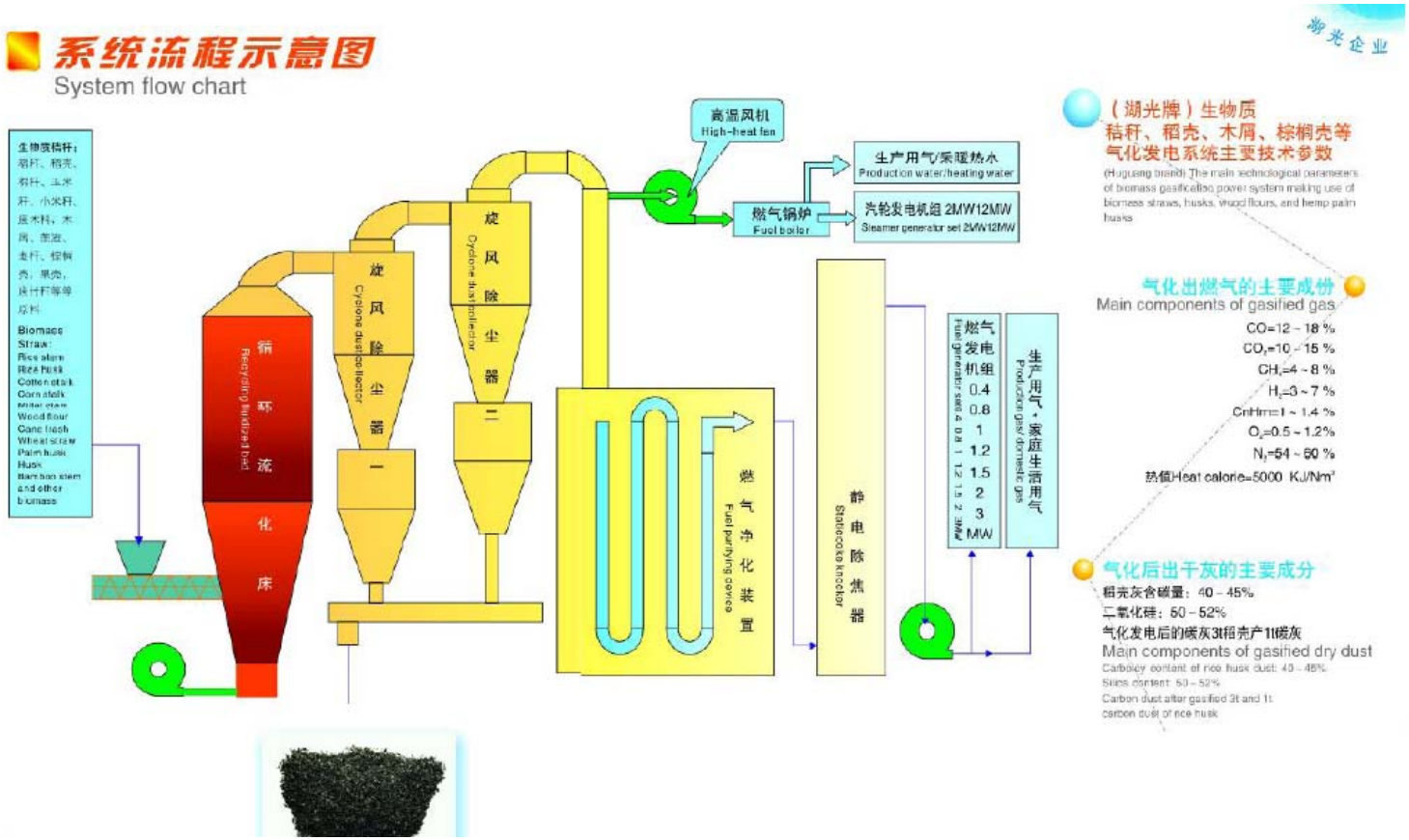

Other gasifier manufacturers (export)

- WuXi HuGuang industry furnace co.ltd

1 MWe, China

GaoYou 5 MWe gasification plant –Heat, Electricity, Gas

- Feedstock: straw briquette

Very limited available Information…

- Updraft fixed bed gasifier + gas turbine
- Gas treatment: water scrubbers + electrostatic tar precipitators
- Gas heating value: 7000 MJ/m^3
- 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:

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Appendix 1

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

	Unit	Specification	Limit
Smoke	mg/Nm^3	Average value	80
Smoke intensity	Lingeman blackness	Max value	1
CO	mg/Nm^3	Average value per hour	150
NOx	mg/Nm^3	Average value per hour	400
SO_2	mg/Nm^3	Average value per hour	260
HCl	mg/Nm^3	Average value per hour	75
Hg	mg/Nm^3	Average value	0.2
Cd	mg/Nm^3	Average value	0.1
Zn	mg/Nm^3	Average value	1.6
Dioxin	ng TEQ/Nm^3	Average value	1.0

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