Fast Start – Flexible Natural Gas Recip Technology for Municipal Applications

Oct 2017
GE Power: Generation Portfolio

Wide range of products within GE Power to meet efficiency expectations
Distributed Power portfolio

GE Recips, Jenbacher*

Technology
- 0.3-10 MW recips

Applications
- Gas Power
- Gas CHP

Differentiators
- Efficient
- Flexible

Installed Base
- 16,000 engines
- 20 GW

Jenbach, Austria
- ~1,500 employees
- ~1,200 engines / year

*Indicates a trademark of the General Electric Company
GE’s Distributed Power portfolio

GE Gas Engines (kW) – 60 Hz

- **J920**
- **J624**
- **J620**
- **J616**
- **J612**
- **J420**
- **J416**
- **J320**
- **J412**
- **J316**
- **J312**
- **J208**

**Type 9** ... 49.9%

**Type 6** ... 46.3%

**Type 3&4** ... 40-43.4%

**All Engines:**
Performance based on ISO conditions (25°C, 30% RH, 100m asl);
NG fuel with MN>80, PF @ 1.0, Gen. up to 11.5 kV, NOx @ 500 mg/Nm³ (@ 5% O2).
Efficiency with 5% tolerance according to ISO 3046 and based on LHV, all direct driven pumps incl.
Global Mega Trends
Mega trends driving global growth

1. Emerging economies
2. Abundant gas
3. Renewables
4. Distributed power
5. Digital
6. Hybrid models

Renewables drive the need for Fast Start, NG-DG solutions
Hybrid

Solution: 10MW/4.3MWh ES + 50MW J920s

Value: Dispatch economically spin support, black start for critical facilities

Enhanced features:
- Zero Pmin, 10 to 50 MW range, 10 MW of PFR, 50 MW spin, ~8MVAR w/o fuel burn, instant start, 25 MW of high speed regulation, Black Start configured

Recip Fast Start Model

Muni & Coop Connection-selected
Opens up reg mkt … Provide “spin” when shut off + “reg”

Spin payment = $5/MWh x 50MW x 7500 = $1.9M
Reg payment = $20/MWh x 15MW x 8000 = $2.4M

Super peaker upgrade … 50MW, 6ms response or 15MW / 6MWh + 10yr battery life guarantee

$4M Revenue, 3 year payback in Markets … or Diesel-like response in Critical Power segment
Applications and solutions for critical onsite power: microgrids & hybrid solutions

Hybrids (generation + storage)

- Application suitability for utility scale (example shown) or behind the meter
- Onsite power capabilities:
  - Uninterruptable power
  - Power quality
  - “0 sec” generation response
  - Frequency/voltage support
  - Reduced fuel use

World’s first battery storage + gas turbine hybrid: The EGT Hybrid

- 10MW Li Power Battery
- GE Brilliant 1.25MVA Inverters
- OpFlex Hybrid Upgrade Package
- Mark Vie based control system
- Proprietary software to balance state of charge
- Performance backed by GE
Recip Engine Advantages
Typical Environmental footprint summary

NOX mg/Nm³ @5% O₂:
• Engine out: 500mg or 250mg
• Less than 25mg or 7.5ppm with after-treatment

Water usage:
• Closed loop engine circuit uses no water
• Radiator cooling circuit ~3L per week

Noise:
• 75dB(A) @ 10m standard
• 55dB(A) @ 10m option

Aesthetics:
• Low silhouette with no visible emissions
Plant flexibility while keeping efficiency

Constant high simple cycle plant efficiency – 50MW example

- Engine dispatching to maintain plant efficiency
- Run individual engines at part load with minor effect on total plant efficiency
- Suitable for grid firming (ancillary services)
- Plant turn down to 20% load or 2% with one engine

Meet power reliably while maintaining efficiency

Quantity of Shafts: Analysis

Example: 6 x 9MW units

3 x 18MW units

1 x 50MW

- Modularity provides lower plant output drop if unit trips
- Statistically unlikely more than 1 or 2 units tripped at the same time
- Drives high plant output reliability, availability & redundancy
Fast start capability

- Start-up in 3 mins with pre-heated engine
- Starting ramp rate of >100kW/s

100% load within 3 mins ... 10% load after <45s
Designed for flexible operation

Customers face dynamic environments, GE understands their challenges and economics

The J920 FleXtra solution:
- Full plant output synchronizing
- Multiple design & operating modes
- Flexible solutions for dynamic markets
- High efficiency at part load
- Fast load ramping and shedding
- 10MW unit: 20% load on unit
- 100MW plant: turn down to 2% load

J920 FleXtra has superior load-following capabilities compared to turbines
Creating customer value

Best-in-class SC efficiency

Unique features create value

- Fast-start for peak grid price realization
- Redundancy for high availability
- Redundancy for max revenue capture
- No water usage

6% fuel efficiency delivers $2.3M/yr fuel savings

($5/MMBtu, 6000hr/yr, 55MW plant)

1. 60 Hz, ISO, no tolerance, pf 1, HHV, genset terminals
Source: Gas Turbine World, Product Brochures from websites
Performs better on hot days & at high altitudes

**Power vs. temperature**
Aero w/ EVAP - 60 Hz, 0m, 60% RH

**Power vs. altitude**
Aero w/ EVAP - 60 Hz, 25°C, 60%RH

**Efficiency vs Part Load (%Diff)**
Aero, HD and Recips – EVAP, 60Hz, 25C, 60%RH

Twin stage turbo charging performs no matter what the conditions
Wastes no water

Water usage - kpph (kilo pounds per hour)

- Simple cycle gas turbine: $70k/yr*
- Combined cycle gas turbine: $350k/yr*
- J920 reciprocating engine: $0/yr

Gas turbines includes NOx water, Sprint water and chiller water
*Excluded the investment for Water Treatment Plant

J920 FleXtra eliminates water consumption in power plants
Can be deployed 2x faster than CC plants

Deploy to COD cycle advantage of J920: 100 MW project (example)

- Spark spread 3c/kWhr

Large Recips 15-18 months COD

Combined Cycle 24-30 months COD

Delivering the J920 12-18 months faster than CC. A J920 plant could already generate ~$14 million of electricity revenues before a CC goes online.

~$14 Million extra per year in electricity revenues

Faster commissioning provides +$14 M US with 100 MW J920 plant
Maximizing total efficiency with cogeneration

If total efficiency is important?

Hot water temperature
194 – 266°F
At 25 MMBtu/hr

Return temperature
122 – 176°F

Steam Product with HRSG
~6,000 lb/h @ 185 psi w/ 185°F feed water
~8,000 lb/h @ 75 psi w 185°F feed water

J920 Recoverable Heat: 8.5 to 10.5 MWth

Maximum fuel efficiency over 90-95%
**GE’s Jenbacher J920 FleXtra**

### Specification: B801 & B8101 models

<table>
<thead>
<tr>
<th>Specification</th>
<th>B801</th>
<th>B8101</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>Nat. gas</td>
<td></td>
</tr>
<tr>
<td>Fuel gas pressure</td>
<td>130 psig</td>
<td></td>
</tr>
<tr>
<td>MN</td>
<td>&gt;70</td>
<td></td>
</tr>
<tr>
<td>Gen. Voltage 60Hz</td>
<td>13.8 kV</td>
<td></td>
</tr>
<tr>
<td>Start-up to Full Load</td>
<td>3 min</td>
<td></td>
</tr>
<tr>
<td>No kW Derating up to</td>
<td>118 F, 2000 m (6,562 ft)</td>
<td></td>
</tr>
<tr>
<td>Std. NOx emissions</td>
<td>1.2 g/kWh</td>
<td></td>
</tr>
<tr>
<td>Std. Maintenance Int.</td>
<td>40 / 80 k oh</td>
<td></td>
</tr>
<tr>
<td>Lube oil consumption</td>
<td>&lt;0.3 g/kWh</td>
<td></td>
</tr>
<tr>
<td>Oil change interval</td>
<td>4-6000 oh</td>
<td></td>
</tr>
<tr>
<td>Steam: B8101 from exhaust only</td>
<td>~6,000 lb/h @185 psi – 190°C, 85°C Feed Water</td>
<td>~8,000 lb/h @75 psi - 153°C, 85°C Feed Water</td>
</tr>
<tr>
<td>Hot Water: B8101 from HT water &amp; exhaust</td>
<td>Provide 194°F ~25 MMBtu/hr to the plant</td>
<td></td>
</tr>
</tbody>
</table>

### Units

<table>
<thead>
<tr>
<th>Units</th>
<th>J920 FleXtra (60Hz / 900 rpm) with 5% tolerance on fuel consumption</th>
<th>J920 FleXtra (60Hz / 900 rpm) with 0% tolerance on fuel consumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>El. Output</td>
<td>kWel</td>
<td>9,350</td>
</tr>
<tr>
<td>El. Efficiency (LHV)</td>
<td>%</td>
<td>49.9</td>
</tr>
<tr>
<td>Heat Rate (LHV)</td>
<td>BTU/kWh</td>
<td>6,838</td>
</tr>
<tr>
<td>El. Efficiency (HHV)</td>
<td>%</td>
<td>45.0</td>
</tr>
<tr>
<td>Heat Rate (HHV)</td>
<td>BTU/kWh</td>
<td>7,590</td>
</tr>
<tr>
<td>Thermal Output</td>
<td>kWth</td>
<td>7,510+</td>
</tr>
<tr>
<td>Total Efficiency (LHV)</td>
<td>%</td>
<td>90-95</td>
</tr>
<tr>
<td>Total Efficiency (HHV)</td>
<td>%</td>
<td>81-86</td>
</tr>
</tbody>
</table>

Output and efficiency at generator terminals, ISO 3046, Nat. Gas MN >80, Power Factor 1.0, 500 mg/Nm3 (@ 5% O2) NOx, Efficiency at LHV/HHV with ratio 1.11, all direct driven pumps incl., numbers with 0% tolerance are expected numbers.

### Dimensions

<table>
<thead>
<tr>
<th>Engine</th>
<th>Lengths</th>
<th>Width</th>
<th>Height</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>27.5 ft</td>
<td>10.5 ft</td>
<td>11.2 ft</td>
<td>201,000 lb</td>
</tr>
<tr>
<td>Generator</td>
<td>17.1 ft</td>
<td>8.2 ft</td>
<td>9.5 ft</td>
<td>130,000 lb</td>
</tr>
<tr>
<td>TC Module</td>
<td>10.5 ft</td>
<td>12.8 ft</td>
<td>16.7 ft</td>
<td>57,300 lb</td>
</tr>
</tbody>
</table>
Power Plant Solutions
BoP Systems

GE Jenbacher will work with the EPC & Customer’s DoR...to optimize value
Multi Unit Recip Power Plant Concept

<table>
<thead>
<tr>
<th>Output</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gen-set</td>
<td>&lt;50MW</td>
</tr>
</tbody>
</table>

Exhaust system with SCR, silencer and stacks
PowerHouse Building
Electrical Workshop
Pump room
Tank farm
Fin fan cooler

GSU: 64 meters
64 meters

Output Efficiency
Gen-set <50MW 49.9%

Electrical Workshop
Pump room
Tank farm

Fin fan cooler

GSU: 64 meters
64 meters
The Value of Prefabricated Modular Power Plants

1. Lowers total capex costs
   ... potential to reduce capex costs significantly compared to traditional power house design

2. Reduces execution risks
   ... GE has already delivered forty-eight (48) J624 containerized power plants globally

3. Provides single point-of-responsibility
   ... modular plant shipped to site with assembly supervision by our team

4. Reduces performance risk
   ... complete warranty coverage for complete prefabricated system, not just the genset

5. Get power plant online faster
   ... Can go from notice-to-proceed to COD in 47 weeks, installation time is ~1 week / container

6. Increases residual value which helps achieve better financing rates
   ... power plant is modular & movable, enables better underwriting
Overview of J624 Prefabricated Solution

Key facts

✓ One containerized package = 3 modules
  • Engine Module
  • Ventilation Module
  • Auxiliary Module
✓ Electrical Output = 4,373 kW
✓ Heat Rate = 8,603 BTU/kWh (HHV, 0% Tolerance)
✓ Dimensions of single module = 56 ft x 10 ft x 10.5 ft
✓ Footprint of 1x engine container = 1098 sqft
✓ Assembly supervision & responsibility = GE and Partners
✓ Assembly time = 1 week per containerized package
✓ Sound = 75 dB(A) @ 33 ft
✓ Number of J624 containers delivered = 48 globally

Delivering an entire power plant
J920 PowerPack solution overview

Advantages:
• 10MW to 80MW
• Pre-engineered solution
• Pre-fabricated in the factory
• Pre-tested modules
• Fast installation <8 wks
• Fast commissioning <8 wks
• Less than 16 months order to COD
• Sound 75dB(A) at 10m as standard, lower if required
• Remote start/stop & surveillance reducing labour requirements
• Modular: mobile & easy MW additions
• Surveillance
• Perfect for Remote sites or power islands

J920 PowerPack ... fast, flexible power
PowerPack complete prefabricated modular plant solution

- Stack with silencer
- Lube oil & urea tanks
- Step-up transformer
- PCC
- Plant control room, parts, storage, workshop container

PowerPack provides a market value with Efficiency...time onsite, schedule management and heat rate
J920 FleXtra Reference Projects

Sky, USA
Sky Global Partners
Peaking Power
6 units

Stapelfeld, GER
HanseWerk Natur
CHP & Peaking
1 unit

Kiel, GER
SW Kiel
CHP & Peaking
20 units

Roma, ITA
Acea
CHP district heating
2 units

Rosenheim, GER
SW Rosenheim
CHP & Peaking
1 unit

<table>
<thead>
<tr>
<th>Units</th>
<th>COD</th>
<th>Operating hours</th>
</tr>
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<tbody>
<tr>
<td>GER</td>
<td>1</td>
<td>2013</td>
</tr>
<tr>
<td>GER</td>
<td>1</td>
<td>2015</td>
</tr>
<tr>
<td>USA</td>
<td>6</td>
<td>2016</td>
</tr>
<tr>
<td>ITA</td>
<td>2</td>
<td>2017</td>
</tr>
<tr>
<td>GER</td>
<td>20</td>
<td>2018</td>
</tr>
<tr>
<td>Accumulated</td>
<td>30</td>
<td>24,634</td>
</tr>
</tbody>
</table>

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Sky Global Partners – 6 x J920s in Texas

- 51 MW in operation
- 49.3% electrical efficiency (ISO)
- Sky Global IPP selling power to San Bernard Coop
- GE provided engines, SCR, Oxidation Catalysts, Silencers, Multi-year O&M agreement
Prefabricated J624 reference projects North America

Yukon site – 2 units operating since 2014

Alabama site – 4 units assembled in February

A proven track record of delivering our modular power plants
In Summary

• Recips pushing the bar for flexible power
• Highest class simple cycle efficiency
• Twin stage turbocharging = no derating up to 118°F
• Modular prefabricated design for ease of transport, installation, & service access
• High plant flexibility & availability
• New horizons with hybrid energy storage systems
• Backed by long term service agreements

Flexible power generation for your needs