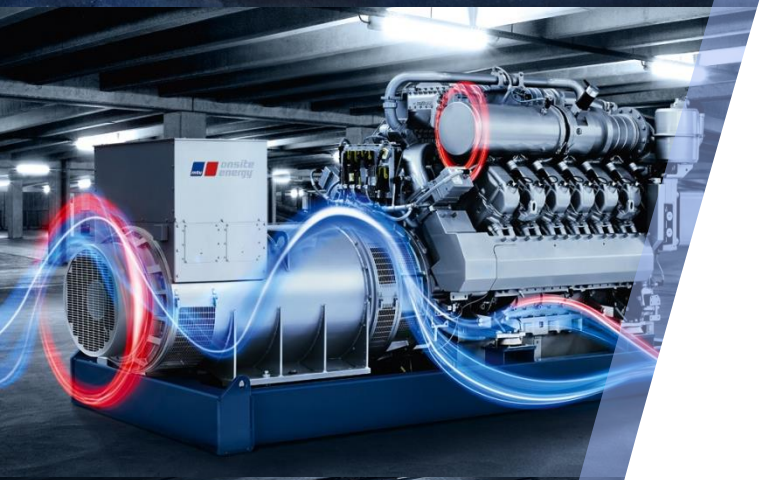
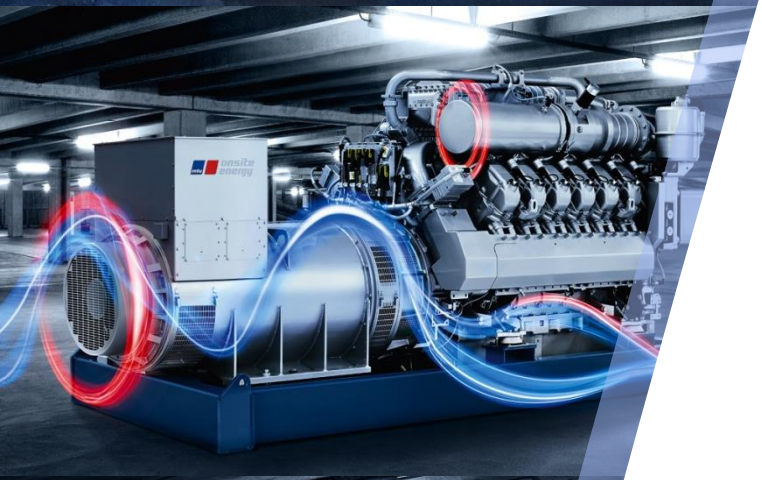


ROLLS-ROYCE POWER SYSTEMS & MTU ONSITE ENERGY

High-Speed and Medium-Speed Engine Technology for CHP Installations

Christian Mueller
Sales Engineer - Gas Power Systems
MTU America, Inc.

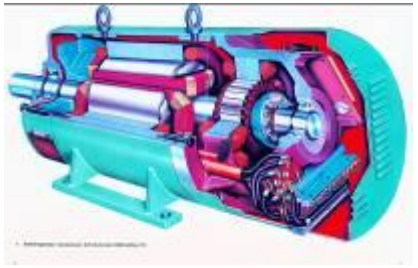
A Rolls Royce Power Systems Company



AGENDA

CHP TECHNOLOGY
CONCEPT OF COMNINED HEAT AND POWER

Primary Energy → **Mechanical Energy** → **Electrical Energy**



Thermal Energy from Exhaust Gas and Cooling Water

Via Generator

Usable Energy: Heat and Electricity

CHP TECHNOLOGY
WHAT APPLICATIONS ARE SUITABLE FOR CHP?

1) High Thermal and Electric loads that occur coincidentally (**Quantity**)
   - Central heating and cooling system
   - Low/mid pressure steam (or thermal fluid) demand
   - Hot water and/or hot air demand
   - Chilled water

2) Temperature of thermal load (steam pressure) compatible with engine **(Quality)**

3) Consistent electrical, cooling or heating needs **(Load Profile):**
   - Only hot water can be stored

4) Suitable gaseous fuel available

5) Long operating hours, generally >6000 h/year

CHP TECHNOLOGY
WHAT APPLICATIONS ARE SUITABLE FOR CHP?

6) Sufficient “Spark Spread”

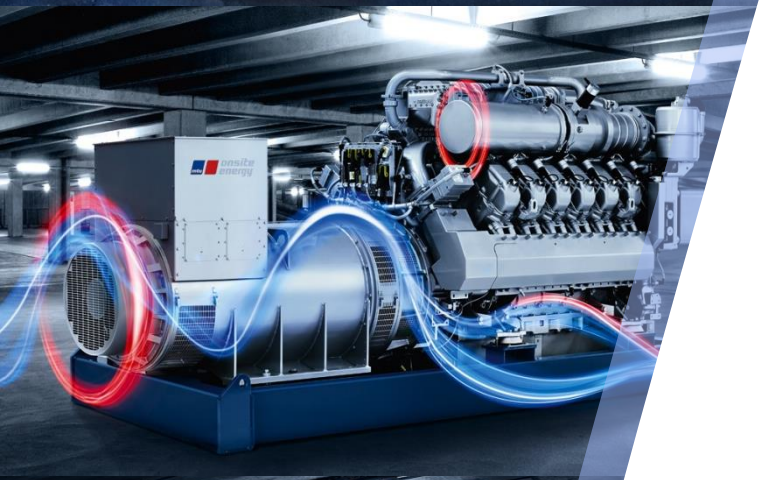
- Gas prices vs. Electricity price

7) High peak power rates

8) Additional benefits**:**

- Backup capability for power outages
- Restricted grid capacity
- Incentives for CHP systems

CHP TECHNOLOGY
FOUR UNIQUE BUSINESS CLUSTERS



AGENDA

01. CHP Technology

02. Engine Technology & Installations

03. Aftersales and Life Cycle Costs

ENGINE TECHNOLOGY
HIGH SPEED VS. MEDIUM SPEED

High Speed (HS)

- Typically above 1000 rpm
- Gas and liquid fuels – good on alternative gases
- Dominate up to ~3.5 MW
- High power density
- High volume production
- Distributor model

MTU

Medium Speed (MS)

- Typically 300-1000 rpm
- Gas and liquid fuels – good on HFO
- Typical range 2 MW to 20 MW
- Project driven market
- Through life business model

Rolls-Royce

Bergen Engines

Slow Speed – 2 stroke (SS)

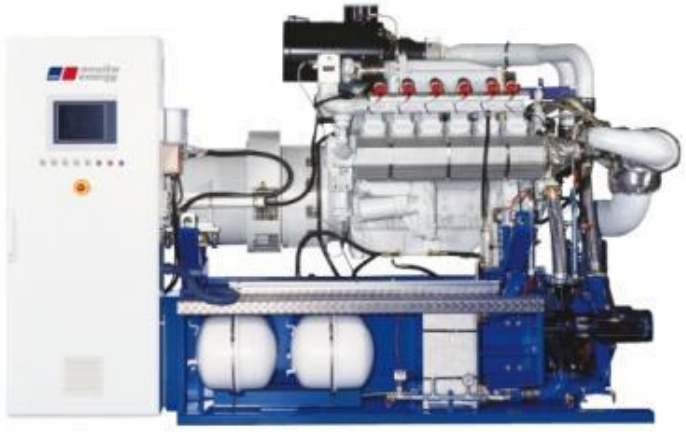
- Typically below 300 rpm
- Liquid fuels – good on heavy and low grade fuels
- Typically large power >15 MW
- Marine merchant focus
- Major barriers to entry

Increasing capital cost (per kW)

Increasing fuel efficiency

ENGINE TECHNOLOGY
HIGH SPEED <500KW

Small scale cogeneration systems



MTU 12V400GS – 358kWe

Engine

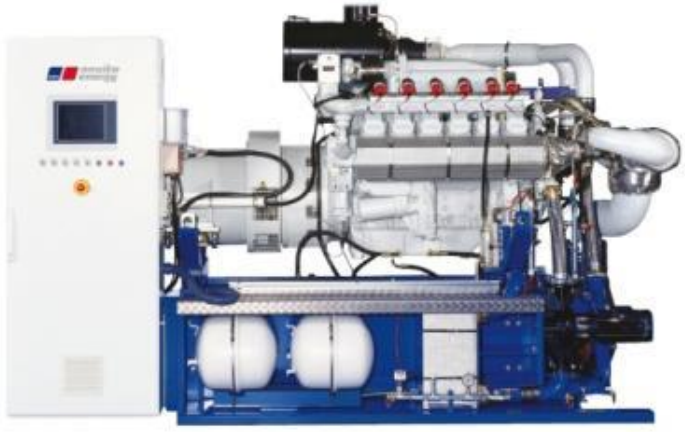
- 1800rpm (60Hz)
- 33-39% electric efficiencies
- Lean burn engines
  - High power output from small footprint
- Rich burn engines
  - Low emissions with 3-Way Catalyst
  - Good block loading characteristics
- Rapid starting times
- Natural gas and non-natural gas (biogas, sewage, landfill)

ENGINE TECHNOLOGY
HIGH SPEED <500KW

Small scale cogeneration systems

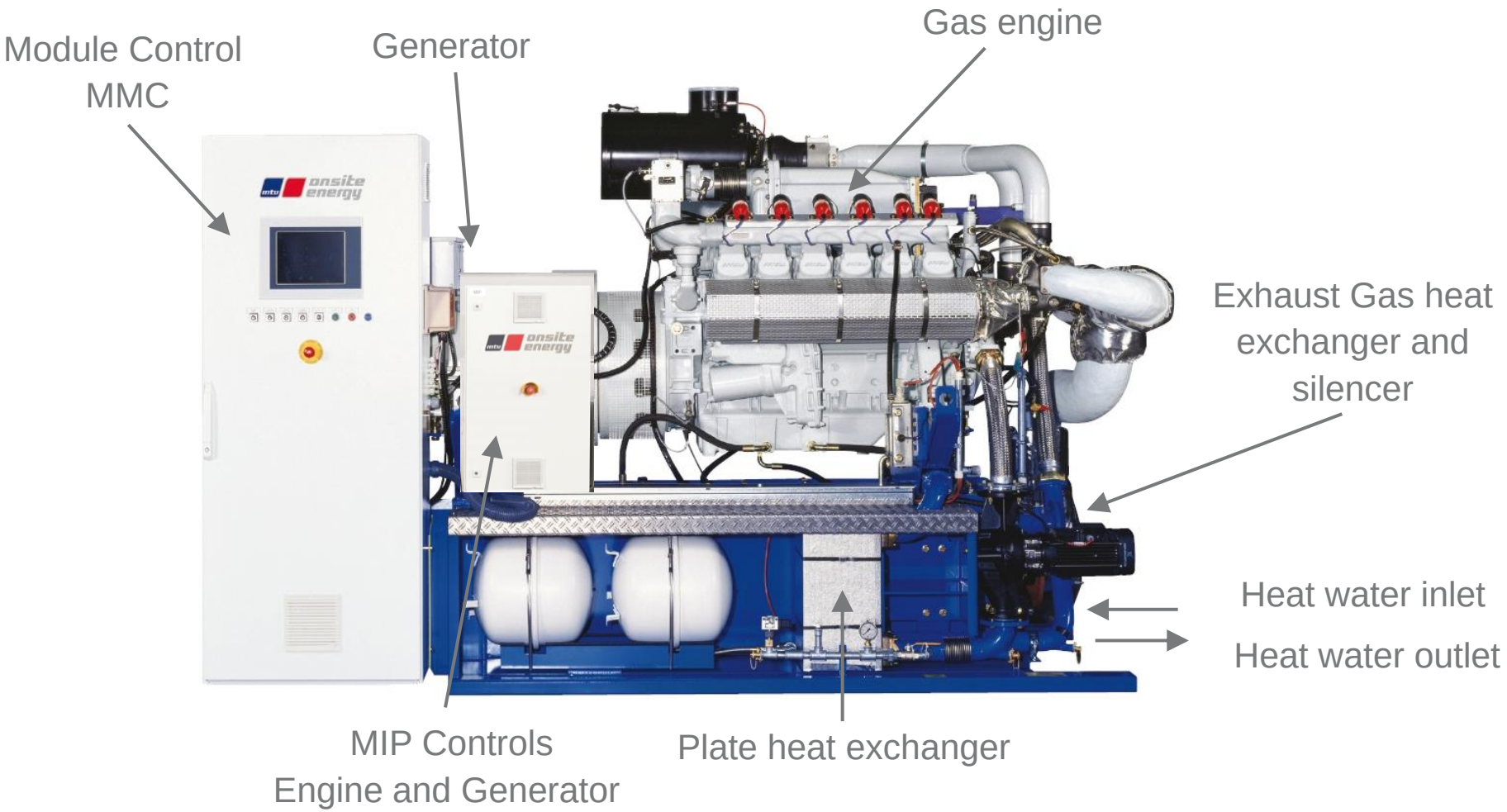
<u>System</u>

- Easy to install / transport
- Factory packaged heat recovery systems
- Sound attenuated enclosures
- Hot water thermal output



MTU 12V400GS – 358kWe

ENGINE TECHNOLOGY
HIGH SPEED <500KW – HEAT RECOVERY SYSTEMS



EXAMPLES OF CHP INSTALLATIONS
High School

MTU 6R400 GS

Location: Medina, Ohio

Electrical output: 125 kWe
Heating output: 731 kBTU/h

Rich burn, natural gas CHP system

Cogeneration package to supply hot water into the school's heating circuit. Integration in boiler feed water.

EXAMPLES OF CHP INSTALLATIONS
Community Recreation Center

MTU 12V400 GS

Location: Dublin, Ohio

Electrical output: 248 kWe
Thermal output: 2,496 kBTU/h

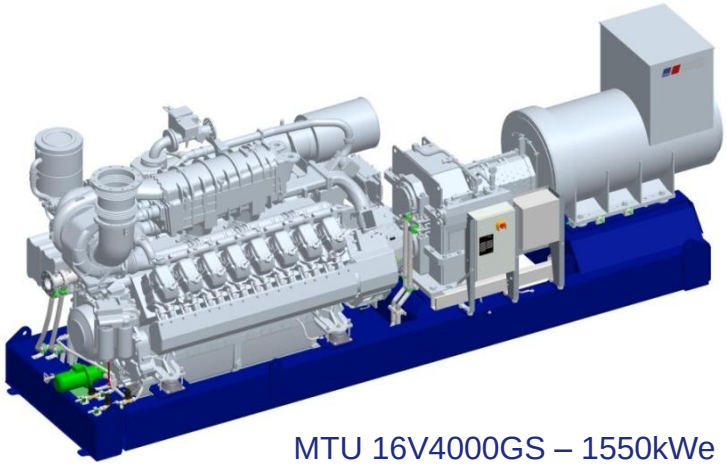
Rich burn, natural gas CHP system

Supplies thermal output to heat the recreation center and swimming pool

Provides back-up power during outages

ENGINE TECHNOLOGY
HIGH SPEED 750 – 2500KW

Medium sized cogeneration systems



MTU 16V4000GS – 1550kWe

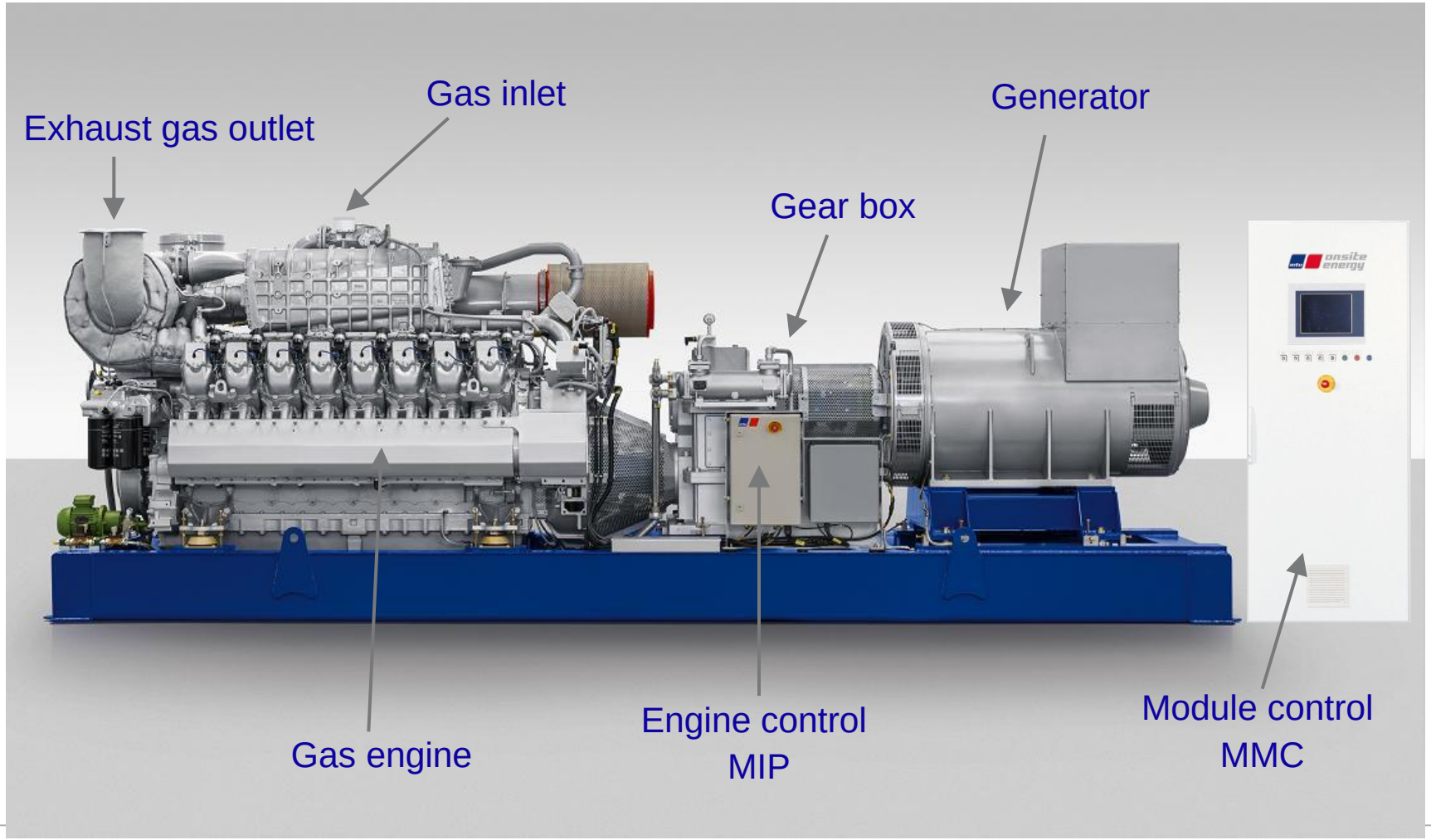
Engine

- 1800 or 1500rpm (60Hz with gearbox)
- 40-44% electric efficiencies
- Lean burn engines
  - High power output from small footprint
  - Customizable engine configuration for high altitude and temperature
- Natural gas and non-natural gas (biogas, sewage, landfill)

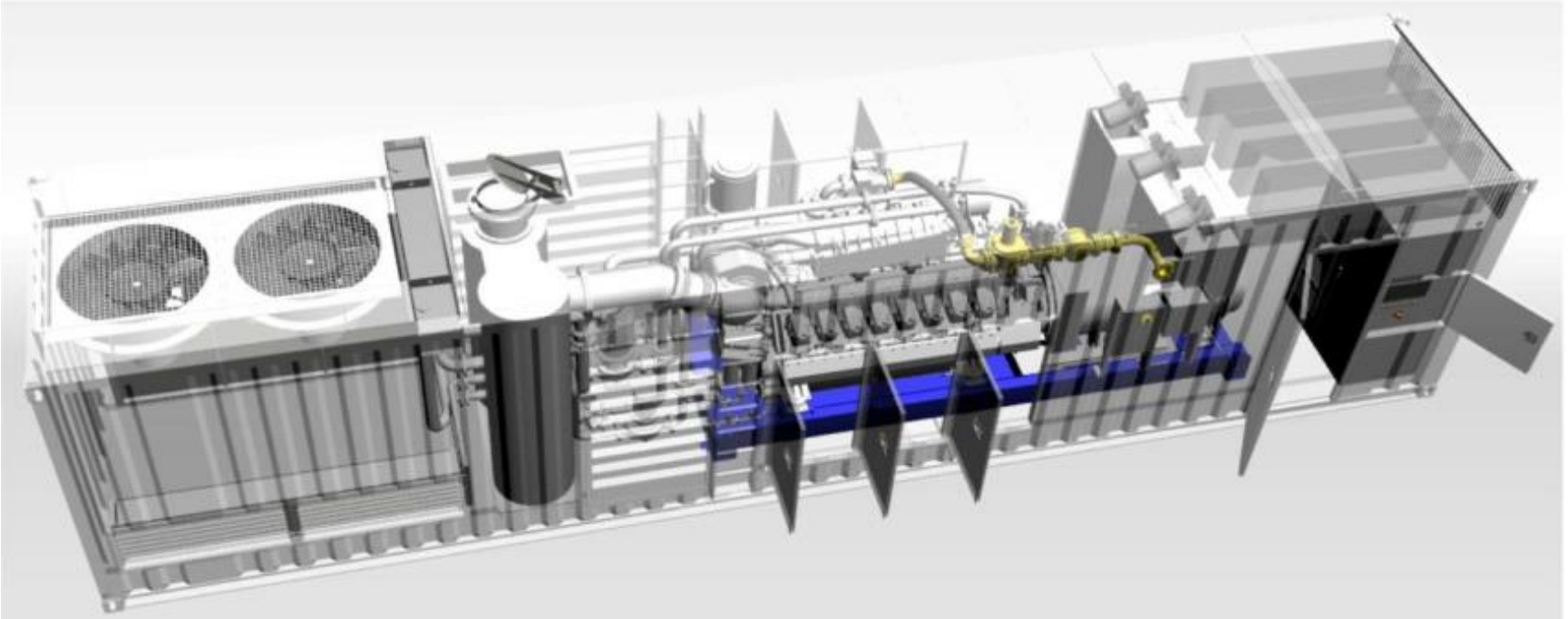
System

- Hot water/steam/chilled water CHP
- Containerized or locally installed

ENGINE TECHNOLOGY
MTU 16V4000 GS



ENGINE TECHNOLOGY
CONTAINERIZED SYSTEMS



EXAMPLES OF CHP INSTALLATIONS
CASINO

Location: Baltimore, Maryland

Application: Casino

Electrical output: 1149 kWe
Heating output: 4,500 kBTU/h

MTU 12V4000GS - Containerized package

Cogeneration – supplies hot water for heating demand of casino. Expansion to trigeneration for cooling demand planed in future.

EXAMPLES OF CHP INSTALLATIONS
DAIRY DIGESTER

Location: Madison, WI

Application: Dairy digester

Electrical Output: 762 kWe
Heating Output: 2,429 kBTU/h

MTU 8V4000 GS Biogas

4000 Head Dairy Farm

Supplies Thermal Output to Heat the Digester

EXAMPLES OF POWER PLANT INSTALLATIONS
Rural IPP Cooperative

Location: Pto. Suarez, Bolivia

Electrical output: 4.5+ MWe

Special Generator Pitch 8/9 to suit existing Equipment needs

3x MTU 20V4000 GS Natural Gas

Pure Power for MicroGrid Network

Operates in Grid Parallel-BakUp Modes

ENGINE TECHNOLOGY
MEDIUM SPEED 3.5-10MW

Large sized cogeneration systems

Bergen B35:40 - 5540kWe

Engine

- 720rpm (60Hz)
- >48% electric efficiencies
- Lean burn engines
- Long engine life 25+ years
- Natural gas

System

- Permanent installations – Power Plant
- Hot water/steam/chilled water CHP

EXAMPLES OF INSTALLATIONS
GREENHOUSES

Customer	**P3P / APS Salads**
Place	**Kent, UK**
Delivery	**2 x B35:40V16AG**
Total output	**15 MWe**
Fuel	**Natural Gas**

CO2 from the exhaust is cleaned in catalytic converter and fed back in precisely measured quantities to the plants.

Thermal output used to heat the greenhouse.

EXAMPLES OF INSTALLATIONS
INDUSTRIAL INSTALLATIONS

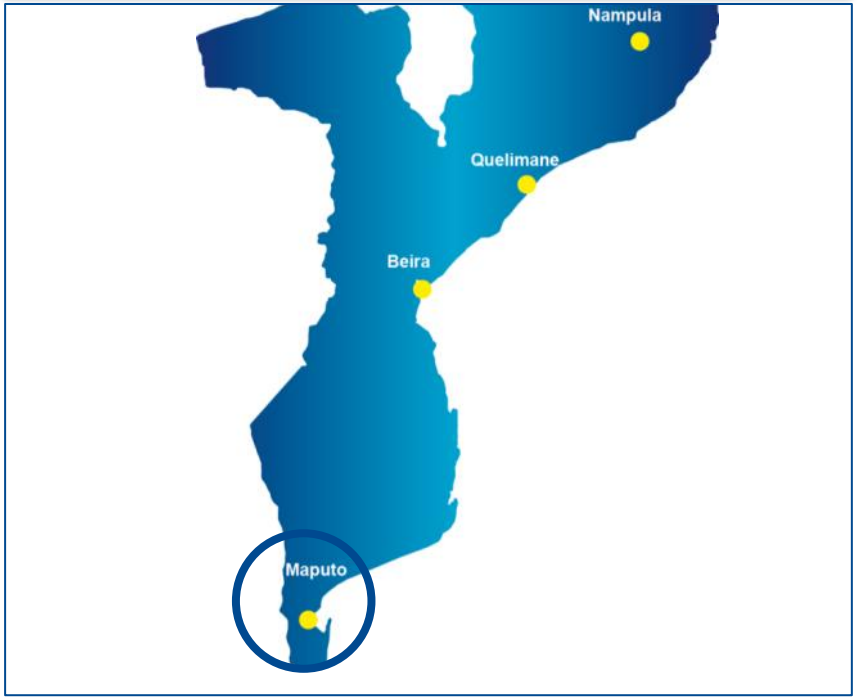
Customer	**Viscofan**
Place	**Pamplona, Spain**
Delivery	**4 x KVGS-18G,** **4 x B35:40V20AG** **1 x B35:40V12AG**
Total output	**50 MWe**
Fuel	**Natural Gas**

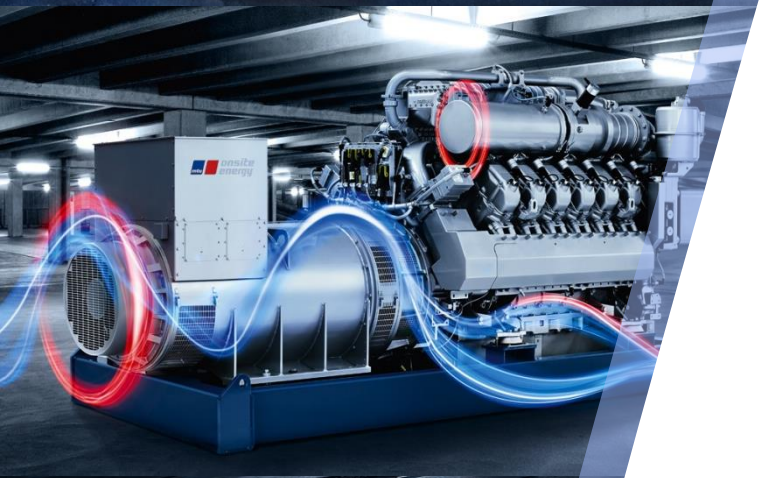
50MWe base load and steam to the production of plastic film to meat industry. The first engines (delivered 1992) have more than 160.000 running hours.

EXAMPLES OF INSTALLATIONS
BASE LOAD POWER PLANT

Customer	**Gigawatt Mozambique**
Place	**Ressano Garcia**
Delivery	**13 x B35:40V20AG2**
Total output	**122 MWe**
Fuel	**Natural Gas**

The generator sets are the core equipment of the 122 MW plant owned and operated by the independent power provider Gigawatt Mozambique. To ensure reliability, a 15 year Long Term Service Agreement (LTSA) was signed with TSK, the company that will operate and maintain the plant.





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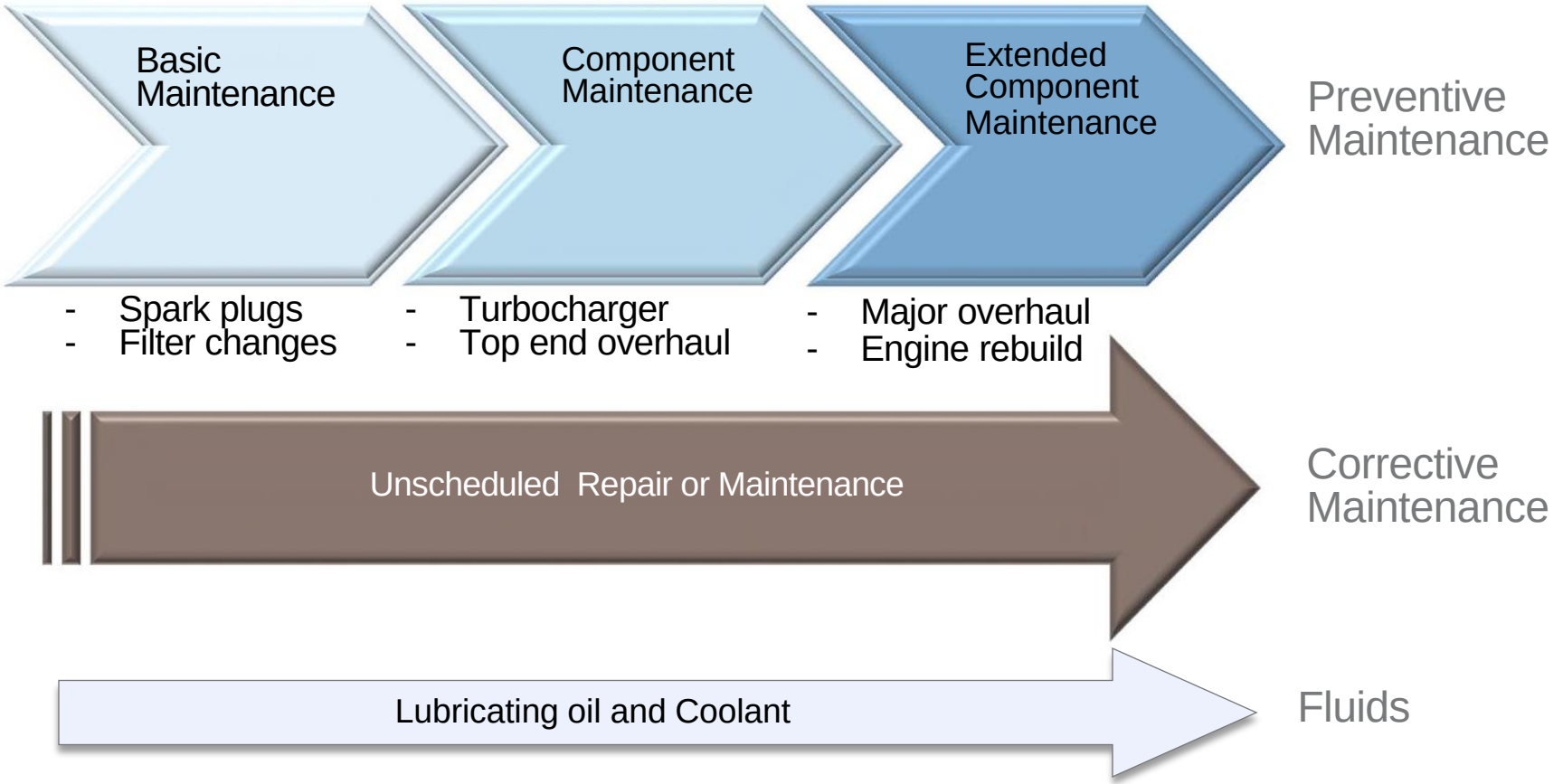
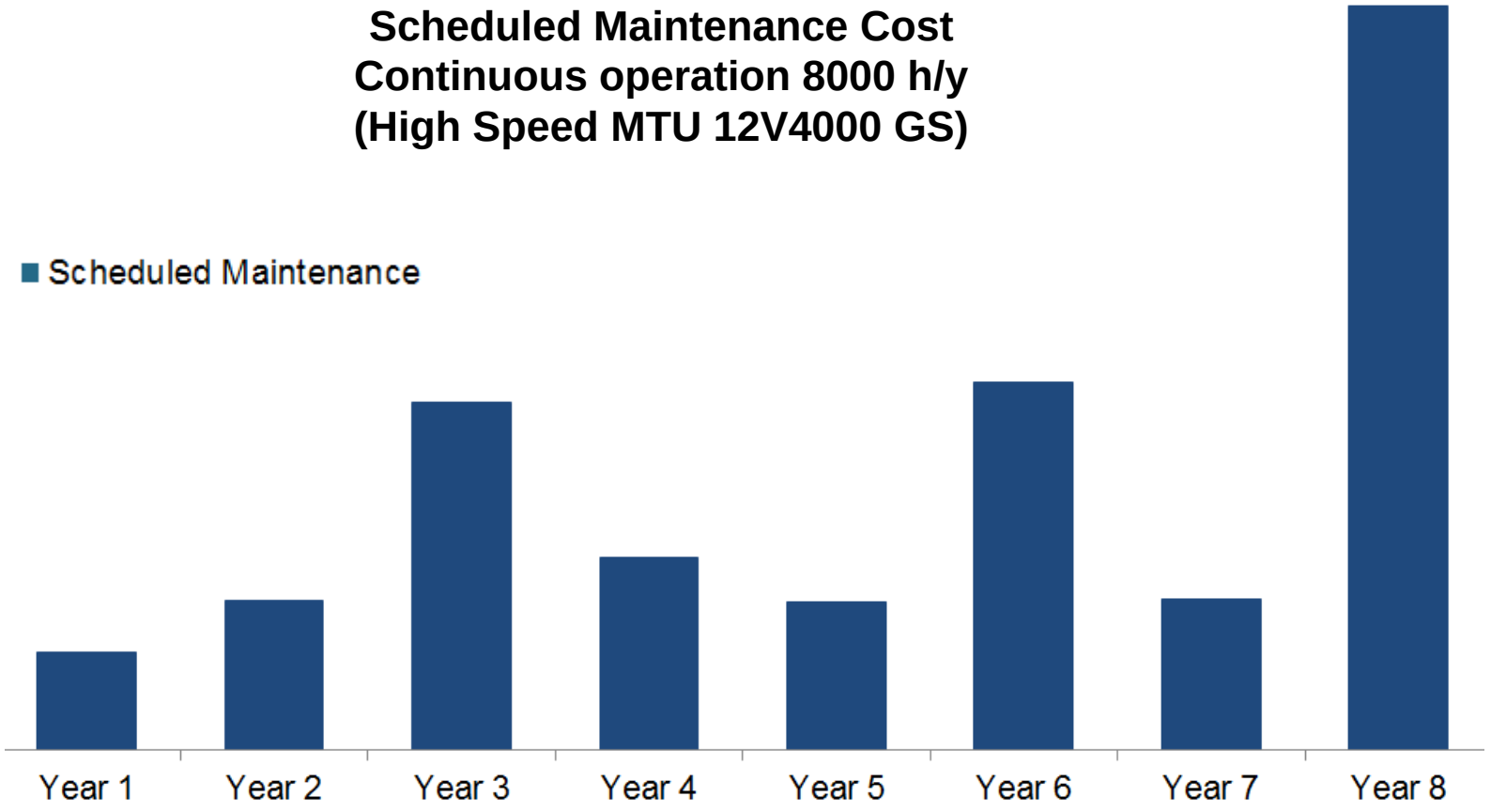
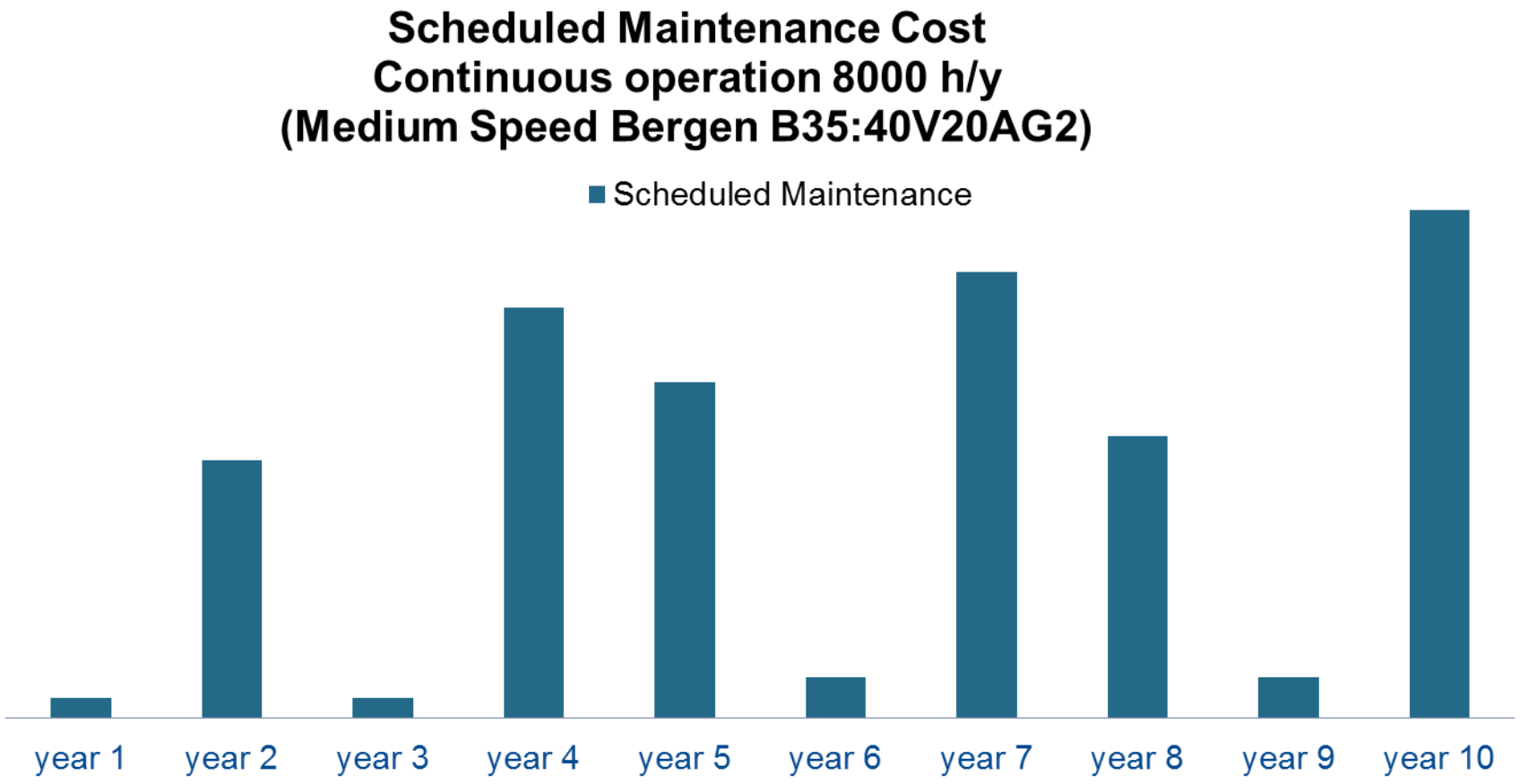
LCC ANALYSIS
MAINTENANCE CONCEPT



Life Cycle Costs
High Speed Engine



Life Cycle Costs
Medium Speed Engine



Thank you for your attention!