GE Energy
Jenbacher gas engines

FECC - GTZ
Training for Biogas Design Institutes - Beijing

From Biogas to electricity-CHP-use in operation

Thomas Elsenbruch
GE Energy Infrastructure

Employees: 65,000  •  ‘08 revenue: $38.6B  •  Operating in 140 countries

Power & Water
- Power generation
- Renewables
- Gas Engines
- Nuclear
- Gasification
- Water treatment
- Process chemicals

Energy Services
- Contractual agreements
- Smart Grid
- Field services
- Parts & repairs
- Optimization technologies
- Plant management

Oil & Gas
- Drilling & completion
- Subsea, offshore & onshore
- LNG & Pipelines
- Pipeline integrity
- Refining
- Processing
GE’s Jenbacher gas engines

A leading manufacturer of gas fueled reciprocating engines for power generation

1,700 employees worldwide, 1,300 in Jenbach/Austria

9,100+ delivered engines / 10,800+ MW worldwide
   Power range from 0.25 MW to 4 MW

Fuel flexibility
   Natural gas, biogas, flare gas, landfill gas, steel gas, coal mine gas

Advanced system solutions
   Generator sets, container modules
   cogeneration, trigeneration, CO₂-fertilization

Environmental benefits
   Low emissions
   ecomagination solutions

Lifetime services plus (parts, repair, CSA, upgrades)
   2,000 units under CSA
Product Program 2010: Biogas, Sewage Gas and Landfill Gas

- **Electrical output [kW]**
- **Thermal output (70°/90°C) [kW]**

Natural gas standard

NOx ≤ 500 mg/Nm³ (dry Exhaust gas; based on 5 % O2)
The whole Jenbacher biogas fleet:

- Sewage gas: more than 450 installed engines (313 MW)
- Biogas: more than 1500 installed engines (1065 MW)
- Landfill gas: more than 1400 installed engines (1370 MW)
### Jenbacher - Biogas engines in some EU and Asian countries

Installed in Biogas plants up to 31.12.2009:

<table>
<thead>
<tr>
<th>Country</th>
<th>Engines</th>
<th>MW</th>
</tr>
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<tbody>
<tr>
<td>Germany</td>
<td>945</td>
<td>527</td>
</tr>
<tr>
<td>Italy</td>
<td>161</td>
<td>130</td>
</tr>
<tr>
<td>Austria</td>
<td>90</td>
<td>48</td>
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<tr>
<td>Netherlands</td>
<td>69</td>
<td>72</td>
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<tr>
<td>Denmark</td>
<td>46</td>
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<tr>
<td>Czech Rep.</td>
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<tr>
<td>Belgium</td>
<td>32</td>
<td>36</td>
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<tr>
<td>Spain</td>
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<td>30</td>
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<td>UK</td>
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<td>12</td>
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<td>Poland</td>
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<td>6</td>
</tr>
<tr>
<td>Hungary</td>
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<td>3</td>
</tr>
<tr>
<td>Slovakia</td>
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<tr>
<td>Thailand</td>
<td>42</td>
<td>51</td>
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<tr>
<td>India</td>
<td>37</td>
<td>32</td>
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<tr>
<td>Indonesia</td>
<td>28</td>
<td>30</td>
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<tr>
<td>China</td>
<td>10</td>
<td>12</td>
</tr>
</tbody>
</table>
Gas engines play core role in biogas plants

Biogas-cogeneration units are core part of biogas plant, in combination with enhanced digester-technology

(in case of food waste)
Targets of development optim. Biogas engine

**Target:**
Optimized efficiency in operation with Biogas

**Basic engines**
Optimized specific output

**Frame conditions:**
- Biogas
- Exhaust emissions
- Thermodynamic Optimum
Internal efficiency – combustion duration

Higher compression-ratio helps the efficiency
Comparison of efficiency of different concepts

The optimum of compression ratio and BMEP must be found
GEJ spark plugs/ ignition system development

J316 Kläranlage Eugene / pme 17bar

Ignition voltage in [kV]

operating hours

P1
P2
P4
P7
P5

P2
P3.V3
P7.4V1S1

GE Jenbacher / Thomas Elsenbruch
August 13, 2010
WWTP Straß/A JMS 208 GS.B.LC

WWW Strass Zillertal/A
1 x JMS 208 GS B.LC

Electrical output
330 kW
Thermal output
420 kW

Electr. efficiency
$\eta_{el} = 39\%$
Therm. efficiency
$\eta_{th} = 48\%$
Optimization of combustion Type 2/3/4

Optimized Combustion

Acceleration by „heart-shaped“ piston bowl

Minimized crevice volume

• 30% lower HC
• 30% lower CO

increased compression ratio in combination mit „Miller“-timing
Efficiency increase in Biogas

El. efficiency

Type 4 A25 – 2007
Type 3 C21 2002
Type 3 B21 1997
Type 3 B27 1994
Type 4 B25 2011

Load [%]

0 20 40 60 80 100 120

0,2 0,24 0,28 0,32 0,36 0,4 0,44
Important criteria for gas engine selection
Lean-burn combustion with gas engines

- Lean combustion to ensure low NOx emission limits (500 mg/Nm³ and lower)
- Reduced combustion temperatures enable higher specific outputs and efficiency

Air Fuel ratio ($\lambda$)

Emissions

NOx

TOTAL HC

CO

LEAN Combustion

Misfiring
Details: „Gas engine concept“

Advantages:
• “Cross flow” cylinder head (external exhaust gas manifolds)
• Clear separation of cold mixture inlet and hot exhaust gas
• Exactly defined thermal zones in the cylinder head
• Long cylinder head life time
• Better accessibility to the exhaust gas manifolds
**LEANOX® - Lean-burn combustion control**

- Sensors in non critical measurement ranges (pressure, temperature, deposits...)
- Reliable and durable compliance with exhaust emission limit at changing operational conditions (fuel gas compositions...)
- Controlled combustion and subsequently controlled stress of various components (valves, cylinder heads, spark plugs...)

*GE Jenbacher / Thomas Elsenbruch  
August 13, 2010*
The Networking Concept
Important criteria for gas engine selection

- Select a specifically designed biogas cogeneration unit
- Modern gas engine concept ("Cross-flow" cylinder head, no derived Diesel engine)
- Turbocharged engine for high power density and efficiency
- Electronic NOx-emission control, preferably with sensors outside the combustion chamber and exhaust gas manifolds
- Enhanced ignition control system (preferably with integrated electronic ignition voltage control)
- Knocking control (at least 1 sensor/cylinder-line)
- Enhanced engine control system with alarm management (remote monitoring, diagnosis and control recommended)
- Interfaces between engine control and system control
Typical operation and maintenance figures

• Main maintenance intervals:
  – Every 1,000 (2,000) ophs: spark plug and valve re-gapping, lube oil change (according oil analysis)
  – Btw 5,000 and 10,000 ophs: overhaul of turbocharger, water pump...
  – Minor or top-end overhaul btw. 15,000 and 30,000 ophs depending on manufacturer and engine condition (change of cylinder heads, pistons, liners, ...)
  – Major overhaul: btw. 40,000 and 60,000 ophs depending on manufacturer: exchange of core-engine

• Specific maintenance cost:
  – 1.5 – 2 US$/kWh for preventive and corrective maintenance
  – Major overhaul: Appr. 60% of the initial investment for the genset.

O&M costs of genset appr. same as initial genset investment
Example Biogas Gosdor– Outstanding Reliability

- Achieved 8,740 out of 8,760 oph/y in´05
- 99.8% Availability with Biogas
- Average 98+% fleet reliability at Biogas (450+ units)
Heat recovery opportunities with gas engines
Cogeneration of heat and power (CHP)

CHP systems utilize the waste heat incurred during engine operation to generate overall plant efficiencies of more than 90%.

- **HE 1**: Mixture intercooler
- **HE 2**: Oil exchange heater
- **HE 3**: Engine jacket water heat exchanger
- **HE 4**: Exhaust gas heat exchanger
Energy savings through CHP technology

Primary energy savings: roughly 40%

\[(1 - \frac{2.5}{4.33}) \times 100 = 42\% \text{ savings of primary energy with cogeneration}\]
# Temperature levels of different heat sources

<table>
<thead>
<tr>
<th>Heat Source</th>
<th>Min.</th>
<th>Max.</th>
<th>Danger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engine Jacket water</td>
<td>57°C</td>
<td>95°C</td>
<td>Overheating</td>
</tr>
<tr>
<td>Lube oil</td>
<td>70°C</td>
<td>90°C</td>
<td>Viscosity</td>
</tr>
<tr>
<td>Intercooler</td>
<td>55°C</td>
<td>80°C</td>
<td>Condensation</td>
</tr>
<tr>
<td>Exhaust gas</td>
<td>(50°C)</td>
<td>220 (180)°C</td>
<td>Acid dewpoint Condensate!</td>
</tr>
</tbody>
</table>
Recoverable Heat w/ Integration 70/90°C

Hot water circuit

Recoverable thermal output = 558 kW
Hot water flow rate = 24.0 m³/h

Low temperature circuit (calculated with Glykol 37%)

Heat to be dissipated = 23 kW
Cooling water flow rate = 15.0 m³/h
Heat utilization in Biogas-CHP
JMS 312 GS-B.L (C225)

Electr. Output: 526 kW
Recov. Heat: 524 kW
LT-IC heat: 23 kW
Therm. Efficiency: 40.3%
Steam production with Gas engines

JMS 312 GS-B.L

Electr. Output: 526 kW

Therm. Output
- Hot wat. 65/85°C: 325 kW
- Sat. steam, 8 bar: 345 kg/h (= 231 kW)
- LT-IC heat: 19 kW

Therm. efficiency: 42.7%

Feed water must be conditioned!
Advantages of trigeneration systems over conventional refrigeration technology

- Operated with heat, utilizing inexpensive "excess energy"
- No moving parts in absorption chillers, no wear and therefore low maintenance expenses
- Noiseless operation of the absorption system
- Low operating costs and life-cycle costs
- Water as refrigerant, no use of harmful substances for the atmosphere
Trigeneration with gas engines

Electr. Output: 526 kW
Recoverable Heat: 550 kW
LT-IC heat: 40 kW
Cold production: ~385 kW
Therm. efficiency: 42.2%
Drying process with Gas engines

JMS 312 GS-B.L

Electr. Output: 526 kW
Recoverable heat: 653 kW
LT-IC heat: 24 kW
Therm. efficiency: 50.2%
Brickyard LUNDGAARD
Stoholm - Denmark

1 x JMS 212 GS-N.LC

Electr. Output: 465 kW
Recoverable heat: 699 kW
Therm. efficiency: 59.0%
What is the right path with biogas?

Biogas utilisation – An effective biofuel

Fuel equivalent (Liters/ha)

- Biogas
- Biomass-to-liquid (FT-Diesel)
- Bioethanol from sugar cane (BR)
- Bioethanol from cereals
- Biodiesel from rapeseed

Data Source:
German Federal Agency for Renewable Resources - FNR
What is the right path with biogas?

### Biogas utilisation – GHG-savings

<table>
<thead>
<tr>
<th>kg CO₂e-Savings / GJ Biogas (raw)</th>
<th>Local gas engine</th>
<th>Biogas upgrading</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Electricity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electricity + 20% surplus heat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Electricity + 80% surplus heat</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gas engine 100% CHP-operation</td>
<td></td>
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<tr>
<td></td>
<td>Natural gas substitution</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CNG-car, Gasoline substitution</td>
<td></td>
</tr>
</tbody>
</table>

Data Source: Optimierungen für einen nachhaltigen Ausbau der Biogaserzeugung und -nutzung in Deutschland (ifeu et al. 2008)
Summary – Biogas in CHP

- **Biogas** plants are operated – weather independent – for base load supply
- **Biogas** plants can be seen as *state-of-the-art technology*
- Because of low energetic density of source materials, **biogas** should be used *decentralized*
- Using biogas in **CHP-modules** generates *highest GHG-savings*
Important design criteria
Gas Requirements:

- gas pressure
- methane number
- gas temperature/relative Humidity
- heating value fluctuation
- contaminations
  - Sulphur,
  - Halogens,
  - Ammonia,
  - Silica......

In general these are important criteria for Non Natural gases.
Gas – plant:

- Emergency flair
- Gas train
- Blower
- Main valve
- Standard Interface at gas train 80 – 200 mbar
Gas Requirements:

- Gas temperature < 40°C
  - mixture temperature
  - limited by rubber materials of gas train

- Relative humidity < 80%
  - condensate in gas supply
    - filter; pressure regulator; gas train, etc.
  - condensate in engine/intercooler
Example a) and b): follow step 1 - 4:
Through heating of a gas with a dew point of 24°C to:
a) 28°C - reduce the rel. humidity from 100 to 80%
b) 37°C - reduce the rel. humidity from 100 auf 50%

Gas heating does not reduce the water content. It increase the offset to the dew point!
Gas humidity / cooling:
Gas Requirements TI 1000 – 0300:

Condensate in the intercooler
Reduce humidity:

Gas pipe + pre heating → second best solution

- Only reduction of rel humidity; works only at a low gas temperature level
- Water content is not changed
- Avoid condensate drain off in subsequent parts
- Gas cooling because of gas pipe mounted in soil possible but not sure

Active humidity reduction → best solution

- Effective reduction of water content
- Reduce risk of having condensate in the gas system
- Reduce risk of corrosion!
Active gas drying / biogas example:

Schmack 1/Deutschland
1 x JMS 312 GS-B.L
500 KWel

- Gas cooling / drying / dehumidification
- Electr. chiller
Layout example:

Condensate trap at the deepest point

Condensate drain below the blower
Gas Requirements TI 1000 - 0300

Sulfur:

\[ \text{H}_2\text{S} < 700 \text{ mg/10 kWh (without catalyst)} \]
\[ < 200 \text{ mg/10 kWh (with catalyst)} \]

\( \sum \text{H}_2\text{S} < 1200 \text{ mg/10 kWh} \)

\( \Rightarrow \) „modified“ maintenance schedule

\( \Rightarrow \) acidification of oil

\( \Rightarrow \) reduced Oil lubricity

\( \Rightarrow \) \( \text{SO}_x + \text{H}_2\text{O} \) → corrosion

\( \Rightarrow \) deposits in exhaust gas heat exchanger, when temperature is below dew point
Gas Requirements TI 1000 – 0300

Sewage Treatment Plant
Sulfate deposits
exhaust gas temperature
below dew point
Sulfur/ash-deposits in an exhaust gas heat exchanger:
Solution: special biogas heat exchanger

- Cooling down to 180°C or 220°C
- Exhaust gas heat exchanger without pipes at the bottom → no condensate around the pipes
- Big condensate trap (DN50) + falling condensate pipes
International references
Biogas plant Kogel, Germany

No. of units and engine type: 1 x JMC 420 GS-B.L
Fuel: Biogas (potato peelings/pig manure)
Electrical output: 1,413 kW
Thermal output: 751 kW
Steam production: 3 bar(g) 1,037 kg or 698 kW steam production
Commissioning: Year 2002
Biogas plant Præstø, Denmark

No. of units and engine type: 1 x JMS 312 GS-B.L
Fuel: Biogas from pig manure
Electrical output: 625 kW
Thermal output: 726 kW
Commissioning: June 2002
Biogas plant DeQingYuan, China

<table>
<thead>
<tr>
<th>Description</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>No. of units and engine type</td>
<td>2 x JMS 320 GS-B.L</td>
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<tr>
<td>Fuel</td>
<td>Biogas from Chicken Dung</td>
</tr>
<tr>
<td>Electrical output</td>
<td>2126 kW</td>
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<tr>
<td>Thermal output</td>
<td>1234 kW</td>
</tr>
<tr>
<td>Commissioning</td>
<td>Sept 2008</td>
</tr>
</tbody>
</table>
Cow manure “methane-to-energy” plant in Ludhiana - India

Biomass Input: 235 ton/day cattle manure
Electrical output: 1 MW
Organic fertilizer: 35 ton/day

No. of units and engine type: 1 x JMC 320 GS-B.L
AD of biomass – Natural palm Oil - Thailand

Biomass:
- POME - palm oil mill effluent

Basic conditions:
- 12m³/h POME
- Temperature of POME fresh from mill 80°C -> cooling-down in open lagoon

1 x JGS 320 GS-B.L.C

Power output:
1064 kWel.

Commissioning:
2005
AD of biomass – Natural palm Oil - Thailand

Biogas:
H2S content up to 2000ppm
- desulphurization is a must!
- done with a „BioGasClean-System“

Heat demand of the “Palm Oil Plant“:
- steam 22.5 to/hr (3.5bar; 0.5to/FFB)

Steam production:
- with “Palm Fiber”
- in addition with exhaust gas
AD of biomass – Kanoria I + II – India:

Biomass:
- Spent wash – 675 m³/d
  -> effluent removed after fermenting sugar cane molasses (ethanol production)

1 x JMS 320 GS-B.L
1 x JMS 420 GS-N/B.L

Power output:
1034 kWel. / 1416 kWel.

Thermal output:
Water: 586 kWth. / 748 kWth.
Steam: ~ 1350 kg/h; 10bar

Commissioning: 1998 / 2003
Biogas plant Highmark, Canada

No. of units and engine type: 1 x JMC 320 GS-B/N.LC
Fuel: Biogas from cow manure
Electrical output: 1,060 kW
Thermal output: 1,240 kW
Commissioning: March 2004
Thank you for your attention!

Further Questions?