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Overview of Gas Products & Applications

Michael Dressler / Annika Böhm

CES Product Line Management

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Agenda

- Why Gas Engine Power Plants / Market Trends
- What is important for our customers
- Products and technologies
- Applications

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Why Gas Engine Power Plants Market Trends

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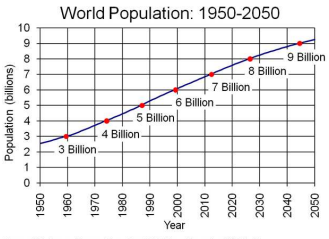
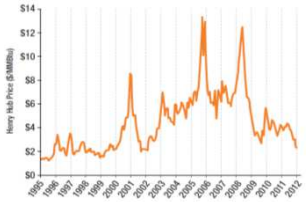
Why Gas Engine Power Plants



Source: U.S. Census Bureau, International Data Base, December 2010 Update.



Nat. Gas Price. ***Source:*** *EPA, « CHP , A clean energy solution »*

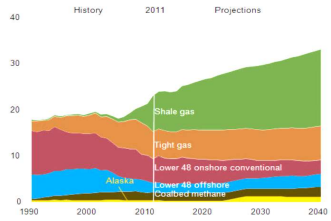
Growing demand for energy

Gas is widely available

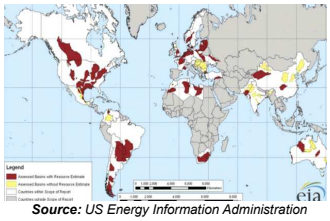
Gas is clean

Gas is cheap

Gas is perfect for load management and energy storage



Natural gas production by source, 1990-2040 [tfz³]
Source: EIA (2013): Market Trends — Natural Gas



Source: *US Energy Information Administration*

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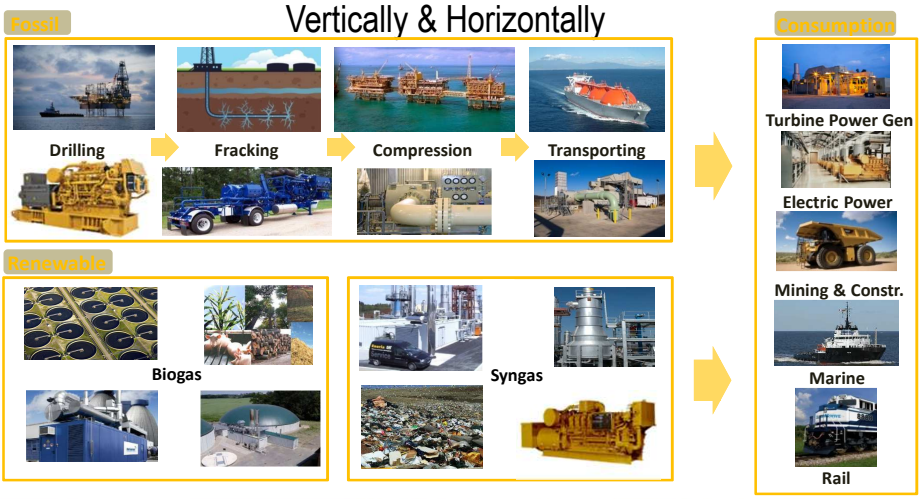
Gas, a Growing Opportunity:



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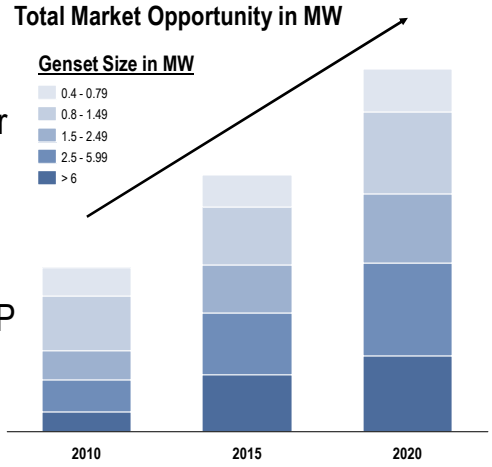
Market trends

- Growing market for gas power generation
- Biggest growth for the larger power plants
- Stable share of pipeline gas
- Increasing share of load management, stand-by, CHP and CCHP



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What is important for our Customers?

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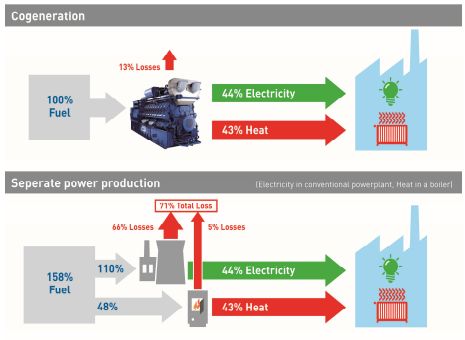
Advantages of Gas Gensets for Power Production

- Decentralized energy production The energy is produced were it is needed and according to the consumers needs (heat led or power led)
- No transportation losses
- Total efficiency up to 95 %. Cost decrease through higher efficiency of the complete energy supply
- Independency from outages or grid problems. Load management
- Use of waste heat for heating, cooling, steam or heat recovery for power generation

CHP - Independency with higher efficiency



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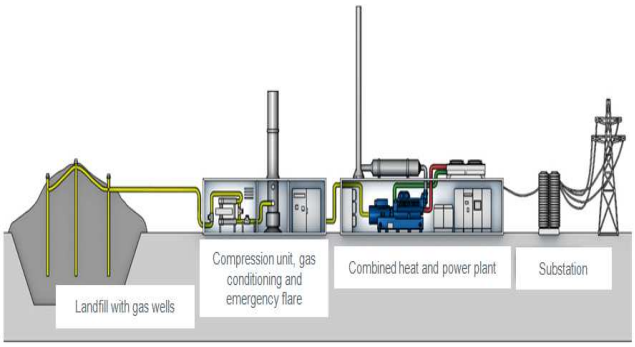
Advantages of Gas Gensets for Power Production

- Possibility to use energy resources which are not used otherwise:
- Landfill and sewage gas
- Coal mine gas
- Digester biogas from food waste or other waste
- Propane
- Pyrolysis gases from waste and other syngases

Use of waste energy sources



Key buying criteria

Differ for customers, markets and applications:

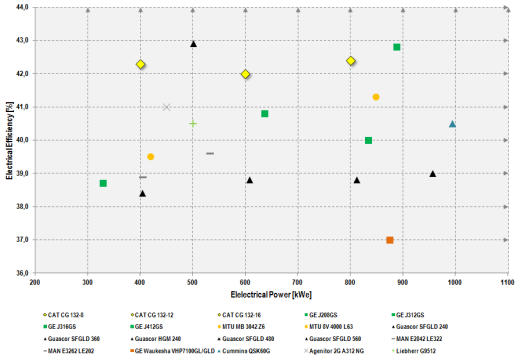
- Life cycle costs like Efficiency; Maintenance costs …
- Investment
- Fuel availability or earnings on gas or biomass utilization
- Availability
- Subsidies
- Others (Dynamic load response, emissions, …)

Consequences of LCC/project driven approach

- Optimization of all products and projects mainly for LCC (Life cycle costs) >> That means first of all to get the best efficiencies
- Derating factors are normally not used at CES even at extreme site conditions. We have different turbocharger configurations for the different altitudes and temperatures, the goal is not to derate
- Use Design temperature
- Other options available for best performance:
  - Different compression ratios
  - Different gas mixer, gas trains
  - Optimization of Charge air cooler inlet temperature (Coal mine gas)
  - Special scopes of supply (Fuel preparation, heat recovery, balance of plant …)

Why Optimisation?

A difference of 2 – 4 % efficiency is equal to the full investment cost for the genset making a LCCA (Life cycle cost analysis) over 8 years



Gas Engines vs. Turbines

Criteria	Engines	Turbines
Emissions	Low emissions	Low Emissions
Best efficiency	Electricity	Heat
Operation mode	Variable load / load management	Better for constant operation
Revenue driver	Electricity	Heat / Steam
Heat extraction	Preferable Hot Water	Preferable Steam
Fuels	Low BTU and pipeline	Pipeline and high BTU Fuels (low sensibility to MN)
Costs	Lower initial costs	Less maintenance costs
At Site conditions	Better for HA	Low weight and minimal space

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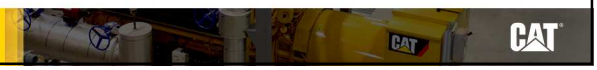

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Products and Technologies

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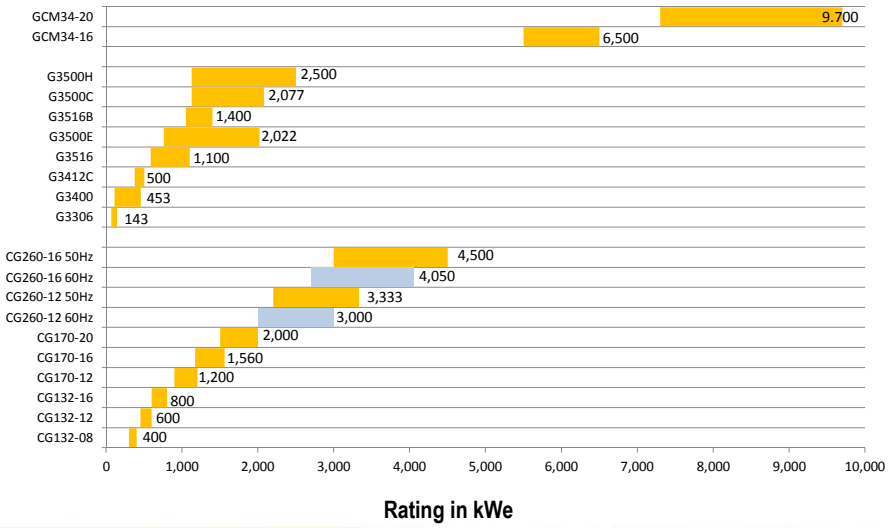
One Unified Product Program



CG132 – The Highest Efficiency In It's Class

CG132	Available in 8, 12 or 16 cylinders
Power Range	400 – 800 kWe
Electrical Efficiency	41.3% - 42.8%
Thermal Efficiency	42.1% - 46.5%
First Service Interval	4,000 Oh
Major Overhaul	64,000 Oh
Useable Gases	NG, CMM, Biogas

- Highest efficiency in combination with flexible possibilities for applications, even under extreme setup conditions
- High availability because of long maintenance intervals
- Low investment- and operation costs through low fuel and lube oil consumption with an extremely compact design at the same time

Installed capacity of more than 2,100 MWe with over 3,700 gensets worldwide

CG170 – Different Versions for Customer Needs

CG170	V12, V16, V20
Power range	1,000 – 2,000 kWe
Electrical efficiency	40.0% - 43.7%
Thermal efficiency	43.2% - 47.0%
First service interval	4,000 h
Major overhaul	64,000 h
Useable gases	NG, CMM, Biogas

- Higher return on investment due to improved efficiency utilizing the miller combustion cycle
- High altitude and temperature capability on the otto cycle version of the CG170
- Gear box utilization at 60Hz provides improved cost of ownership and higher availability
- Flexible application with fluctuating gas composition and quality

Installed capacity of more than 5,600 MW_{el} with over 4,000 gensets worldwide

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CG260 – Proven Reliability

CG260	V12, V16
Power range	3,000 – 4,500 kWe
Electrical efficiency	42.2% - 44.6%
Thermal efficiency	38.6% - 42.7%
First service interval	4,000 h
Major overhaul	80,000 h
Useable gases	NG, CMM, Biogas, Syngas

- High reliability and low maintenance costs due to open combustion chamber technology
- Low operating costs due to 30% lower lube oil consumption in comparison to similar products
- Increased exhaust heat recovery options and full power at extreme ambient conditions
- Optimized engine and plant control enables the use of different gas types and fluctuating gas qualities

Installed capacity of more than 2,800 MW_{el} with over 740 gensets worldwide

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(CG) Gas Genset Technology

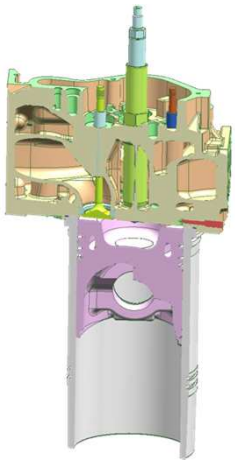
- 4-stroke SI-gas-engine
- Homogeneous lean-burn operation
- Turbo charging and Miller cam-timing
- Controllable gas-mixer
- Swirl pre-chamber spark plugs
- 2-stage mixture cooling
- Flame-filter in receiver
- Electronic engine and plant control
- NOX control by combustion chamber temperature
- Single cylinder head units, 4 valves per cylinder
- Combustion chamber optimized for gas operation
- Single exhaust gas primary modules
- Cylinder-selective anti-knock control/detonation sensors

Maximum Efficiency

With continuous and secure emission regulation

Regulation of NOx-emissions by combustion chamber temperature

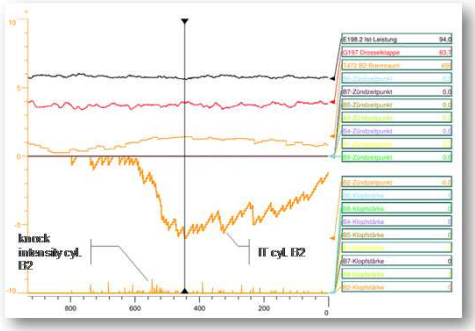
- Measurement of the average temperature in the combustion chamber every cylinder
- This results in a quick regulation of the combustion chamber mixture
- Continuous operation with optimum efficiency
- Quick response to varying gas qualities without affecting emissions



Maximum Efficiency

Via effective and reliable anti-knock regulation

- Using the full engine potential
- Knocking combustion can occur e.g. at varying gas qualities
- Therefore every cylinders is controlled for knocking combustion by a detonation sensor
- Based on the measured knocking the ignition time is individually adapted for every cylinder
- Operating at the knocking limit means exploiting the maximum potential of the engines



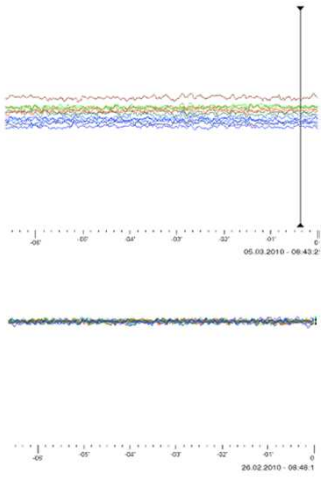
Individually adapted ignition time for every cylinder

Less Load at Higher Performance

By combustion temperature based cylinder balancing

Individual peak loads of cylinder are

- reduced by even load distribution on all cylinders
- Less variations of temperature and mechanical load for components by variable adjustment of the ignition time
- This leads to slight improvements in the efficiency because the average load on the cylinders can be increased due to the greater distance to the knock limit
- Equal mechanical stress for each component

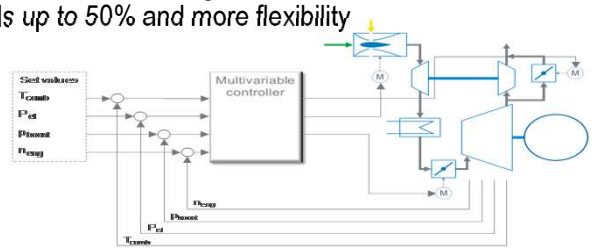


Improved Start-up to Full-load Performance

By using a multivariable controller

Independent adjustment elements are perfectly combined by a new regulation concept

- Combined adjustment of gas mixer, engine throttle and exhaust wastegate
- Comparison of target values and actual values in TEM for perfectly combined adjustment elements
- In combination, these arrangements lead to a reduction of the amount of load levels *up to 50% and more flexibility*



G3516H – Lowest Lifecycle Costs

G3516H	V16
Power range	2,000 kWe
Electrical efficiency	44.5% (HR) – 44.7% (HE)
Thermal efficiency	43.1% (HR) – 41.8% (HE)
First service interval	2,000 h
Major overhaul	80,000 h
Useable gases	Natural Gas

- Top tier electrical efficiency
- Lowest maintenance and overhaul costs
- Low oil consumption
- Extended service intervals
- High Efficiency version optimized for fuel efficiency
- High Response version optimized for altitude and ambient capability and transient response

20% Reduction of Maintenance & Overhaul Costs Compared to the G3520E

G3520H – Lowest Owning & Operating Cost

G3520H – 50Hz	
Power*	2,518 kW_{el}
Electrical Efficiency*	45.3% (HE) , 45.1% (HR), 44.8% (HA)
Thermal Efficiency	41.0% (HE) , 41.1% (HR), 41.4% (HA)
Service Interval	2,000 hrs
Major Overhaul	80,000 hrs
Electrical Frequency	50 Hz
Fuel	Natural Gas

*ISO 3046/1 at 500mg NOx Emissions, 1.0 Power Factor

- Top tier electrical efficiency
- Lowest maintenance and overhaul costs
  - Low oil consumption
  - Extended service intervals
  - Reduced downtime
- Three Configurations:
  - High Efficiency (HE) – Optimized for Fuel Efficiency
  - High Response (HR) – Optimized for Higher Ambient Capability Flexibility
  - High Altitude (HA) – Optimized for More Extreme Ambient Capability Flexibility

G3500H Gas Genset Technology

Engine Technology

- Long stroke design with 21 Bar BMEP
- Cuffed cylinder liners
- Hydraulic valve lash adjusters
- Cold throttle actuator
- Active turbo bypass
- Ridged rail engine harness
- Canister style oil filter
- Package mounted air cleaner option

Available Installed Options

- EMCP4.3 for 400-3300V generators
- Generator mounted circuit breakers
- Engine driven water pumps
- Corrosion resistant

Efficiency, Altitude/Ambient Capability, Power Density

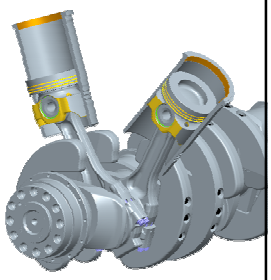
- Enabling Technologies
  - 215mm Stroke
  - 21 Bar Brake Mean Effective Pressure
  - New High Compression Ratio Steel Pistons
  - High Efficiency Turbo (ABB A140H-H66 Turbo)
  - Generator Electrical Efficiency 97.4% at 10.5kV at 1.0 Power Factor
- Benefits:
  - ISO Electrical Efficiency: 45.3% (HE), 45.1% (HR), 44.8% (HA)
  - 48% Reductions in Total Unburned Hydrocarbons (Compared to Current G3516H)
  - ISO 8528-5 G1 Transient Performance with HR & HA Configurations
  - Power Dense Footprint:
    - 50Hz: L-6310mm, W-2165mm, H-2427mm, Weight-22,314kg

Maintenance Costs

- Enabling Technologies
  - Cuffed Liners to Manage Deposits for Long Life and reduced Oil Consumption
  - Auxiliary Sump & Canister Type Oil Filters to Extended Oil/Filter
  - Niridium Electrode Pre-Chamber Spark Plugs
  - Hydraulic Valve Lash Adjusters
- Benefits:
  - .122 g/kwh (0.0002 lbs/bhp-hr) Midlife Oil Consumption
  - 2,000 Hour Oil/Oil Filter Change at 725 Liters/Oil Change
  - 2,000 Spark Plug Change Intervals
  - Extended Valve Lash to 4,000 Hours

Overhaul Costs

- Enabling Technologies
  - Hardened Cuffed Liners to Extend Life of the Piston, Ring & Liner
  - Valve Stem Seals to Increase Head Life
  - Increased Lubrication on the Valve Train
- Benefits:
  - 20,000 Operational Hours to Top End Overhaul at B-10
  - 40,000 Operational Hours to In-Frame Overhaul at B-10
  - 80,000 Operational Hours to Major Overhaul at B-10



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Controls and Electronics

- Enabling Technologies
  - HarEMCP 4.3: Genset Controller
  - A4:E4: Engine Controller
- Benefits:
  - Wall Mount EMCP 4.3 – Genset Control, Protection & Monitoring
    - Integrated Load Feedbank Signal
    - Primary and Accessory CAN Data Links, RS-485 Annunciator Data Link, Modbus TCP (10BT Ethernet), Modbus RTU (RS-485 Half Duplex)
    - 12 Programmable Digital Inputs, 16 Programmable Digital Outputs
    - Remote Monitoring and Control Capability
    - Optional EMCP 4.3 Expansion Modules
  - A4:E4 – Electronic Ignition, Speed Governing, Air/Fuel Ratio & Turbo Bypass Control
    - Improved Stability & Response

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System Components – More than just Gensets

Gas dryer and desulfurization

- Individual modules available
- Biogas treatment ensures that gas from the digester (warm, humid, uncompressed and with high sulfur) will be treated in such a way (dried, compressed and desulfurized) that a Mannheim biogas genset with exhaust gas treatment can be operated reliably
- The biogas treatment closes the gap between digester and genset

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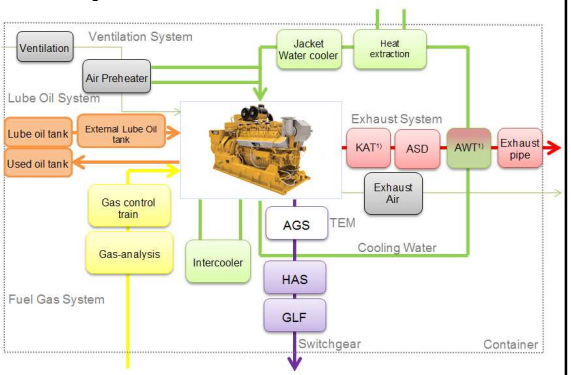
System Components – More than just Gensets

Containers for CG132 and CG170

- Modularized system – therefore a lot of flexibility combined with full product support and availability
- Safe operation and maximized efficiency
- Dynamic sizing for all components



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System Components – More than just Gensets

Compact buildings for CG260

- The goal is a modularized concept
- Up to six units in one block
- Short delivery times and commissioning times due to pre-manufactured modules
- Less risk during the commissioning and operation as the engineering is done by us

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Product Compliance

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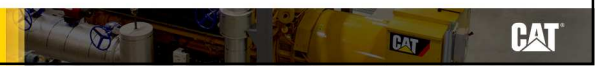
Overview of CES certificates/declaration

Company and Product Certificates	Valid in Country	Affected Series	Valid Since	Valid Until	Certifizer
ISO 9001/ISO 14001/OHSAS 18001	worldwide	facility	10.04.2015	09.04.2018	TÜV Süd
ISO 3834	worldwide		29.09.2013	28.09.2016	SLV
DIN 18800	worldwide		29.09.2013	28.09.2016	SLV
EC	EU	CG 132, CG170, CG260	projectspecific document without validation time		
BDEW	Germany	CG132	07.04.2014	06.04.2019	FGH
		CG170	11.09.2014	10.09.2019	
		CG260	26.09.2014	25.09.2019	
EAC	Russia, Belarus, Kazakhstan	CG 132, CG170, CG260	17.02.2014	16.02.2017	Madi
GOST-R certificate Gen CG	Russia		04.02.2013	03.02.2018	EMCC
Rostechnadzor certificate GEN	Russia		28.02.2012	27.02.2017	EMCC
Expertise for industrial safety	Russia	CG 132, CG170, CG260	16.11.2015		EMCC
Ukraine product certificate	Ukraine	CG 132, CG170, CG260	22.12.2015	21.12.2016	EMCC
UkrSEPRO conformity declaration	Ukraine	CG 132, CG170, CG260	24.12.2015	20.12.2016	EMCC
Turkish product certificate	Turkey	CG 132, CG170, CG260	29.07.2015	28.07.2020	Yildiz Technical University
SONCAP	Nigeria	CG 132, CG170, CG260	23.09.2015	01.04.2016	Intertek UK



Emission Regulations Worldwide

Country Requirements	Fuel Type	Power Range	Operating Hours	NOx	CO	CH2O	VOC	PM	SO2	THC
EU MCPD	Natural gas	1 - 50 MWth		250						
	Biogas			500					107	
TA-Luft	Natural gas	> 1MWth		500	300	60				
	minegas	> 1MWth		500	650	60				
	Bio-/sewagegas	< 3MWth		1000	2000	40				
	Bio-/sewagegas	> 3MWth		500	650	40				
	Landfillgas			500	650	60				
Netherlands	Biogas	1-50MWth	>500h/a	302					178	
	Natural gas	< 2.5MWth	>500h/a	302					178	
	Natural gas	> 2.5MWth	>500h/a	88.9					178	1333

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Applications

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Gensets for base load – IPP
Load management plants
Standby
Small Distributed Power Generation (DG)

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Combined Heat & Power (CHP)
Trigeneration
Steam
Greenhouses

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Biogases (AG, Landfill, Wastewater)
Propane
Syngases

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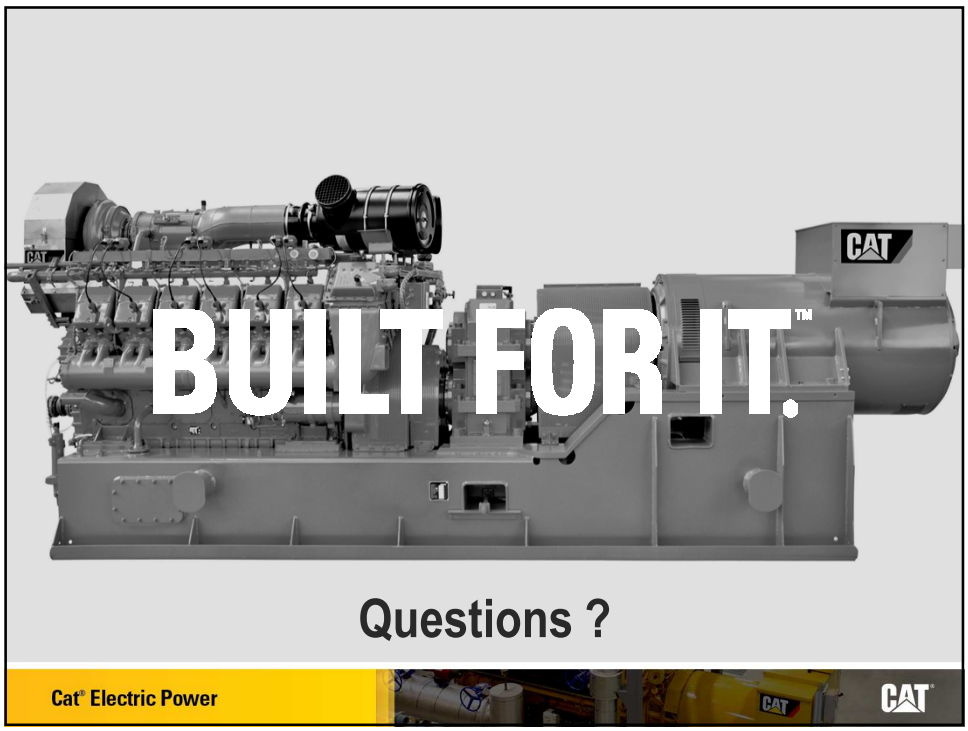

Questions?

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