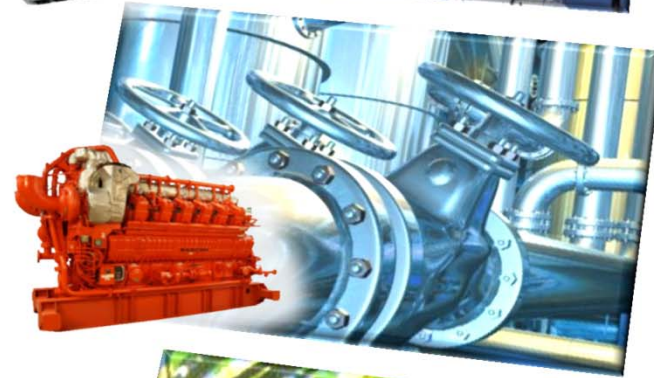


GE Energy

Gas Engines  
business

Business  
Presentation



# Three main areas of use

## Renewables and waste-to-energy utilization

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- Reducing CO<sub>2</sub> 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)

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- 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

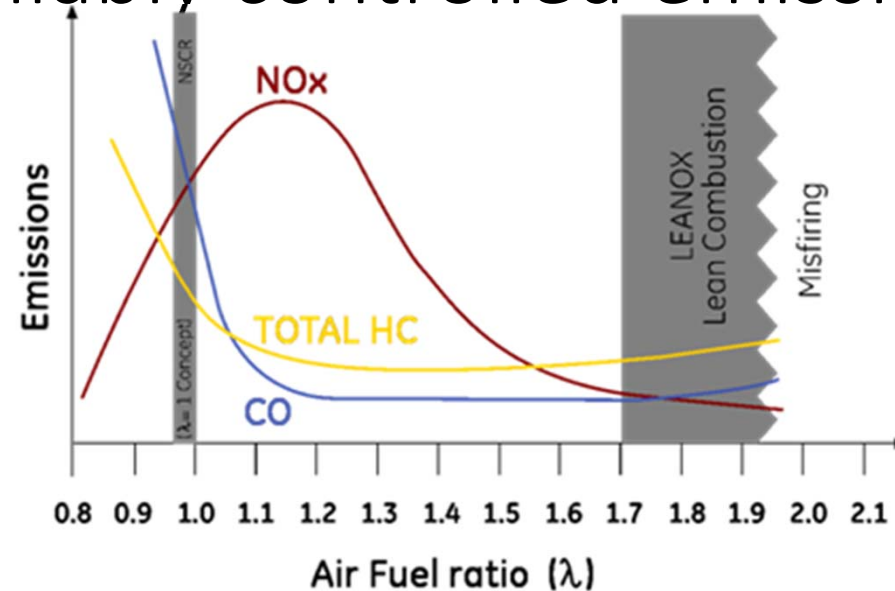
## Oilfield power (associated petroleum gas)

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- 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

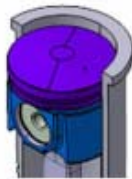
- Top efficiency (up to 46.5 %)
- >100 times higher ignition energy than open combustion
- Stable combustion at low emissions
- Robust against glow ignition
- Superior transient performance
- Less sensitive against gas variations
- Standard for large recip (>8MW)



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



## Improved technologies



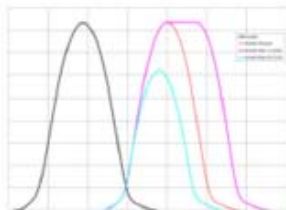
Steel piston

- 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

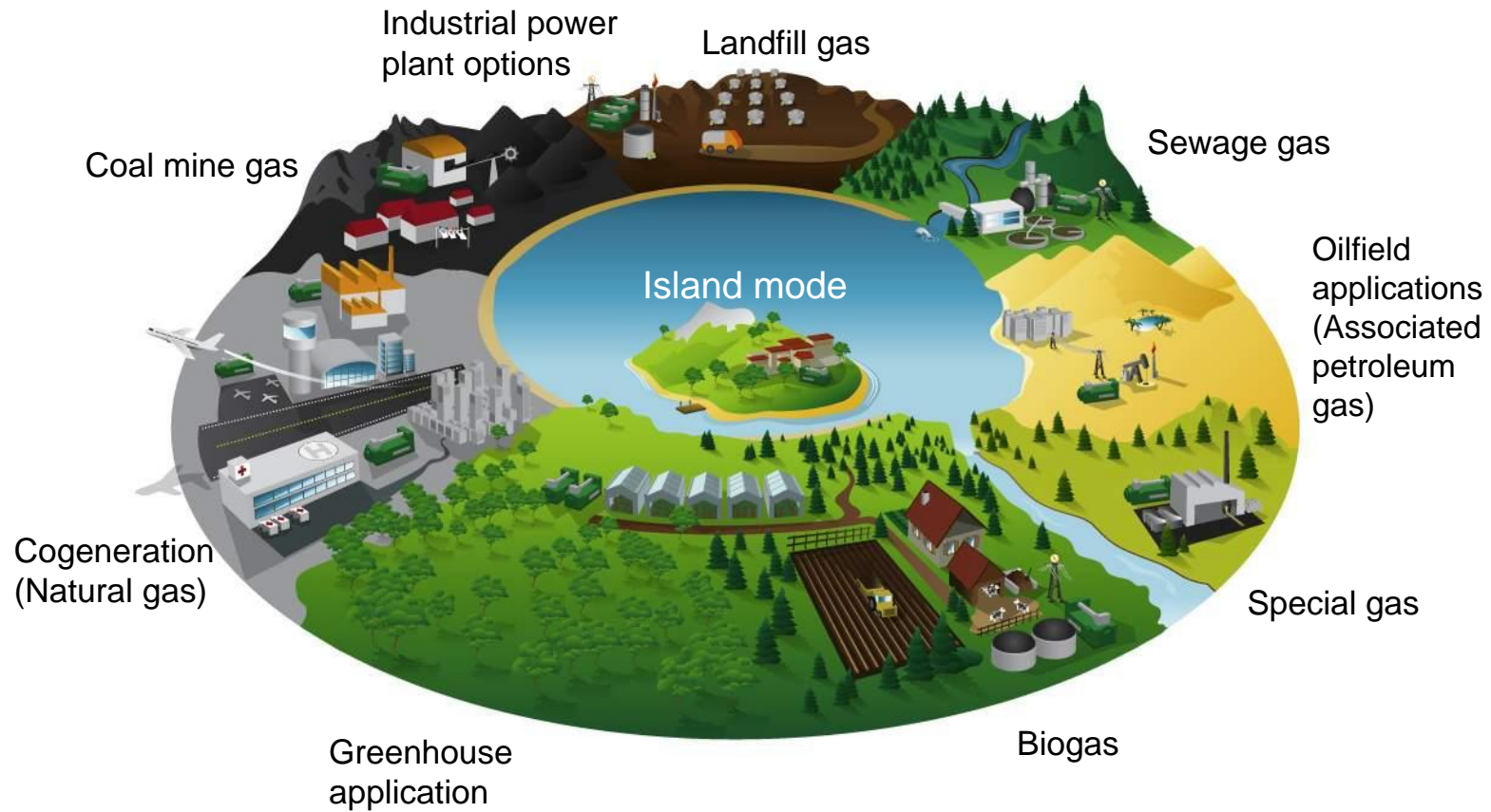
Type of EPA Area	NOx MST (tons per yr)
Attainment area	100
Non-attainment area – marginal	100
Non-attainment area – moderate	100
Non-attainment area – serious	50
Non-attainment area – severe	25
Non-attainment area – extreme	10

- 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:
  - $8000 \text{ hrs} * 1.1 \text{ gm/bhp-hr} * 1340 \text{ bhp/MW} * (1.1 * 10^{-6}) \text{ tons/gm} =$   
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  $25/13 =$  approx 2MW of natural gas generation (assuming there are no other sources of NOx on the site such as boilers)

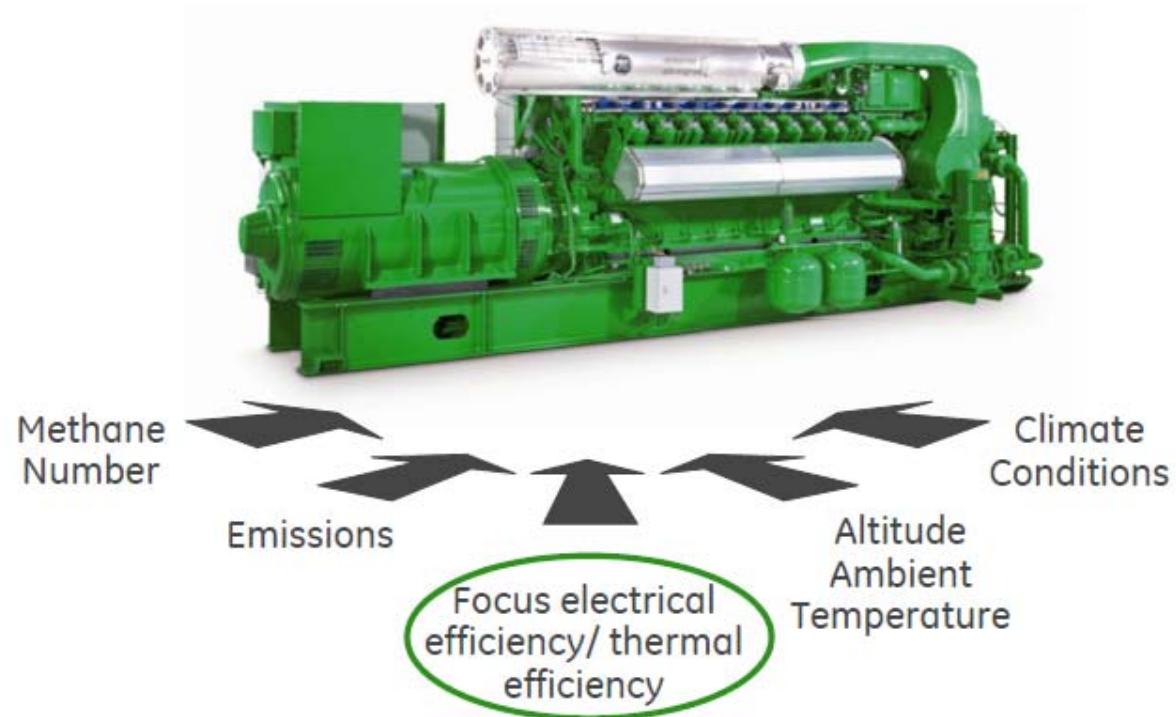


- For natural gas engines the available emission control technologies are:
  - **Oxidation Catalyst (DOC)** to deal with CO and unburned Hydrocarbons - odor
  - **Selective Catalytic Reduction (SCR)** to meet NOx requirements

# Fuel flexibility and tailor-made solutions



## Design parameters/flexibility



Choose the best solution with/for the customer





## Gas Quality Limits To Need Treatment

Equipment	H2S	Siloxanes
MicroTurbine	<5,000 ppmv	<100 ppbv
IC Engine	<100 - 500 ppmv	<100 - 1,000 ppbv
Boiler	<100 - 500 ppmv	<500 - 2,000 ppbv
Vehicle Fuel	Non-Detect	<100 ppbv

*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





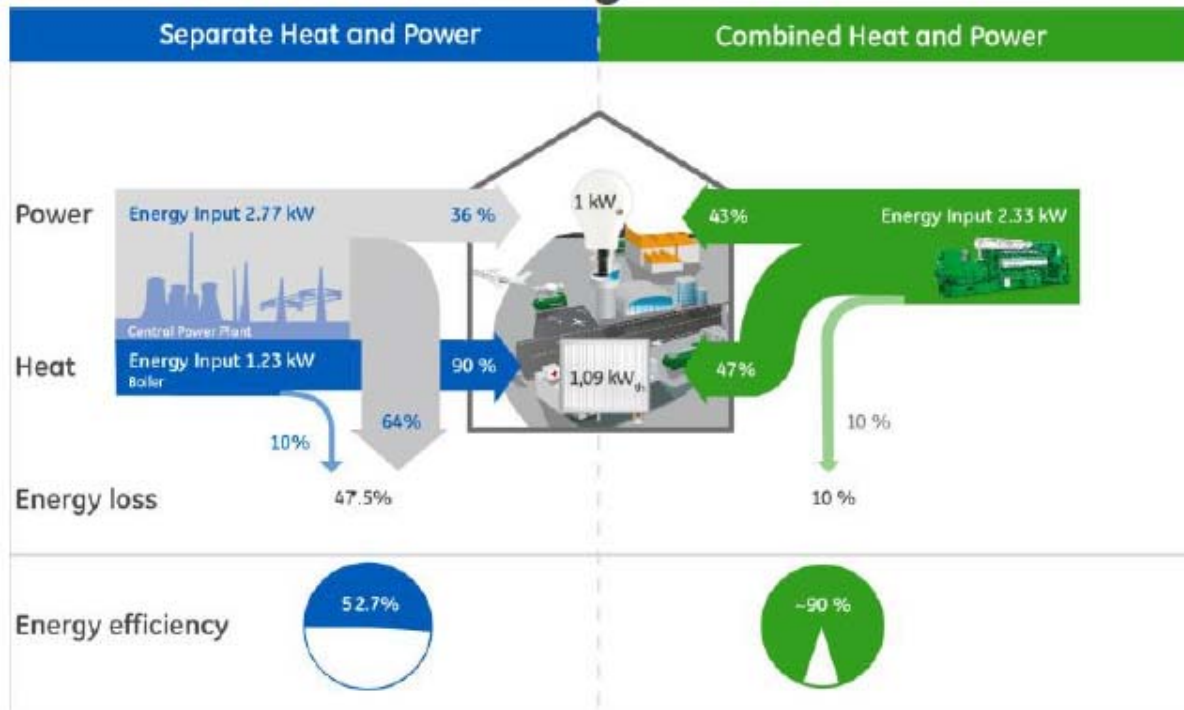
## Budgetary Biogas System Costs

- 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*

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# Gain an innovative edge with CHP



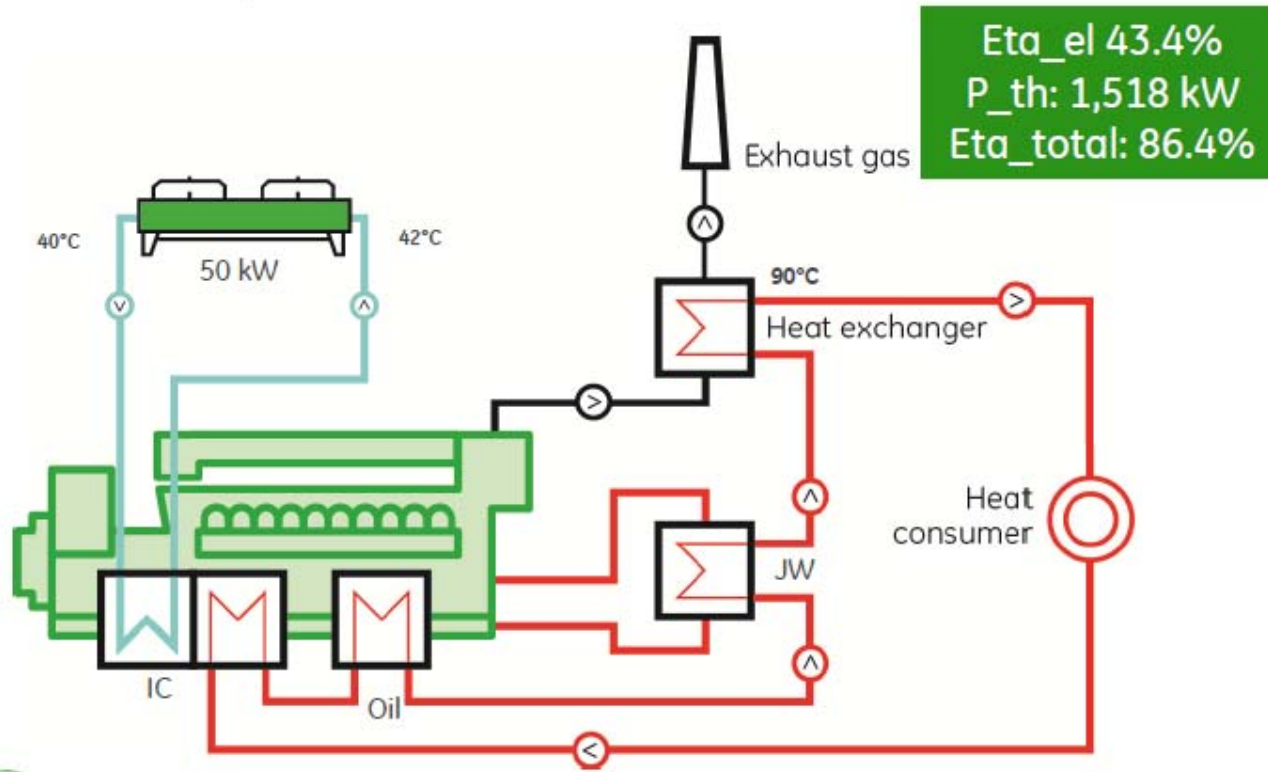
**Combined heat and power can cut your energy use\* by more than 40 percent**

\* Naturally occurring energy sources such as natural gas, crude oil, coal, wood without loss of downstream conversion and transport processes

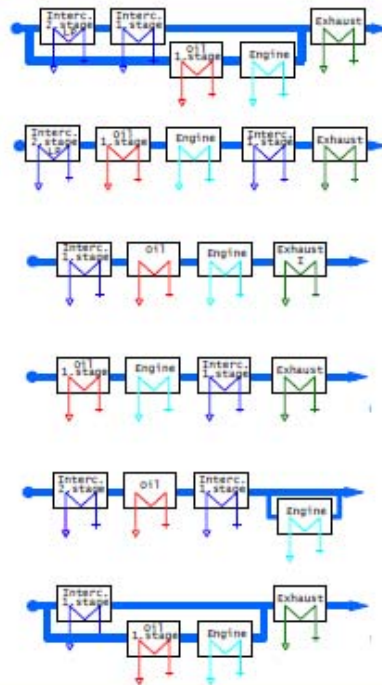


J420 B09 (CR 13.5:1) MN > 70  
60°C – 90°C/ 140°F – 194°F

focus  $\eta_{el}$



## 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



Picture: Example Type 4 biogas container

### 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%

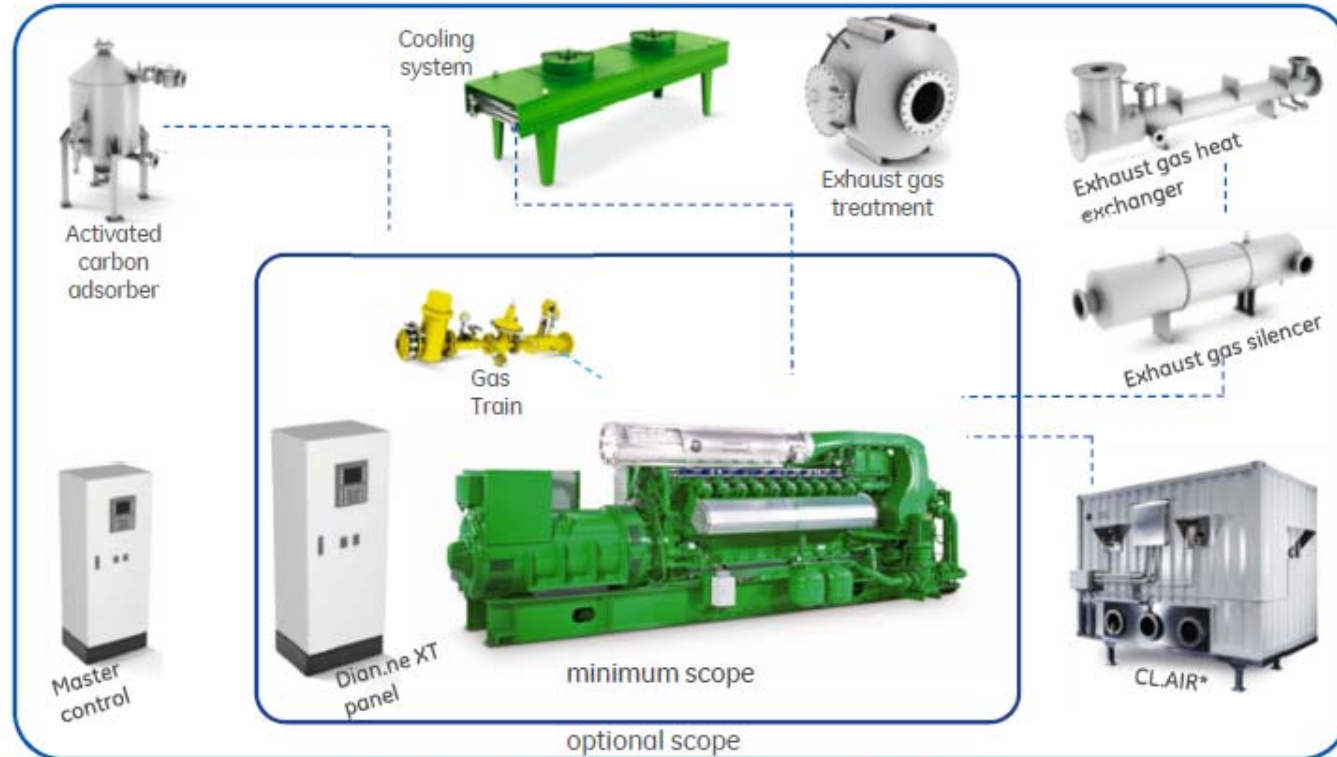
### Availability

- 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 ElHuemul, Argentina



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



2 x J416 fueled with natural gas with CO<sub>2</sub> fertilization in The Netherlands

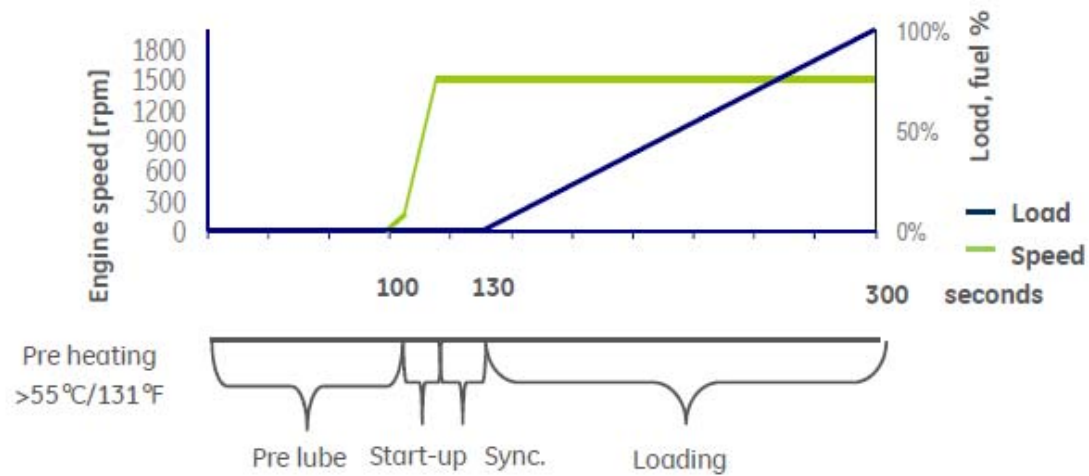


## Driving innovation ... the world's first 24-cylinder gas engine





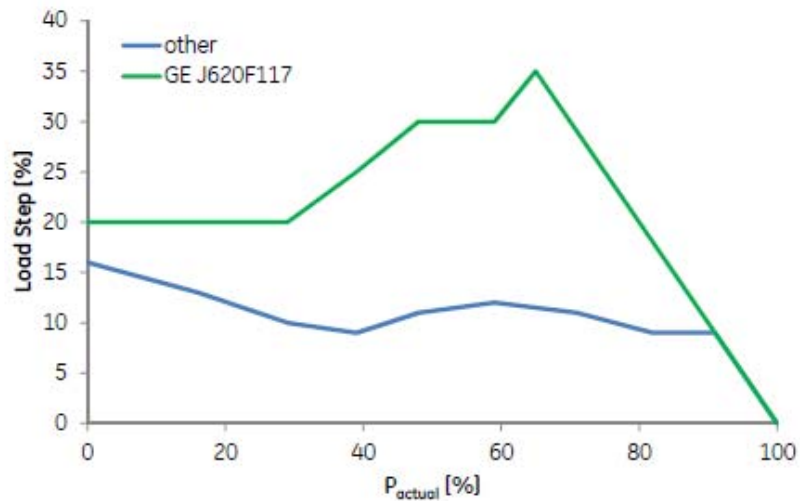
## Type 6 starting sequence and loading



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

