WASTE HEAT RECOVERY

INCREASE YOUR ENERGY EFFICIENCY WITH ORC TECHNOLOGY.
They believe in us
Turn waste heat into useful power

Turboden Organic Rankine Cycle (ORC) units enable power production by converting residual, low-grade heat into useful power in industrial processes and in combined cycles when coupled with reciprocating engines and gas turbines. Turboden turbogenerators in this field can generate up to 20 MW electric per single shaft.

**PRODUCTION PROCESS**
Unexploited heat streams produced by industrial processes like cement, glass, steel, ferroalloy, non-ferrous metals (copper, aluminum, etc.), silicon metal, carbon black, etc.

**COMBINED CYCLES**
When coupled with gas turbines, reciprocating engines, and fuel cells.

Electric power / Mechanical power
Why choose ORC for energy efficiency?

- GENERATE PROFIT FROM LEVERAGING A WASTE HEAT SOURCE
- REDUCE SPECIFIC PRODUCTION COST BY DECREASING ENERGY DEMAND
- IMPROVE ENERGY-INTENSIVE INDUSTRY SUSTAINABILITY
- REDUCE CO₂ EMISSIONS

- ease of integration with no impact on production process or prime equipment (engine, gas turbine) operation
- no water consumption
- negligible fluid refilling required
- automatic operation with no operator attendance required
- high cycle efficiency up to 30%
- heat input from gaseous, liquid and condensing streams (from 100°C)
- high-efficiency and full flexibility operation from 10% to 110% of the nominal load
The ORC turbogenerator makes use of a closed thermodynamic cycle to convert heat into electricity. The thermal power recovered from the waste heat vaporizes a suitable organic working fluid, which then expands through the turbine, and produces clean and reliable electric power through the alternator. Thanks to the regenerator, an internal heat recovery takes place improving the cycle efficiency. Downstream the regenerator, the organic vapor is condensed and pumped back to start the cycle again. The heat of condensation can be either used by the heat users or dissipated.

The waste heat from production process is transferred to the ORC working fluid by means of an intermediate circuit or directly via the exhaust gases in direct exchange systems. The media used in the intermediate circuits are thermal oil, saturated steam or superheated water.
Make your process more sustainable

Energy-intensive industries have unexploited waste heat streams. For example, in cement production process, Turboden ORC systems can produce electric power by recovering waste heat from two hot gas streams: kiln pre-heater gas and clinker cooler air.

Example of a cement production plant integrated with a Turboden ORC system.
Make your plant more sustainable

Designed upon specific site features, the ORC-based heat recovery system exploits the gas turbines’ exhausts to produce up to 30% ÷ 40% of additional useful power. The ORC system follows the gas turbines’ operation mode producing additional power (for the station itself or for external users) without any impact on the gas compressor station operation.

Example of gas turbines bottoming with ORC technology.
Add free power to your cycle

In combined cycles, Turboden ORC units can be installed downstream of:
- Gas turbines (GT), with up to 40% of additional power
- Reciprocating engines (RECIPS), with up to 10% of additional power

In both cases the combined cycle achieves an efficiency greater than 50%.

**GAS TURBINES**

30÷40% ORC additional power*

<table>
<thead>
<tr>
<th>GT USEFUL POWER</th>
<th>ORC UNIT</th>
<th>EXHAUST GAS**</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 ÷ 30% USEFUL POWER***</td>
<td>80 ÷ 68% THERMAL POWER</td>
<td>2% THERMAL LOSSES</td>
</tr>
</tbody>
</table>

**RECIPROCATING ENGINES**

10% ORC additional power*

<table>
<thead>
<tr>
<th>RECIPS USEFUL POWER</th>
<th>ORC UNIT</th>
<th>EXHAUST GAS**</th>
<th>JACKET WATER</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 ÷ 26% USEFUL POWER***</td>
<td>80 ÷ 72% THERMAL POWER</td>
<td>2% THERMAL LOSSES</td>
<td></td>
</tr>
</tbody>
</table>

* ORC power output compared to GT or RECIPS shaft capacity (e.g. 10 MW GT -> 3÷4 MWe ORC).
** Min. flow to ORC: 10-15 kg/s.
*** Mechanical and/or electric power, calculated on thermal power input to ORC.
<table>
<thead>
<tr>
<th>Company</th>
<th>Country</th>
<th>Size (MWe)</th>
<th>Status</th>
<th>Production Process</th>
<th>Cooling System</th>
<th>Heat Carrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>HOLCIM ROMANIA (LAFARGEHOLCIM GROUP)</td>
<td>ROMANIA</td>
<td>4</td>
<td>in operation since 2012</td>
<td>cement</td>
<td>water cooled condenser + cooling towers</td>
<td>thermal oil</td>
</tr>
<tr>
<td>CRH (FORMER HOLCIM)</td>
<td>SLOVAKIA</td>
<td>5</td>
<td>in operation since 2014</td>
<td>cement</td>
<td>water cooled condenser + cooling towers</td>
<td>thermal oil</td>
</tr>
<tr>
<td>JURA-CEMENT-FABRIKEN (CRH GROUP)</td>
<td>SWITZERLAND</td>
<td>2.3</td>
<td>in operation since 2016</td>
<td>cement</td>
<td>water cooled condenser + cooling towers</td>
<td>superheated water</td>
</tr>
<tr>
<td>CARPATCEMENT (HEIDELBERGCEMENT GROUP)</td>
<td>ROMANIA</td>
<td>3.8</td>
<td>in operation since 2015</td>
<td>cement</td>
<td>air cooled condenser (no water consumption)</td>
<td>thermal oil</td>
</tr>
</tbody>
</table>
AGC - ITALY
- SIZE: 1.3 MWe
- STATUS: in operation since 2012
- PRODUCTION PROCESS: float glass
- COOLING SYSTEM: water cooled condenser + cooling towers
- HEAT CARRIER: thermal oil

ÇALBIYIK GROUP / DÜZCECAM - TURKEY
- SIZE: 6.2 MWe
- STATUS: under construction
- PRODUCTION PROCESS: float glass
- COOLING SYSTEM: air cooled condenser (no water consumption)
- HEAT CARRIER: thermal oil

FERALPI - GERMANY
- SIZE: 2.7 MWe
- STATUS: in operation since 2013
- PRODUCTION PROCESS: steel (electric arc furnace)
- COOLING SYSTEM: water cooled condenser + cooling towers
- HEAT CARRIER: saturated steam

ARVEDI - ITALY
- SIZE: 10 MWe
- STATUS: in operation since 2018
- PRODUCTION PROCESS: steel (electric arc furnace)
- COOLING SYSTEM: water cooled condenser + cooling towers
- HEAT CARRIER: saturated steam
CEMENTI ROSSI - ITALY
- SIZE: 2 MWe
- STATUS: under construction
- PRODUCTION PROCESS: cement
- COOLING SYSTEM: air cooled condenser (no water consumption)
- HEAT CARRIER: not present, direct exchange

ORI MARTIN - ITALY
- SIZE: 2.2 MWe
- STATUS: in operation since 2016
- PRODUCTION PROCESS: steel (electric arc furnace)
- COOLING SYSTEM: water cooled condenser + cooling towers
- HEAT CARRIER: saturated steam

UZNEFTEGAZDOBYCHA - UZBEKISTAN
- SIZE: 5.5 MWe
- STATUS: under construction
- HEAT SOURCE: exhaust gas of GE LM 2500 gas turbine in the gas compressor station serving Shurtan Gas Chemical Complex
- COOLING SYSTEM: air cooled condenser (no water consumption)
- HEAT CARRIER: not present, direct exchange

ORTADOĞU ENERJI - TURKEY
- SIZE: 3 X 2.3 MWe
- STATUS: under construction
- HEAT SOURCE: exhaust gas of 12x1.4 MW GE Jenbacher (site 1) and 28x1.4 MW GE Jenbacher + 4x1.2 MW MWM (site 2) gas engines – Landfill gas
- COOLING SYSTEM: air cooled condenser (no water consumption)
- HEAT CARRIER: thermal oil
**UZTRANSGAZ - UZBEKISTAN**
- SIZE: 1 MWe
- STATUS: under construction
- HEAT SOURCE: exhaust gas of 3x15 MW GE gas turbines in the gas compressor station serving the Hodzhaabad Underground Storage System
- COOLING SYSTEM: air cooled condenser (no water consumption)
- HEAT CARRIER: thermal oil

**CEREAL DOCKS - ITALY**
- SIZE: 0.5 MWe
- STATUS: in operation since 2012
- HEAT SOURCE: exhaust gas of 1x7 MWe Wärtsilä diesel engine
- COOLING SYSTEM: water cooled condenser + closed water loop with air-coolers
- HEAT CARRIER: not present, direct exchange

**TRANSGAS - CANADA**
- SIZE: 1 MWe
- START UP: in operation since 2011
- HEAT SOURCE: exhaust gas of 3.5 MWe Solar gas turbine in a gas compressor station along TransGas pipeline
- COOLING SYSTEM: water cooled condenser + closed water loop
- HEAT CARRIER: thermal oil

**HSY - FINLAND**
- SIZE: 1.3 MWe
- START UP: in operation since 2011
- HEAT SOURCE: exhaust gas of 4x4 MWe MWM gas engines - Landfill gas
- COOLING SYSTEM: water cooled condenser + closed water loop
- HEAT CARRIER: thermal oil
Turboden, a Mitsubishi Heavy Industries company, is an Italian firm and a global leader in the design, manufacture and maintenance of Organic Rankine Cycle (ORC) systems, highly suitable for distributed power generation. ORC systems can generate electric and thermal power exploiting multiple sources, such as renewables (biomass, geothermal energy, solar energy), traditional fuels and waste heat from industrial processes, waste incinerators, engines or gas turbines.

Mitsubishi Heavy Industries, Ltd. (MHI), headquartered in Tokyo, is one of the world’s leading industrial firms with 80,000 group employees and annual consolidated revenues of around 38 billion U.S. dollars (year 2016). For more than 130 years, the company has channeled big thinking into innovative and integrated solutions that move the world forward. MHI owns a unique business portfolio covering land, sea, sky and even space. MHI delivers innovative and integrated solutions across a wide range of industries from commercial aviation and transportation to power plants and gas turbines, and from machinery and infrastructure to integrated defense and space systems.

Why Turboden?

PART OF MITSUBISHI HEAVY INDUSTRIES GROUP

Turboden has the constant support of its parent company regarding financial solidity, sharing of business practices (including customer warranties) and technological development.

CAPABILITIES & EXPERIENCE

With over 35 years of experience, a global presence, 500+ MWe installations, and 350+ plants in 40 countries, Turboden is a market leader in the proprietary design and manufacturing of ORC optimized turbines.

CUSTOMER ORIENTATION

Optimized solutions for each customer and a qualified service department exclusively dedicated to customer assistance.
Feel our strengths

- **FLEXIBILITY**
  - Range size up to 20 MW per single shaft
  - Different primary energy sources
  - Large rangeability
  - Cogeneration or power-only mode
  - Ease of integration
  - Island mode

- **RELIABILITY**
  - High availability (98%+)
  - Long life

- **TURBODEN ORC**

- **SUSTAINABILITY**
  - Core system for renewable energy and energy efficiency
  - Clean generation of power and heat
  - Reduction of CO₂ emissions

- **EASY TECHNOLOGY**

- Simple technical features: low pressures involved, low speed turbine, limited number of stages of the turbine (≤6), self-lubricating fluids, no water required

- Easy and cost-effective operation & maintenance: automatic operation (no qualified operator required), minimal maintenance activities, no major overhaul (turbine not subject to erosion or corrosion), fast start-stop procedures, no chemical and water treatments, low refilling of fluid required
Always by your side

24/7 SUPPORT*

<2h REACTION TIME

97% PLANTS WITH AFTER-SALES CONTRACTS

*up to

GLOBAL COVERAGE

- 3 service subsidiaries and 5 international service partner companies

CUSTOMIZED SERVICES

- single contact for requests for support
- dedicated staff to on-site and remote technical support
- assistance of an international network of companies able to provide technical support
- wide range of services provided
- prompt assistance and customized after-sales services
- remote technical support using innovative tools
- dedicated spare parts warehouse

CUSTOMER REQUEST OR TURBODEN PLANNED CHECKS

TREND ANALYSIS WITH LOCAL OPERATOR SUPPORT

FOCUSED TEAMWORK AND TECHNICAL DECISIONS

REACTION PLAN: REMOTE OR ON-SITE

SATISFIED CUSTOMER
Meet our global and proven experience

PLANTS: 359
COUNTRIES: 40
TOTAL CAPACITY: 564 MWe
CUMULATIVE OPERATION TIME: 13 million hours
AVERAGE AVAILABILITY: 98+%