Continuous Gas Power Generation in a Changing World

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Rolls Royce Solutions America

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Agenda

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01

Power Generation in a Changing World

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Renewable Energy

- Geothermal
- Hydropower
- Wind
- Solar

- Sewage sludge could potentially meet 12% of national electricity demand.
- Renewable fuels could be the bridge to solve the variability and transportability problems of some of the other power sources

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SOLAR ENERGY

GEOTHERMAL ENERGY

WIND ENERGY

OCEAN ENERGY

HYDROPOWER

BIOENERGY

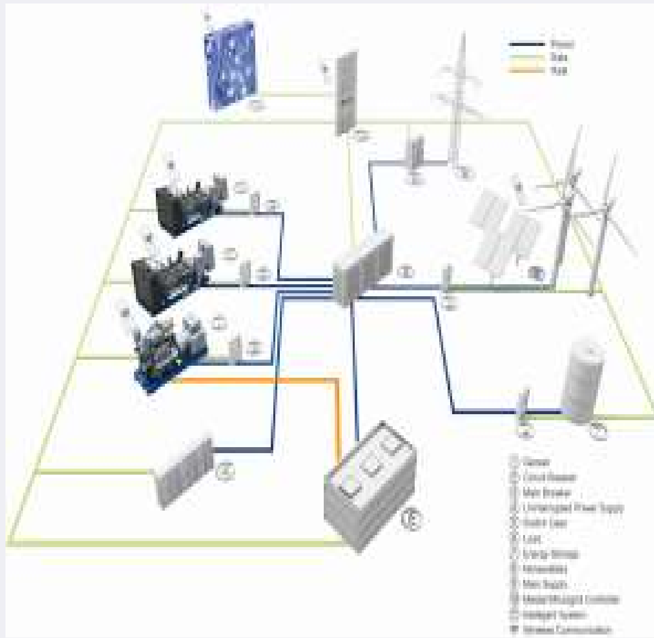
Sewage sludge could potentially meet 12% of national electricity demand.

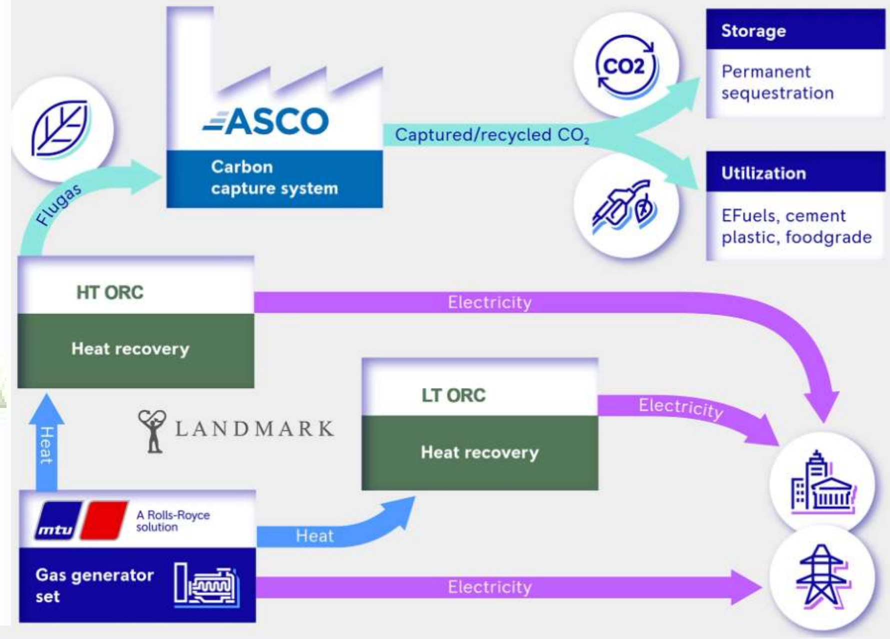
RENEWABLE FUELS

Power Generation in a Changing World

Powering the Future

Carbon Capture Systems





- Renewables
- Decentralized systems
- Microgrids
- Plant specific business models
- CHP

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What Does It Mean to Digitize the World?
IOT EveryTHING is Connected!

Data Center Dynamics
https://www.datacenterdynamics.com › news › us-data-...

US data center power consumption to double by 2030 - DCD

Jan 15, 2024 — Data center power consumption in the US is set to **reach 35GW by the end of the decade, almost double its 2022 level**.

Danfoss
https://www.danfoss.com › integrated-energy-systems

The future of data center power consumption

The average power usage effectiveness **(PUE) ratio for a data center in 2020 was 1.58**, only marginally better than 7 years ago, according to the latest annual ...

Data Center Dynamics
https://www.datacenterdynamics.com › news › global-d...

Global data center electricity use to double by 2026 - IEA report

In the US, which the report said is home to 33 percent of the world's data centers, consumption is expected to rise from 200TWh in 2022 to 260TWh in 2026, some six percent of all power use across the country.
Jan 26, 2024

Energy Institute Blog
https://energyathaas.wordpress.com › 2023/10/09 › dat...

Data Centers Are Booming - Energy Institute Blog

Oct 9, 2023 — Big improvements in "power usage effectiveness" (PUE) meant that **global data center energy use increased by only 6% between 2006-2018** while ...

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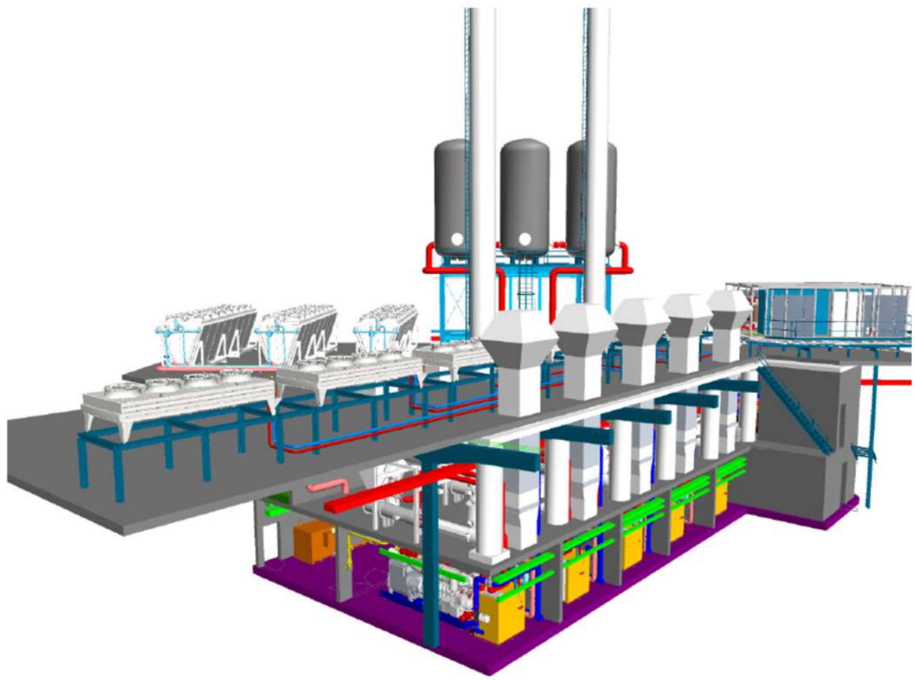
Continuous Gas Solution Initial Questions

1. **What type of facility? Will it be CHP (Combined heat and power)?**
2. **Type of Gas? Natural Gas, Hydrogen, Bio Gas, Syn Gas, Well Head Gas - is there a gas analysis available already?**
3. **How much electricity and heat may be required? kW Voltage Frequency required?**
4. **Load Profile?**
5. **Start Time Requirement?**
6. **Local Emission Requirements?**
7. **Where will it be installed?**
   a) Altitude
   b) Ambient site conditions, etc.
   c) Available Space
8. **In which operation mode will the unit run?**
   a) Grid parallel operation only and/or
   b) Island operation



02

Key Factors in Gas Systems

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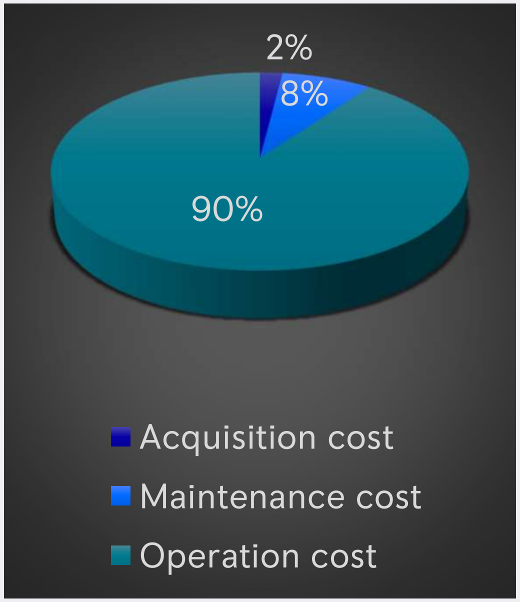
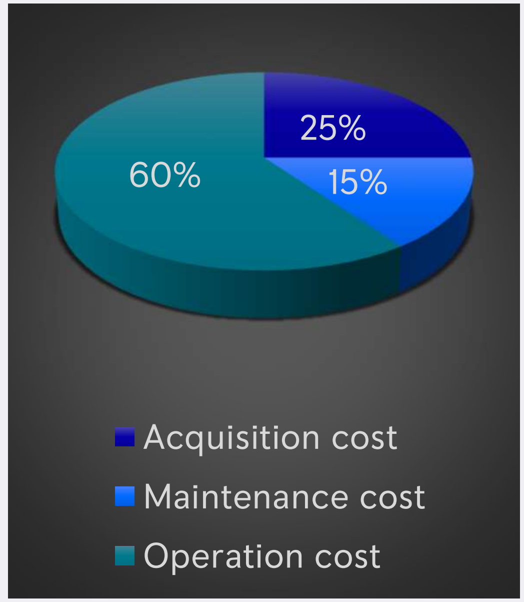
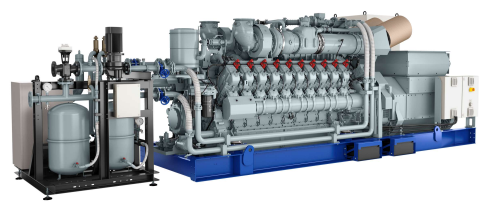
Cost Comparison

Continuous Operation (Gas)

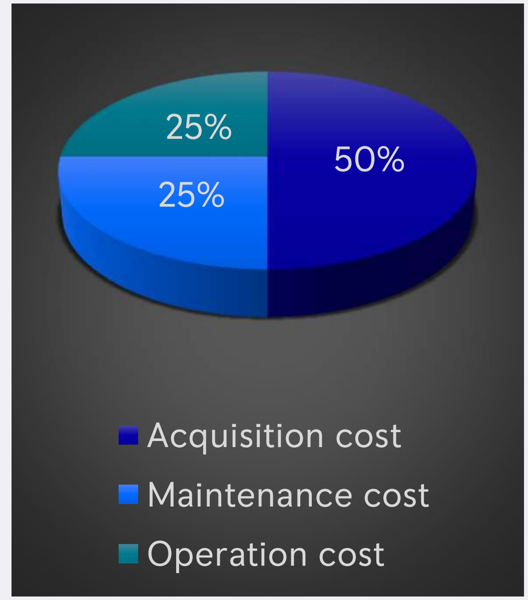


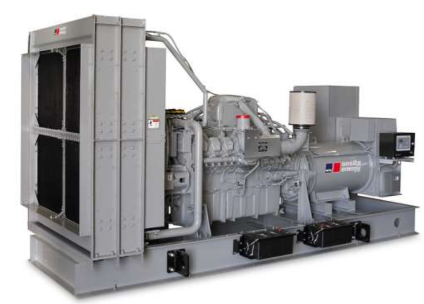
Prime Operation (Gas)





Emergency Operation (Diesel)





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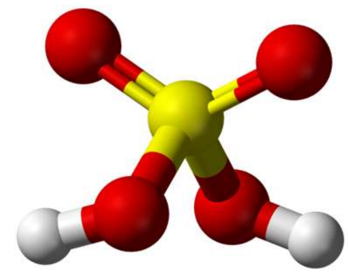
Key Factors for Gas Systems

GAS COMPOSITION

Why is it so important?

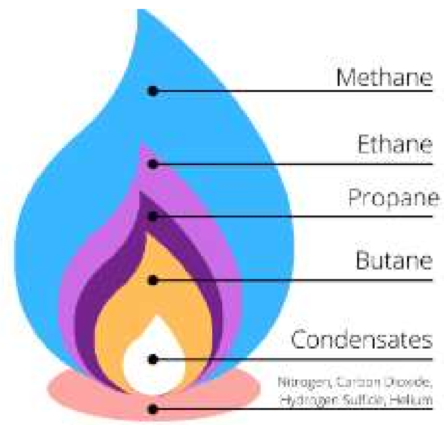
- **There are a number of different Gas variations , i.e. Natural- or Bio Gases**
- **Each of them has different and variable physical and chemical Properties**
- **Different Types of Gases require a special Selection of Genset Type**
- **Harmful Components must be detected and extracted from the Gas, i.e. Sulfur or Siloxanes**



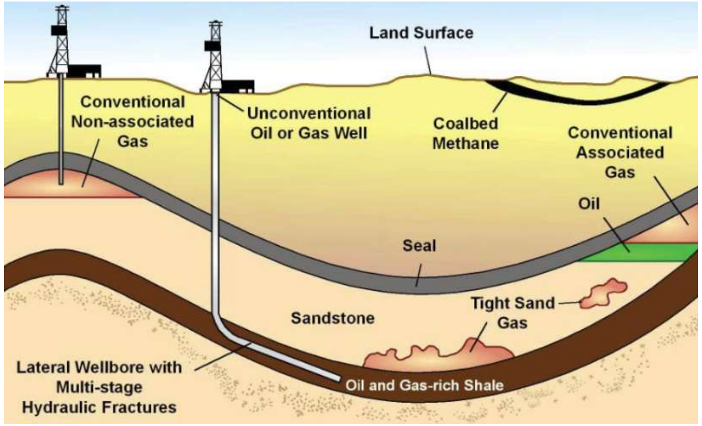
Sulfur Acid

What Steps are required?

- **Find out what Gas Family you are dealing with, i.e. Natural Gas or special Gas**
- **Find out what Gas Quality is on site.**
- **Whenever non- Natural Gases or NG Equivalents, a Gas Composition is required**



What are NGL's –Natural Gas Liquids-



Natural Gas produced out of wells typically goes through numerous stages of purification as it makes its way to the end user. The steps necessary are determined by what needs to be removed from the gas, but typically the gas goes through different pipelines of increasing purification specs. The first big step is eliminating everything that is not a gas, typically at the well pad or the first gathering location. This is when the gas can be sent into the distribution lines that feed the end users, such as your house or your local power plant, to make electricity. These sites may also have the equipment to remove most water vapor, CO_2, H_2S, and some heavier hydrocarbons. Further down the line, the gas may go through more stringent processing facilities to prepare it for fractionation. Extensive facilities then collect large amounts of natural gas to remove nearly everything that is not methane from the gas and separate the other valuable hydrocarbons for sale. The gas we get as consumers, like what shows up at your house, is nearly entirely pure methane. Natural gas is considered "lean" or "dry" when almost pure methane exists. When heavier hydrocarbons are present, the gas is considered "rich" or "wet."

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Key Factors for Gas Systems

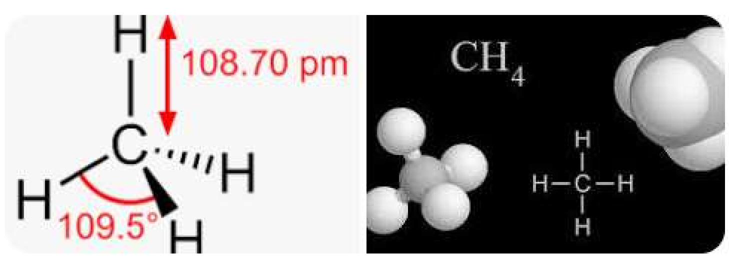
METHANE NUMBER

Why is it so important?

- **Value for the knock resistance of the gas, responsible for best output and smooth operation**
- **The higher the methane number, the more robust the combustion**
- **Methane Numbers suitable for Gas Systems start at Range of MN30 and go up to MN140**
- **Best Case is a standard Natural Gas with MN of >80**

What Steps are required?

- **Ask for the Methane Number in your Project**



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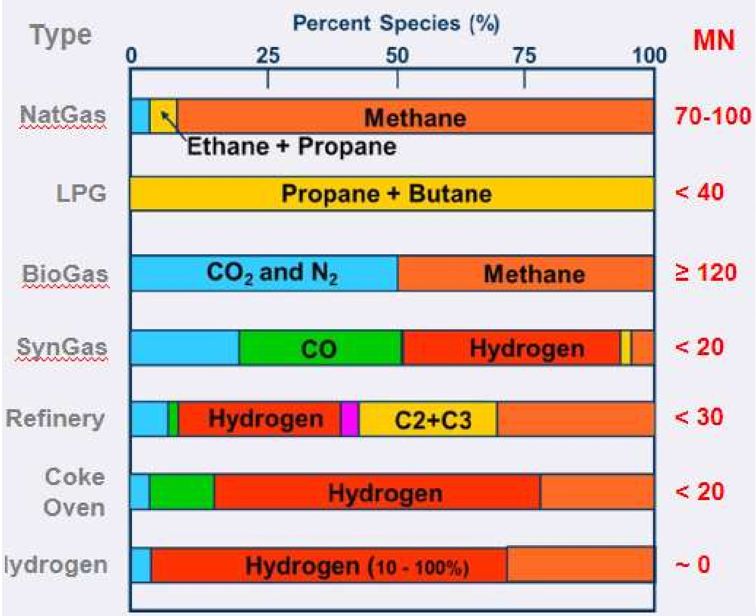
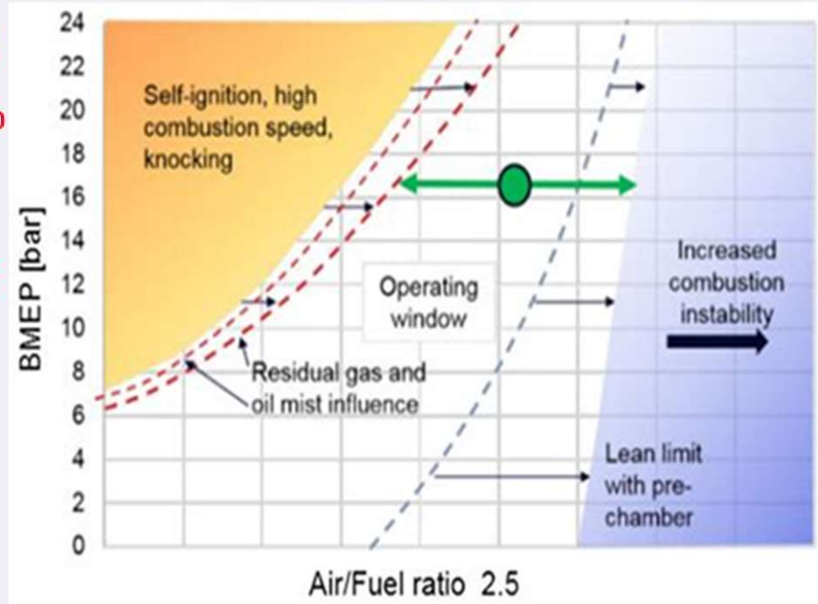
Methane Number

The density of methane (gas) used in the calculation is 0.657 kg/m^3, at a temperature of 25 °C and pressure of 1 atm. Changes attributable to different temperatures and/or pressures can be calculated using the ideal gas equation (PV=nRT).

Methane Number – BMEP – Fuel Flex



Source: Int. Turbomachinery



The Methane Number is a measure of the resistance of natural gas to detonation when it is burned as a motor fuel in an engine. Pure Methane is assigned a Methane Number of 100 and pure Hydrogen is assigned a Methane Number of zero.

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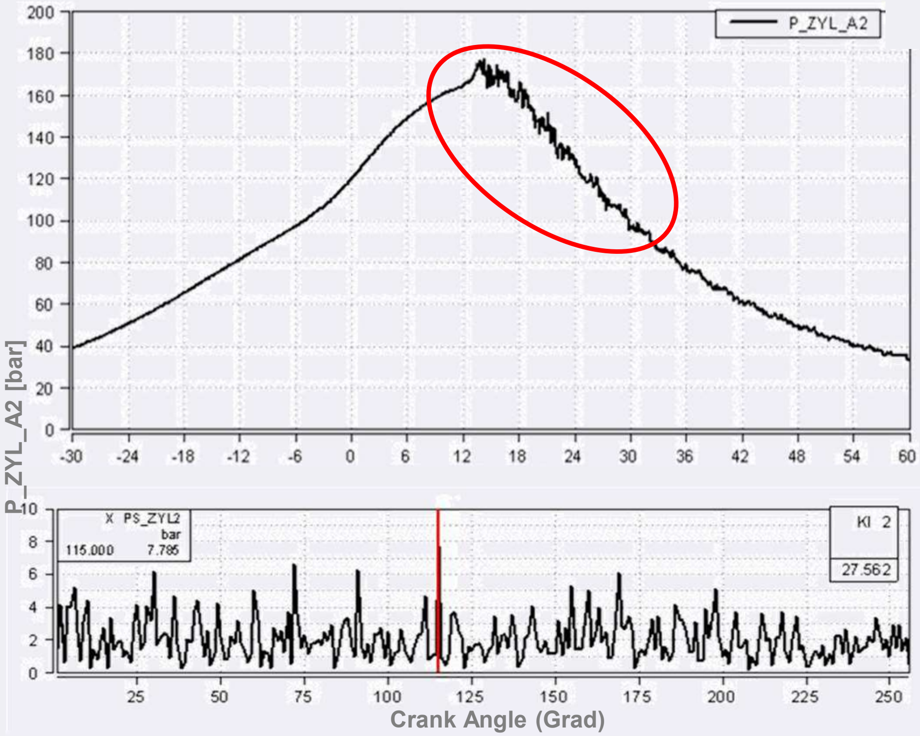
What is Knock

ECU's knock protection system immediately reduces power and **Protects engine**

Knocking Combustion → Detonation of Air & Gas Before Correct Piston Position

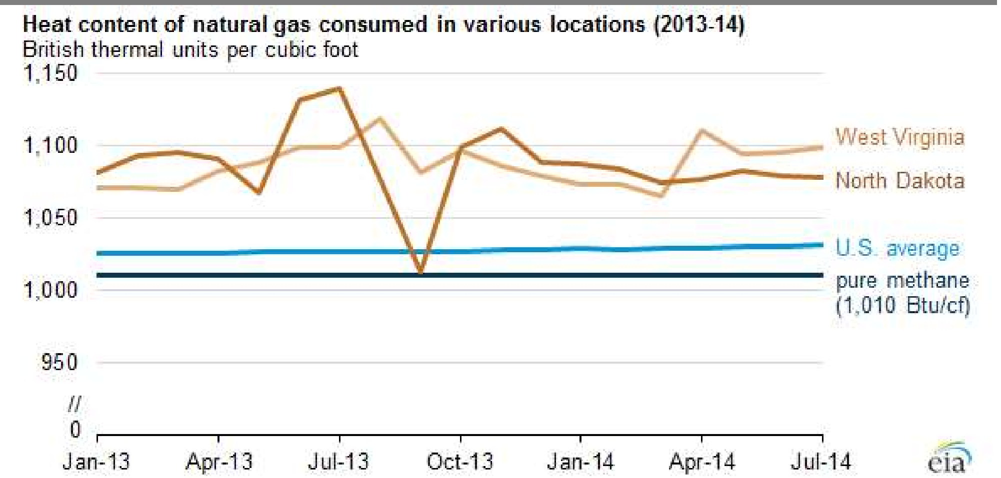


Key Factors for Gas Systems

HEAT CONTENT

Why is it so important?

- **The heat content value defines how much energy is in a certain amount of gas**
- **It is a crucial Factor for the selection of the right genset**
- **Typical heating values (LHV):**
  natural gas about 10 kWh/m³
  Biogas about 4 to 6 kWh/m³



Source: U.S. Energy Information Administration, *Natural Gas Monthly*

What Steps are required?

Find out Heat Content Value of your Gas Project

The heat content of natural gas, or the amount of energy released when a volume of gas is burned, varies according to the extent that gases with higher heat content than methane are included in delivered gas.

Hydrogen

Clarify variations in Hydrogen space

Storage is a big topic due to the H2 is very «light» and leakages + ignition / explosion exposure.

The future of hydrogen

Hydrogen can be used to power vehicles, generate electricity, power industry and heat our homes and businesses. It could make a huge difference on our carbon emissions and will be critical to achieving net zero.

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BLUE HYDROGEN – From LNG with or without carbon capturing (carbon neutral or not)

GREEN HYDROGEN – FROM Renewable production (Sun – Wind –Hydro)

GREY HYDROGEN – From fossil fuel production

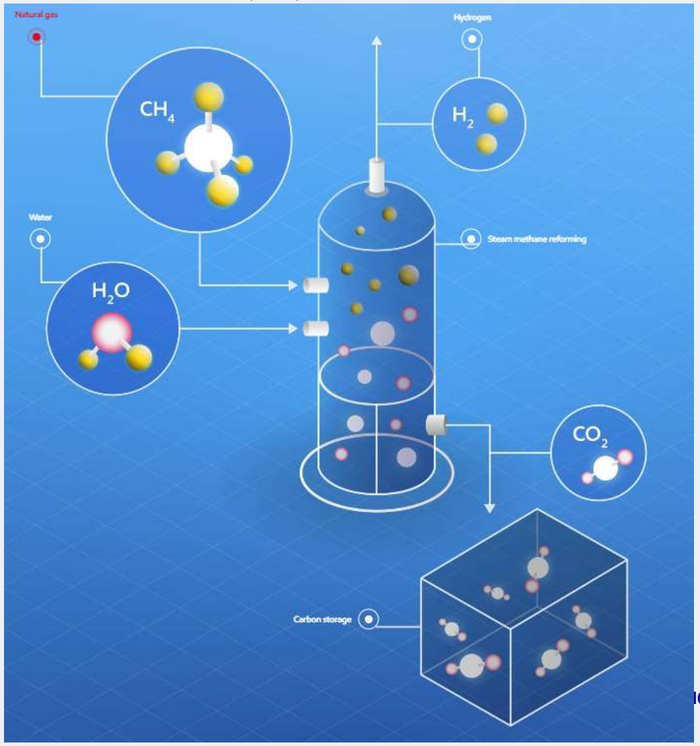
PINK HYDROGEN – From Nuclear production

YELLOW HYDROGEN – From Grid (depending on grid source)

Turquoise hydrogen - hydrogen produced from methane pyrolysis

What are the potential brakes to speeding up hydrogen use as a clean energy?

For hydrogen to be a viable alternative to methane, it has to be produced at scale, economically and the current infrastructure needs to be adapted.
The good news is that hydrogen can be transported through gas pipelines, minimizing disruption and reducing the amount of expensive infrastructure needed to build a new hydrogen transmission network. There would also be no need for a culture change in our home lives, as people are used to using natural gas for cooking and heating, and hydrogen energy equivalents are emerging.



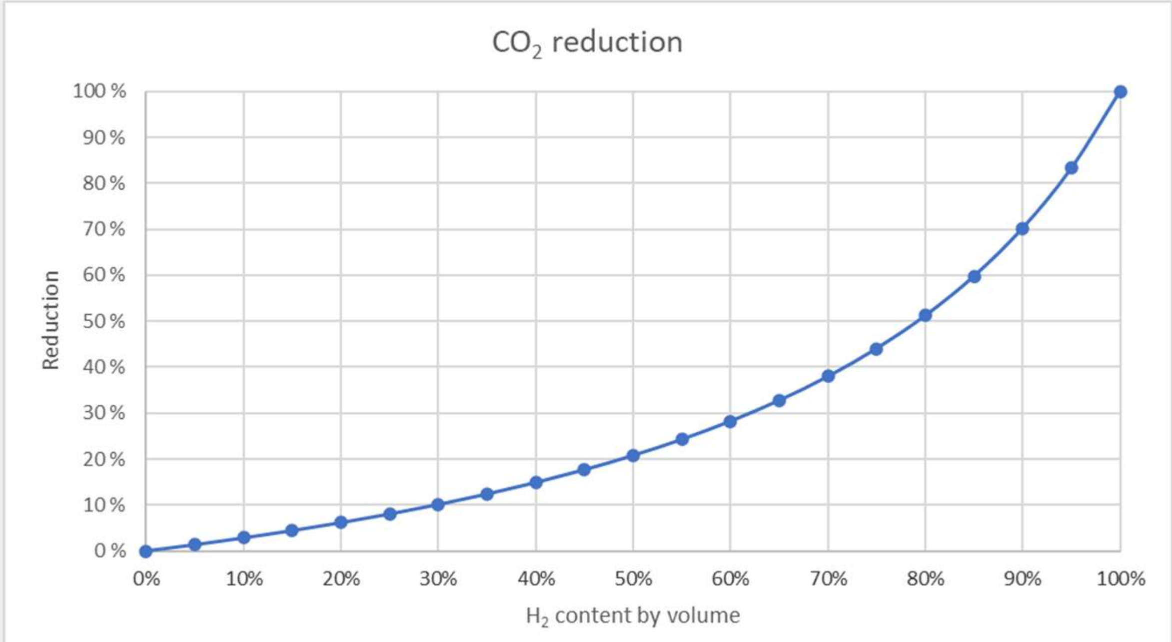
Hydrogen CO2 reduction pr volume %

As a guide we can state that 20% H2 will give 7% CO2 reduction

80% H2 will give 50% CO2 reduction

Fuel mix will only payoff if the H2 is subsidized or that the Emission tax is higher than the delta! !.

When hydrogen burns, it generates energy in the form of heat, with water as a by-product. That means energy created from hydrogen generates no atmosphere-warming carbon dioxide.



To reduce exhaust emissions on stoichiometric engines (lambda = 1, without excess air), 3-way catalytic converters are used.

To reduce exhaust emissions due to incompletely burned combustion products on engine with lean operation (operation with excess air), oxidation catalysts are used.

For additional reduction of NOx emissions with lean operation engines, SCR catalytic converters (selective catalytic reduction) can be used. The reducing agent (urea solution with an urea concentration of 32.5 %) in such catalysts reduces the nitrogen oxide emissions.

To guarantee the range of functions of the catalytic converters over a specific runtime, all specifications in the Fluids and Lubricants Specifications (with regard to fuels, intake air, lube oils) must be observed.

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Fuel Flexibility

Fuel Flexibility

Application examples:

- **BioGas** with fluctuating quantity blended with NatGas
- **Weak Gas** (low LHV) upgraded by NatGas
- **Hydrogen** mixed to NatGas to reduce Emissions
- In case of emergency the NatGas engine can be switched to **Propane**

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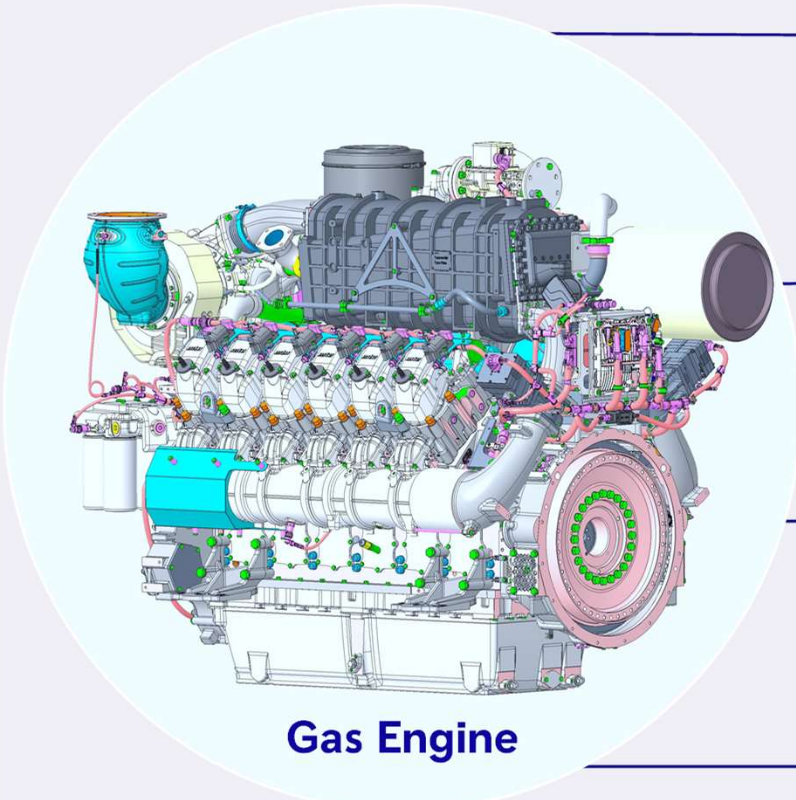
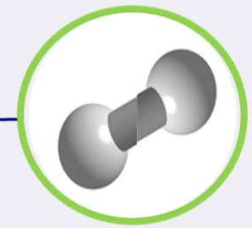


Blending

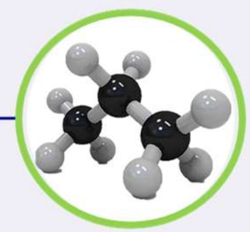
with two or gas fuels



H2-Addition

In the NatGas Grid

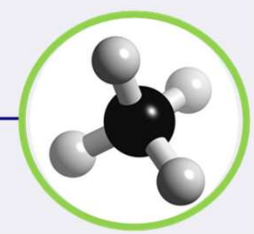
100% H2



Propane Engine

100% COP, and

Emergency Operation



BioGas

with Performance Improvement

Blending of 2 Gases

Application examples:

- **BioGas** with fluctuating quantity blended with NatGas
- **Weak Gas** (low LHV) upgraded by NatGas
- **Hydrogen** mixed to NatGas to reduce Emissions
- In case of emergency the NatGas engine can be switched to **Propane**

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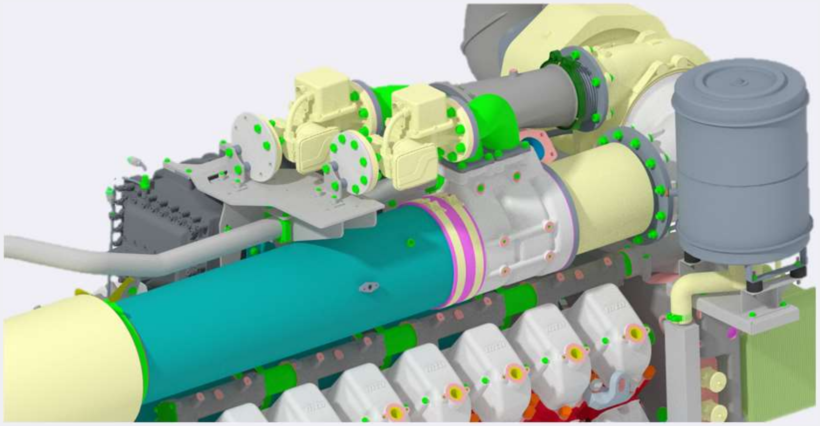
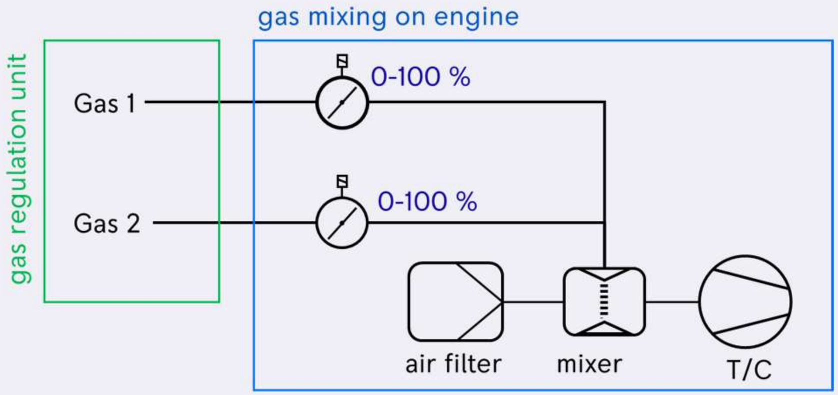
Fuel Blending Possible

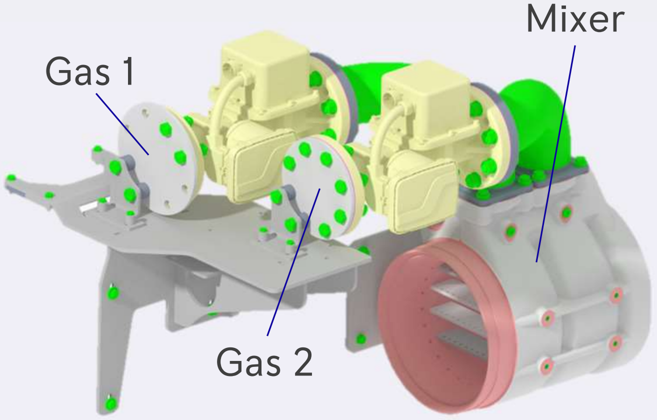
Mixing of 2 gases via metering valves on the engine

Control of the mixture by the engine controller

Highest possible flexibility for individual customer projects







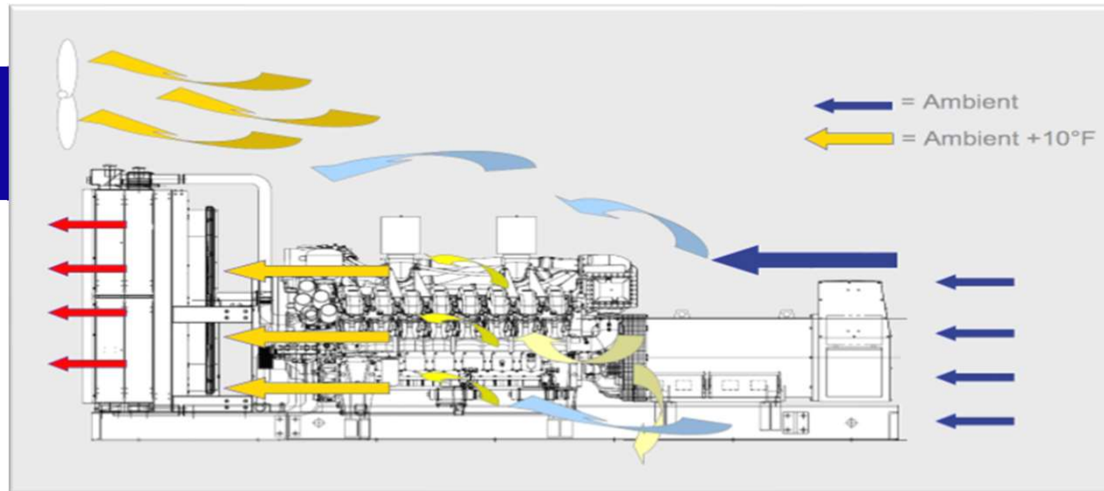
Environmental Concerns

Ambient Air Temperature

Max. 40 °C!- 104F

Humidity

Elevation



Room ventilation		
Genset ventilation heat [17)]	kW	167
Inlet air temperature: (min./design/max.)	°C	30 / 35 / 40.0
Min. engine room temperature [18)]	°C	15
Max. temperature difference ventilation air (in / out)	K	20
Min. supply air volume flow rate (combustion + ventilation) [19)]	m³ i.N./h	33500

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Key Components of CHP

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Combined Heat & Gas into Energy

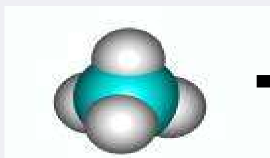
Total Efficiency =

Electrical Efficiency +

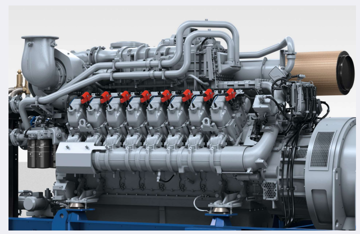
Thermal Efficiency

You can see a 90% Efficiency

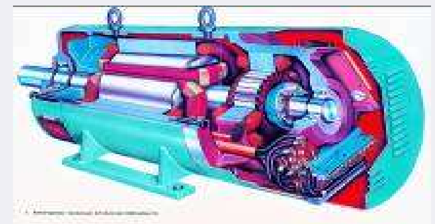
Chemical Energy



Mechanical Energy



Electrical Energy



47%* Thermal Energy

43%* Electrical Energy

*Example

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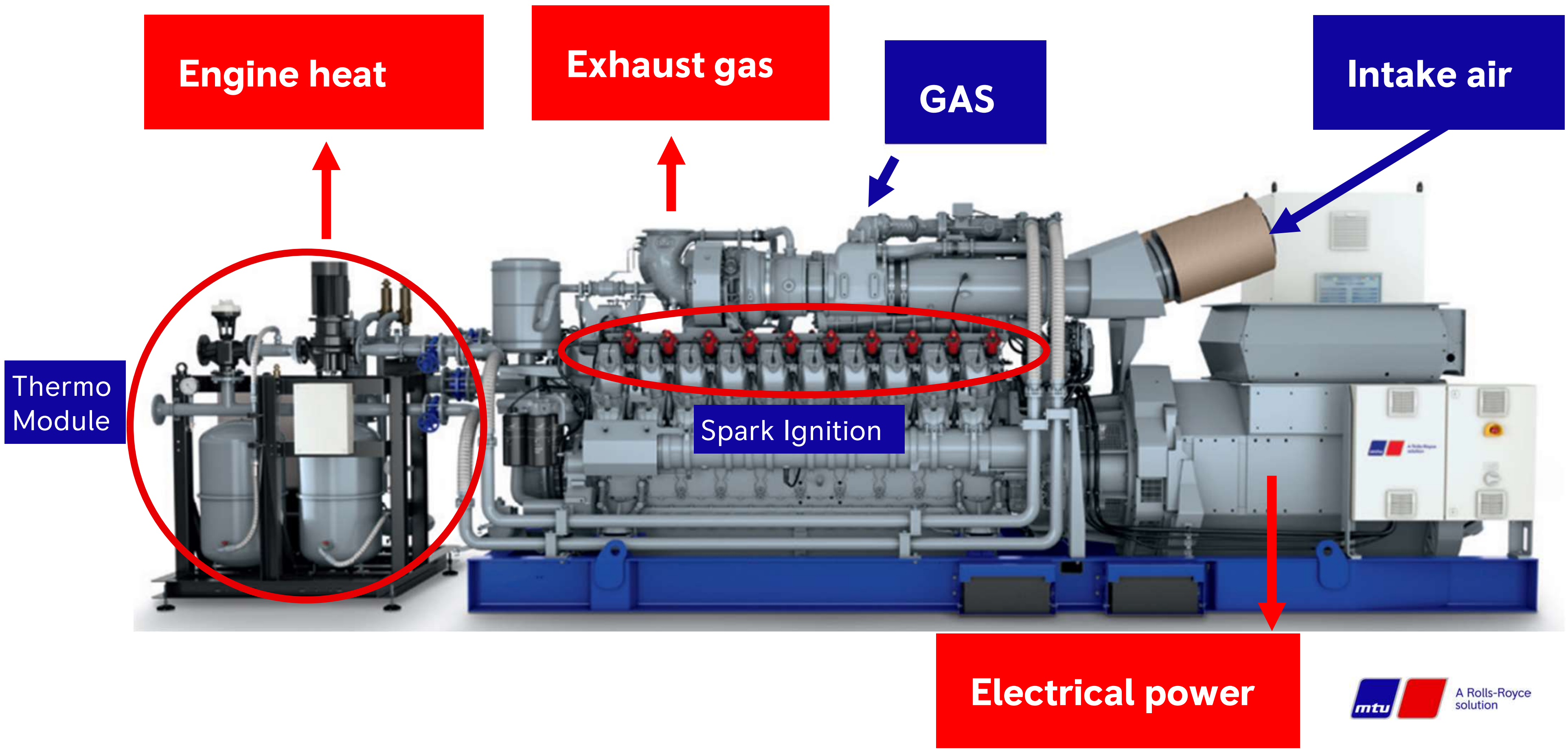
Complete Energy Utilization



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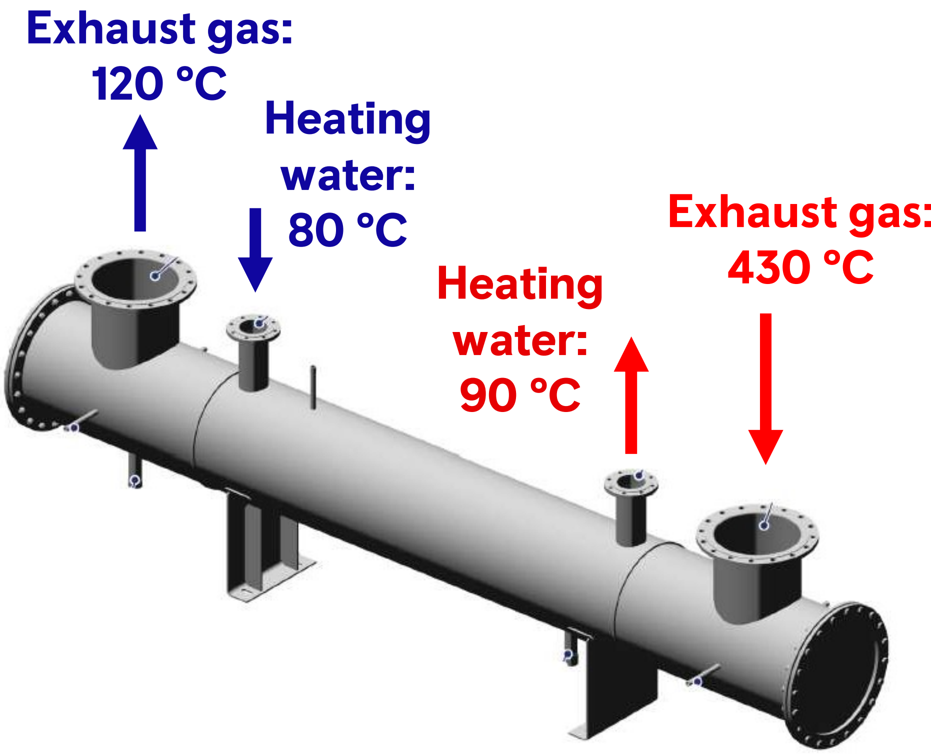
Exhaust Heat Exchanger



Energy balance	%	100	75	50
Electrical Power [2) 3)]	kW	2538	1904	1269
Energy input [4) 5)]	kW	5896	4506	3164
Thermal output total [6)]	kW	1492	1085	744
Thermal output engine (block, lube oil, 1st stage mixture cooler) [6)]	kW	1492	1085	744
Thermal output mixture cooler 1st stage [6)]	kW			
Thermal output mixture cooler 2nd stage [6)]	kW	212	140	84
Exhaust heat (120 °C) [6)]	kW	(1205)	(1053)	(806)
Engine power ISO 3046-1 [2)]	kW	2600	1957	1316
Generator efficiency at power factor = 1	%	97.6	97.3	96.4
Electrical efficiency [4)]	%	43.0	42.3	40.1
Total efficiency	%	88.8	89.7	89.1
Power consumption [7)]	kW			

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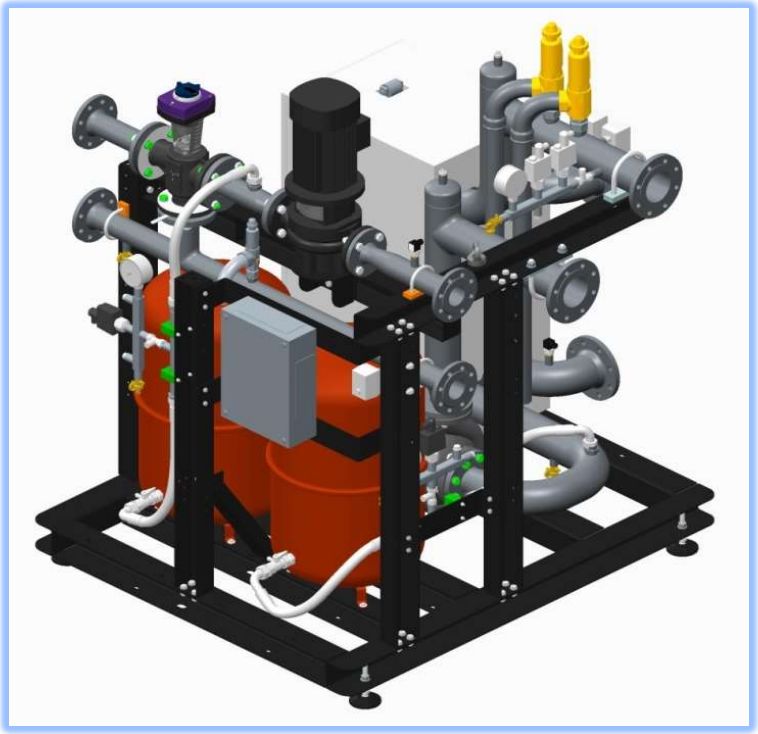
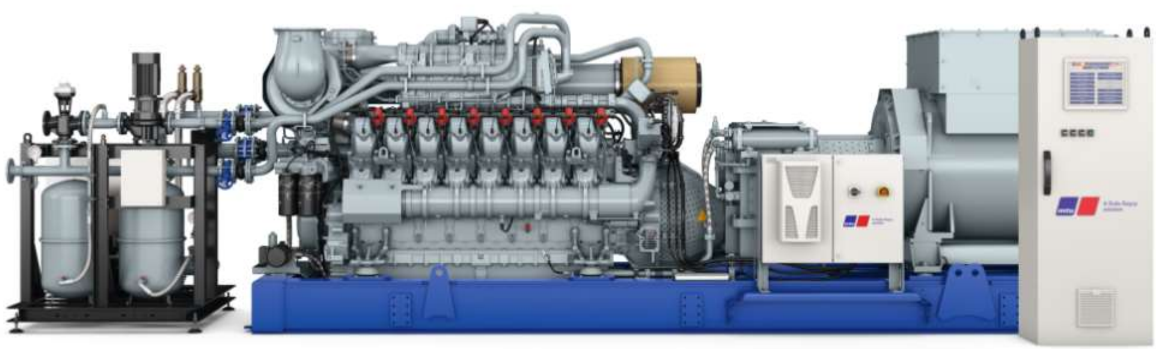
Engine Cooling Heat Recovery





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Oil Reserve Tank

Oil Reserve
Oil Cooling

The oil volume (in additional tank) is determined as follows:

$$\text{Oil volume} = \frac{\text{Oil change interval}}{\text{Oil service life in Refill}} * \text{Lube oil in engine} + \text{oil change interval} * \text{lube oil consumption}$$

Example calculation for 12V L64:

$$\text{Oil volume} = \frac{3000h}{1000h} * 280l + 3000h * 0.18dm^3/\ h = 1380l$$

If an additional tank is used, the oil change interval can be extended to the corresponding (maintenance) intervals. In this case, the additional oil volume is a calculated value which can be used to determine the minimum size of the oil tank.

This indicated oil volume is the total oil volume (including the initial filling) in order to achieve the corresponding (maintenance) intervals.

If the additional oil volume is reduced, then the oil circulation with oil bleed system principle no longer works because the oil consumption will limit the oil service life due to the low volume. This means that the tank is empty before the oil has aged.

It is recommended to have two oil tanks for each system to be able to have two separate dates for oil deliveries and for oil changes and thus to minimize downtimes.

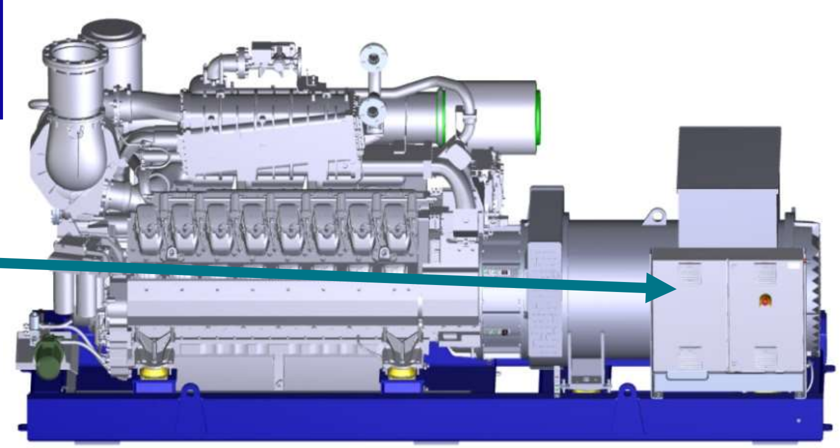
The selection of a suitable engine oil for gas engines depends primarily on the type of gas used to power the engine. The gas engine must only be operated with approved engine oil.

The oil service lives should be regarded as empirical values and guide values. They can deviate depending on the load profile, gas quality, temperature level, oil grade and oil consumption of the engine

Controls

Interface Panel

- Genset Controller, Engine Controller Access, Alarm Functions
- The IP is included in the minimum scope of supply
- Several Interfaces (e.g. Modbus RTU)



Module Control

- Provides full functionality of Genset/CHP Plant
- Comfortable Visualization for the customer via IPC
- Data-Logging and Remote access
- Heating water system pump control, valve, and Fans
- And many other available functions.

Multiple Plant Control System MCS

- Additional functionality for multi-unit power plant control
- Selection (Start/Stop) of CHP Modules according to Heat or Power demand
- Complete island mode and grid failure control logic of multi-unit power plants
- Up to 30 Assets can be controlled by one MCS

Questions?!

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