TURBODEN clean energy ahead®

MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

TURBODEN
OIL & GAS

Cod. 15-COM.P-10-rev.28

ENERGIZE YOUR FUTURE. DON’T WASTE YOUR POWER.

OUR PRODUCTS

Designed for decarbonization.

ORC SYSTEM

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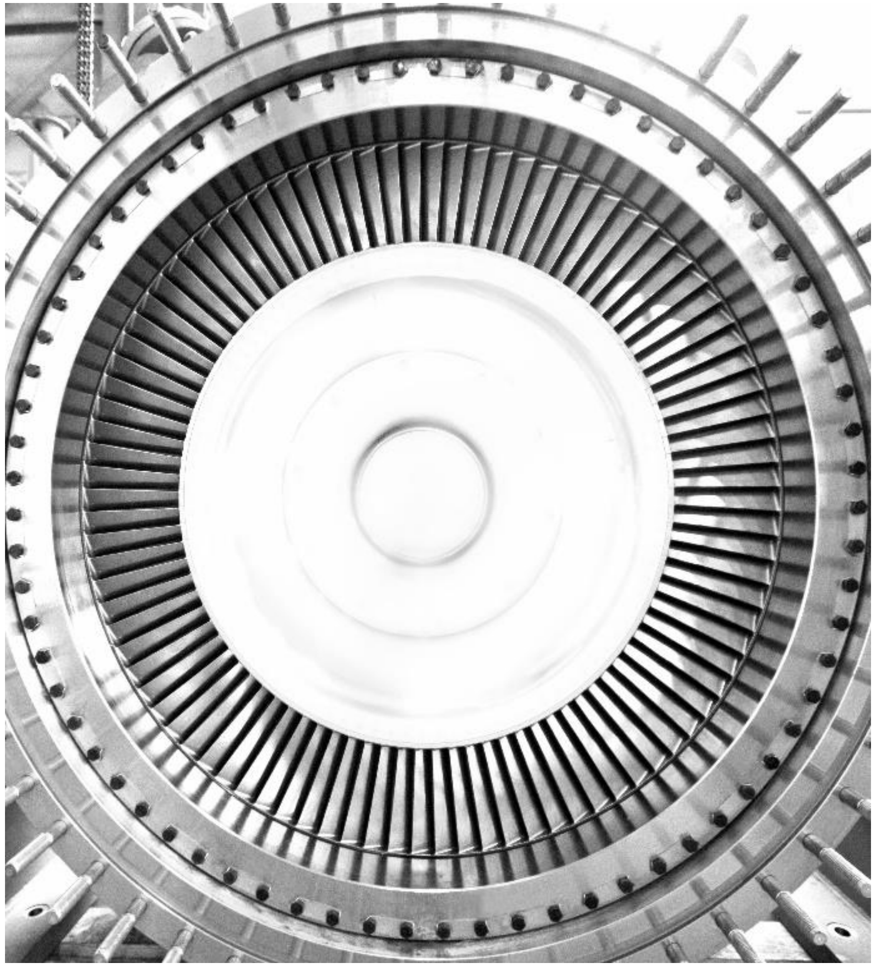


Turboden Organic Rankine Cycle (ORC) units can produce electricity by recovering residual low-grade heat from **industrial processes** and from **internal combustion engines**, **gas turbines**, and fuel cells operating on open cycle. The generated power ranges up to **20 MW electric** per single shaft.

WHY CHOOSE ORC FOR ENERGY EFFICIENCY?

- Generate profit by valorising a waste heat source
- Reduce specific production cost by decreasing energy demand
- Improve company sustainability
- Contribute to lower carbonisation and combat climate change

ENERGY EFFICIENCY FOR YOUR BUSINESS

GAS TURBINES OR ICE

- Gas compressor stations
- Gas storage
- Oil pumping stations
- Sea water injection systems

PROCESS HOT STREAMS

- Refinery hot streams
- Thermal oil used in Oil & Gas process
- Geothermal and associated hot water

ASSOCIATED PETROLEUM GAS

- Boilers
- Gas turbines or internal combustion engines

OUTPUT

ELECTRIC POWER and/or MECHANICAL POWER

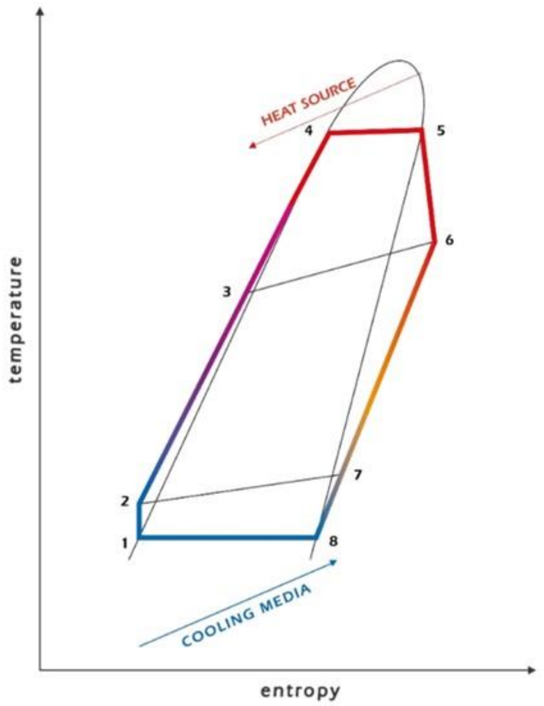
THE ORC CYCLE – HOW IT WORKS

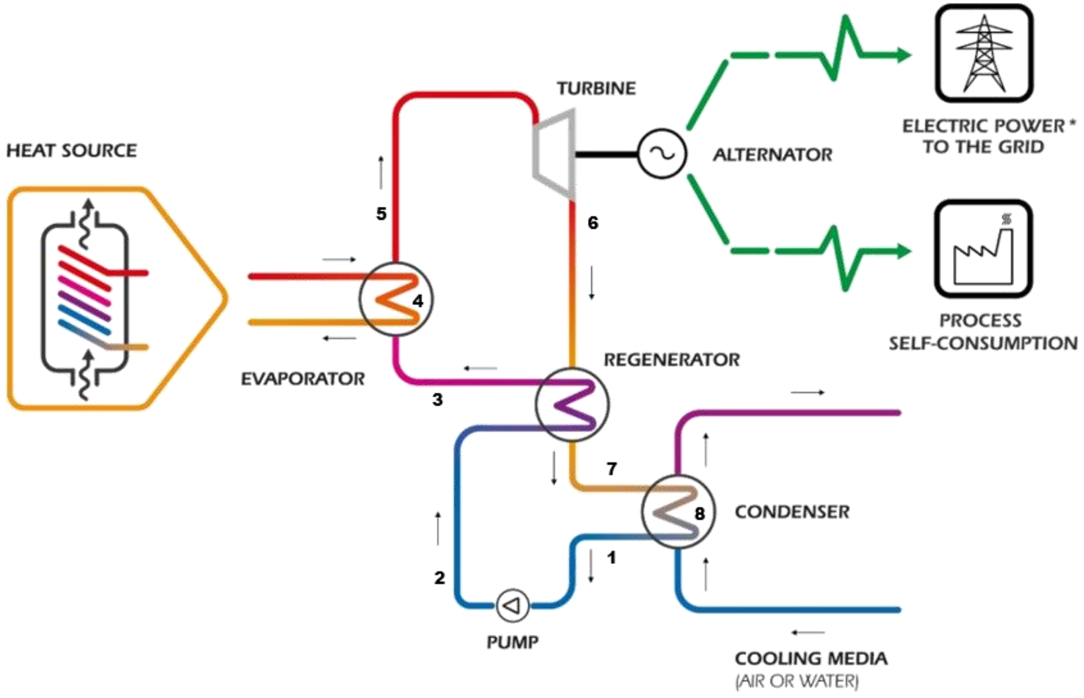
The ORC turbogenerator uses medium-to-high temperature thermal oil to preheat and vaporize a suitable organic working fluid in the evaporator (4>5).

The organic fluid vapor rotates the turbine (5>6), which is directly coupled to the electric generator, resulting in clean, reliable electric power.

The exhaust vapor flows through the regenerator (6>7), where it heats the organic liquid (2>3) and is then condensed in the condenser and cooled by the cooling circuit (7>8>1).

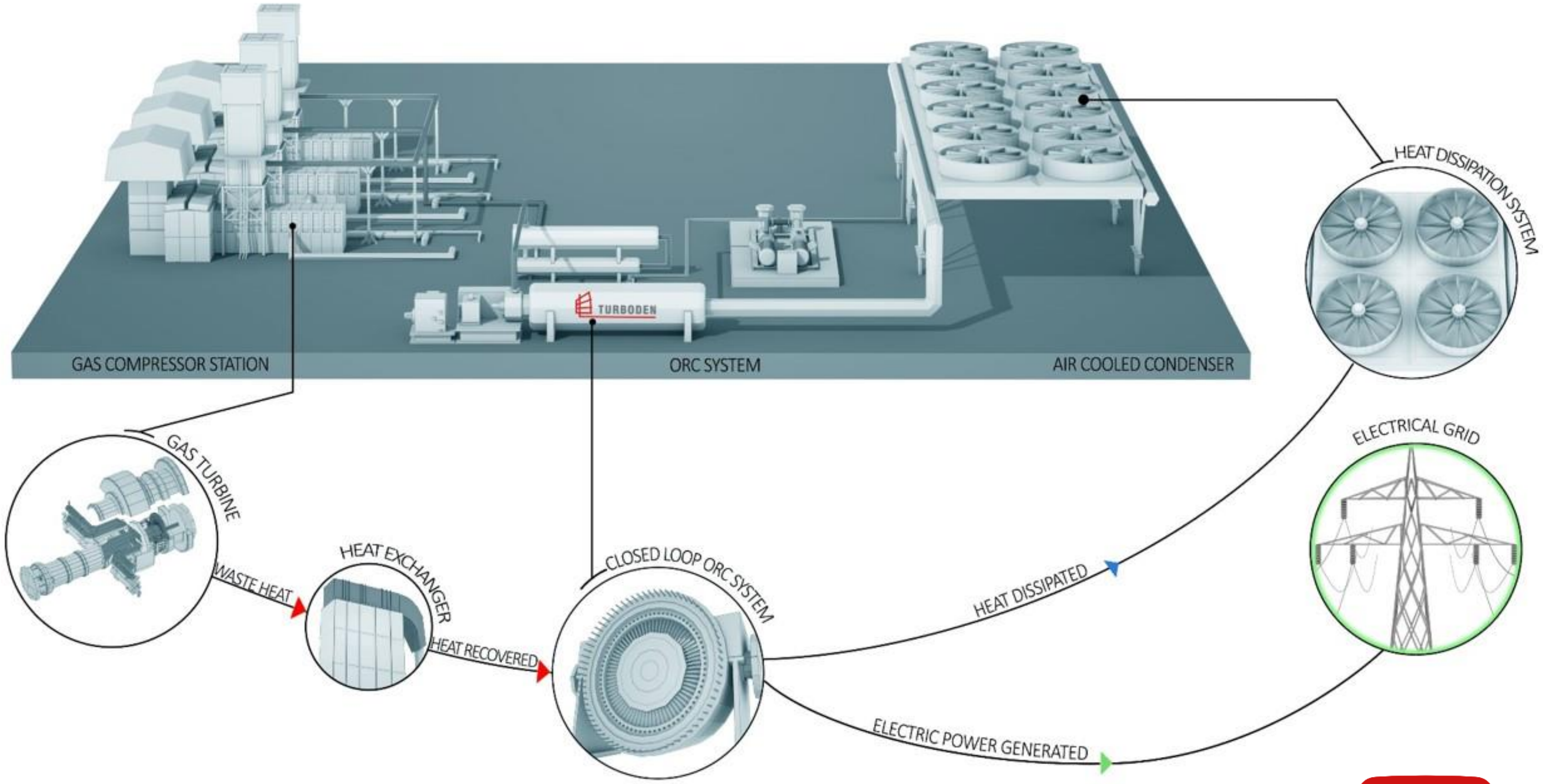
The organic working fluid is then pumped (1>2) into the regenerator and evaporator, thus completing the closed-cycle operation.





* ORC units can produce electric and/or mechanical power

GAS COMPRESSOR STATION

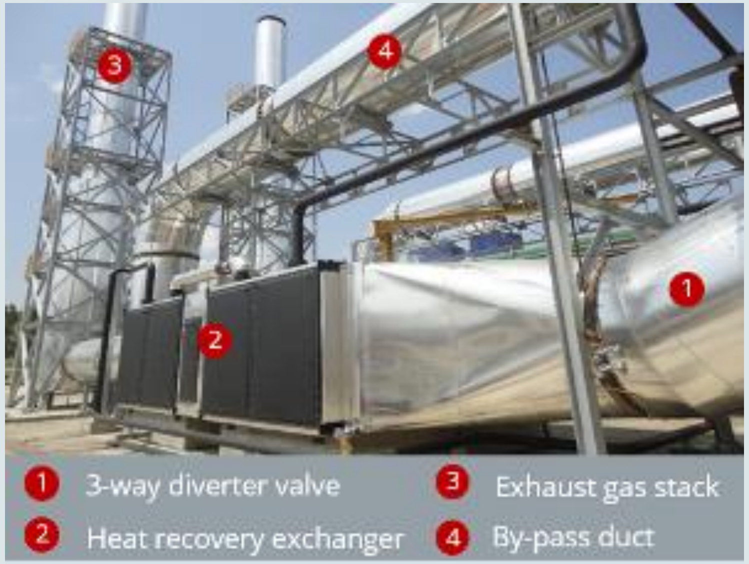


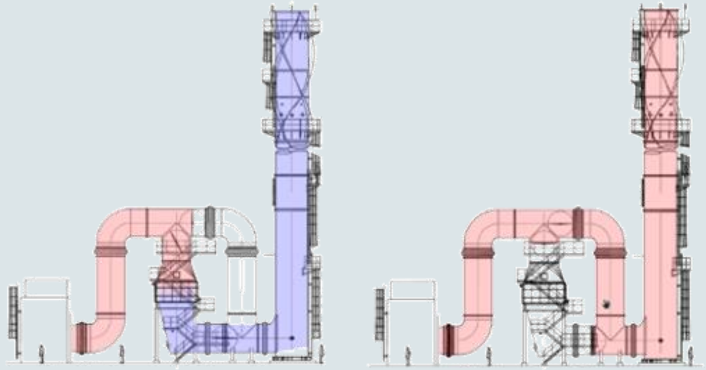
- Combined cycle configuration with multiple gas turbines
- ORC output from 1 to 20 MW per single turbine
- Combined cycle output 30÷40% higher than open cycle output
- Power produced can be exported to the grid or used for internal consumption, especially electrical motor-driven compressors

Watch the video

EXHAUST GAS HEAT RECOVERY EXCHANGER CONFIGURATION

- EGHEs installed in **by-pass** to the main exhaust gas ducting in order to **avoid any impact on the gas turbines operation** in any circumstance.
- **EGHEs completely isolable** with a diverter prior to the EGHEs and an insulation valve right after it. Diverter equipped with air sealing to ensure 100% insulation. This permits to **insulate the EGHEs, ensuring gas turbines operation** even in case of major issues on the EGHEs.
- Pneumatic **safety-closed diverter** to avoid any impact on gas turbines operation even during emergency situation.
- EGHE equipped with sparking detector, flame detector and thermocouples in different bundle position to **ensure the maximum safety of the system.**
- **False air** fan installed in order to keep the EGHE temperature at acceptable level even in case of gas turbines particular operation cases.

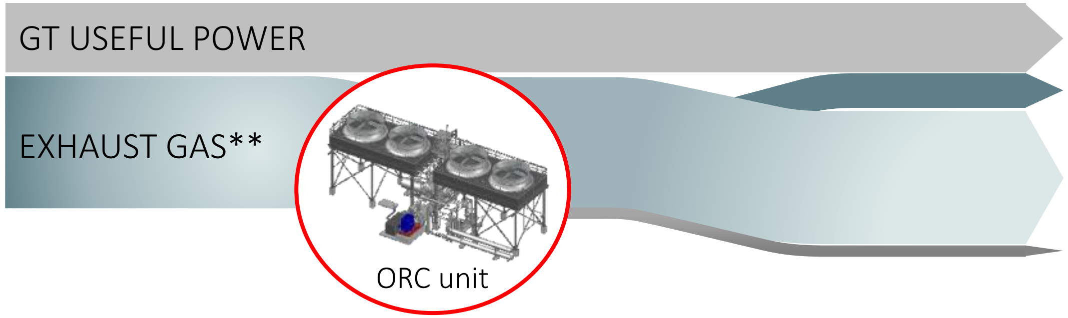




OVERALL PLANT PERFORMANCES

GAS TURBINES

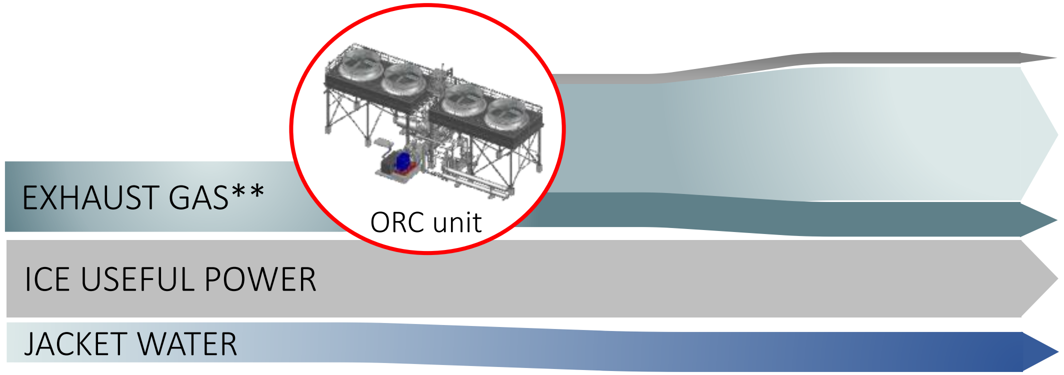
30÷40% ORC additional power*



18 ÷ 30%	Useful power ***
80 ÷ 68%	Thermal power
2%	Thermal losses

INTERNAL COMBUSTION ENGINES

10% ORC additional power*



2%	Thermal losses
80 ÷ 72%	Thermal power
18 ÷ 26%	Useful power ***

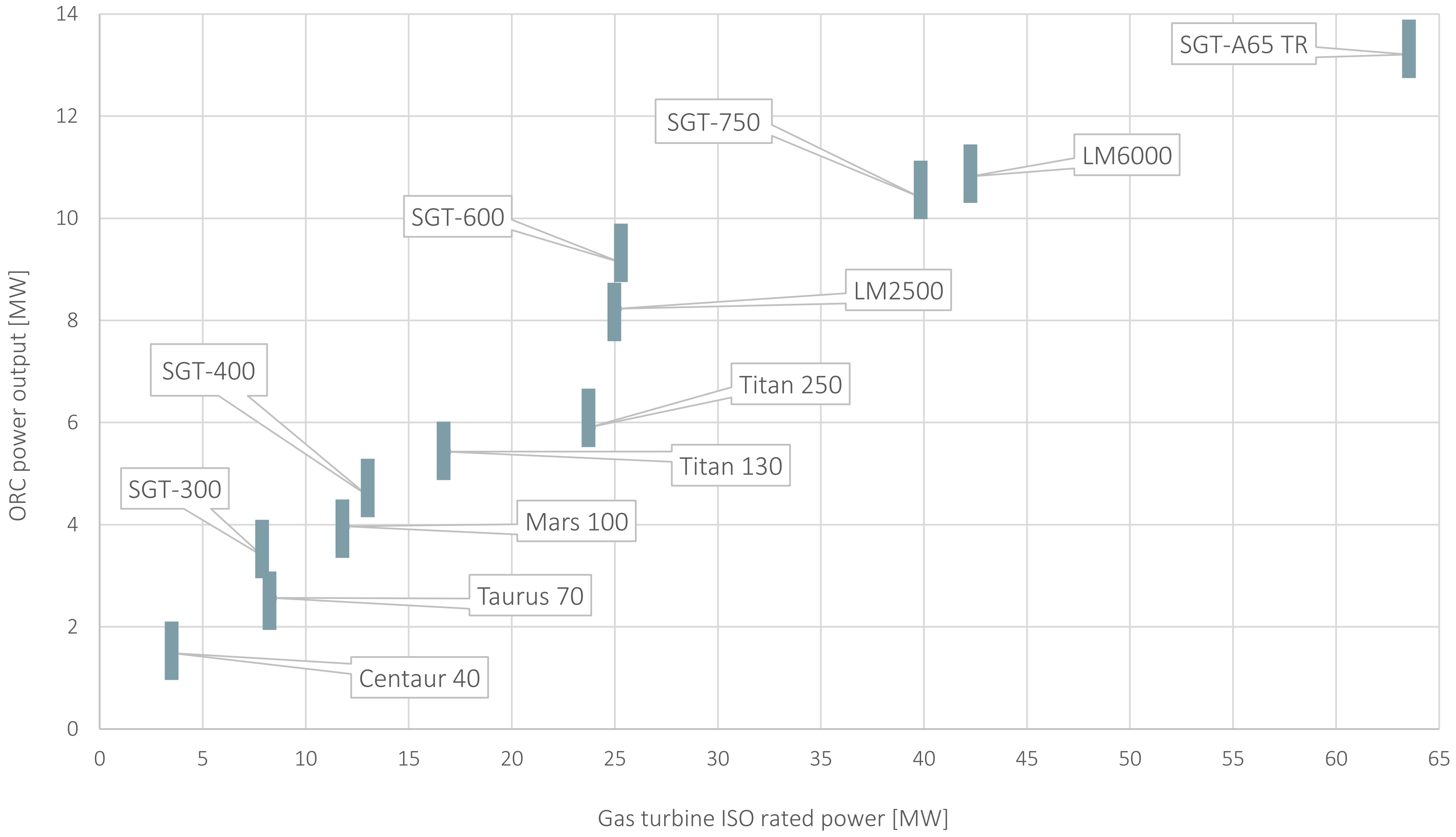
* ORC power output compared to GT or ICE shaft capacity (e.g. 10 MW GT → 3÷4 MWe ORC; 10 MW ICE → approx. 1 MWe ORC).

** Min. flow to ORC: from GT 10-15 kg/s; from ICE 30-40 kg/s.

*** Mechanical and/or electric, calculated on thermal power input to ORC.

GAS TURBINE BOTTOMING WITH ORC

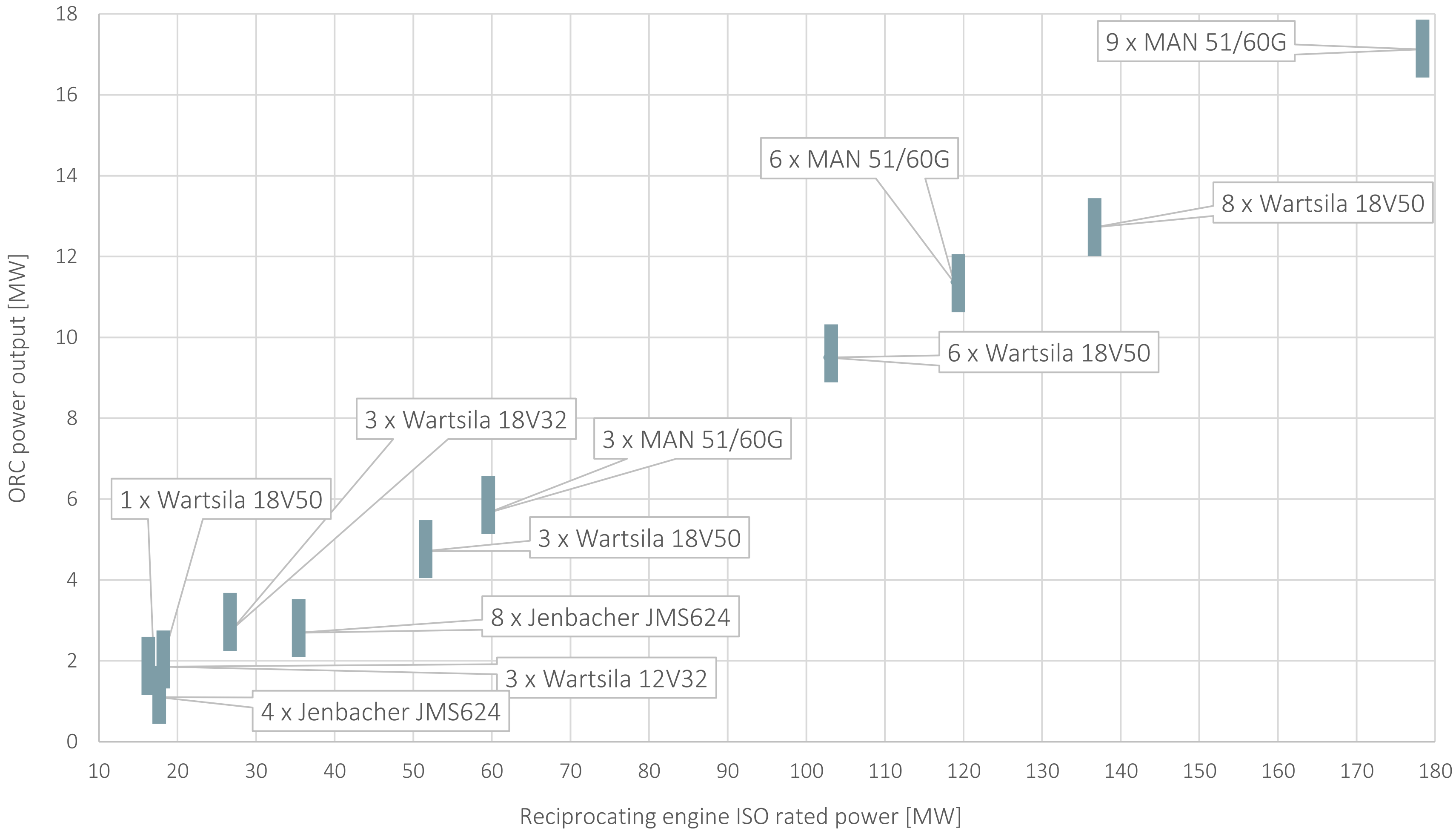
Based on the GT operation parameters and ambient conditions, the ORC can generate from 30% up to 40% of additional power.



NOTES:

- Indicative values assuming gas turbines operating at nominal load with exhaust gas properties as reported by suppliers.
- Shaded area represents the potential ORC power output in relation to gas turbine(s) shaft power. ORC performance may vary depending on specific project features.

INTERNAL COMBUSTION ENGINES BOTTOMING WITH ORC



NOTES:

- Indicative values assuming ICE operating at nominal load with exhaust gas properties as reported by suppliers.
- Shaded area represents the potential ORC power output in relation to engine(s) nominal power. ORC performance may vary depending on specific project features.

THERMODYNAMIC CYCLE: ORC VS STEAM

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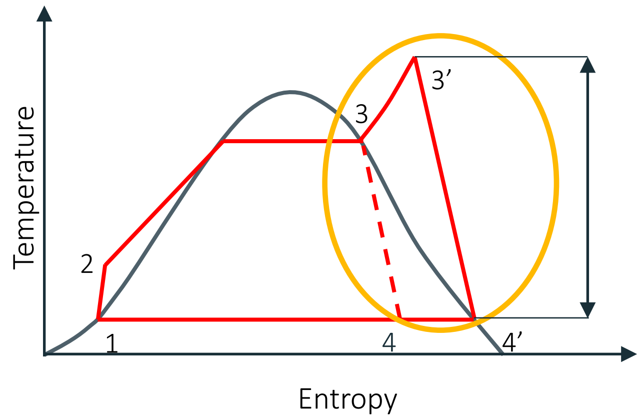
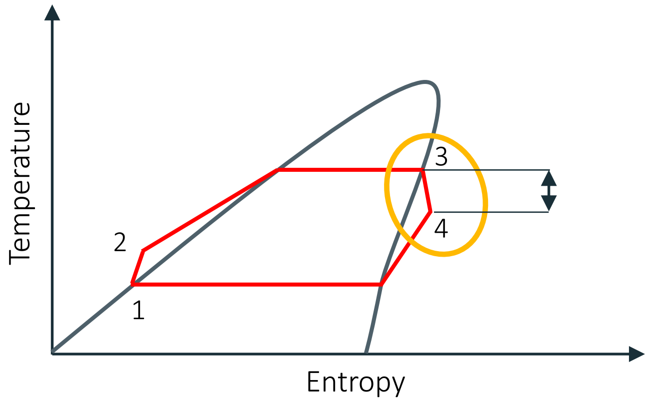
	STEAM RANKINE CYCLE	ORGANIC RANKINE CYCLE
		
Thermodynamic features and consequences	▪ Superheating needed ▪ Risk of blade erosion due to possible liquid formation during the expansion ▪ High enthalpy drop – turbine with high stage number	▪ No need to superheat ▪ No risk of blade erosion thanks to dry expansion in the turbine ▪ Small enthalpy drop -turbine with low stage number
Operation and maintenance costs	▪ Water treatment required ▪ Highly skilled personnel needed ▪ Periodic major overhaul	▪ Water-free system ▪ Minimum Operation & Maintenance cost ▪ No major overhaul ▪ Completely automatic
Other features	▪ Low flexibility with significantly lower performances at partial load ▪ Convenience for large plants and high temperatures	▪ High flexibility - Wide operational range from 10% to 110% ▪ High availability (average >98%)

REFINERY HOT STREAMS

HEAT RECOVERY

OF LOW-ENTHALPY STREAMS

(e.g. hot diesel)

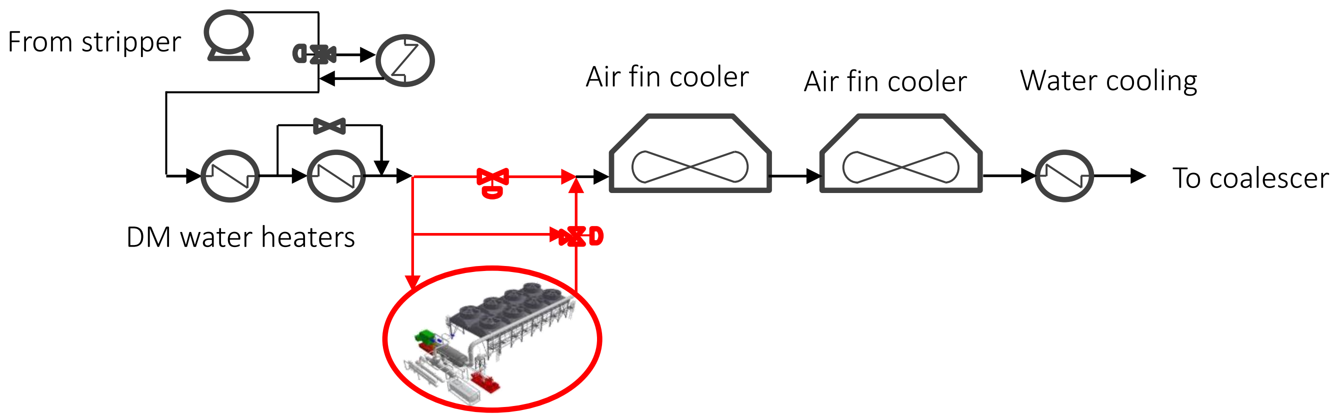
O&G FACILITIES PRESENT DIFFERENT LOW-ENTHALPY SOURCES

- Diesel hot streams in refineries
- Exhaust gases of distillation columns
- Condensing steam in gas treatment process
- Exhausted or not used wells
- Others.....

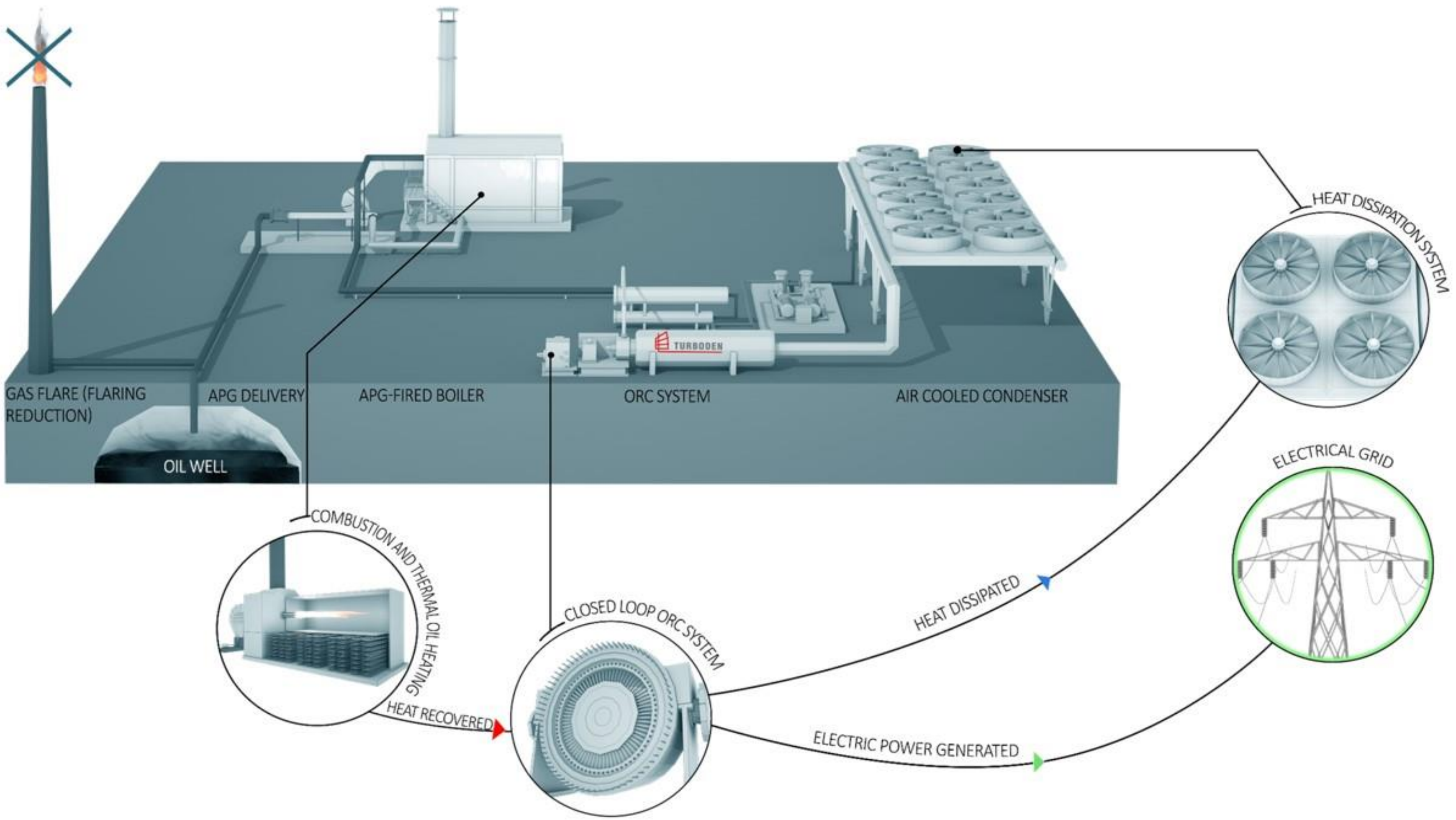
DIESEL PRODUCTION PROCESS

ENERGY EFFICIENCY IMPROVEMENT:

- Plant power consumption reduction
- CO_2 emission reduction
- Fuel-free additional electricity



FLARE GAS



- Flare gas exploitation up to 50 MW: streams up to 7,500 Sm3/h
- Heat value from 15 MJ/Sm3 and variable chemical composition
- Multiple burning solution in case of high flare flows or high fluctuation (20÷100%)
- ORC output from 1 to 20 MW per single turbine

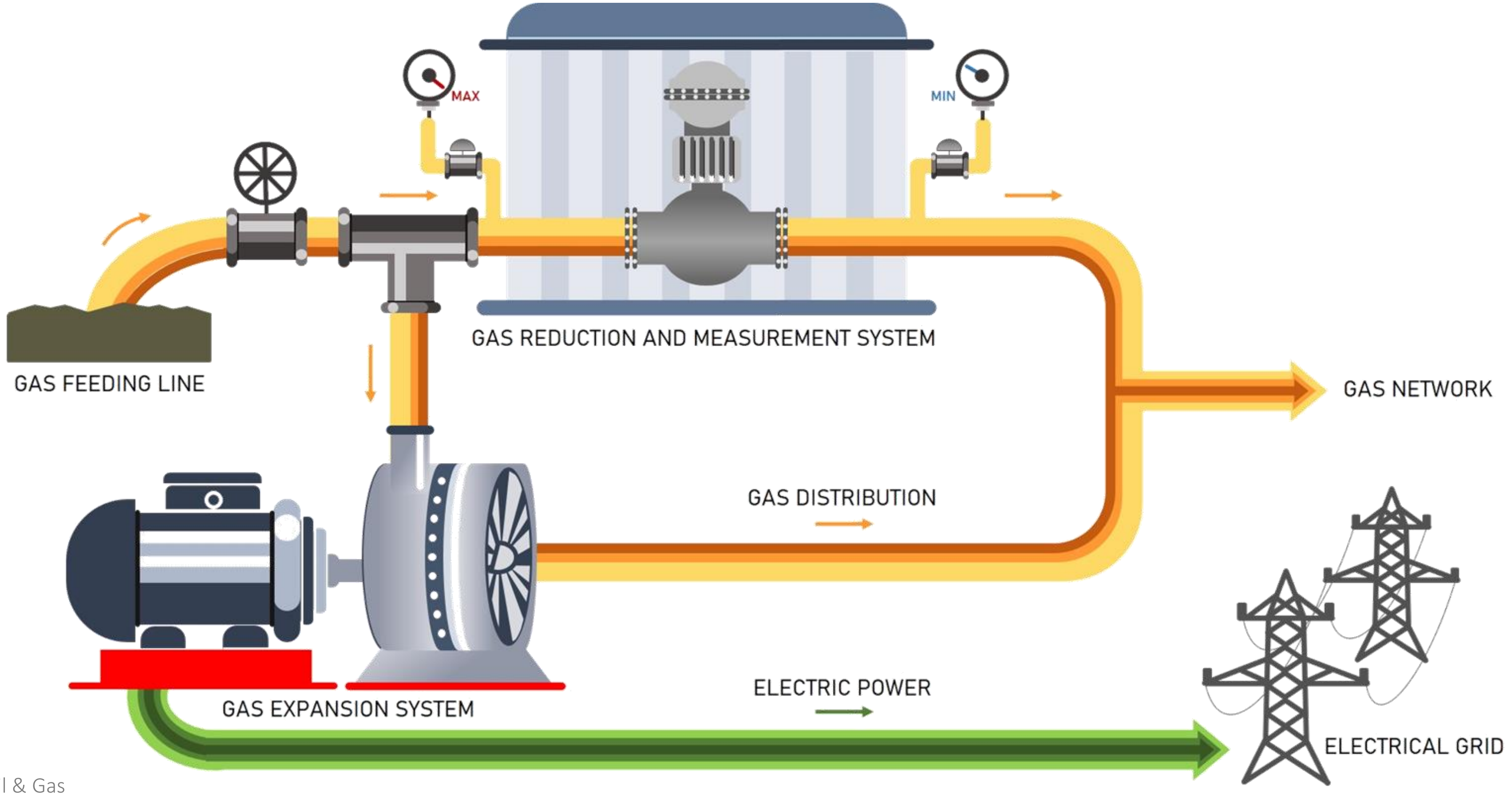
GAS EXPANDER

Turboden gas expander is a solution to enhance the energy efficiency of a natural gas network infrastructure, producing electricity by taking advantage of the reduction of gas pressure from the delivery level to the one required by the network. The decarbonised electricity is available to the infrastructure, reducing the associated costs.

KEY POINTS

- Design based on 40+ years of experience, leveraging Mitsubishi Heavy Industries support
- Long experience in the energy efficiency sector
- Profit generation while reducing the gas pressure
- Solution for natural gas network decarbonisation
- Unmanned installations, thanks to specific technology features
- Turn-key equipment capabilities
- Over 60 Turboden turbine models within the 400 power plants fleet

THE CONFIGURATION

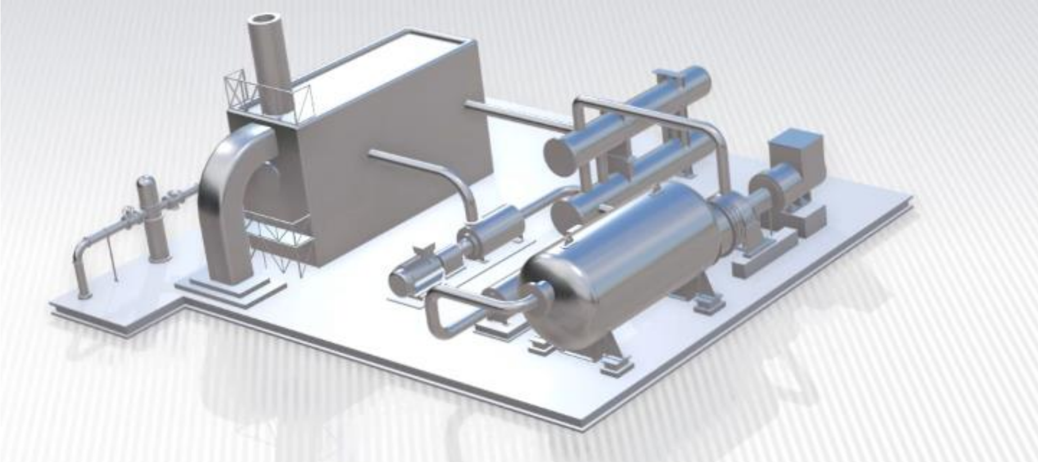


TURBODEN GAS EXPANDER RATING

EXPANDERS SIZES	EXP 400	EXP 600	EXP 900	EXP > 1 MW
✓ Turbine stages/admission	Single stage radial turbine	Multi stages axial turbine		
✓ Flow rate	>5,000 Sm3/h	20,000 – 100,000+ Sm3/h		
✓ In - out gas pressure range	70 - 1 bar(g)			
✓ Bearings	Rolling bearings	Self-lubricated rolling bearings		
✓ Seals	Single tight casing for impeller and generator	Mechanical		
✓ Generator	Permanent Magnet generator	A/Synchronous LV - Eff. 97%		
✓ Containerization	Sandwich panel REI 120 if 10m gate distance possible; or concrete if 2m gate distance possible. Necessary to segregate electrical panel and hot water boiler.			
✓ Gas pre-heating	Hot water boiler fed by natural gas and shell & tube heat exchangers + possible combination with electrical heaters and heat pumps – custom based on project specific.			

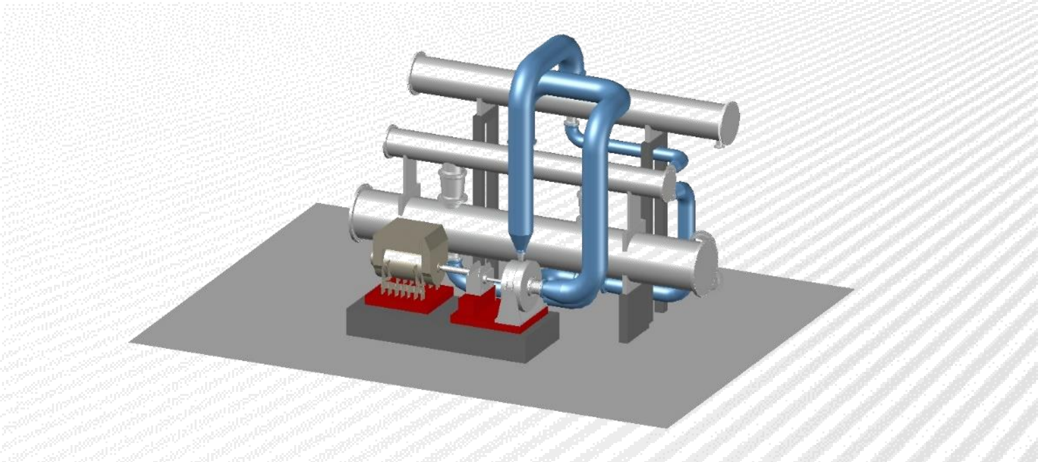
OTHER TURBODEN SOLUTIONS

Among Turboden portfolio of products, two additional solutions are available to **produce thermal power** serving the facility process.



HIGH-TEMPERATURE COGENERATION SOLUTIONS

ORC produces both electricity and a valuable high temperature heat carrier, such as steam (5 - 30 bar), directly exploitable in Oil & Gas processes.



LARGE-SCALE HEAT PUMPS

LHP allow to transfer large quantities of heat from a colder source to a higher temperature heat user, like refinery process.

REFERENCES

400
POWER PLANTS

50
COUNTRIES

REFERENCES

Gas compressor station

PROJECT AWARDED

CUSTOMER: GASCO, Egypt

CONFIGURATION: power generation from waste heat from 5 simple cycle gas turbines (4 in operation, 1 in standby) in a gas compressor station operated by GASCO

ORC POWER: 28 MWe

FEATURES: ORC system feeds EMD compressors; +25% compression capacity with no additional fuel consumption

Gas compressor station

2011

CUSTOMER: Transgas, Canada

CONFIGURATION: power generation from waste heat from Solar Centaur 40 gas turbine in a gas compressor station operated by Transgas

ORC POWER: 1 MWe (more than 28% of gas turbine shaft power)

GAS TURBINE PRIME MOVER: 3.5 MWm Solar Centaur

Gas compressor station

2021

CUSTOMER: Uztransgaz, Uzbekistan

CONFIGURATION: power generation from waste heat from 3 GE LM 1600 gas turbines in Hodzhaabad gas compressor station operated by Uztransgaz

ORC POWER: 1 MWe

FEATURES: solution with air-cooled condenser, no water needed; by-pass mode, with no impact on GT operation

REFERENCES

CUSTOMER: LUKoil, Russia

CONFIGURATION: power generation from heat released by flare gas combustion (boiler designed to burn gas with a minimum lower calorific value of 4,500 kcal/Nm3)

ORC POWER: 1.8 MWe

CHP MODE: inlet/outlet water temperature (65/95 °C) exploited for oil pumping

CUSTOMER: Italgas, Italy

CONFIGURATION: power generation from gas pressure reduction in a natural gas network infrastructure

ORC POWER: 1.3 MWe (2 gas expanders, 650 kWe each)

FEATURES: high efficiency project, electrified by two turboexpanders and two cogenerative gas engines

CUSTOMER: Shurtanneftegaz, Uzbekistan

CONFIGURATION: power generation from waste heat from 1 MW GE LM 2500 gas turbine in Shurtan gas compressor station operated by Shurtanneftegaz

ORC POWER: 5.5 MWe

FEATURES: non-flammable working fluid directly evaporated in the heat recovery exchanger

DAHSHOUR - FIRST OF KIND SUSTAINABLE GAS COMPRESSOR STATION

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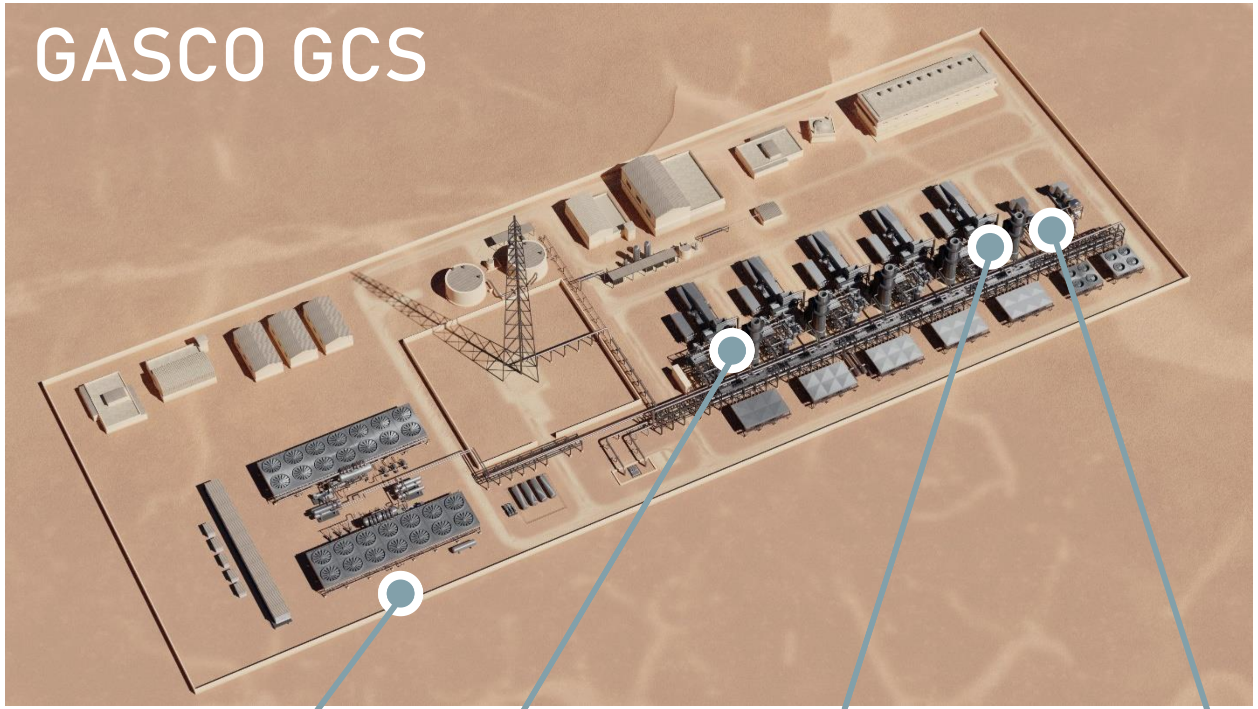
THE NEED

extend facility pumping capacity by 652+ MMSCFD (70% of existing compression capacity)

THE SOLUTION

2 x 12 MW ORC driving 2x EMD compressors of 10 MW each (extra 4 MW to cover station auxiliaries) for 25% of the extra power required +1 new GT for the 45% of extra power.



24 MWe ORC SYSTEM
(two ORCs of 12 MWe net each)

NEW GAS TURBINE COMPRESSION TRAIN
50 MW GT driven train

ELECTRICAL MOTOR DRIVEN TRAINS
(two trains of 10 MW each)

WASTE HEAT RECOVERY SYSTEM
one WHR exchanger for each GT (4 existing GTs + 1 new GT)

DAHSHOUR - FIRST OF KIND SUSTAINABLE GAS COMPRESSOR STATION

THE PROJECT

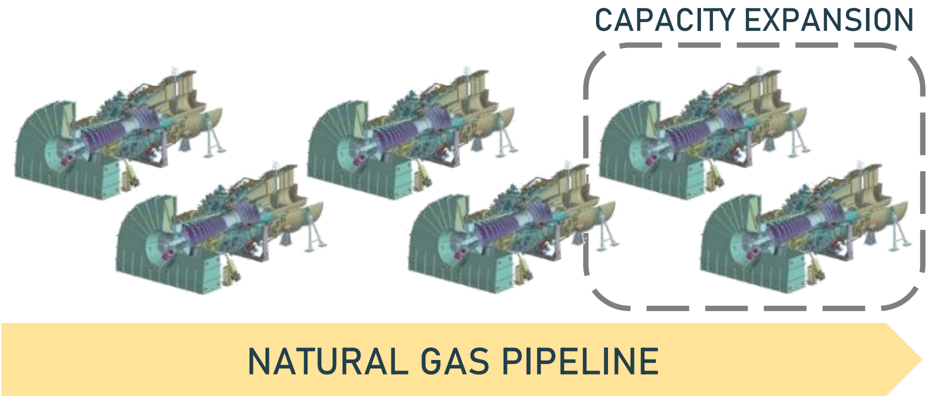
Heat recovery from 5 simple cycle GTs (4 in operation 1 in standby) in gas compressor station. **The ORC system will produce 24+ MWe to feed two electrical motor driven compressors** that will empower compressor station pumping capacity.

THE RESULTS

- 2 ORC of 12+ MWe each
- 192 GWh/year of fuel free electricity
- **Save 120,000 tons/year of CO_2**
- Fuel savings: approx. 65 MSm3/year
- Lower O&M costs
- **Increased GCS pumping capacity – 25% of additional compression capacity without any additional fuel consumption**

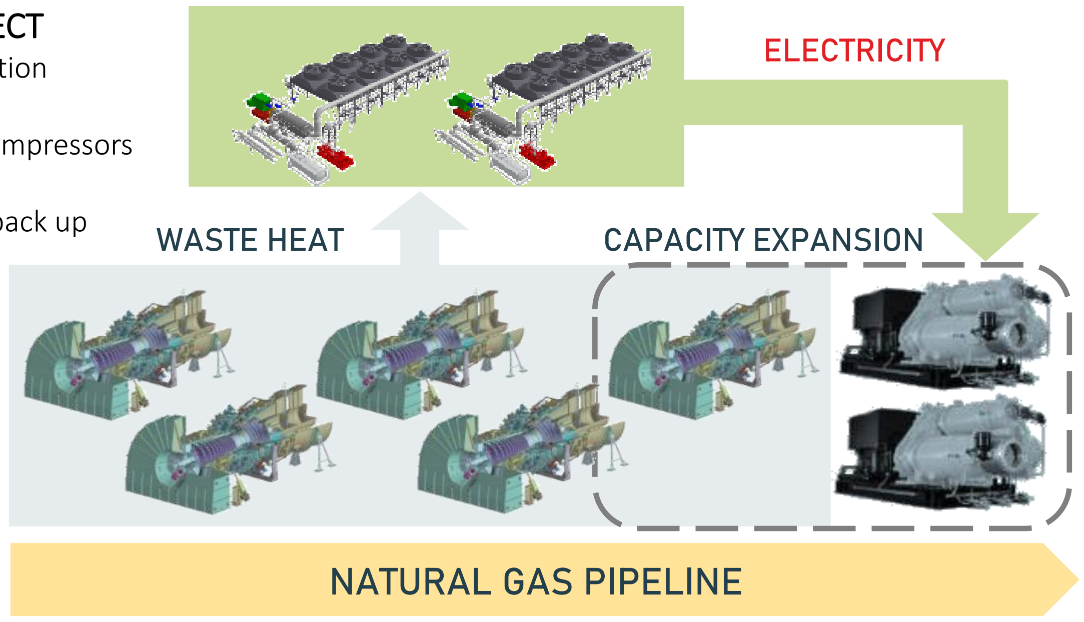
ORIGINAL PLAN

- 4 x GTs in operation
- 1 x new GT in operation
- 1 x new GT for back up



CURRENT PROJECT

- 4 x GTs in operation
- 2 x new ORCs
- 2 x new EMD compressors in operation
- 1 x new GT for back up



REFERENCES FROM INTERNAL COMBUSTION ENGINES

PLANT	COUNTRY	START UP	ORC SIZE (MWe)	ENGINES
PISTICCI I	Italy	2010	**1.8**	3 x 8 MWe Wärtsilä diesel engines
TERMOINDUSTRIALE	Italy	2008	**0.5**	1 x 8 MWe MAN diesel engine
PISTICCI II	Italy	2012	**4**	2 x 17 MWe Wärtsilä diesel engines
CEREAL DOCKS	Italy	2012	**0.5** (direct exchange)	1 x 7 MWe Wärtsilä diesel engine
E&S ENERGY	Italy	2010	**0.6**	2 x 1 MWe Jenbacher gas engines + 3 x 0.8 MWe Jenbacher gas engines + 1 x 0.6 MWe Jenbacher gas engine – landfill gas
ULM	Germany	2012	**0.7**	2 x 2 MW Jenbacher gas engines (+ additional heat from process)
KEMPEN	Germany	2012	**0.6**	Gas engines
MONDO POWER	Italy	2012	**1**	1 x 17 MWe Wärtsilä diesel engine
HSY	Finland	2011	**1.3**	4 x 4 MWe MWM gas engines – landfill gas
FATER	Italy	2013	**0.7** (direct exchange)	1 x 8 MWe Wärtsilä diesel engine
ORTADOGU I	Turkey	2020	**2.3**	12 x 1.4 MWe Jenbacher engines – landfill gas
ORTADOGU II	Turkey	under construction	**2 x 2.3**	20 x 1.4 MWe Jenbacher engines + 4 x 1.2 MWe MWM engines – landfill gas
BIOGASTECH	Belgium	2019	**0.7**	4 x 3.3 MWe Jenbacher gas engines

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