TURBODEN clean energy ahead

MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

POWER GENERATION

Oil&Gas

Turboden S.p.A.

A Group Company of MITSUBISHI HEAVY INDUSTRIES

Our Products

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POWER GENERATION
OIL&GAS

ORC System

Turboden Organic Rankine Cycle (ORC) systems are profitably used to produce electric and thermal power from **various kind of waste**.

Depending on waste quantity, characteristics, specific projects' requirements and regulations, the best thermal conversion technology available in the market is selected.

The generated power ranges up to **40 MW electric** per single shaft.

WHY CHOOSE ORC FOR ENERGY EFFICIENCY?

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

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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 streams used in Oil & Gas process
- Steam Assisted Gravity Drainage (SAGD) oil extraction

Associated petroleum gas

- Boilers
- Gas turbines or internal combustion engines
- Flare gas

Electric power and/or Mechanical power

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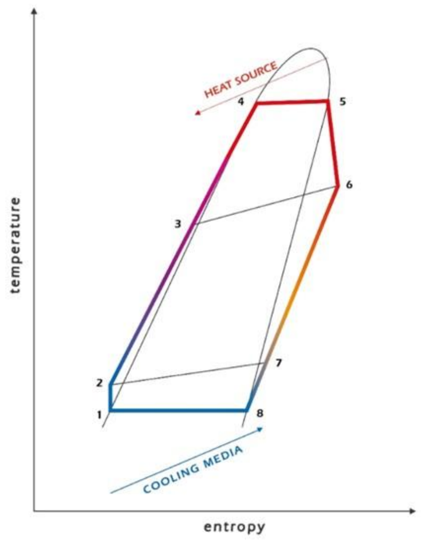
The ORC Cycle – How It Works

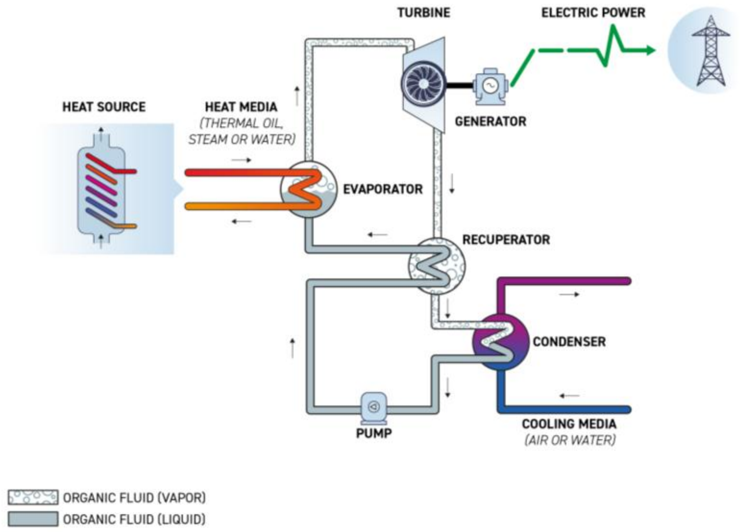
The ORC turbogenerator uses medium-to-high temperature thermal oil to preheat and vaporize a suitable organic working fluid in the evaporator (4>5).

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.





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Gas Compressor Station

- Combined cycle configuration with multiple gas turbines
- ORC output from 1 to 40 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

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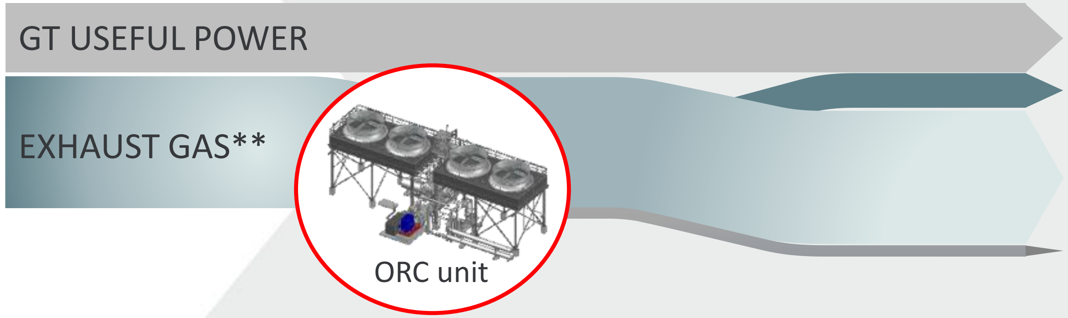
Exhaust Gas Waste Heat Recovery Unit Configuration

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

Overall Plant Performances

GAS TURBINES

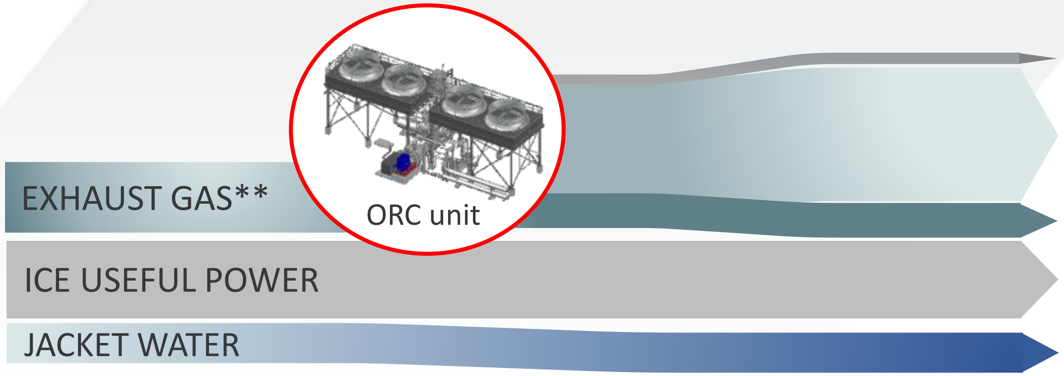
30÷40% ORC additional power*



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

INTERNAL COMBUSTION ENGINES

10% ORC additional power*

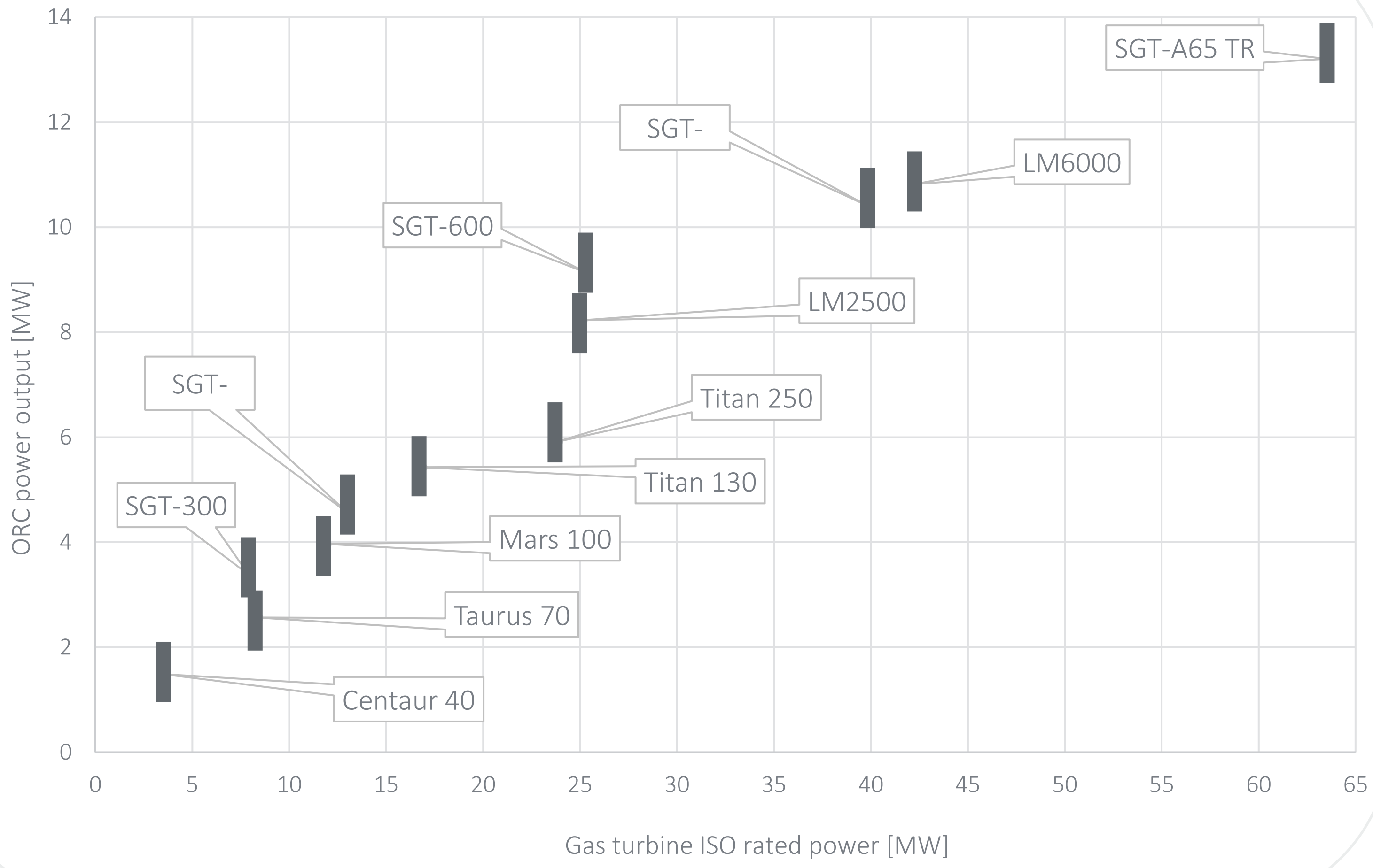


2%	Thermal losses
80 ÷ 72%	Thermal power
18 ÷ 26%	Useful power ***

* 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.

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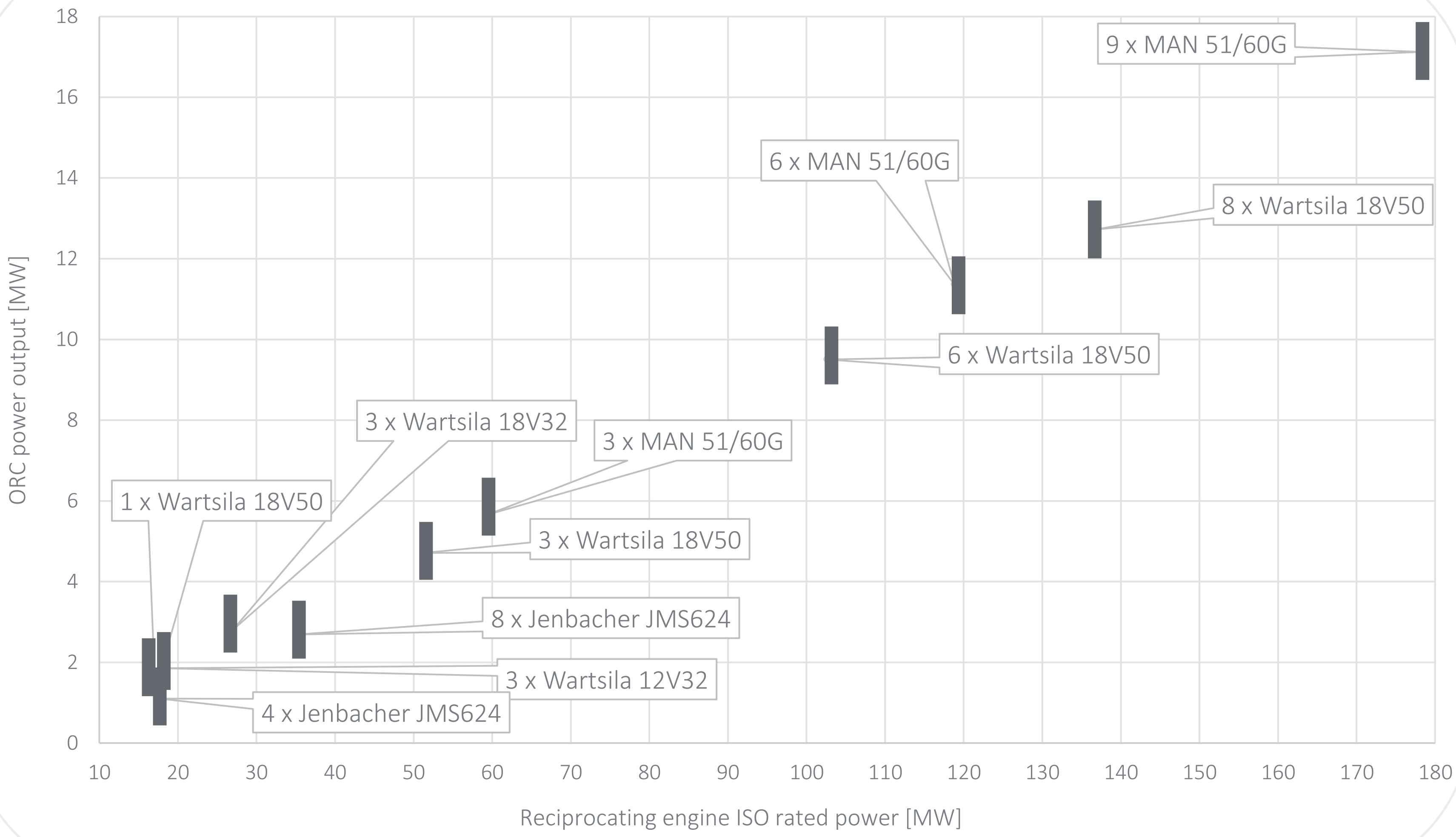
Internal Combustion Engines Bottoming with ORC

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.



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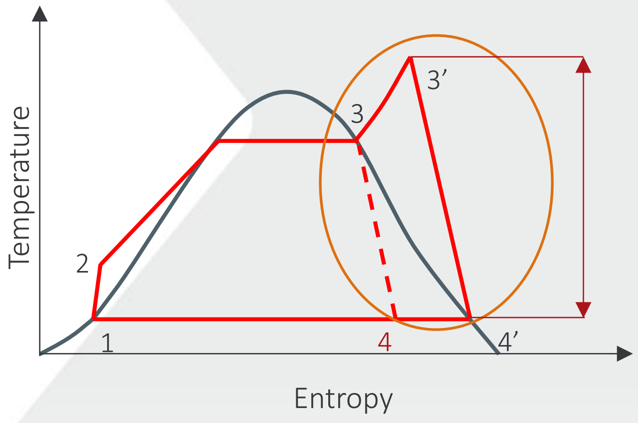
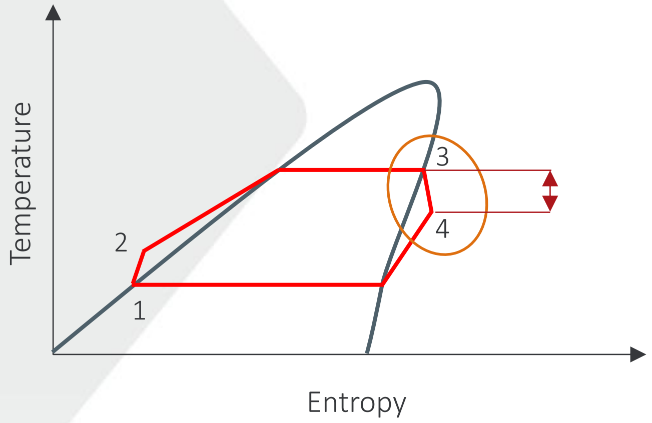
Thermodynamic Cycle: ORC vs Steam

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 stages 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%)

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Refinery Hot Streams

HEAT RECOVERY

OF LOW-ENTHALPY STREAMS

(e.g. hot diesel)

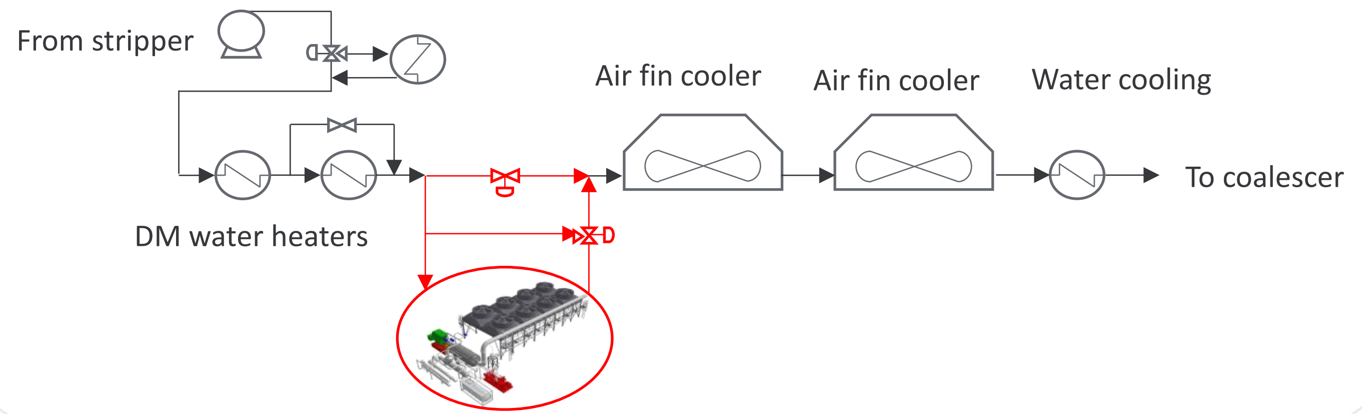
O&G FACILITIES PRESENT DIFFERENT LOW-ENTHALPY SOURCES

- → 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



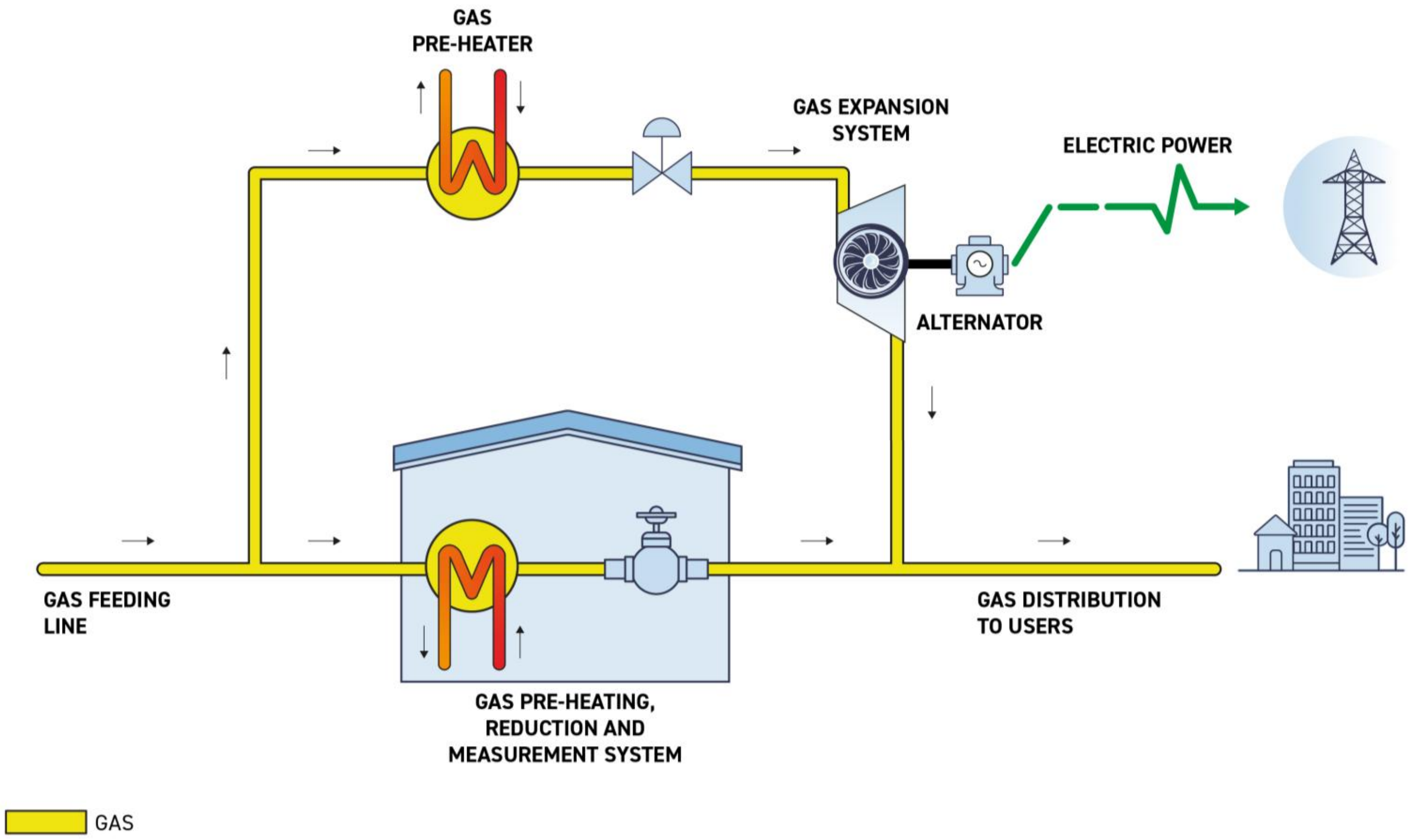
Gas Expander

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 users, be they residential or industrial.

KEY POINTS

- Design based on 45+ 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 decarbonization
- Unmanned installations, thanks to specific technology features
- Turn-key equipment capabilities
- Over 60 Turboden turbine models within the 470+ power plants fleet

The Configuration



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Turboden Rating

EXPANDERS SIZES	EXP 300	EXP 600	EXP 900	EXP > 1 MW
✓ Turbine stages/admission	Single stage radial turbine	Multi stages axial turbine		
✓ Flow rate	> 8,000 Sm3/h	20,000 – 150,000+ Sm3/h		
✓ In - out gas pressure range	50 - 1 bar(g)			
✓ Bearings	Self-lubricated rolling bearings	Rolling bearings		
✓ Seals	Single tight casing for impeller and generator	Double 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	Custom based on project specific features (e.g. gas fired boilers, waste heat, heat pump...)			

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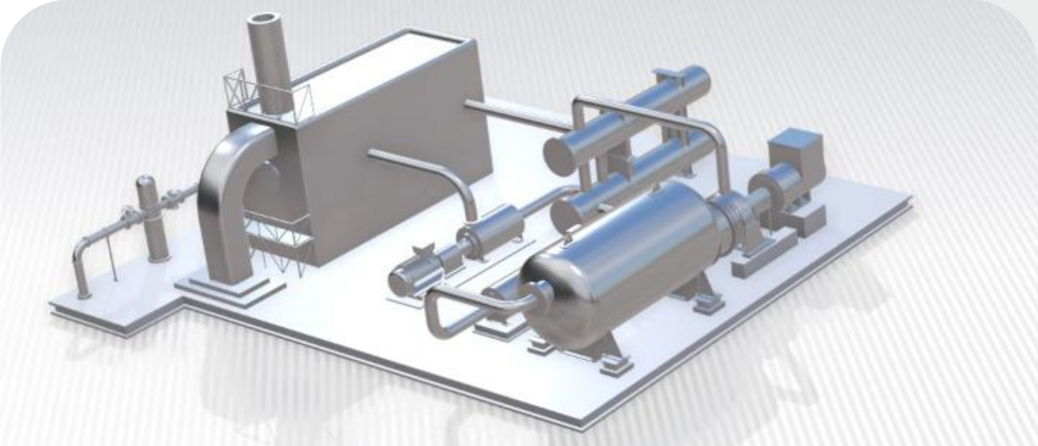
Other Turboden Solutions

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.

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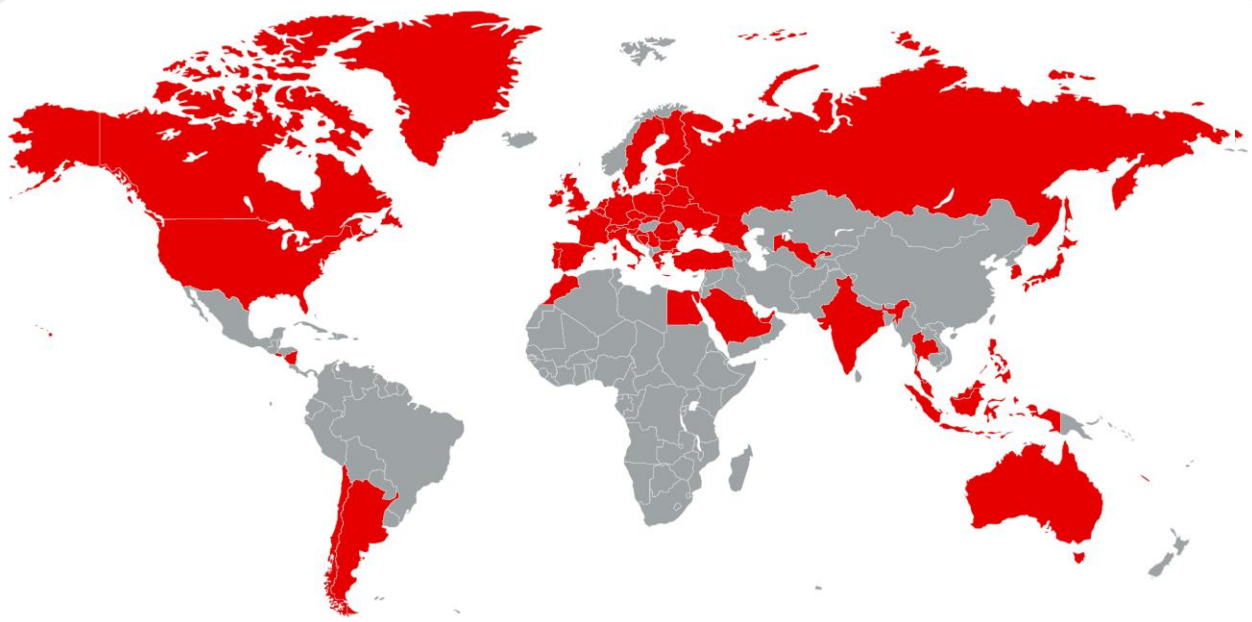
References

20+ plants

Oil&Gas

- → 45+ years experience
- → 50+ countries presence
- → Tailor-made EPC solutions
- → High availability (98%)
- → Customized after-sales service



Last update: Feb 2026

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References

Gasco Dashour

Egypt

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

ORC POWER: 25 MWe

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

Italgas

Italy

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

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

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

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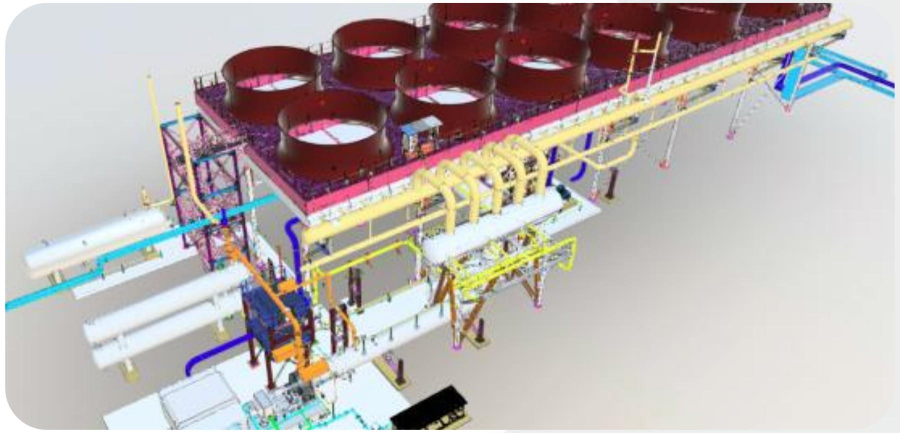
References



Tallgrass Energy Washington Court House

Ohio

CONFIGURATION: power generation from exhaust gas of 1 x Solar Mars 100 gas turbine + 2 Solar Mars 90 gas turbines in a gas compressor station operated by Tallgrass Energy

ORC POWER: 10 MWe

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

Strathcona Orion

Canada

CONFIGURATION: power generation in Steam Assisted Gravity Drainage (SAGD) oil extraction

ORC POWER: 19 MWe

FEATURE: exploitation of low-grade heat streams to generate up to 80% of the plant electricity needs

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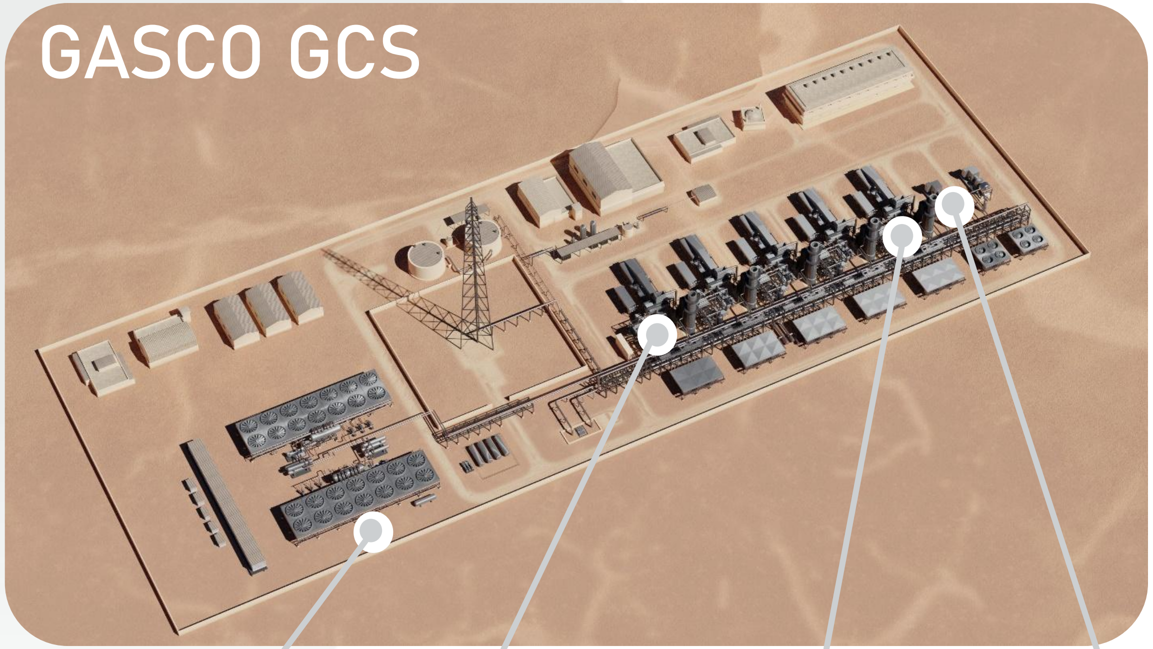
Dahshour – Sustainable Gas Compressor Station

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)

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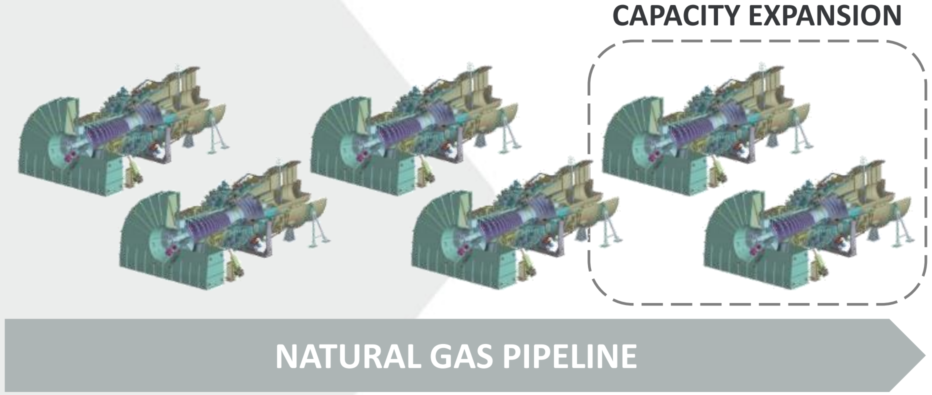
Dahshour – First of Kind Sustainable Gas Compressor Station

THE PROJECT

Heat recovery from 5 open 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.

ORIGINAL PLAN

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

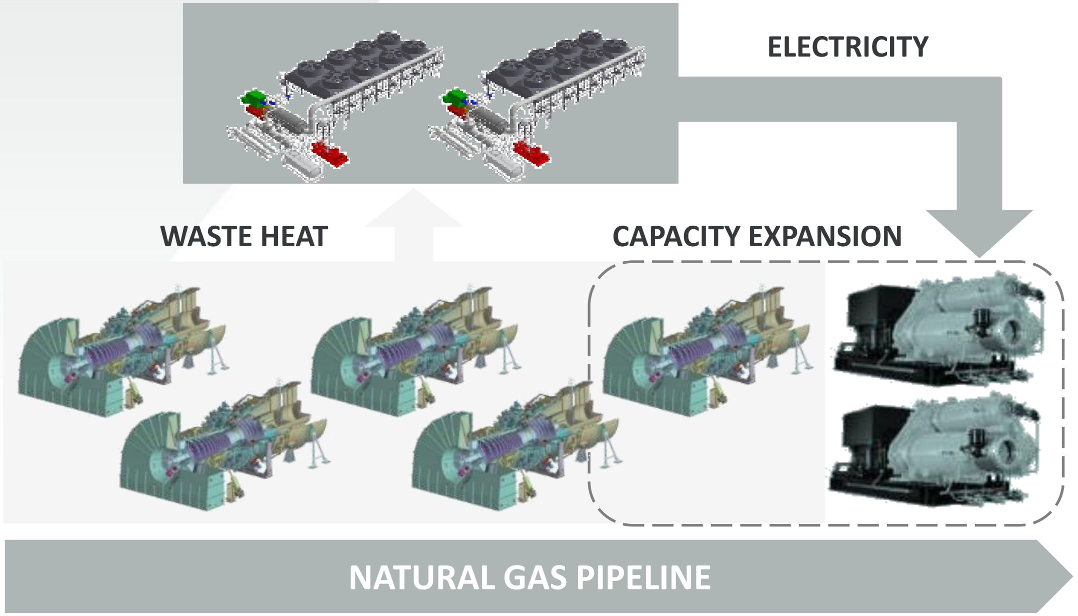


THE RESULTS

- 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**

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



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Turboden References in O&G Sector

PLANT	COUNTRY	START UP	HEAT SOURCE	HEAT CARRIER	ORC GROSS EL. POWER (kW)
TRANSGAS	Canada	2011	1 x Solar Centaur 40 gas turbine in gas compressor station	thermal oil	1,000
UZTRANSGAZ	Uzbekistan	2021	3 x GE LM 1600 gas turbines in gas compressor station	thermal oil	1,000
ULM	Germany	2012	2 x 2 MW Jenbacher gas engines (+ additional heat from process)	thermal oil	700
PISTICCI I	Italy	2010	3 x 8 MWe Wärtsilä diesel engines	thermal oil	1,800
TERMOINDUSTRIALE	Italy	2008	1 x 8 MWe MAN diesel engine	thermal oil	500
PISTICCI II	Italy	2012	2 x 17 MWe Wärtsilä diesel engines	thermal oil	4,000
CEREAL DOCKS	Italy	2012	1 x 7 MWe Wärtsilä diesel engine	none - direct exchange	500
BIOGASTECH	Belgium	2019	4 x 3.3 MWe Jenbacher gas engines	none - direct exchange	700

Turboden References in O&G Sector

PLANT	COUNTRY	START UP	HEAT SOURCE	HEAT CARRIER	ORC GROSS EL. POWER (kW)
E&S ENERGY	Italy	2010	2 x 1 MWe Jenbacher gas engines + 3 x 800 kWe Jenbacher gas engines + 1 x 600 kWe Jenbacher gas engin	thermal oil	600
GASCO DASHUR	Egypt	Under commissioning	5 X 30 MWe gas turbines (4 in operation, 1 in stand-by) in gas compressor station	thermal oil	25,000
MONDO POWER	Italy	2012	1 x 17 MWe Wärtsilä diesel engine	thermal oil	1,000
HSY	Finland	2011	4 x 4 MWe MWM gas engines - landfill gas	thermal oil	1,300
ORTADOGU I	Turkey	2023	28 x 1.4 MWe Jenbacher engines + 4 x 1.2 MWe MWM engines - landfill gas	thermal oil	4,600
ORTADOGU II	Turkey	2020	12 x 1.4 MWe Jenbacher engines - landfill gas	thermal oil	2,300
TALLGRASS Washington Court House	Ohio	under construction	1 x Solar Mars 100 gas turbine + 2 Solar Mars 90 gas turbines in gas compressor station	thermal oil	10,000

Turboden References in O&G Sector

PLANT	COUNTRY	START UP	HEAT SOURCE	HEAT CARRIER	ORC GROSS EL. POWER (kW)
STRATHCONA ORION	Canada	2025	low-grade heat streams in Steam Assisted Gravity Drainage (SAGD) oil extraction	direct exchange	19,000
UNDISCLOSED	Ohio	under construction	3 x Solar Mars 100 gas turbines in gas compressor station	thermal oil	11,000
UNDISCLOSED	Indiana	under construction	3 x Solar Mars 100 gas turbines in gas compressor station	thermal oil	11,000
UNDISCLOSED	Ohio	under construction	4 x Solar Mars 100 gas turbines in gas compressor station	thermal oil	14,000

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