Jenbacher gas engines
a variety of efficient applications

București, October 28, 2010
Thomas Elsenbruch
Global trends ...

Population  Consumption  Energy security  Environment

... Create big challenges
Meeting big challenges ... with big solutions

Diverse
Gas
Biomass
Wind
Solar
Oil
Geothermal
Hydro
Natural gas

Efficient
Driving Cost of Electricity Down
Efficiency
Reliability
Emissions

Affordable, reliable & environmentally responsible
Four types of gas engines

**Type 2**
- Electrical output from 250 to 330KW
- 8 cylinder
- 1,500 rpm (50Hz) / 1,800 rpm (60Hz)
- Delivered engines: more than 850
- Since 1976 in the product program

**Type 3**
- Electrical output from 500 to 1,100KW
- V12, V16 and V20 cylinder
- 1,500 rpm (50Hz) / 1,800 rpm (60Hz)
- Delivered engines: more than 5,000
- Since 1988 in the product program

**Type 4**
- Electrical output from 800 to 1,500KW
- V12, V16 and V20 cylinder
- 1,500 rpm (50Hz) / 1,800 rpm (60Hz)
- Delivered engines: more than 750
- Since 2002 in the product program

**Type 6**
- Electrical output from 1.5 to 4MW
- V12, V16, V20 and V24 cylinder
- 1,500 rpm (50Hz, 60Hz with gear-box)
- Delivered engines: more than 2,200
- Since 1989 in the product program
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)

GE Power & Water - Jenbacher gas engines
14.02.2011
Three basic configurations – customized for each customer’s requirements

• Generator sets
  Reliable on-site power generation on demand
  Energy independence

• Cogeneration systems
  Combined generation of power and heat
  Maximum efficiency in the conversion of energy with minimum emissions

• Container solutions
  Maximum flexibility with fully functional containerized plant
  Compact design and service oriented accessibility
Jenbacher gas engines – what makes the difference?
Details: „Gas engine concept“

**Advantage:**

“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

GE Power & Water - Jenbacher gas engines
14.02.2011
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...)
LEANOX – Now impact from deposits

Oxidation of exhaust gas valve area

Si deposits on spark plug (Biogas/LFG)

No Sensor in hot & critical areas

No risk of deposits on sensors

No aging of sensor
GE’s Jenbacher SPARK PLUG

- Efficient & reliable combustion
- Low emission (NOx)
- Enables high specific output
  - Low specific product cost
  - Low specific service cost

- Low specific spark plug cost
- Long regapping interval
- Low emissions
- High reliability
Biogas Gosdorft/AT achieved 8,740 out of 8,760 oph/y in '05
99.8% Availability with Biogas
average 98+% fleet reliability at Biogas (450+ units)
DIA.NE® XT3 + WIN

- Large screen (10.4” vs 5.7”)
- Help system applicable
- Customer and expert view
- Improved trend function
- Alarm display improved
- Identical information at DIA.NE® WIN

User friendly
Asian characters possible
Easy navigation
Biogas

- More than 1,500 Jenbacher biogas engines with an electrical output of about 1,100 MW worldwide
- Anaerobic digestion produces fuel gas
- Renewable – from organic and animal waste
- 7,000 cows can power 1 MW plant
GE’s Jenbacher gas engine business offers customized biogas solutions

Jenbacher biogas-cogeneration units are core part of biogas plant, but enhanced digester-technology needed

(in case of food waste)
Operational conditions of the fermentation process

- **Temperature**
  - mesophile process: 35 - 40°C
  - thermophile process: 50 - 55°C

- **Retention time**
  - minimum 15 days
  - range: 20 - 50 days
  - common: 25 - 30 days

- **Dry matter concentration**
  - dry fermentation: 20 - 30%
  - wet fermentation: 10 - 15%
  - Absence of oxygen
  - pH value from 6.5 to 7.5

**Gas mixture composition:**
- 50 – 70% methane (CH4)
- 30 – 50% carbon dioxide (CO2)
The whole Jenbacher biogas fleet:

More than 1500 installed engines (1065 MW)
Jenbacher - Biogas engines around the world

Installed in Biogas plants up to 31.12.2009:

- **Germany** 945 engines 527 MW
- **Italy** 161 engines 130 MW
- **Austria** 90 engines 48 MW
- **Netherlands** 69 engines 72 MW
- **Denmark** 46 engines 35 MW
- **Czech Rep.** 40 engines 28 MW
- **Belgium** 32 engines 36 MW
- **Spain** 32 engines 30 MW
- **UK** 11 engines 12 MW
- **Poland** 8 engines 6 MW
- **Hungary** 7 engines 3 MW
- **Slovakia** 6 engines 6 MW
- **Thailand** 42 engines 51 MW
- **India** 37 engines 32 MW
- **Indonesia** 28 engines 30 MW
- **China** 5 engines 5 MW
Investment and Cost of electricity basis

Investment costs – based on European figures:

<table>
<thead>
<tr>
<th>Biomass preparation, digester, Gas holder,…</th>
<th>Containerized Cogeneration plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>75%</td>
<td>25%</td>
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</tbody>
</table>

1000 kWel. Plant - approx. 3,500– 4,000 € per kW

Initial cost of electricity – €cent/kWhel:
- 8000 operation hours per year
- Financing based on 10 years

<table>
<thead>
<tr>
<th>Biomass input</th>
<th>500 kW</th>
<th>1000 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>95% manure</td>
<td>~ 10</td>
<td>~ 8</td>
</tr>
<tr>
<td>2/3 energy crops (Corn cost: 30 €/t)</td>
<td>~ 15</td>
<td>~ 13</td>
</tr>
<tr>
<td>palm oil mill effluent (Asia)</td>
<td>~ 6</td>
<td>~ 4</td>
</tr>
</tbody>
</table>
Biogas plant Kogel, Germany

No. of units and engine type: 1 x JMC 420 GS-B.L
Fuel: Biogas from food waste
Electrical output: 1,413 kW
Thermal output: 751 kW
Steam production: 3 bar(g) 1,037 kg/h steam production
Commissioning: Year 2002
Biogas plant – Bösch Herisau/CH

No. of units and engine type: 1 x JMS 320 GS-B.LC
Fuel: Biogas from pig manure/slaughterhouse/ food waste
Electrical output: 1,065 kW
Thermal output: 1,115 kW
Commissioning: March 2005
Two Jenbacher biogas engines generate much needed energy while helping to solve the farm’s waste problems: The farm owns three million chickens, producing 220 tons of manure and 170 tons of wastewater each day.
Sewage gas

- More than 460 Jenbacher sewage gas engines with an electrical output of more than 330 MW worldwide
- Sewage fermentation produces fuel gas
- Waste water from city of half a million powers 1 MW plant
- Covers 100% of energy needed for sewage plant
Sewage Treatment Plant

Function Diagram Sludge Processing

- **Primary Sludge**: High Loaded Biology
- **Excess Sludge**: Low Loaded Biology

**Pre-Thickener**

**Mechanic Thickener**

**Post-Thickener**

**Mixing-Container**

**Digester**

**Chamber Filter Press**
Utilization of Sewage Gas:

- Sewage gas is compressed in a gas compressor and stored in a gasometer.
- The compressed gas is directed to a heat exchanger where it is used for heating a heat consumer.
- Excess heat is used for sludge drying, making agricultural utilization possible.
- The remaining gas is used to generate electrical energy.

This process illustrates the efficient use of sewage gas for power generation and other utilities.
Specific Sewage Gas Production:

• approx. 16.5 [liter/(population equivalence; day)]
  save value for simple process

• up to 20 - 25 [liter/(population equivalence; day)]
  optimized plant over long period

• up to 33 [liter/(population equivalence; day)]
  short term maximum for optimized plants

Example:
• 500,000 inhabitants
• 1 person 20 liter gas per day
• 10,000 m³ sewage gas/ day
• LHV = 6 kWh/m³
• appr. 1,0 MWel
Experience in sewage gas operation
1988 – 2009

More than 450 engines installed (313 MW)
After a record time major overhaul the plant is ideally equipped for the next 60,000 operating hours: A J312 GS engine provides electricity and heat for a facility that generates 120% of its energy demand. The excess power is fed into the local grid.
Landfill gas

- More than 1,350 Jenbacher landfill gas engines with an electrical output of more than 1,300 MW worldwide
- Organic decomposition produces fuel gas
- 1 million tons of waste power 1 MW plant for more than 15 years
- Waste from US city of 1 million can power 8 MW plant
Experience in Landfillgas operation
1988 – 2009

More than 1,500 engines installed (1.370 MW)
Landfill gas is captured by wells and turned into energy with Jenbacher gas engines
Landfill gas project Maribor/SLO

GE’s Jenbacher Generator-Set in operation since 1998 with one J312 engine producing 625 kWel.
Landfill gas project Arpley/UK

Biggest landfill gas installation with 18 x JGC 320 with 18.6 MW el, in operation since 1999
Optimized plant concepts for biogas installations
Gas Requirements:

• gas pressure
• methane number
• gas temperature/relative Humidity
• heating value fluctuation
• contaminations
  – Sulphur,
  – Halogens,
  – Ammonia,
  – Silica ...
Gas Requirements:

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

- relative humidity < 80%
  (at every gas temperature)
  - condensate in gas supply
    - filter; pressure regulator; gas train,.....
    - condensate in engine/intercooler
Gas humidity / cooling:

- Gas filter filled with condensate water
- Distance to dew-point to small
- Amounts of condensate water are significant
- Taking measures upfront is important
Reduce humidity:

Gas pipe + pre heating $\rightarrow$ 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 by gas pipe in soil helpful, but no controlled condensate removal

Active humidity reduction $\rightarrow$ best solution

- Effective reduction of water content
- Reduce danger of having condensate in the gas system
- Reduce risk of corrosion!
Optimum Layout of gas supply:

Condensate trap at the lowest point

Condensate drain below blower level
**CH₄ - Signal only helpful for engine start:**

For optimized engine start behavior in case of LHV fluctuation:

- Flushing pipe to boiler, flare or buffer tank
- Buffer tank
- DIA.NE® XT: 4 gas types
- Signal for gas type selection 1.....4
Gas Requirements

**Sulfur:**

\[ H_2S < 700 \text{ mg/100}\% \text{ CH}_4 \]

† Standard maintenance schedule

\[ \Sigma H_2S < 2000 \text{ mg/100}\% \text{ CH}_4 \]

† „modified“ maintenance schedule

† acidification of oil

† reduced Oil lubricity

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

† 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
Dew-point-line for $\text{SO}_x$

Cooling of exhaust gas **not below 220°C (180°C) recommended!**

- $\approx 100$ ppm $\text{H}_2\text{S}$ in Fuel gas ($\text{LHV} = 6.5 \text{ kWh/Nm}^3$)

Acid dew-point [°C]

Acid concentration in exhaust gas [mg $\text{SO}_x$/m³]
Oil Requirements

Biogas plant DK
Polymerization of oil

H2S approx. 3400 mg/100% CH4
oil change interval exceeded by 100%

Sulfur
H$_2$S reduction:

- **Air dosing**

- Allocation of air is important
- Consider max. air volume
- H$_2$S reduction is not constant
- The additional air increase corrosion activity

- **Biological H$_2$S reduction**

- Saturate the water content of the gas
- The additional air increase corrosion activity
- H$_2$S reduction is stable!
- Higher investment costs
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
Improve fuel gas quality for landfill gas

Activated carbon adsorber
Fuel gas cleaning system

• Sewage gas and landfill gas frequently contain gaseous silicon compounds
• Quality of the gas has a big influence on the availability of the gas engine

The GE solutions:
Automatic self-regenerating TSA (Temperature Swing Adsorber)
• Prevents formation of silica in the engine
• Increases component lifetimes
• Ensures continuous operation over the engine life
Installation surface:

- Evenness < +/- 1.5 mm
- No foundation necessary
- Dynamic load < 3% installation weight

Elastic elements
Sylomer strips
The variety of heat utilization concepts
Natural gas fueled CHP

- More than 4,200 natural gas fueled cogeneration units with an electrical output of more than 6,100 MW worldwide
- Highly efficient generation of power, heat and cooling
- Minimizes transmission losses
- Enhanced total efficiency – greater than 95%
- Reduces fossil fuel use and greenhouse gas emissions
CHP principle

By the combustion of fuel inside the engine, mechanical and thermal power is generated.

• The mechanical power is converted to electrical energy in the alternator
• The thermal output can be used via heat exchangers to heat up media
The right engine for each individual output requirement

Product line 2010 (50Hz)

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

Natural gas
NOx  500 mg/m³ N
(Dry exhaust gas; based on 5% O₂)

JMS 208 GS-N.L 329
JMS 312 GS-N.L 361
JMS 316 GS-N.L 731
JMS 320 GS-N.L 888
JMS 412 GS-N.L 1064
JMS 416 GS-N.L 1190
JMS 420 GS-N.L 1201
JMS 520 GS-N.L 1489
JMS 612 GS-N.L 2674
JMS 616 GS-N.L 2604
JMS 620 GS-N.L 3319
JMS 624 GS-N.L 3238
JMS 624 GS-N.L 4026
JMS 624 GS-N.L 3865

39% 40.8% 43.4% 45.0% 45.4%
Power plant output range

Product line 2009 (50Hz) – Natural gas NO\textsubscript{X} ≤ 500 mg/m\textsuperscript{3}

Electrical Efficiency up to 45%    Thermal Efficiency up to 50%

Additional benefits with multiple engine approach

- High fuel efficiency: engines constantly running at nominal load and efficiency
- Availability and reliability: stable electrical output
- Flexibility: scheduled maintenance in sequence
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
# Temperature levels of different heat sources

<table>
<thead>
<tr>
<th>Heat Source</th>
<th>Min. Temperature</th>
<th>Max. Temperature</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 = 559 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%
# Natural Gas – CHP/Trigen Segments

## District Heating & Cooling
- Regions: Europe (specially EE), ME
- Incentives: Feed in tariffs, fuel tax exemptions

## Supply of buildings
- Worldwide opportunity
- Incentives: Feed in tariffs, fuel tax exemptions

## Industry
- Worldwide opportunity
- Incentives: Feed in tariffs, fuel tax exemptions, investment credits, import duty exemptions

### Utilities, Municipal Utilities

### Hospitals, Airports, Shopping Malls, Universities, Hotels

### Textile, Chemical, Food, Beverage,...*

*) Any industry where electricity & heat are significant portions of the product cost (e.g. textile, chemical industry, food industry...) Industries with high pressure steam demand are NOT target segments (e.g. pulp & paper)
Zelezara Skopje 30MW – 10 x JMS 620

720 GWh

540GWh

Electrical energy

180GWh

370GWh

Losses

170GWh

166 000t CO₂

85 000t CO₂

~ 50% savings in CO₂ emissions
Zelezara Skopje...

... requires about 300 GWh less primary energy
  • equivalent to the energy contained in 180,000 barrels of oil
  • equivalent to the energy contained in 40,000 tons of coal

... reduces CO$_2$ emissions by 80,000 tons
  • equivalent to the emissions of about 41,000 cars on European roads
  • Equivalent to amount of CO$_2$ absorbed annually by 22,000 hectares of UK forest (850 soccer fields)

Electricity for 45,000 European Households
Heat for 16,000 European Households

Annual comparison with the separate production of electricity on the European Grid and Heat by a natural gas fired boiler
Helping Coca Cola to reduce CO$_2$-emissions

Coca-Cola Hellenic Bottling plants throughout Europe utilizing GE Energy’s Jenbacher CHP engines, eliminating up to 40% of their annual carbon dioxide emissions and reducing operational costs by generating onsite heat and power.
In the Cocoa production facility of Altinmarka in Turkey two JMC320 units running on natural gas provide 2 MW electrical and 2.3 MW thermal output, 1.7 t/h as steam at 8 bar.
Trigeneration with gas engines

- 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
Maximum energy efficiency with trigeneration at Cologne/Bonn Airport

Four of GE’s Jenbacher gas engines surpassed 200,000 operating hours, and generated about 46,000 MWh of electricity annually displacing the equivalent of 360,000* tons of CO2 since 1999.

* According to the airports annual report 2007
Greenhouse application

- More than 500 Jenbacher CO₂ fertilization plants with an electrical output of more than 1,000 MW worldwide
- Powers artificial lighting
- Provides heat for greenhouses
- Cleaned exhaust used as fertilizer
- Overall stronger plant growth
Heat, light and carbon dioxide (CO₂) promote plant growth

Enriching the greenhouse atmosphere with CO₂, keeping the temperature on a constant level and providing sufficient lighting, plant growth and harvest yield can be increased significantly.
CO$_2$-Fertilization in Greenhouses

**Electr. Output:** 526 kW  
**Recoverable Heat:** 700 kW  
**LT-IC heat:** 0 kW  
**Therm. efficiency:** 53.8%  

**Additional benefits:**  
- CO$_2$ for fertilization: 380 kg/h  
- Condensation-Heat from the exhaust gas
Driving innovation: The world’s first 24-cylinder gas engine

The world’s first 4 MW 24-cylinder gas engine is powering one of the largest commercial tomato greenhouses in the Netherlands, offering an economic supply of on-site electrical and thermal power while also employing the engines’ cleaned exhaust gas as a fertilizer.
Global Service 2010

Lifetime Services+ plus for Jenbacher gas engines
Where we are...

Jenbacher gas engine
Global Service

- Madrid, Spain
- Bussolengo, Italy
- Mannheim, Germany
- Vienna/Veresegyház (Central Europe)
- Alblasserdam, Netherlands
- Singapore
- Houston, USA

Hubs

Facts

- 450 GEJ service employees worldwide
- 7 Subsidiaries + 2 Hubs
- Presence > 65 countries
- Field service > 3,000 engineers (GEJ and service providers)
How we understand Service

Life-cycle management: The right service at the right time – throughout the lifetime of your engine
Broad Range of Service Solutions

**Contractual Service**
- Operating & maintaining
- Material stream agreements
- Tele Service

**Spare Parts**
- Genuine parts
- Reprocess. parts
- Emergency packages

**Field Service**
- Inspection & repair
- Minor Overhuals
- Commissioning

**Repair Shop**
- Overhauling
- Reprocessing
- Repairs
- Upgrades
- **Products:**
  - Short blocks
  - Long blocks
  - Gensets

**Training Center**
- **Customer:**
  - Operators
  - O & M
  - Overhauling
- **Staff:**
  - Improve/ Secure skill levels

**Customer Support**
- Remote diagnosis
- Event planning
- 2nd level service
- Helpdesk
- Knowledge base

*Lifetime Services+ plus for Jenbacher gas engines*

*GE imagination at work*