CHP – Old Hat or State of Art?

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Global Application Engineering Leader
Sales

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Hot topics in today's world

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Combined Heat and Power

Usable forms of energy from a gas genset

Electricity

Chilled water

Hot water

Steam

Hot air

High electricity to heat ratio favors economics for many CHP plants

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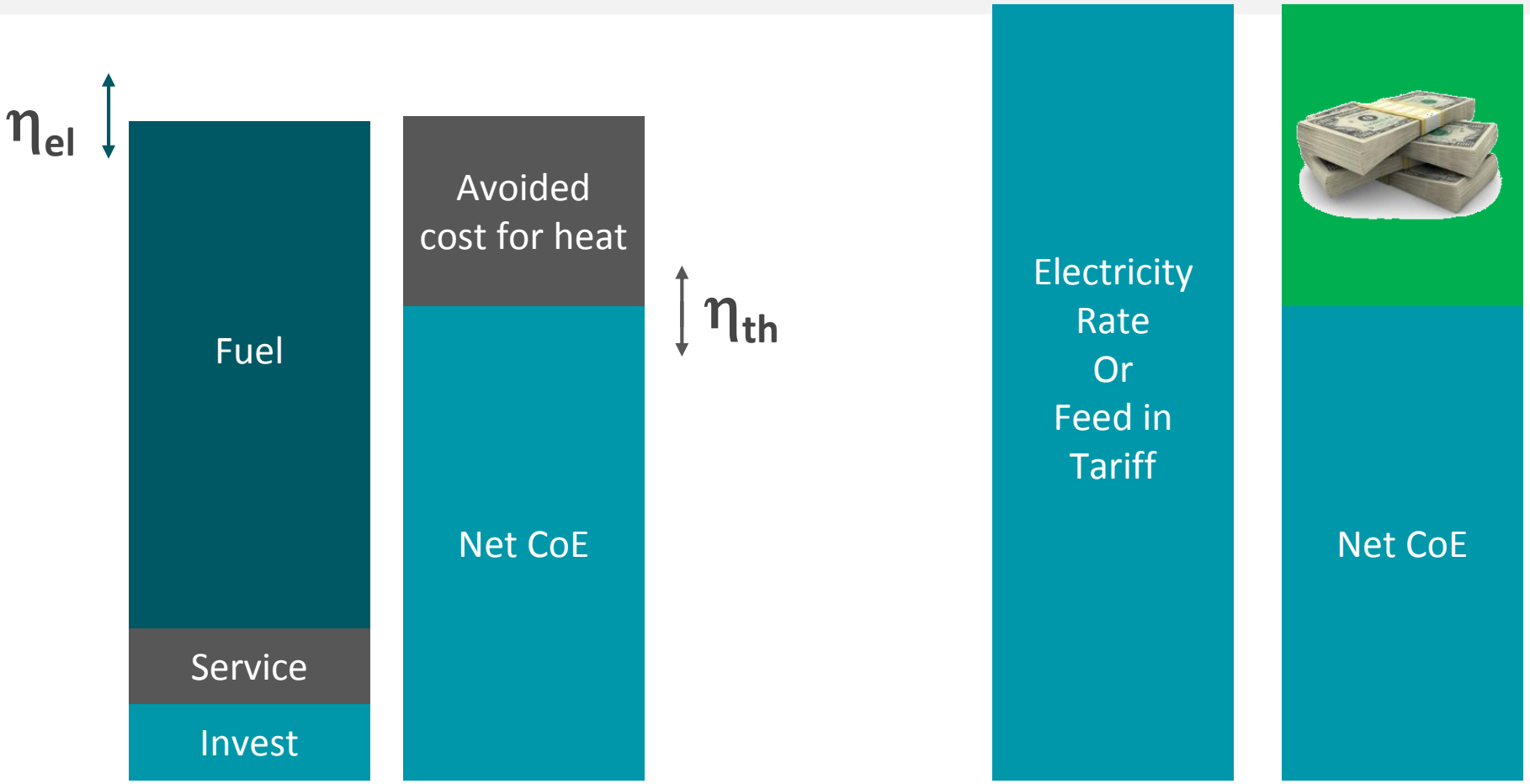
Combined heat and power to reduce energy cost



Fuel efficiency and optimized heat usage are biggest levers to drive down cost of electricity (CoE)

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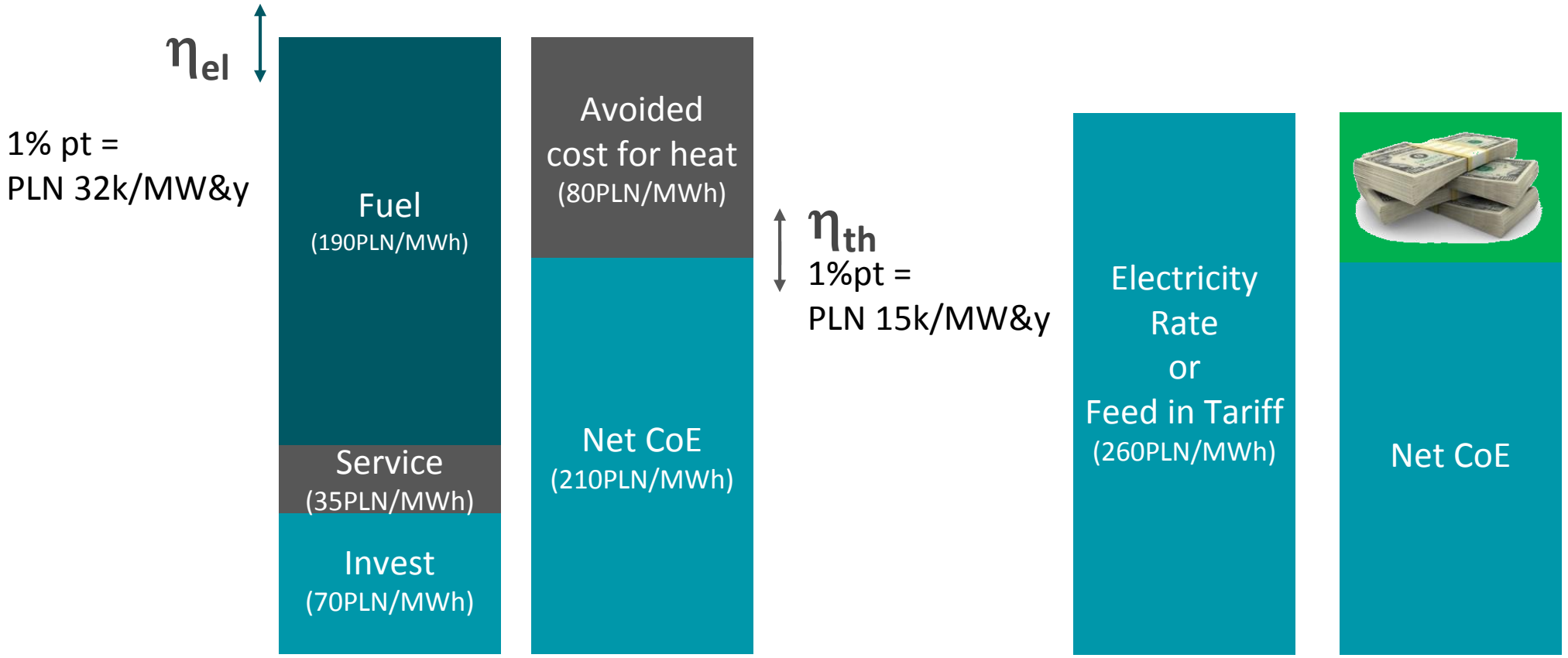
Cost of electricity - Poland



ROI around 4.5 years...

Invest = 3.5MMPLN/MWel, Gas = 80PLN/MWh, Electricity = 260PLN/MWh

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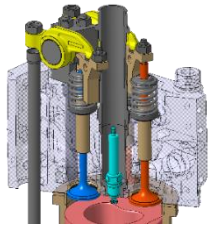
So how do we enable?

Gas engines are not a static piece of iron …

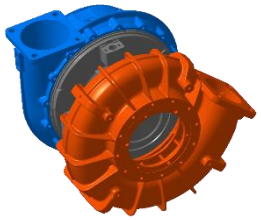
Levers to optimize

Compression ratio (pistons)

Valve timing

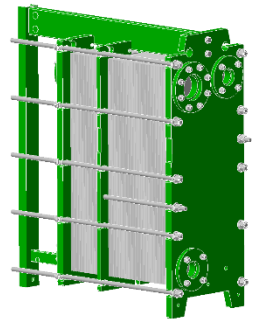


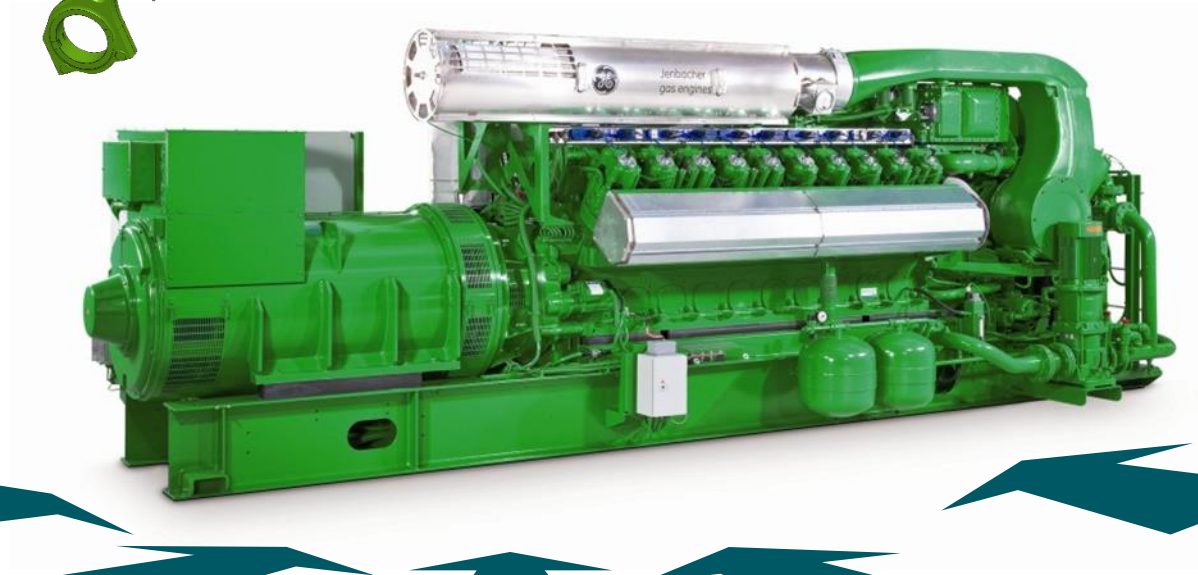
Turbocharger



Ignition timing

Hydraulic variants (heat exchangers)





Requirements/ conditions

Gas quality

Emission

Focus Electrical Efficiency/ Thermal Efficiency

Altitude Ambient Temperature

Climate Conditions

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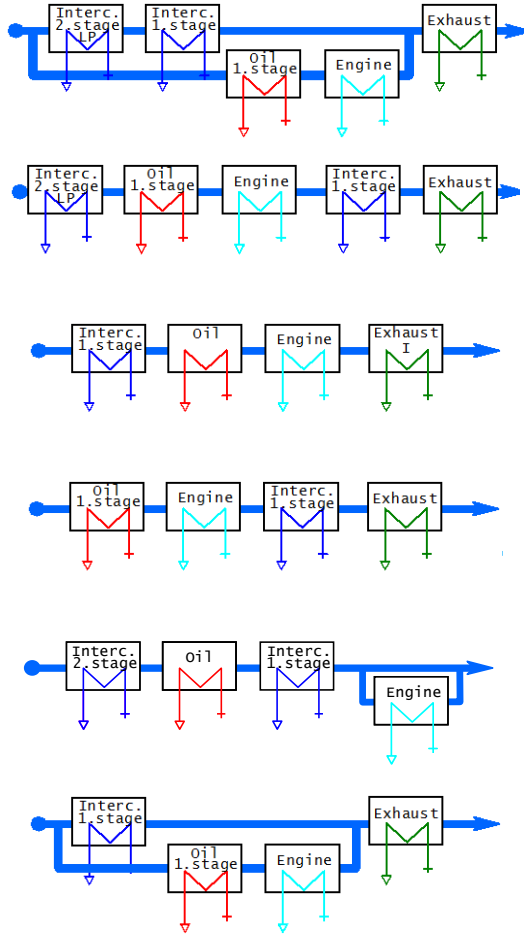
Multiple hydraulic integrations to meet different customer needs

- Two stage oil cooling for high temperature levels
- Heat recovery with return water temperatures from 35°C to 85°C
- Heat recovery with return water temperatures from 70°C to 130°C
- Total efficiencies of up to 92% with single stage exhaust gas heat exchanger



Fully designed, packaged & tested hydraulic integrations enabling max effficiencies

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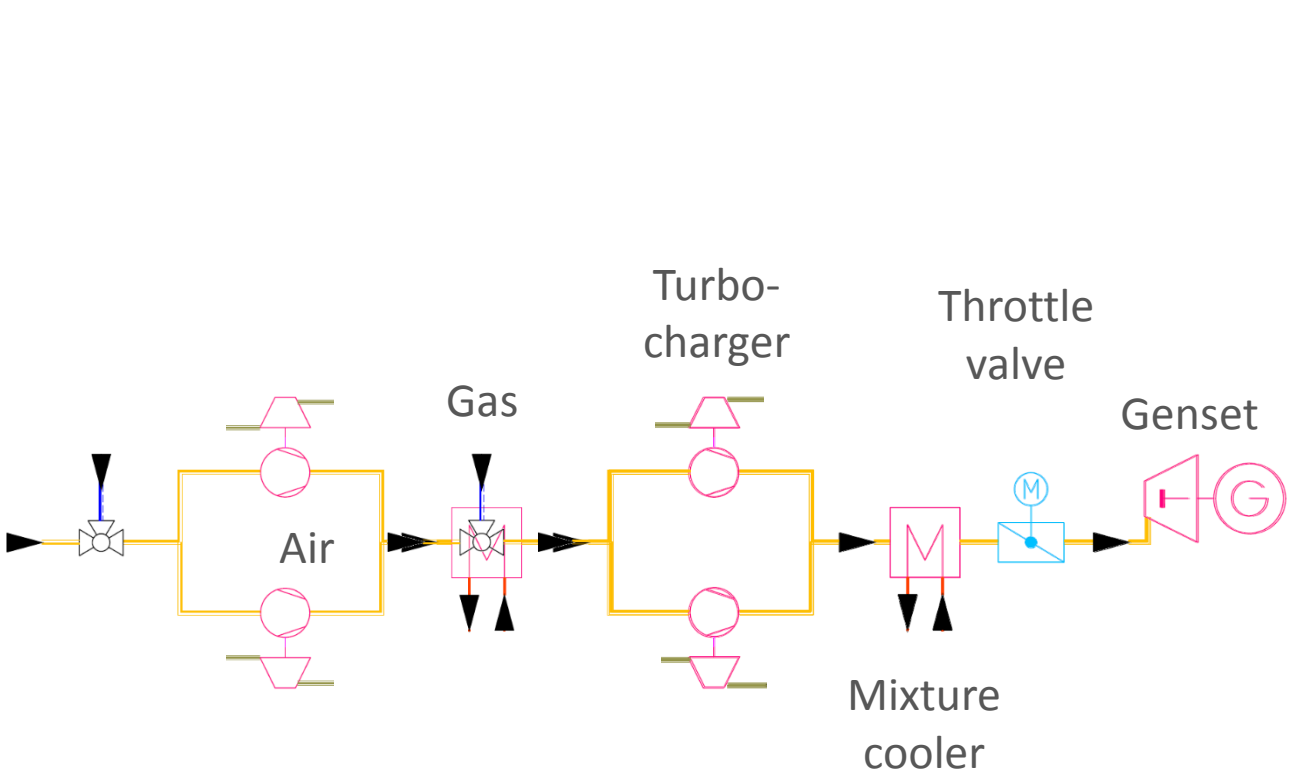
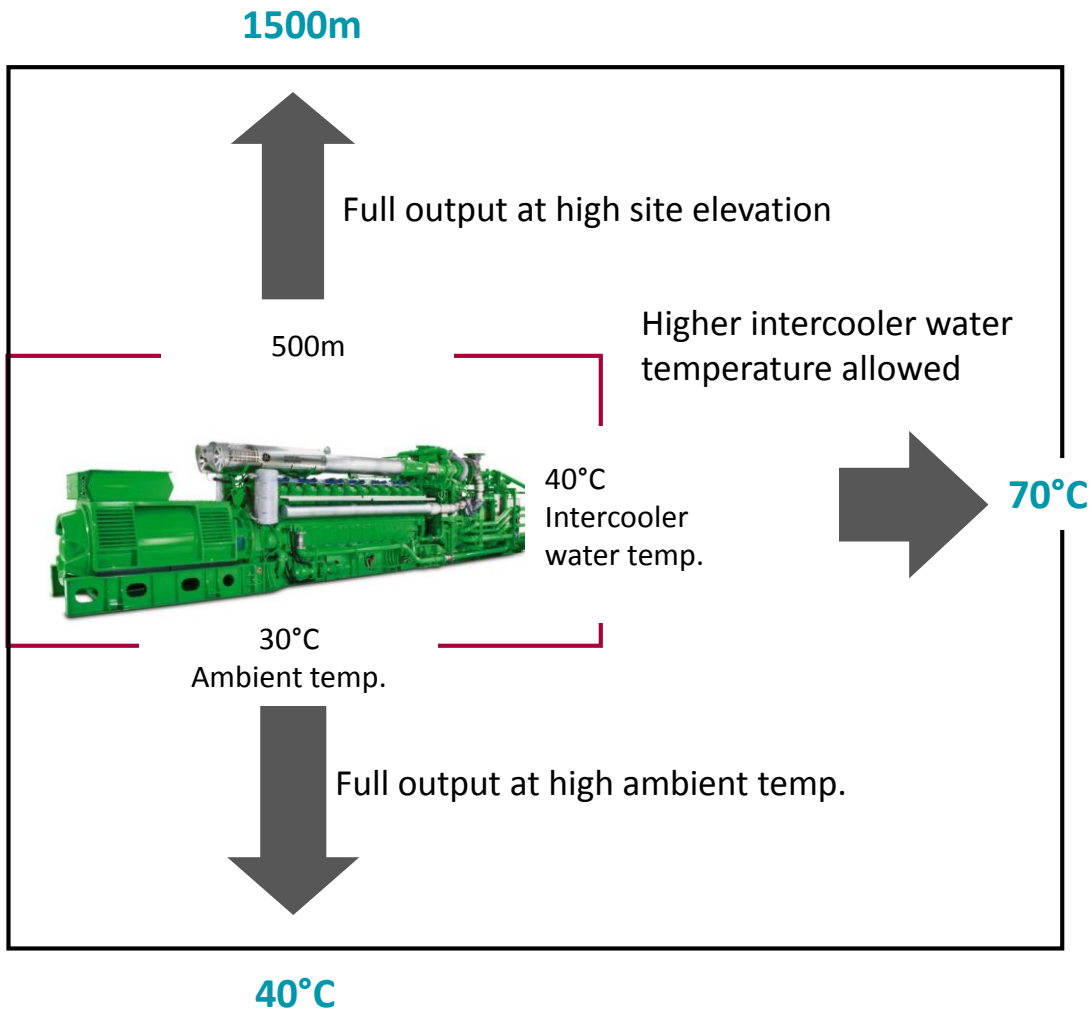
Two stage turbo charging... Improved flexibility, larger operating range





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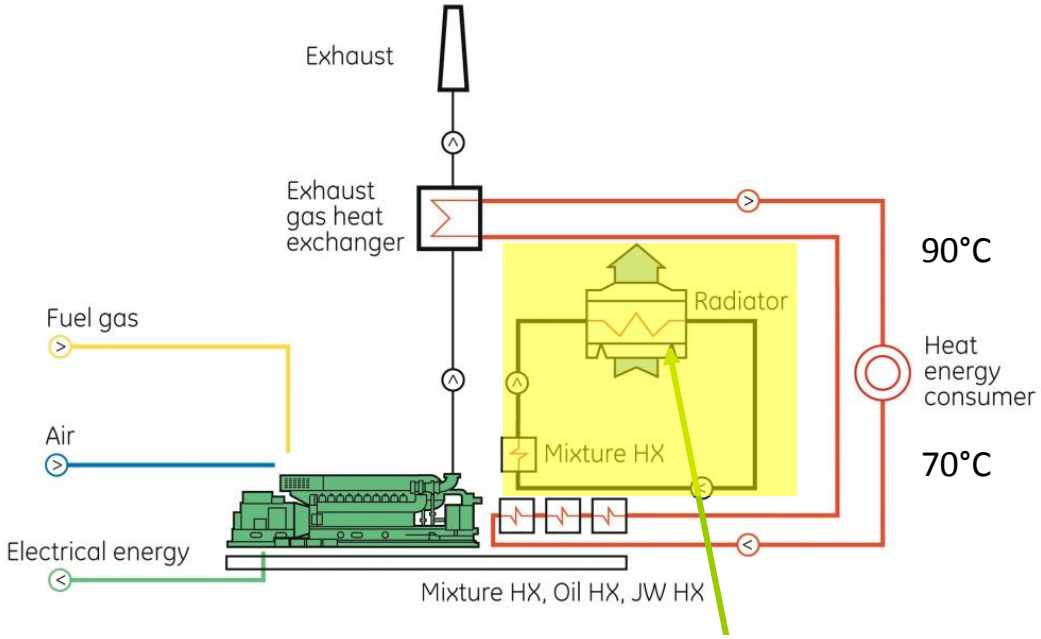
Example J624 - Efficiency optimizations

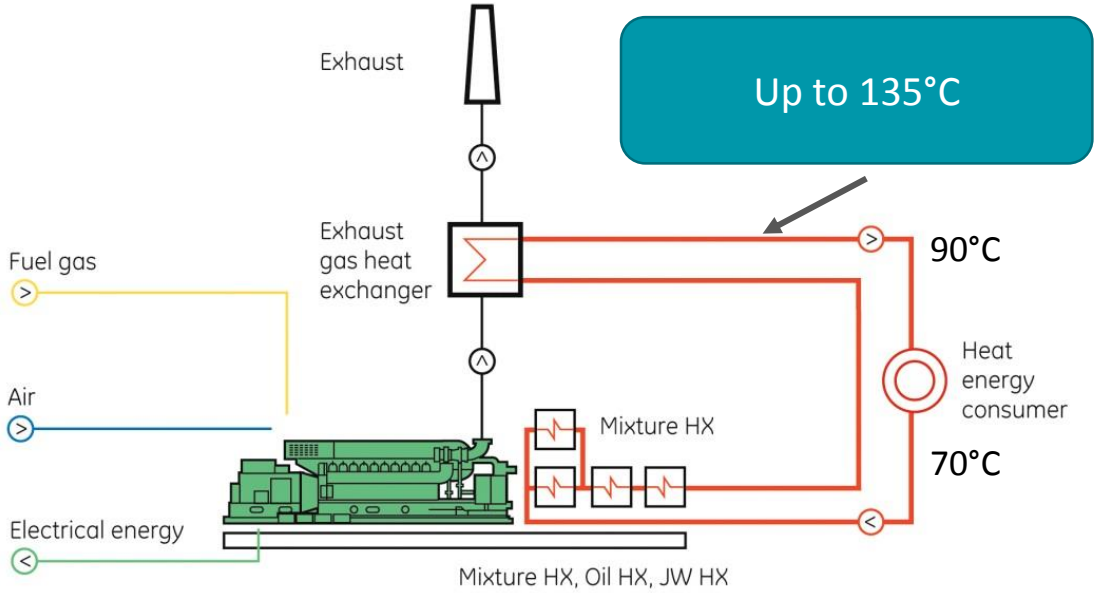
Focus electrical efficiency



Radiator for second mixture cooler (40°C cooling water temp. needed)

Total efficiency	**89.5%**
Electrical efficiency	46.6%
Thermal efficiency	42.9%

Focus total efficiency



Second mixture cooler integrated in HW circuit (70°C)

Total efficiency	**91.9%**	↑
Electrical efficiency	45.6%	↓
Thermal efficiency	46.3%	↑

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Dedicated CHP versions across portfolio

		J420 C05	J420 C511
Pel	[kWe]	1 562	1 562
Pth 70/90°C	[kWth]	1 611	1 810
eta_el (Geno)	[%]	43.3%	42.6%
eta_th	[%]	44.7%	49.3%
eta_total	[%]	88.0%	91.9%
NT Mixture (40°C)	[kWth]	115	~

J620 J01	J620 J511
3 360	3 360
3 147	3 498
45.8%	44.5%
42.9%	46.7%
88.7%	91.2%
280	0

New CHP Versions – maximum efficiency enabled by integrated mixture cooler & increased exhaust temperature

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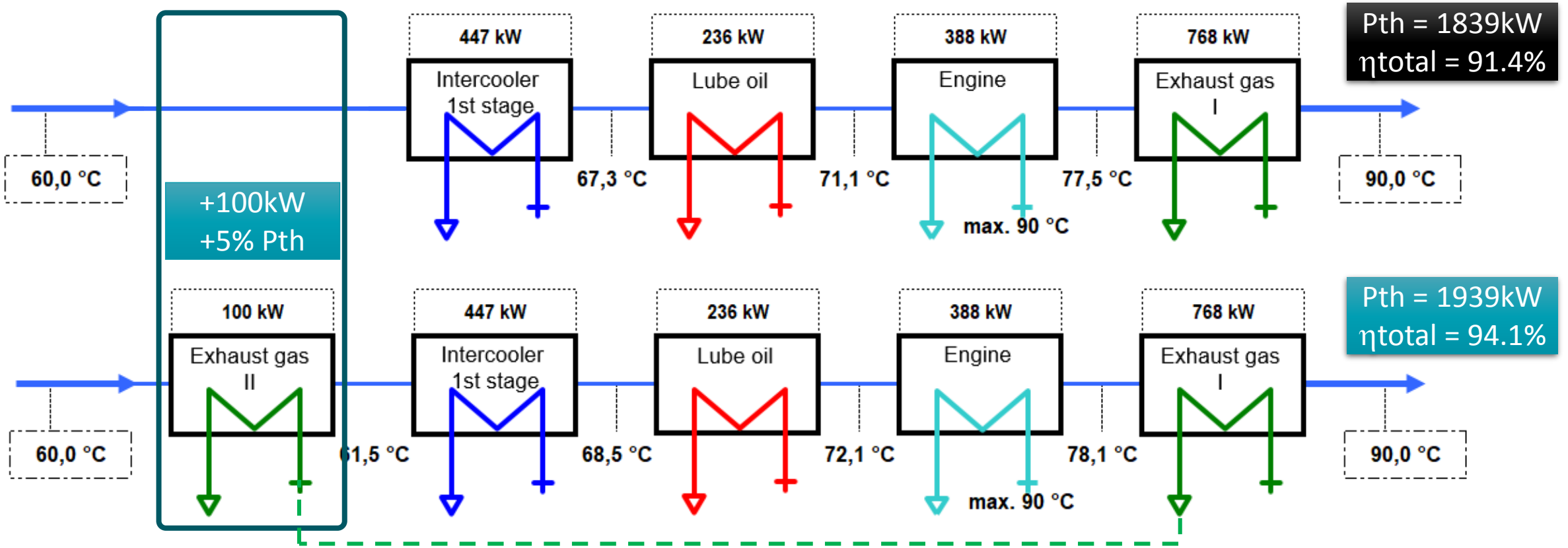
Two stage exhaust heat exchanger - J420 C511



100 kW $_{thermal}$ x 0.05€/kWh x 6,000oh = € 30,000,-/a

Break even <1 year in many cases

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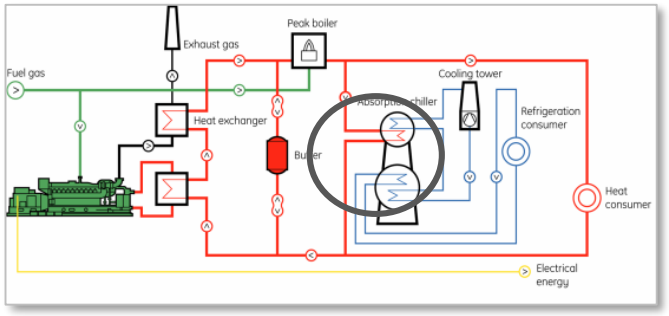
Absorption chillers – Capabilities

Advantages

- Driving power = heat
- Low operating costs
- Electrical energy required: approx. 1% of refrigeration capacity
- Few moving parts → Low servicing and maintenance costs
- Increased annual utilisation ratio of cogeneration plants
- Very good behaviour under part-load
- CFC-free refrigerants

Disadvantages

- Relatively high capital costs
- Low power density, large volume of construction
- High recooling capacity



Hot Water

Hot water
single stage
COP 0.7 – 0.75

Exhaust heat only

Exhaust gas heat
COP 1.2 – 1.35
separate use of hot water

Total heat

Combined exhaust gas + hot water
COP 1.0 – 1.05

Optimum performance = compromise between gas engine and chiller

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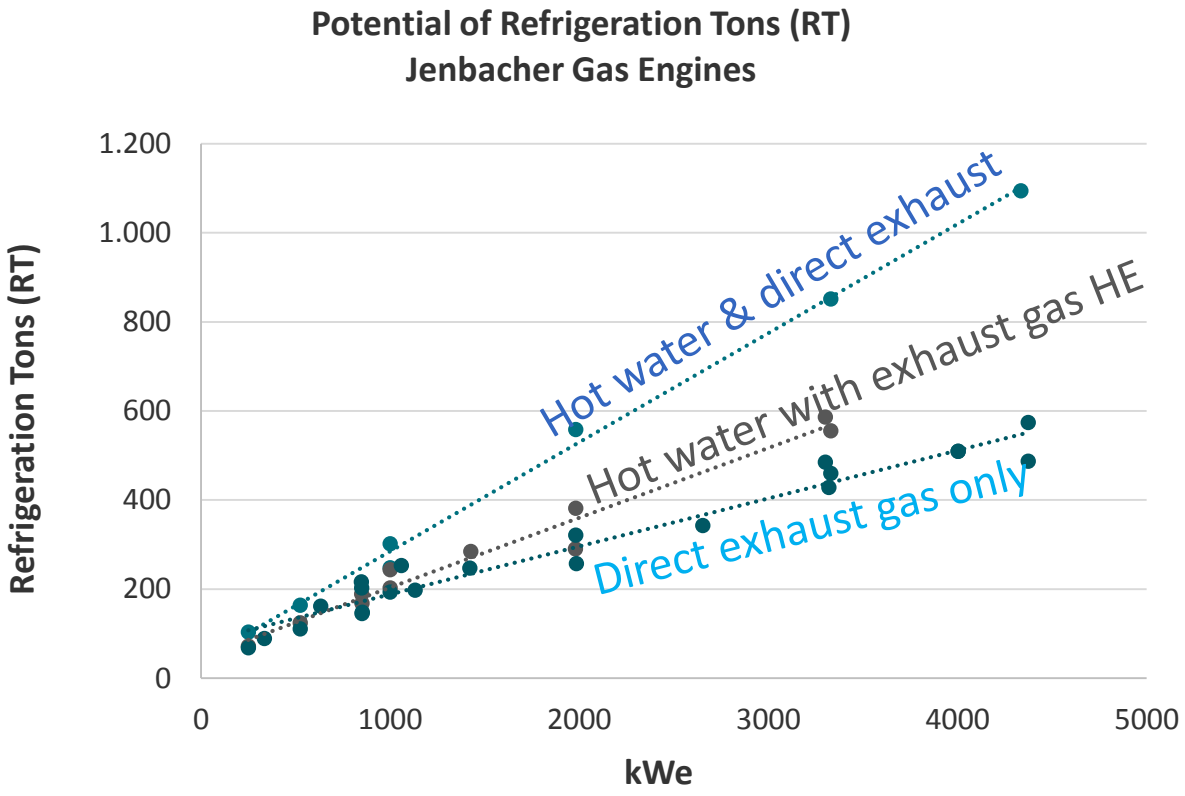
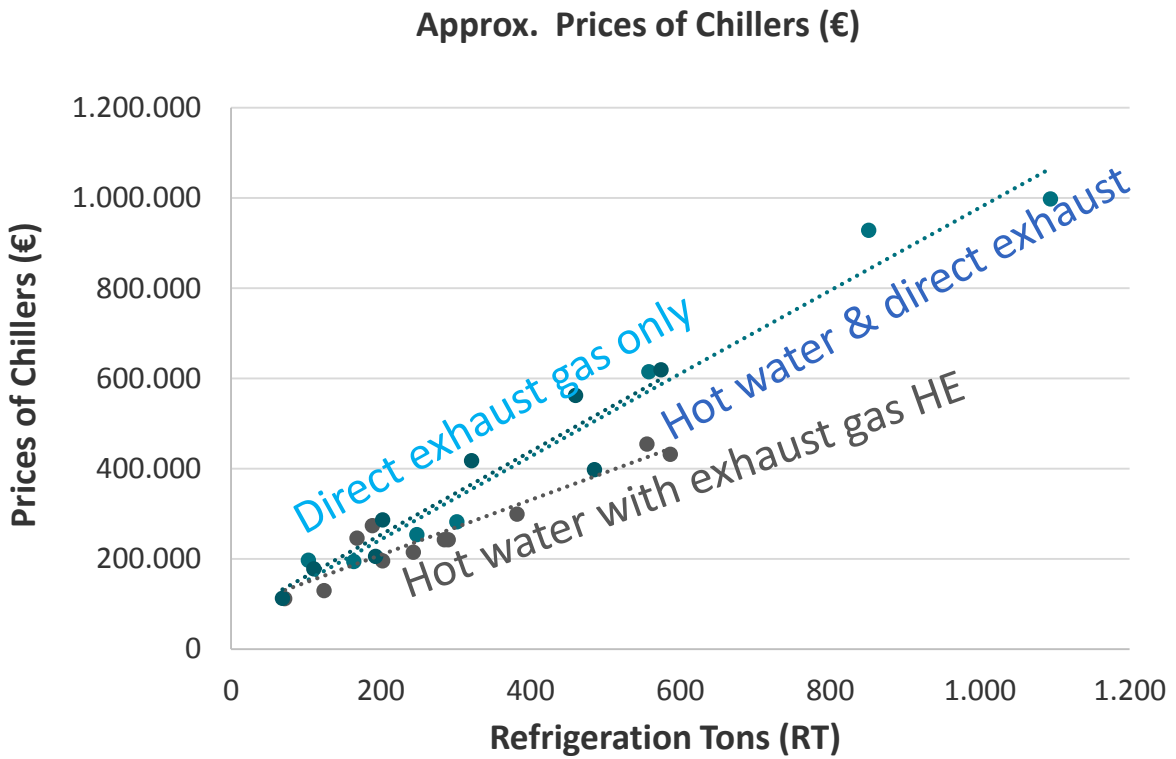
Absorption chillers – facts & figures





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Absorption chillers – capabilities

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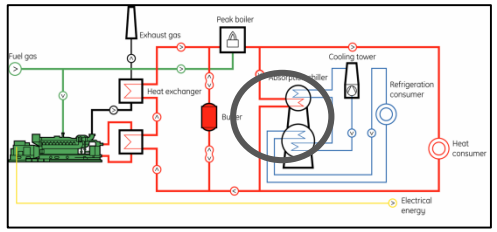

Hot Water

Hot water
single stage
COP 0.7 – 0.75

Best $/kW ratio

Exhaust heat only

Exhaust gas heat
COP 1.2 – 1.35
separate use of hot water

Lowest absolute invest

Total heat

Combined exhaust gas
+ hot water
COP 1.0 – 1.05

Highest chilling yield

Optimum performance = compromise between gas engine & chiller

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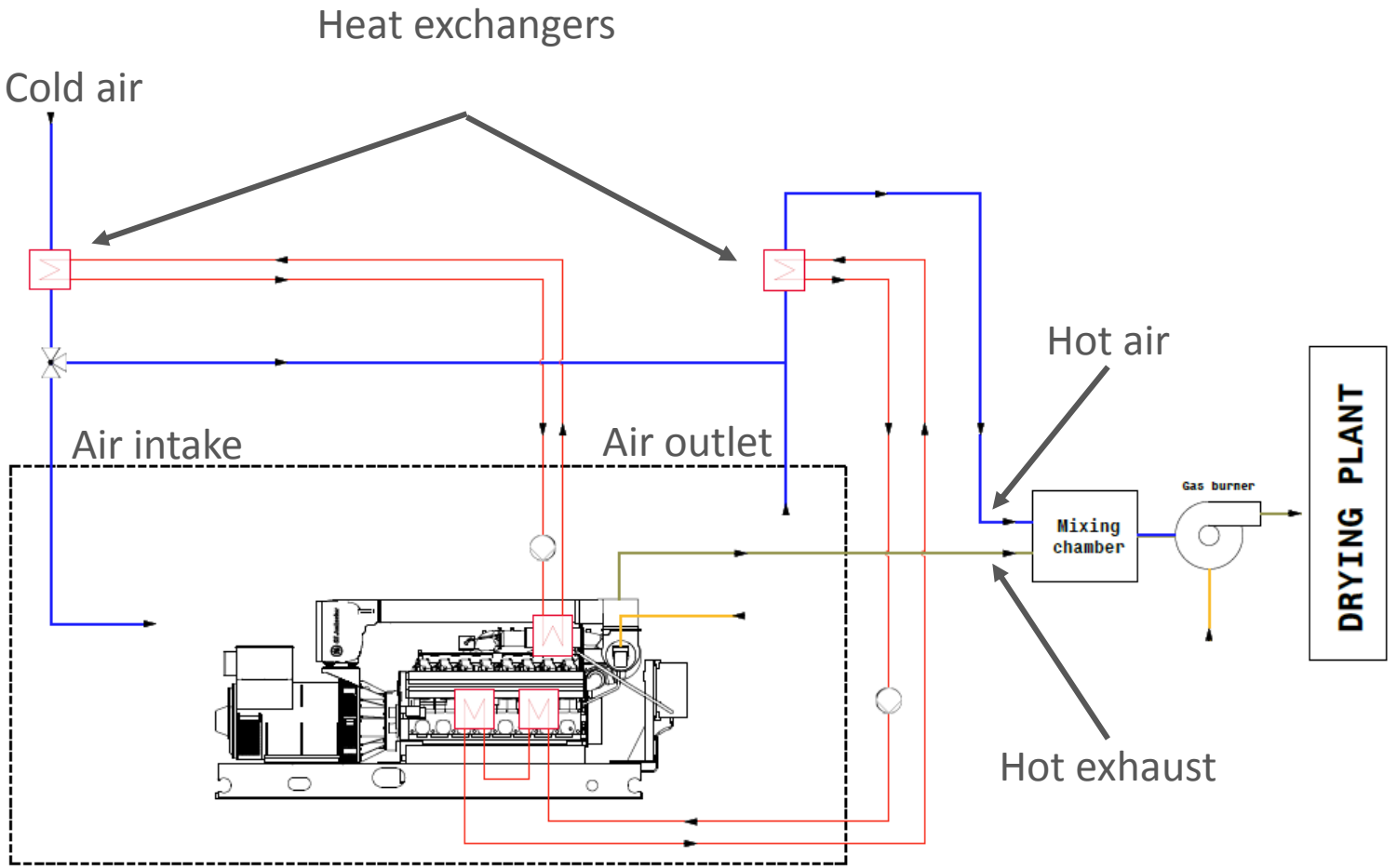
A few examples

Brick industry – drying process (use all engine heat)

Examples:
Brickyard Lundgaard 2x212– Dnk
Wienerberger 1xJ616 – ITA
Cerabrick 6xJ620 – ESP
...
200+ engines; 2,200+MW delivered



95% energy efficiency achievable

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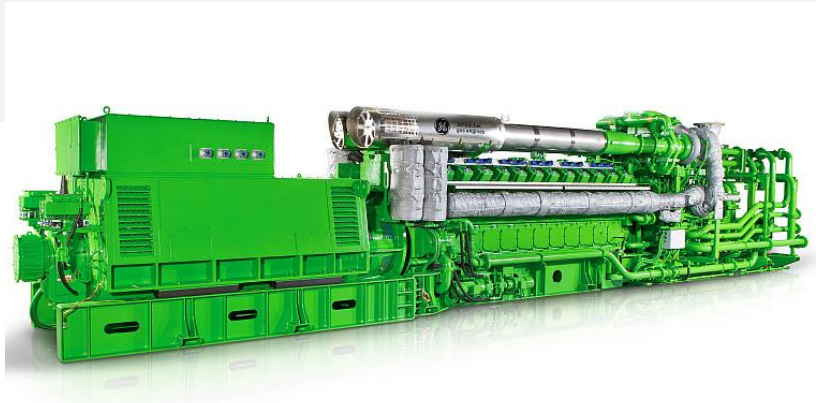
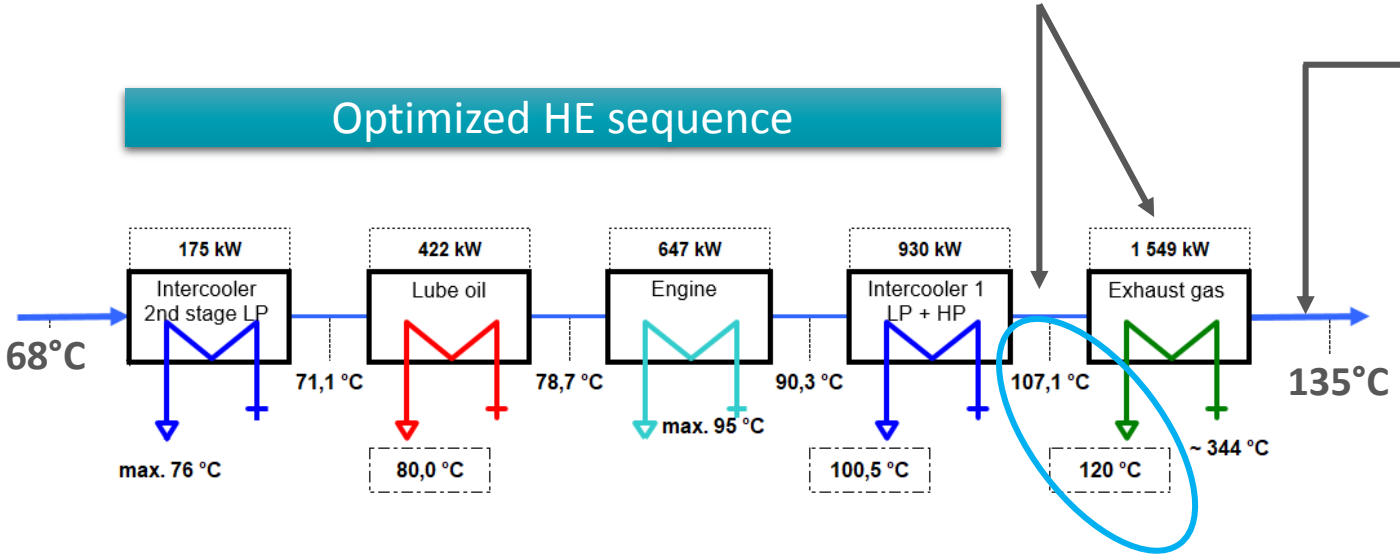
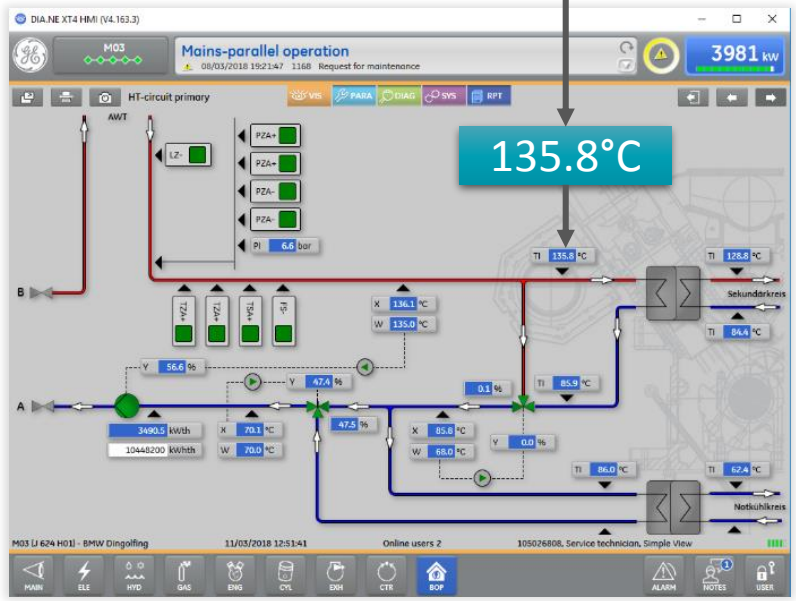
Optimized hydraulic variant J624-H01



Large size Exhaust gas heat exchanger to allow low ΔT

Optimized HE sequence





Recoverable thermal power: 3723kW (41.6%)
Electrical power: 4130kW (46.3%)
Total efficiency: 88%

Up to 135°C reachable with J624 at high total efficiency

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CHP Neuenfelde/INNIO …. J412C + heat pump

99+% total efficiency demonstrated on annual average!

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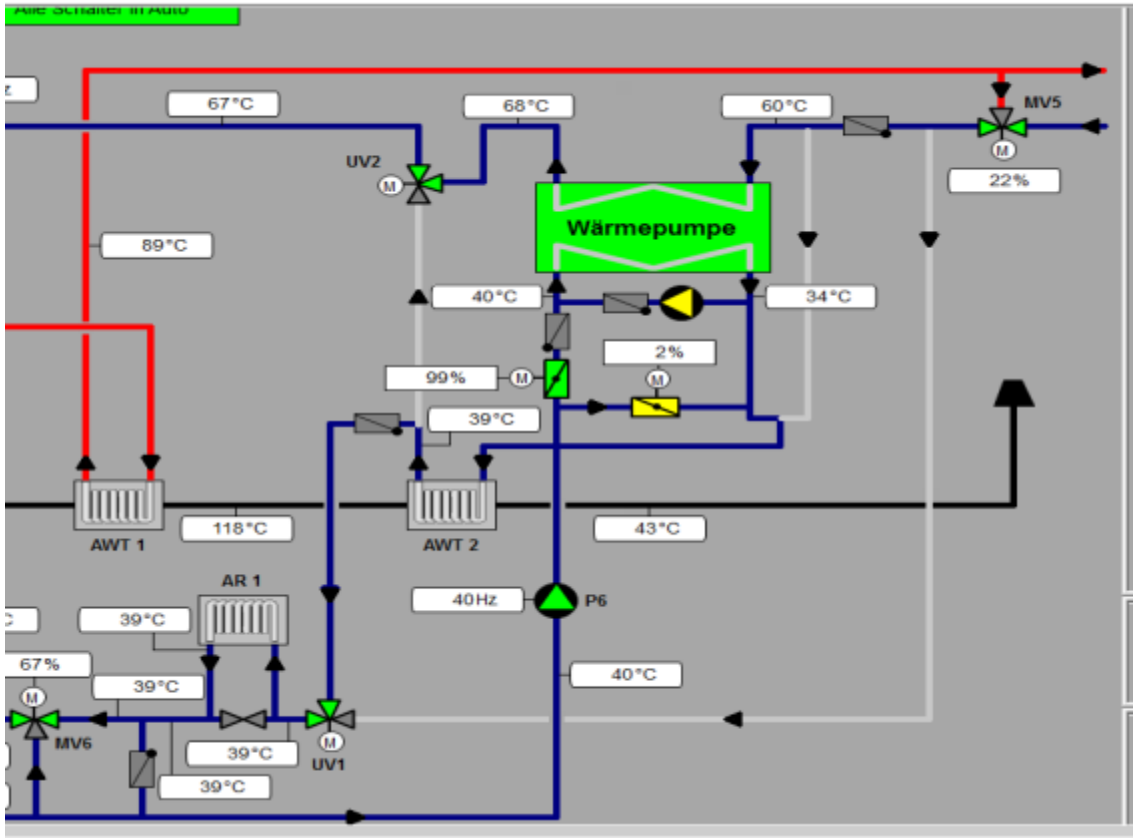
CHP Neuenfelde/INNIO …. J412C + heat pump



Units	CHP	CHP + HP	
Pth	1.007	1.279	[kWth]
HP_Pel	~	-72	[kWel]
Pel_net	937	865	[kWel]
eta_el	43.3%	40.0%	[%]
eta_th	46.5%	59.1%	[%]
eta_ge	89.8%	99.0%	[%]

at 60/90°C

Pth = +272kW (+27%)
COP 3.5-4

Feasible for heat to electricity value <1:3 & high heat rates

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CHP with warm water and steam generation

Pak Maya/Izmit
2 x JMC 320 GS N.L

Saturated steam
2 x 822 kg/h (550kW)
(8 bar)

Electrical power:	**2 x 1,048 kW**
Recoverable heat:	**2 x 630 kW**
Steam:	**~2 x 820 kg/h**
Electrical efficiency:	**38.9 %**
Thermal efficiency (WW):	**23.4 %**
Steam generation efficiency:	**20.4 %**
Total efficiency:	**82.7 %**

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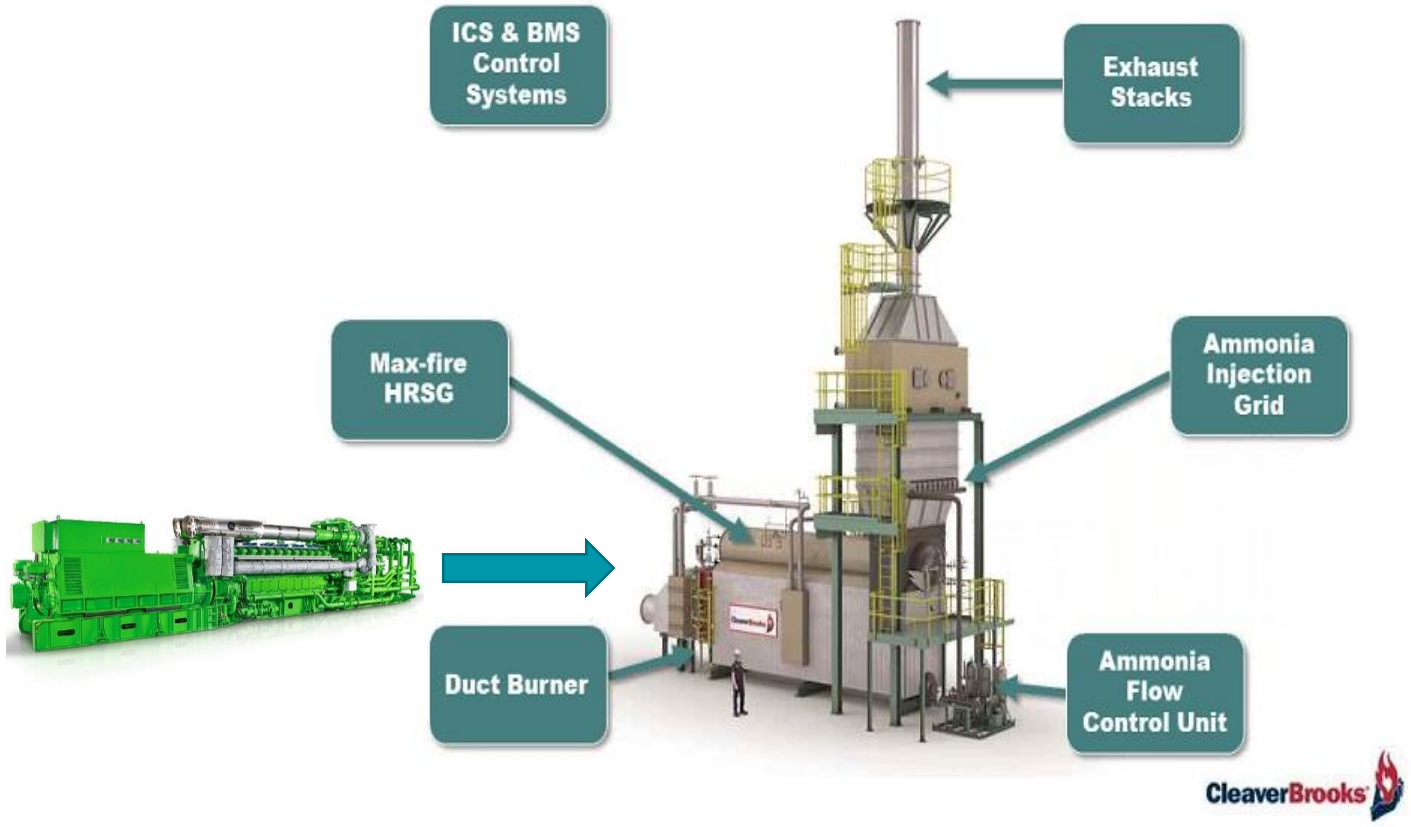
Steam generation with duct burner

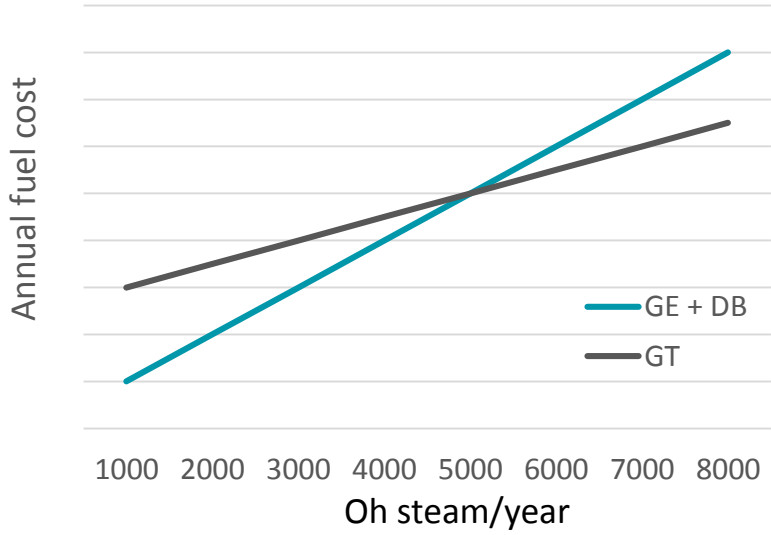


Where it makes sense:

- High altitude & temp. environment
- High electrical power demand hours
- Volatile steam demand
- Steam demand < 4times gas engine capability

Gas cost

continuous electricty, variable steam



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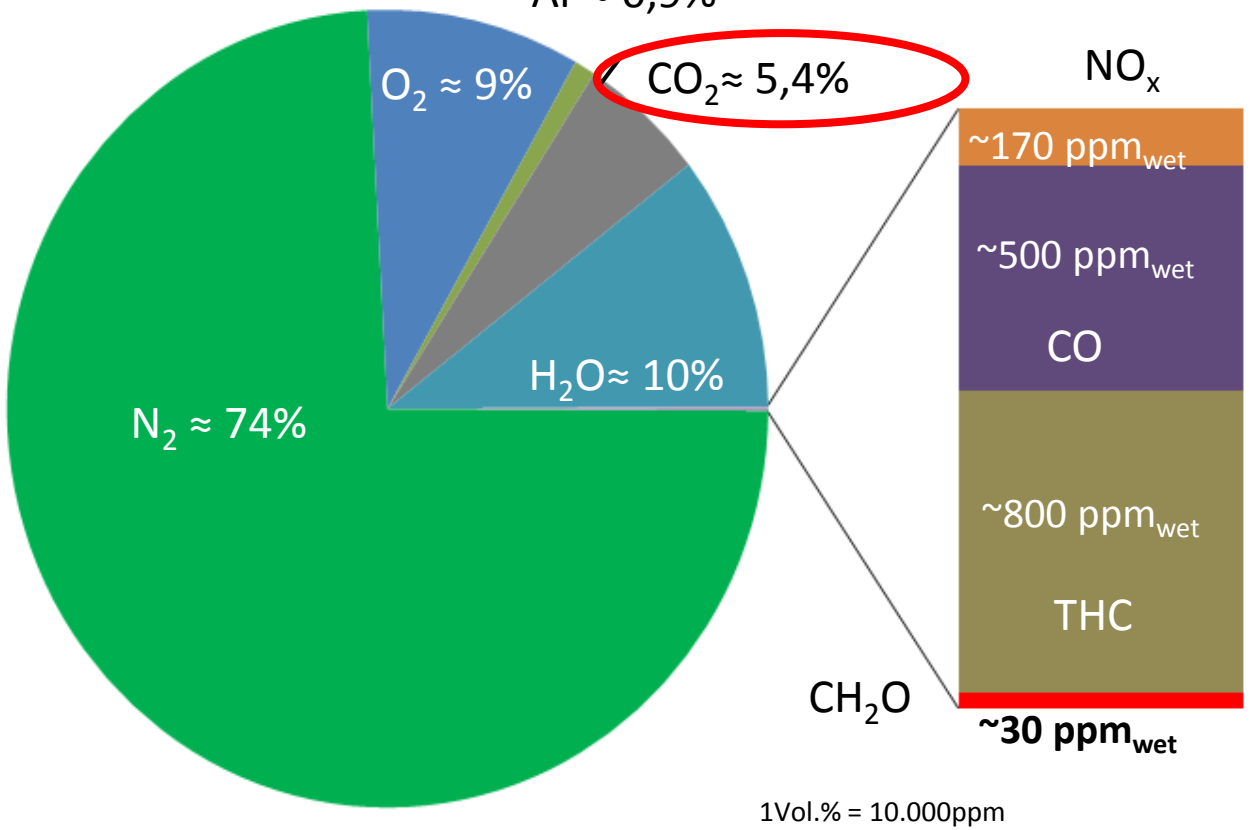
CO_2 as a product:
- Greenhouse
- Food & beverage industry

other utilization of exhaust gas
- Process gas … „zero“ O_2
(Rich burn engines)

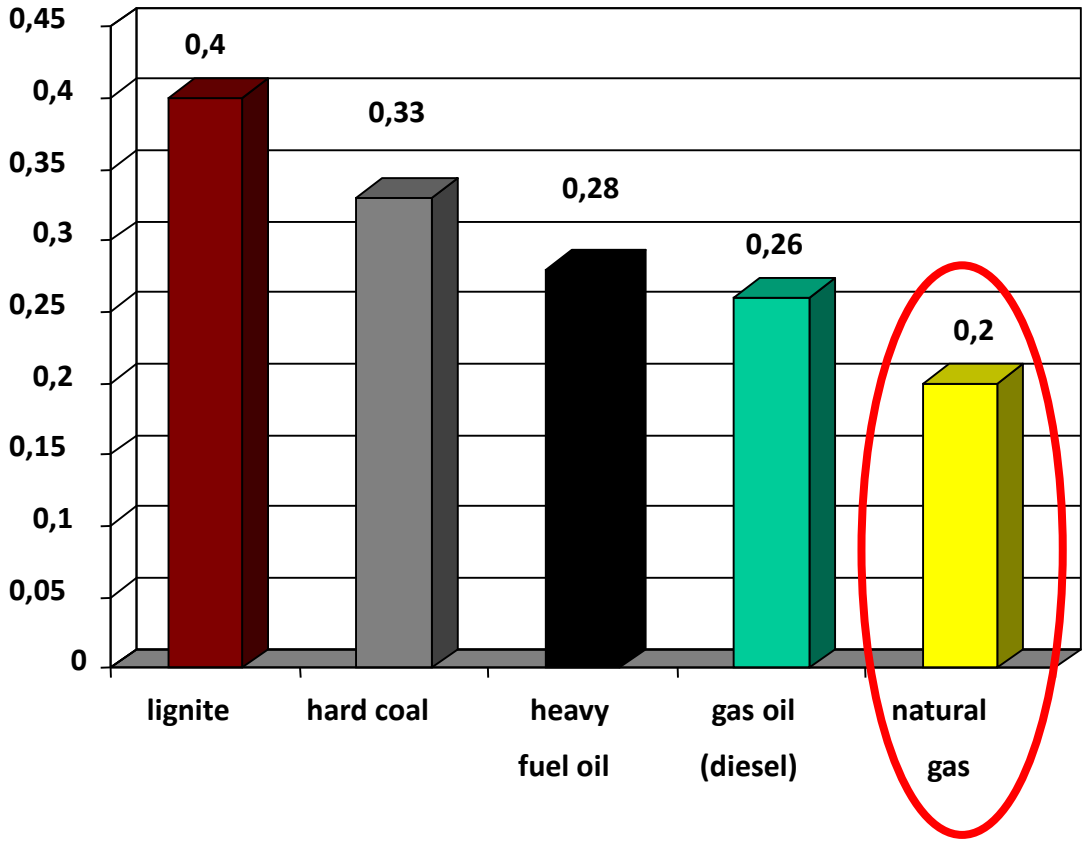
Exhaust gas composition (Example NG Lean burn)

Main components



"Emissions" < 0,2 %

1Vol.% = 10.000ppm



CO_2 can have a value - concentration is driven by fuel & AFR

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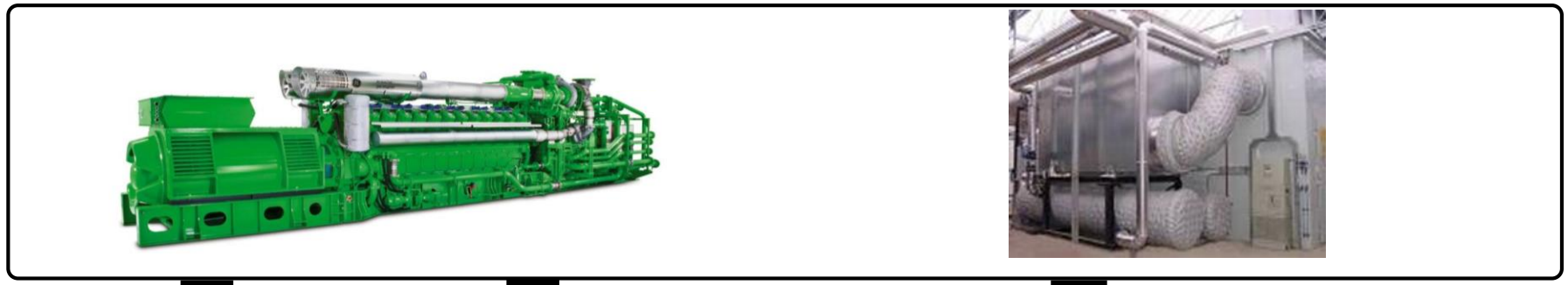
The greenhouse concept … CO_2 as a product



Electricity

Heat

CO_2

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Greenhouse

Growing plants in a controlled environment

- **Increase of crop (production, quality)**
  - Less illness and damage, Increased CO_2 level
- **Timing of harvest (setting)**
  - Price deviation throughout the year
- **Year round cultivation (standardization)**
  - Specialization of equipment
- **Minimize the amount of pesticides**
  - Prevent bugs from coming in, and bees from flying out
- **Lower energy cost**

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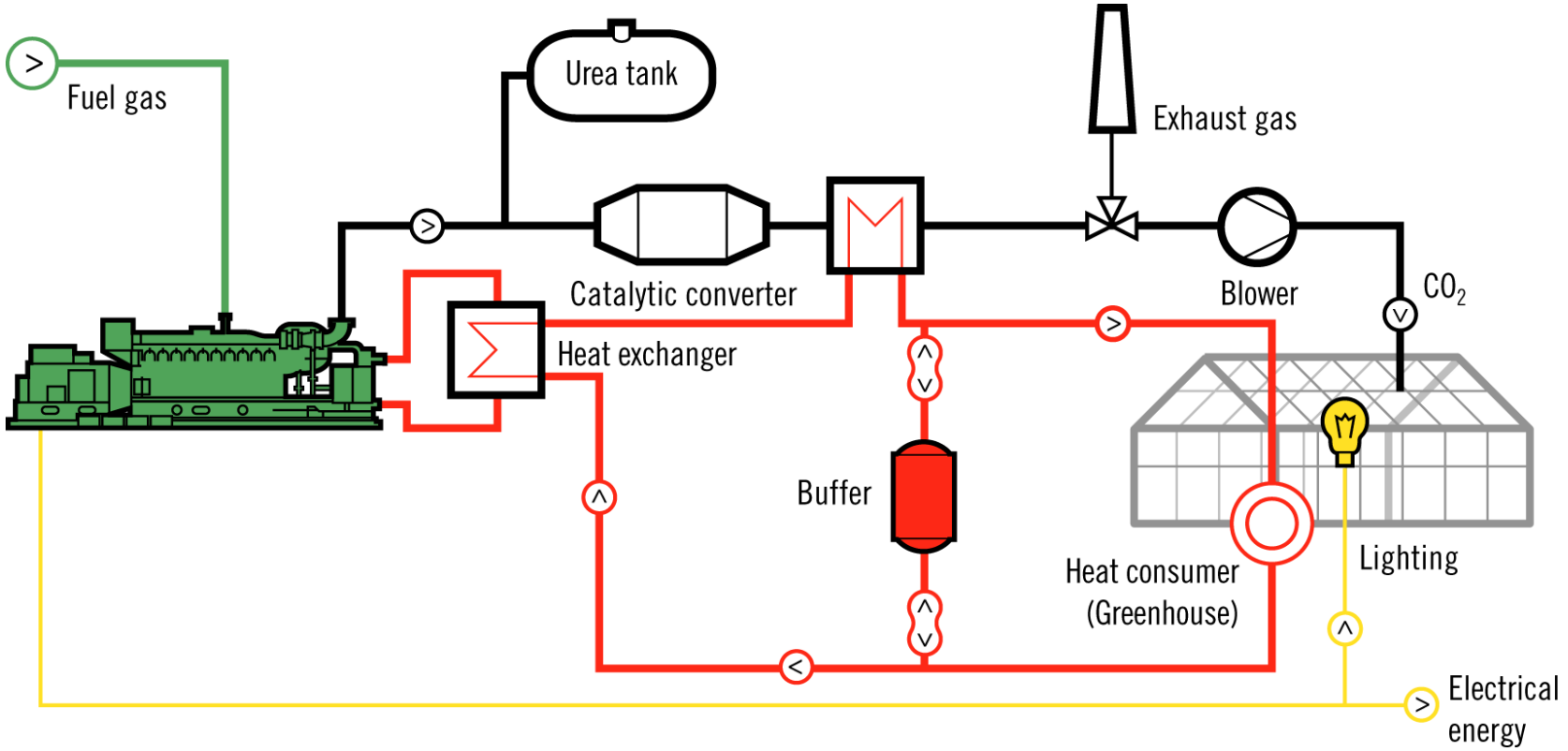
Power plant for greenhouse applications



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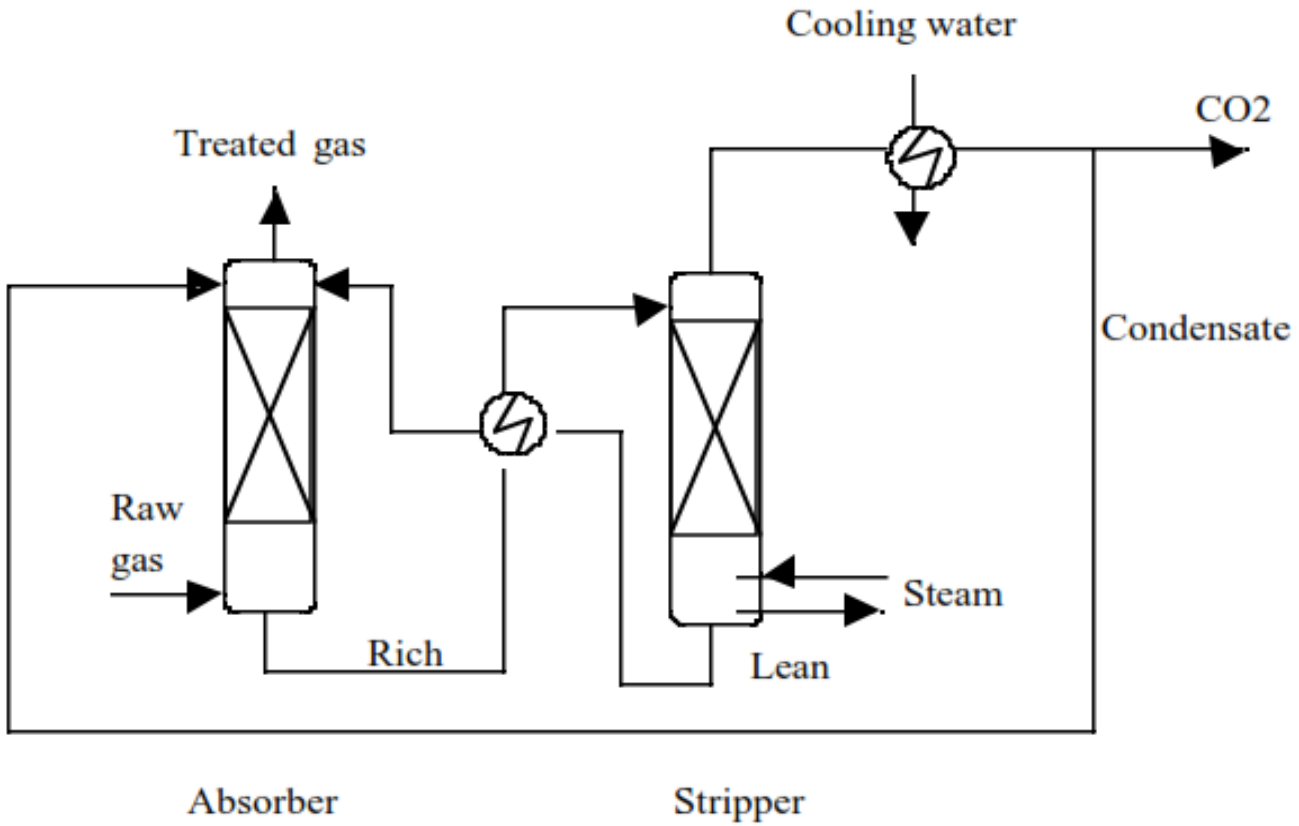
CO_2 seperation with MEA (MonoEthanolAmine absorber)



80 - 90% CO2 absorption efficiency

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Helping Coca Cola to reduce CO2-emissions

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Airbus Stade – exhaust gas as process gas

Exhaust of Waukesha VGF Richburn (RB) engines will be cleaned (TWC), cooled and compressed.
Low O_2 content of RB engines allow utilization of exhaust gas for inertisation of autoclaves for production of high quality fiber-composites e.g. in aviation industry

99+% energy efficiency + utilization of exhaust for inertisation

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Airbus Stade – exhaust gas as process gas

3x L36GSI AIRBUS Stade/INNIOR - COD ´13

- Engine exhaust gas will be cooled to 5°C (3 EXHE)
- Rich burn & TWC enables to meet strict emission requirements (NOx/CO ~10ppm) of process gas
- main advantage is the “zero”-oxygen content of RB for creating a non-explosive environment
- business case is driven mainly by replacing industrial N_2

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99+% energy efficiency + utilization of exhaust for inertisation

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A few examples in Poland

Installed fleet in Poland

Application / Type	Units	MW
Renewable fuels	~55	45
Coal Mine Gas	~20	40
Natual gas	~55	100
Total	**130**	**185**
Type 2/3	70	55
Type 4	30	40
Type 6	30	90

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BRODNICA 2.8MW DISH Plant

2x J320
Natural Gas
Pel = 2x 1027kW

1xJ316
Natural Gas
Pel = 825kW

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BRODNICA 2.8MW DISH Plant

Two JMS 320 GS-N.L 1000kW units and one J316 GS-N.L 800kW unit.

The goal of investment was reduction of greenhause gases 26 338 ton of CO2 equivalent.

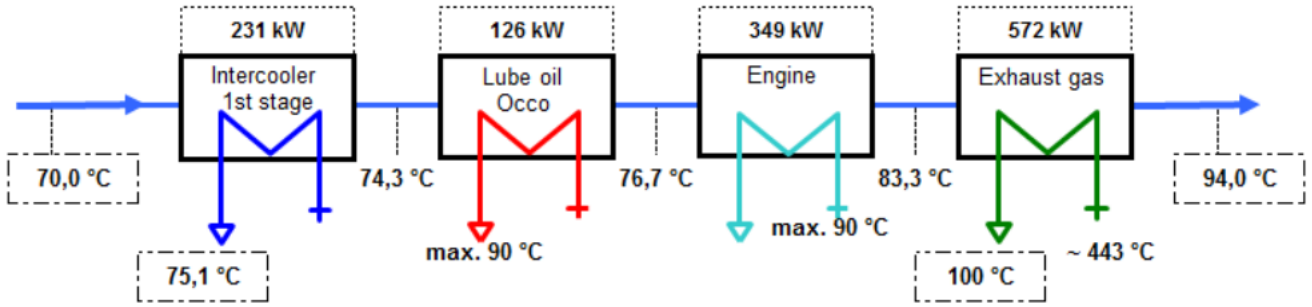
Total efficiency above 90,8% (as measured, without any tolerances)

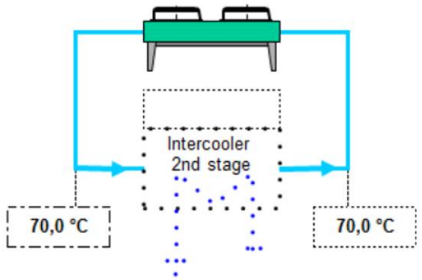
Over 1300kW of heat production.

No LT circuit; all heat from intercooler injected into HT circuit 70/94.

Additional economizer to cool down exhaust gases to 55°C

Approx 700EUR/kW – installed electrical power.





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District heating plants examples

ECO TARNOBRZEG 5.5 MW
2x J 616
Fuel: Natural Gas
Commissioned: March 2019

ECO MALBORK 4.1 MW
2x J612
Fuel: Natural Gas
Commissioned March 2019

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KWK Brzeszcze

1xJ 316 0.8MW CHP Plant
Fuel: Coalmine gas
Commissioned November 2018
Container made by FEROX ENERGY SYSTEMS Sp. z o.o.

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Usable forms of energy from a gas genset

Electricity

Chilled water

Hot water

Steam

Hot air

High electricity to heat ratio favors economics for many CHP plants

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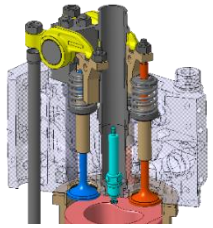
Gas engines are not a static piece of iron …

Levers to optimize

Compression ratio (pistons)

Valve timing



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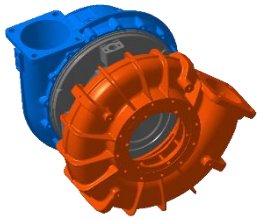
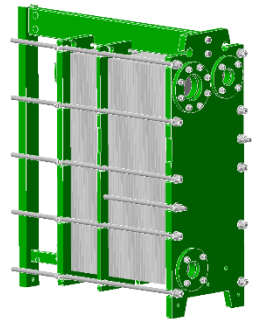
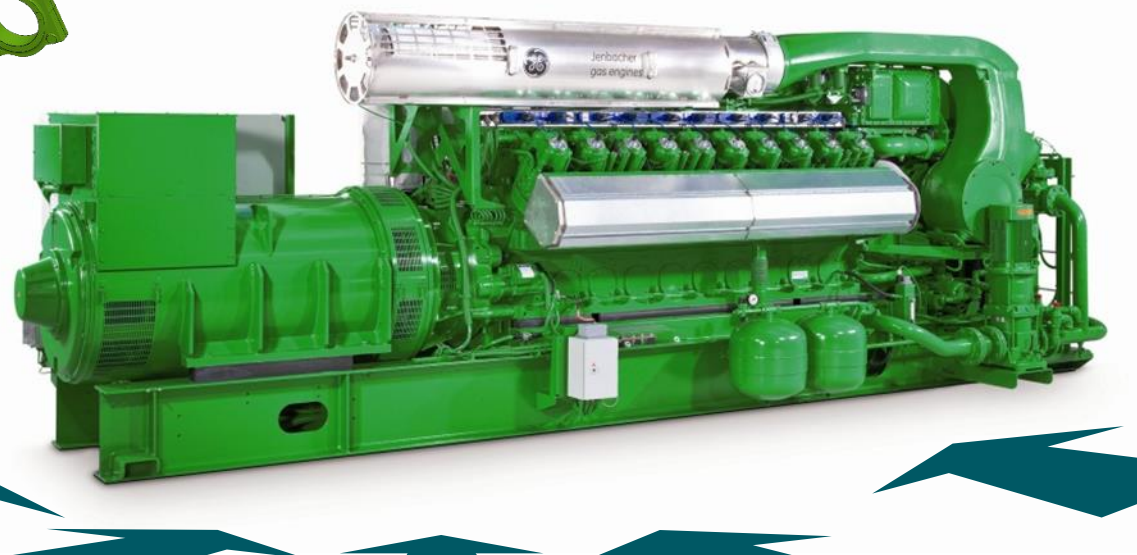


Ignition timing

Hydraulic variants (heat exchangers)





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Climate Conditions

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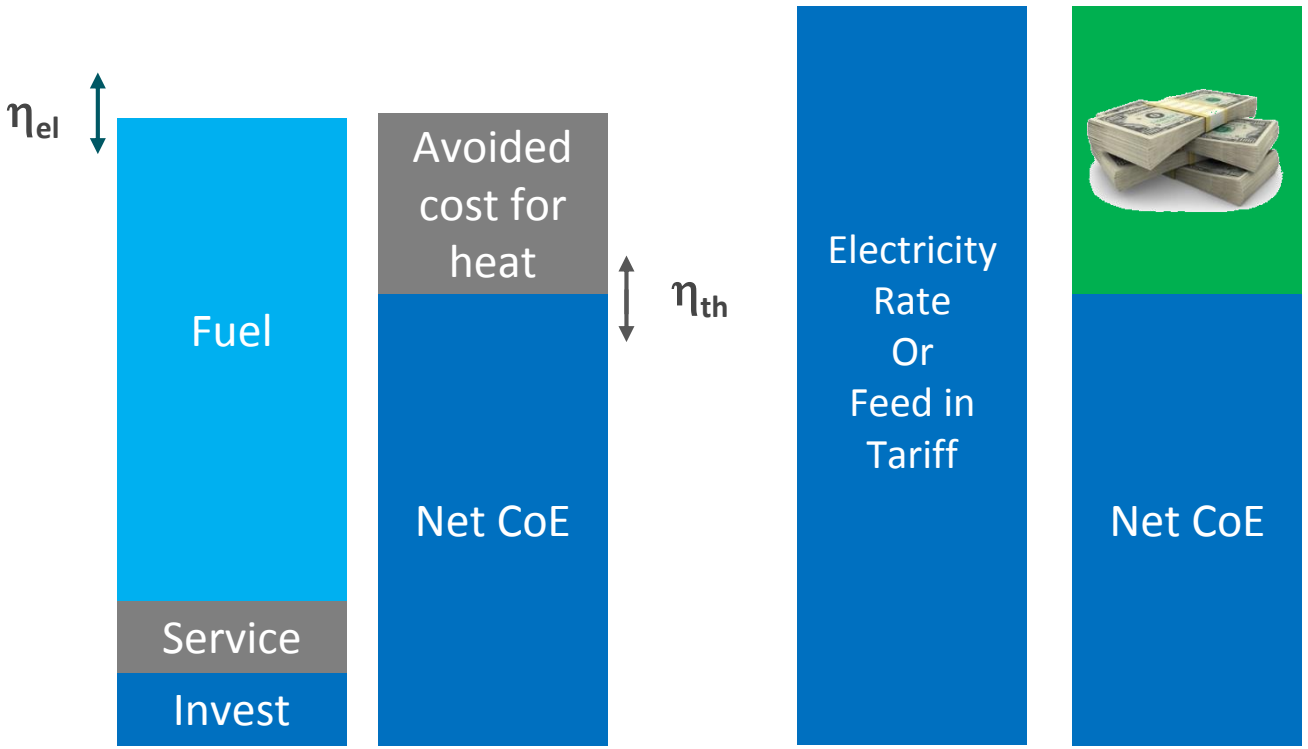
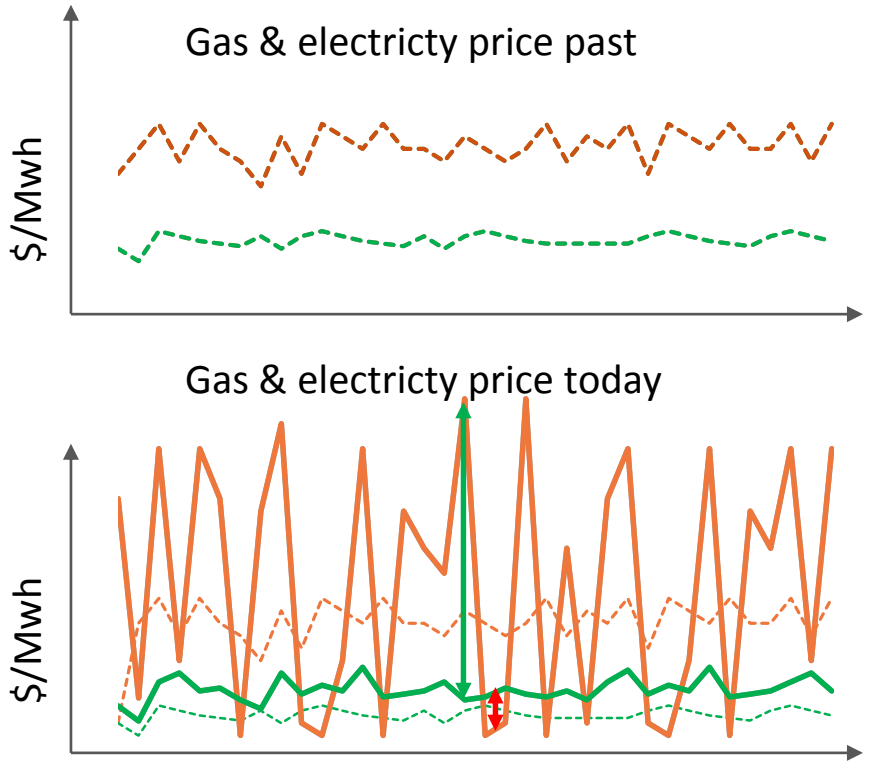
Asset performance management

How do customers make money?





Asset availablity critical at high spark spread times

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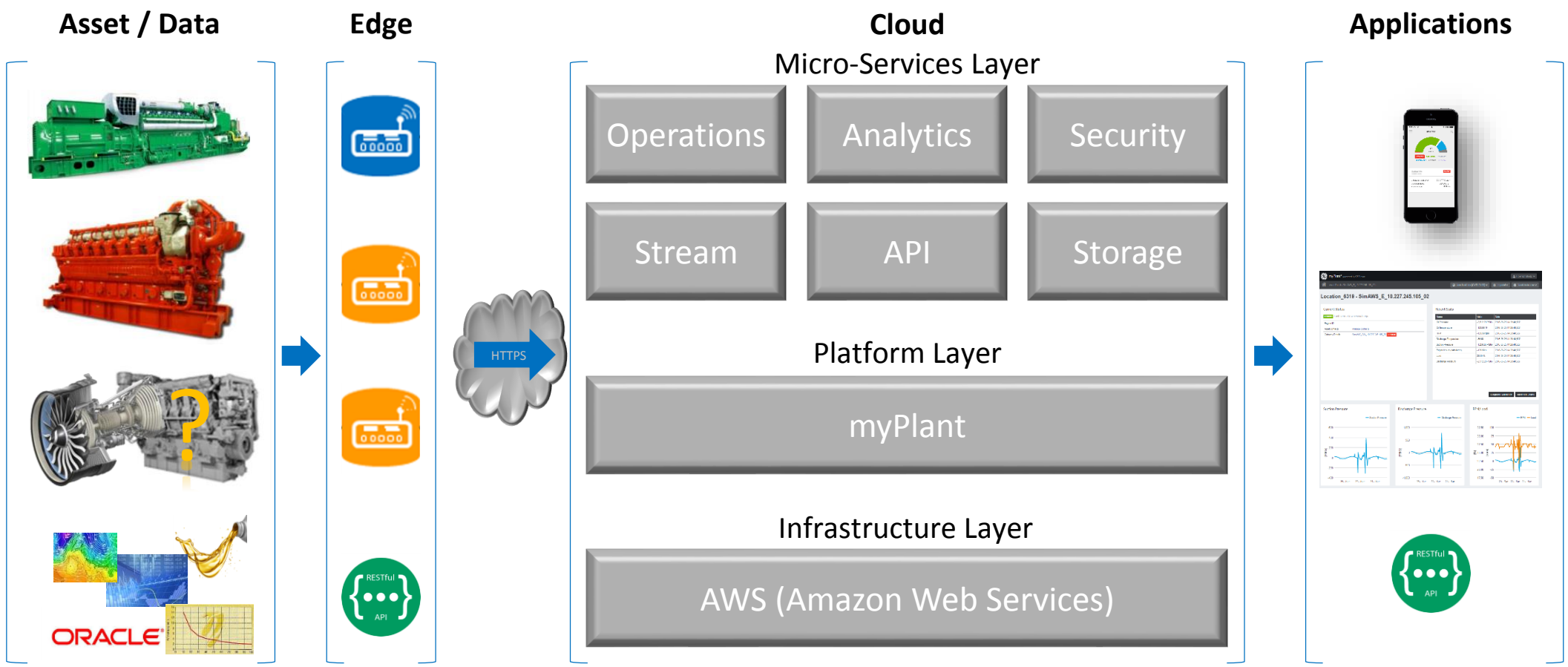
IIoT Platform to enable better asset performance



myPlant - Asset Performance Management

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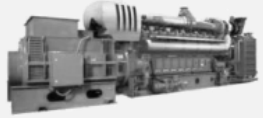
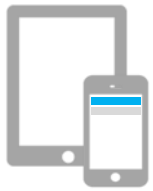
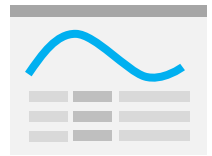
myPlant – Change of our service model

Issue Detection	Personnel	Tools		Engine	Reporting
Proactive	**Reactive**		**Maintenance**	**Troubleshooting**		
	Call service provider		Traditional tools	Traditional sources		Manual data gathering

Today



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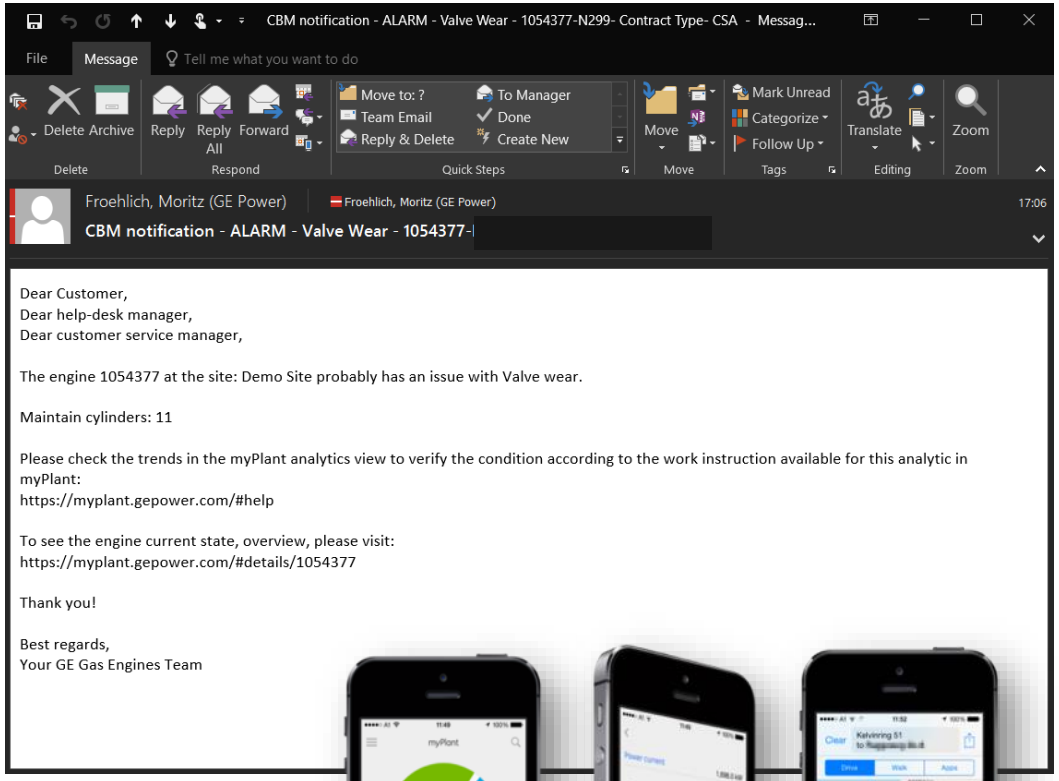
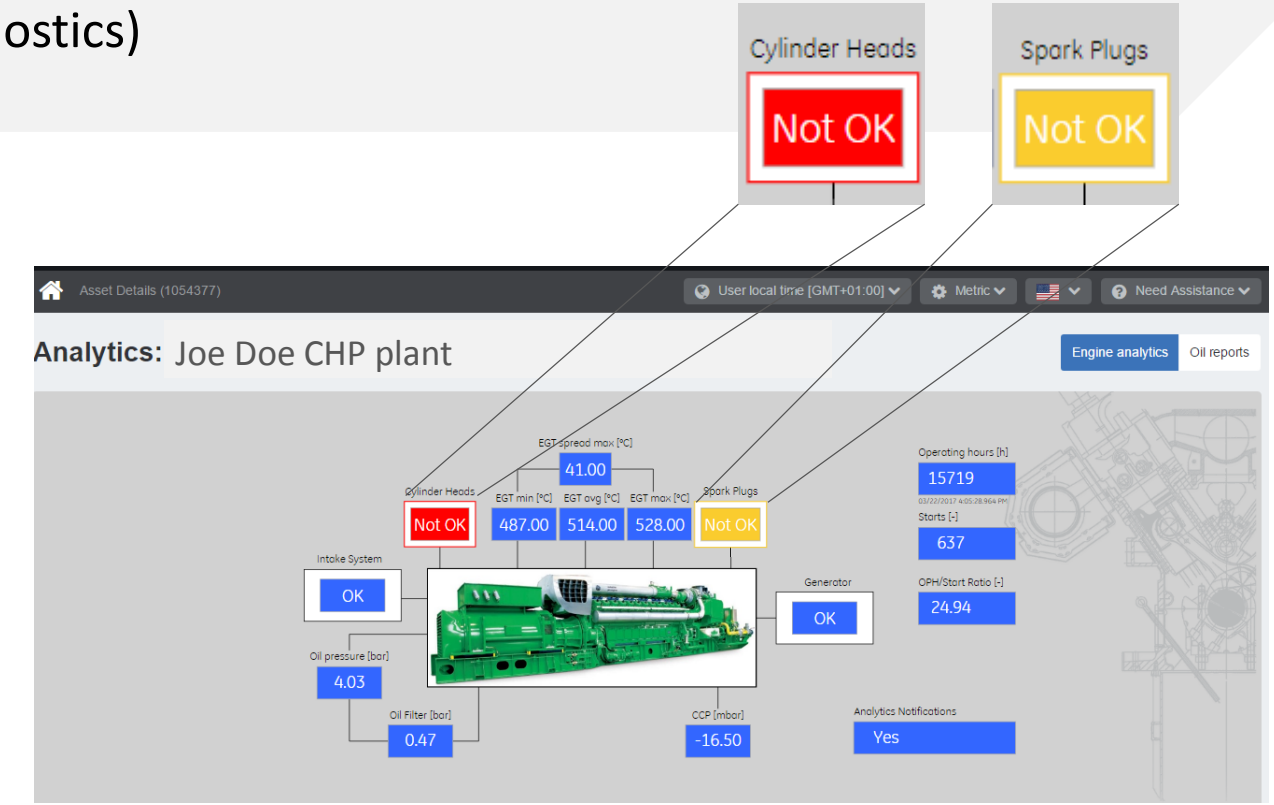
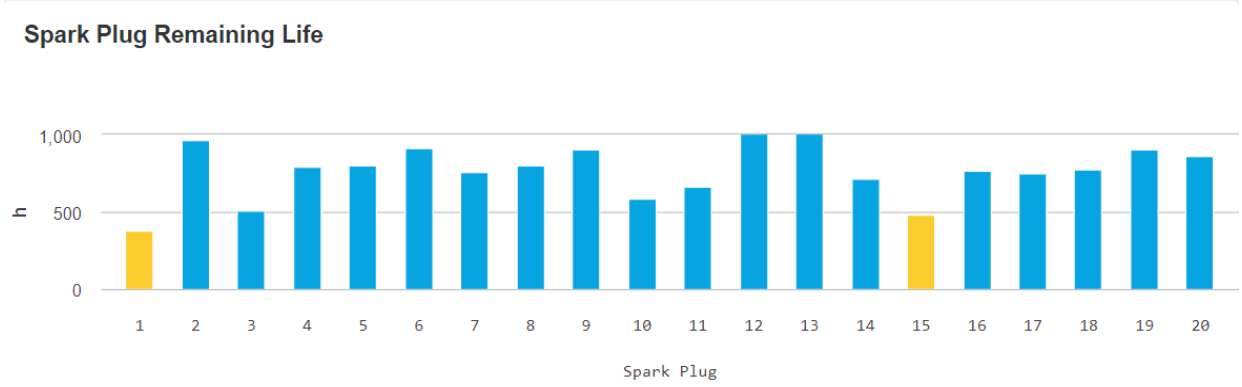
Proactive troubleshooting (alerts & diagnostics)







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Wrap up


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