GE Energy

Gas Engines business

Business Presentation
Three main areas of use

Renewables and waste-to-energy utilization
- Reducing CO₂ emissions
- Alternatives to fossil fuels
- Biogas, landfill gas, coal mine gas, special gases (steel gas, wood gas, process gases)
- Jenbacher Types 2, 3, 4, 6
- Waukesha Type APG 1000

Decentralized power generation and cogeneration (natural gas)
- Reliable energy supply for remote areas
- Supporting local power needs
- Avoiding transport and distribution losses
- Enhanced total efficiency
- Jenbacher Types 2, 3, 4, 6, 9
- Waukesha Type APG 1000

Oilfield power (associated petroleum gas)
- Reliability for rugged, remote applications
- Increased exploration, development in remote regions
- Emission regulations driving increased use of natural gas versus diesel-powered gensets
- Jenbacher Types 2, 3, 4, 6
- Waukesha Types VGF, VHP, 275GL+
Low and reliably controlled emissions

- Much lower NOx-emissions achievable than with Diesel technology
- Reliable compliance with emissions limits
- Higher specific output with lower peak pressures and temperatures
- Longer Part life time for cylinder heads pistons.
Type 6 superior combustion concepts

- Top efficiency (up to 46.5%)
- >100 times higher ignition energy than open combustion
- Stable combustion at low emissions
- Robust against glow ignition
- Superior transient performance
- Less sensitive against gas variations
- Standard for large recips (>8MW)

Most robust combustion with prechamber... already prepared for future emission requirements
Improved technologies

Steel piston
- Enhanced design reduces crevice volume
  → Improved efficiency
  → Lower emissions (THC)
- Superior material
  → Higher power output
  → Higher durability

2-stage Turbocharger
- Lower loading per turbocharger
  → Increased efficiency
- Lower stress on turbocharger
  → Higher durability
- Higher charging pressure
  → Increased power output
  → Enables superior combustion

Enhanced Miller Timing
- Improved knocking distance
  → Increased efficiency
- Higher fuel flexibility (MN)
- Higher IC temperature possible
- Advanced ignition parameters
Title V is complex, but to simplify it applies when:
- The site is a “Major Source”

A “Major source” is defined to be a site which:
- exceeds 10 tons of a single Hazardous Air Pollutant (HAP) per yr
- exceeds 25 tons of any combination of HAP’s per yr
- exceeds Major Source Threshold (MST) for non-HAP’s ie: NOx

<table>
<thead>
<tr>
<th>Type of EPA Area</th>
<th>NOx MST (tons per yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attainment area</td>
<td>100</td>
</tr>
<tr>
<td>Non-attainment area – marginal</td>
<td>100</td>
</tr>
<tr>
<td>Non-attainment area – moderate</td>
<td>100</td>
</tr>
<tr>
<td>Non-attainment area – serious</td>
<td>50</td>
</tr>
<tr>
<td>Non-attainment area – severe</td>
<td>25</td>
</tr>
<tr>
<td>Non-attainment area – extreme</td>
<td>10</td>
</tr>
</tbody>
</table>
Many modern natural gas engines are often available with either a low NOx or regular NOx setup:
- Typically low NOx is in the range of 0.6 gm/bhp-hr
- Typically regular NOx is in the range of 1.1 gm/bhp-hr
- Generally there is an efficiency penalty associated with low NOx machines

Assuming that the engine operates for 8000 hrs per year this results in the following Potential-to-Emit (PTE) for a 1MW regular NOx machine:
- \(8000 \text{ hrs} \times 1.1 \text{ gm/bhp-hr} \times 1340 \text{ bhp/MW} \times (1.1 \times 10^{-6}) \text{ tons/gm} = \text{approx 13 tons/yr/MW}\)
- Based on the above if in a serious non-attainment area we would need NOx emission control equipment if size exceeds \(\frac{25/13}{2} \text{MW of natural gas generation (assuming there are no other sources of NOx on the site such as boilers)}\)
For natural gas engines the available emission control technologies are:

- **Oxidation Catalyst (DOC)** to deal with CO and unburned Hydrocarbons - odor
- **Selective Catalytic Reduction (SCR)** to meet NOx requirements
Fuel flexibility and tailor-made solutions

- Landfill gas
- Sewage gas
- Oilfield applications (Associated petroleum gas)
- Special gas
- Biogas
- Greenhouse application
- Island mode
- Coal mine gas
- Cogeneration (Natural gas)
- Industrial power plant options

Fuel flexibility and tailor-made solutions provide options for various gas applications, including industrial power, cogeneration (Natural gas), and greenhouse applications, among others.
Design parameters/flexibility

Methane Number

Emissions

Climate Conditions

Altitude
Ambient Temperature

Focus electrical efficiency/ thermal efficiency

Choose the best solution with/for the customer
## Gas Quality Limits To Need Treatment

<table>
<thead>
<tr>
<th>Equipment</th>
<th>H2S</th>
<th>Siloxanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>MicroTurbine</td>
<td>&lt;5,000 ppmv</td>
<td>&lt;100 ppbv</td>
</tr>
<tr>
<td>IC Engine</td>
<td>&lt;100 - 500 ppmv</td>
<td>&lt;100 - 1,000 ppbv</td>
</tr>
<tr>
<td>Boiler</td>
<td>&lt;100 - 500 ppmv</td>
<td>&lt;500 - 2,000 ppbv</td>
</tr>
<tr>
<td>Vehicle Fuel</td>
<td>Non-Detect</td>
<td>&lt;100 ppbv</td>
</tr>
</tbody>
</table>

*Leaders in Biogas Technology*
Hydrogen Sulfide Removal Systems

Digester or Landfill → Hydrogen Sulfide Removal → Gas Compression/Moisture Removal → Siloxane/VOC Removal

MicroTurbines → IC Engines → Boilers
Budgetary Biogas System Costs

- **50scfm Systems**
  - Low Pressure Ranges From: $200,000 to $325,000
  - High Pressure Ranges From: $230,000 to $340,000

- **100scfm Systems**
  - Low Pressure Ranges From: $230,000 to $400,000
  - High Pressure Ranges From: $240,000 to $380,000

- **300scfm Systems**
  - Low Pressure Ranges From: $270,000 to $580,000
  - High Pressure Ranges From: $310,000 to $600,000

*Leaders in Biogas Technology*
Gain an innovative edge with CHP

Combined heat and power can cut your energy use* by more than 40 percent

* Naturally occurring energy sources such as natural gas, crude oil, coal, wood without loss of downstream conversion and transport processes
J420 B09 (CR 13.5:1) MN > 70
60°C – 90°C / 140°F – 194°F

focus $\eta_{el}$

Eta_el 43.4%
P_th: 1,518 kW
Eta_total: 86.4%
Type 6 ... Hydraulic Integration options

- 2 stage oil cooler option
- Various predesigned on-skid variants
- Enhanced heat collection for any application
- Ability to cover water return temperatures from 35 to 85 °C
- Ability to cover water forward temperature from 70 to 130 °C
- Efficiencies up to 92%

Flexible integration improves total efficiency
Outstanding reliability enables highest availability

**Examples**
- Biogas Seckach, Germany, 1 x J412 biogas - 99.7%
- Fangel Bioenergi APS, Denmark, 1 x J420 biogas - 99.5%
- Pezza Soc. Agr., Italy, 1 x J416 biogas - 99.3%

**Availability**
- The outstanding **Reliability** of Type 4 results in lowest unscheduled downtime.
- The **Easy to maintain** concept enables lowest scheduled downtime.
- This results in outstanding **Availability** and short return of investment for the customer.

**Average of remotely connected engines have shown an availability of > 98%**
Jenbacher core scope Type 4

Factory tested system solution
Type 4 supports your flexible power generation needs worldwide

1 x containerized J420 fueled with biogas at Kogel, Germany.

11 x J420 fueled with landfill gas at Pinto, Spain.

2 x containerized J420 fueled with coalmine gas at Huainan, China.

20 x J420 fueled with natural gas at El Huemul, Argentina.

2 x J420 fueled with sewage gas at Bergen WWTP, USA.

2 x J416 fueled with natural gas with CO₂ fertilization in The Netherlands.
Driving innovation ... the world’s first 24-cylinder gas engine

The world’s first Jenbacher 4 MW 24-cylinder gas engine of GE is powering one of the largest commercial tomato greenhouses in the Netherlands, offering an economic supply of onsite electrical and thermal power while also employing the engines’ cleaned exhaust gas as a fertilizer.
Type 6 starting sequence and loading

5 min. start-up time ... ready for ancillary segment
J620 - Island mode performance

Boundary condition:
Recovery time: < 10s
Frequency deviation: < 8%

Load steps to full power:
620 F117: 4
Other: 9

J620F117 out performs other engines
Lifetime Services
The right service at the right time – throughout the lifetime of your equipment