ENERGIZE YOUR FUTURE. DON’T WASTE YOUR POWER.
OUR PRODUCTS

Designed for decarbonisation.

ORC SYSTEM

LARGE HEAT PUMP

GAS EXPANDER
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*

GT USEFUL POWER

EXHAUST GAS**

ORC unit

18 ÷ 30% Useful power ***

80 ÷ 68% Thermal power

2% Thermal losses

INTERNAL COMBUSTION ENGINES

10% ORC additional power*

ICE USEFUL POWER

JACKET WATER

EXHAUST GAS**

ORC unit

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

STEAM RANKINE CYCLE

1. Superheating needed
2. Risk of blade erosion due to possible liquid formation during the expansion
3. High enthalpy drop – turbine with high stage number

ORGANIC RANKINE CYCLE

1. No need to superheat
2. No risk of blade erosion thanks to dry expansion in the turbine
3. Small enthalpy drop – turbine with low stage number

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
- CO₂ emission reduction
- Fuel-free additional electricity

From stripper
DM water heaters

Air fin cooler

Water cooling

To coalescer
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

GAS FEEDING LINE

GAS REDUCTION AND MEASUREMENT SYSTEM

GAS DISTRIBUTION

ELECTRIC POWER

ELECTRICAL GRID

GAS NETWORK
## TURBODEN GAS EXPANDER RATING

<table>
<thead>
<tr>
<th>EXPANDERS SIZES</th>
<th>EXP 400</th>
<th>EXP 600</th>
<th>EXP 900</th>
<th>EXP &gt; 1 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Turbine stages/admission</td>
<td>Single stage radial turbine</td>
<td>Multi stages axial turbine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>✓ Flow rate</td>
<td>&gt;5,000 Sm3/h</td>
<td>20,000 – 100,000+ Sm3/h</td>
<td></td>
<td></td>
</tr>
<tr>
<td>✓ In - out gas pressure range</td>
<td></td>
<td>70 - 1 bar(g)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>✓ Bearings</td>
<td>Rolling bearings</td>
<td>Self-lubricated rolling bearings</td>
<td></td>
<td></td>
</tr>
<tr>
<td>✓ Seals</td>
<td>Single tight casing for impeller and generator</td>
<td>Mechanical</td>
<td></td>
<td></td>
</tr>
<tr>
<td>✓ Generator</td>
<td>Permanent Magnet generator</td>
<td>A/Synchronous LV - Eff. 97%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>✓ Containerization</td>
<td>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.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>✓ Gas pre-heating</td>
<td>Hot water boiler fed by natural gas and shell &amp; tube heat exchangers + possible combination with electrical heaters and heat pumps – custom based on project specific.</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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.
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

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

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 kW 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

**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.

GASCO GCS

- 24 MWe ORC SYSTEM (two ORCs of 12 MWe 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)
DAHSOUR - 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 CO₂
- 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

NATURAL GAS PIPELINE
CAPACITY EXPANSION
ELECTRICITY
WASTE HEAT

Copyright © – Turboden S.p.A. All rights reserved
<table>
<thead>
<tr>
<th>PLANT</th>
<th>COUNTRY</th>
<th>START UP</th>
<th>ORC SIZE (MWe)</th>
<th>ENGINES</th>
</tr>
</thead>
<tbody>
<tr>
<td>PISTICCI I</td>
<td>Italy</td>
<td>2010</td>
<td>1.8</td>
<td>3 x 8 MWe Wärtsilä diesel engines</td>
</tr>
<tr>
<td>TECNOINDUSTRIALE</td>
<td>Italy</td>
<td>2008</td>
<td>0.5</td>
<td>1 x 8 MWe MAN diesel engine</td>
</tr>
<tr>
<td>PISTICCI II</td>
<td>Italy</td>
<td>2012</td>
<td>4</td>
<td>2 x 17 MWe Wärtsilä diesel engines</td>
</tr>
<tr>
<td>CEREAL DOCKS</td>
<td>Italy</td>
<td>2012</td>
<td>0.5 (direct exchange)</td>
<td>1 x 7 MWe Wärtsilä diesel engine</td>
</tr>
<tr>
<td>E&amp;S ENERGY</td>
<td>Italy</td>
<td>2010</td>
<td>0.6</td>
<td>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</td>
</tr>
<tr>
<td>ULM</td>
<td>Germany</td>
<td>2012</td>
<td>0.7</td>
<td>2 x 2 MW Jenbacher gas engines (+ additional heat from process)</td>
</tr>
<tr>
<td>KEMPEN</td>
<td>Germany</td>
<td>2012</td>
<td>0.6</td>
<td>Gas engines</td>
</tr>
<tr>
<td>MONDO POWER</td>
<td>Italy</td>
<td>2012</td>
<td>1</td>
<td>1 x 17 MWe Wärtsilä diesel engine</td>
</tr>
<tr>
<td>HSY</td>
<td>Finland</td>
<td>2011</td>
<td>1.3</td>
<td>4 x 4 MWe MWM gas engines – landfill gas</td>
</tr>
<tr>
<td>FATER</td>
<td>Italy</td>
<td>2013</td>
<td>0.7 (direct exchange)</td>
<td>1 x 8 MWe Wärtsilä diesel engine</td>
</tr>
<tr>
<td>ORTADOGU I</td>
<td>Turkey</td>
<td>2020</td>
<td>2.3</td>
<td>12 x 1.4 MWe Jenbacher engines – landfill gas</td>
</tr>
<tr>
<td>ORTADOGU II</td>
<td>Turkey</td>
<td>under construction</td>
<td>2 x 2.3</td>
<td>20 x 1.4 MWe Jenbacher engines + 4 x 1.2 MWe MWM engines – landfill gas</td>
</tr>
<tr>
<td>BIOGASTECH</td>
<td>Belgium</td>
<td>2019</td>
<td>0.7</td>
<td>4 x 3.3 MWe Jenbacher gas engines</td>
</tr>
</tbody>
</table>
OUR EXPERIENCE. YOUR POWER.