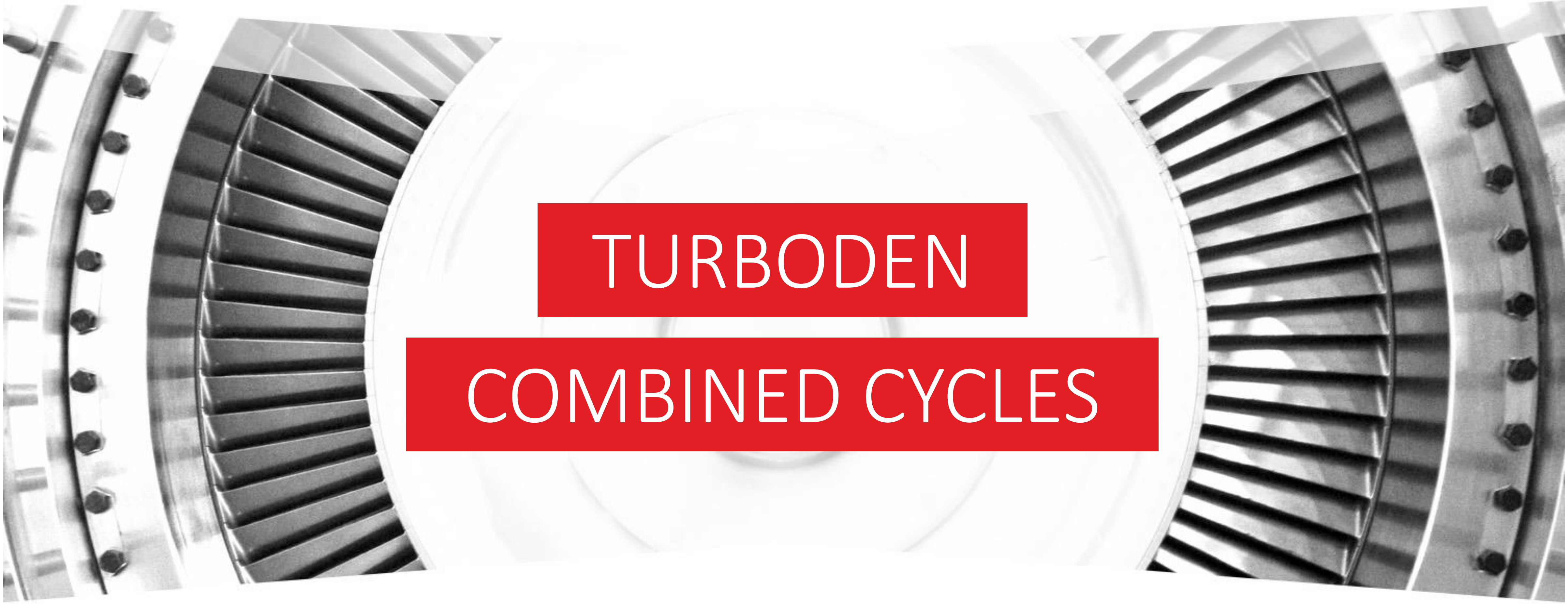
clean energy ahead
TURBODEN®

MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP



# TURBODEN
# COMBINED CYCLES

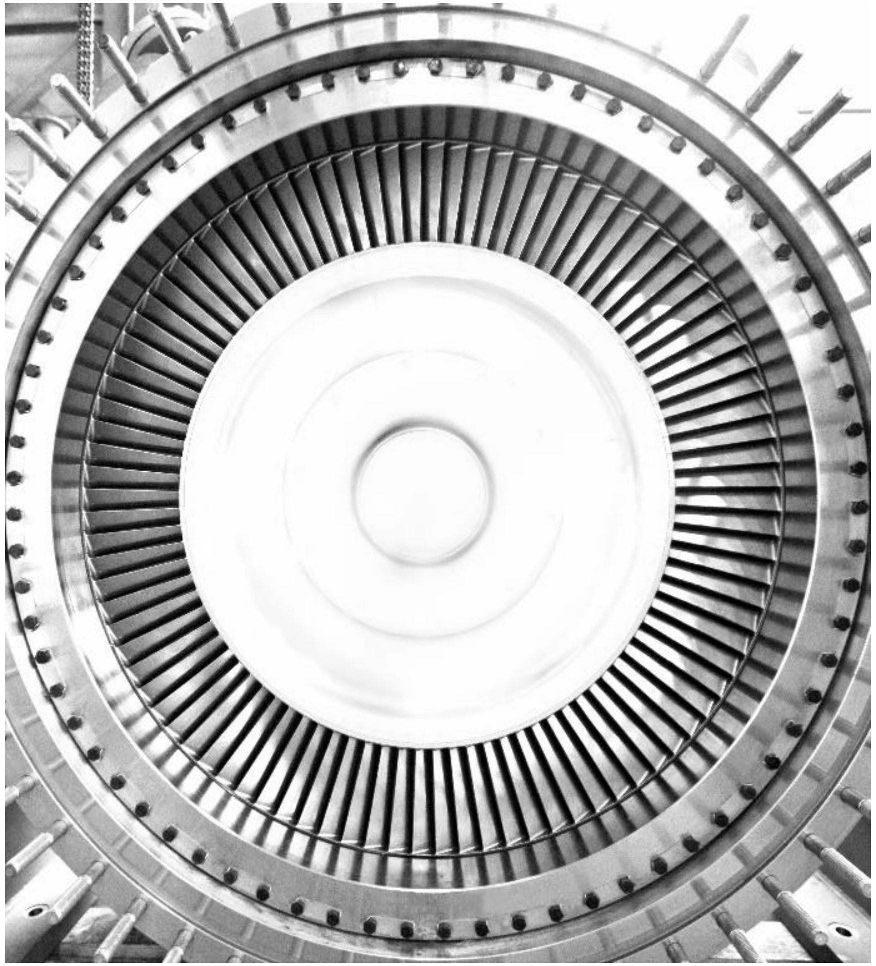
Cod. 20-COM.P-1-rev.2

INCREASE YOUR ENERGY EFFICIENCY WITH OUR SOLUTIONS.

# TURBODEN FOR COMBINED CYCLES

We provide smart, efficient and water-free solutions to close your open cycle power plant.

# ORC SYSTEM

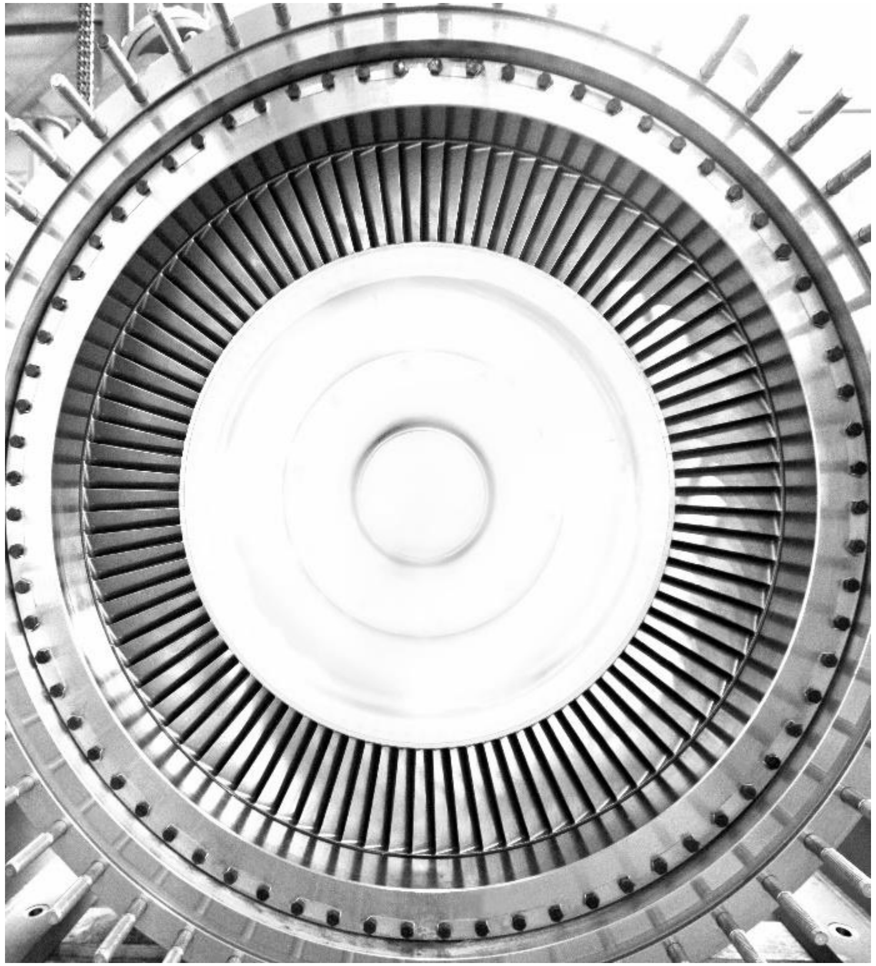


Turboden Organic Rankine Cycle (ORC) units can produce electricity by recovering residual low-grade heat from **industrial processes** and from **internal combustion engines**, **gas turbines**, and fuel cells operating on open cycle. The generated power ranges up to **20 MW electric** per single shaft.

## 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

# ORC SYSTEM FEATURES



## Simplicity

- Remote monitoring and automatic operation
- No water use and treatment required
- Minimal maintenance activities

## Flexibility

- Ease of integration
- Excellent part load capability down to 10% load
- Different primary energy sources

## Dependability

- High availability
- Long life (> 25 years)
- 40 years in the design and production of turbomachinery

## Sustainability

- Core system for renewable energy and energy efficiency
- Clean generation of power and heat
- Reduction of $CO_2$ emissions

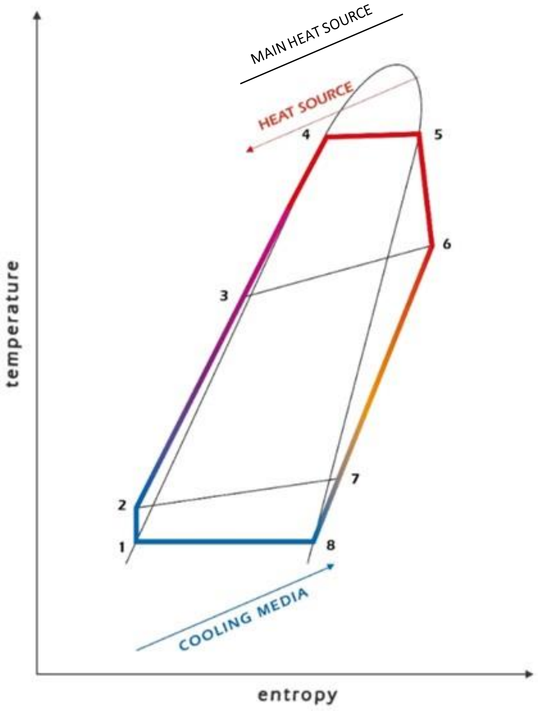
# THE ORC CYCLE – HOW IT WORKS

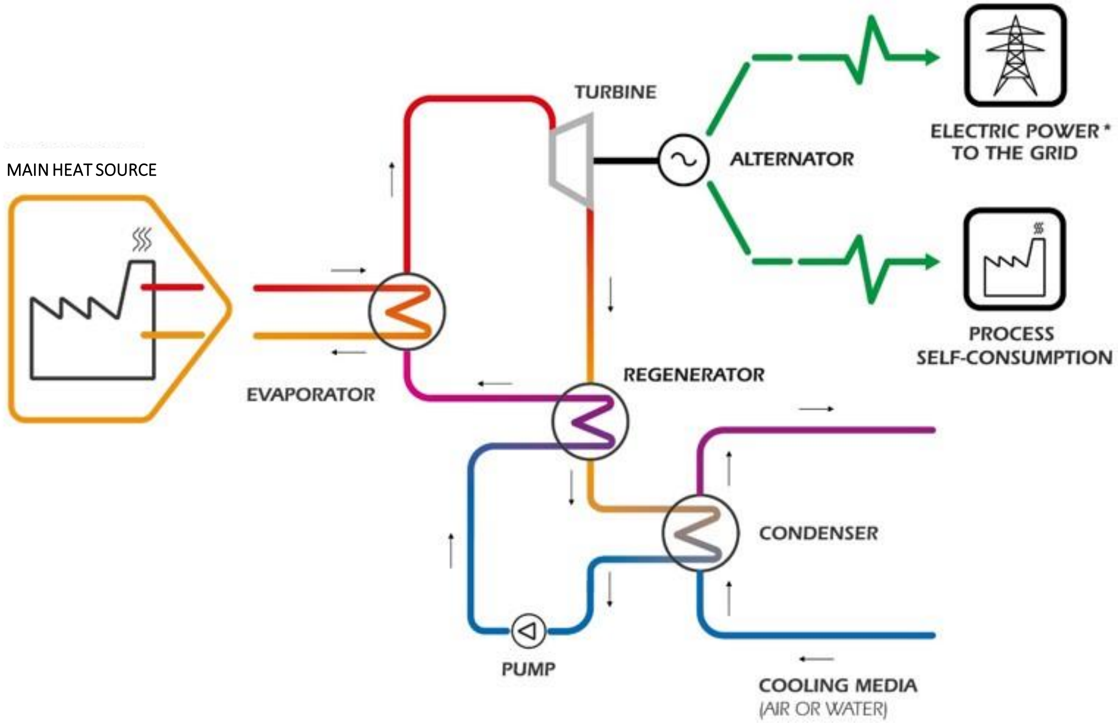
The ORC turbogenerator uses medium-to-high temperature thermal oil to preheat and vaporize a suitable organic working fluid in the evaporator (4>5).

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.

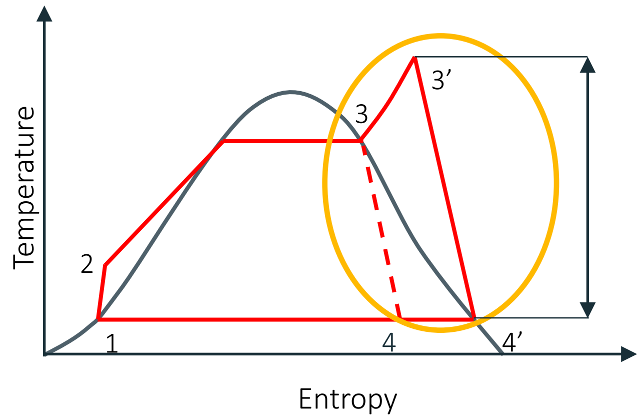
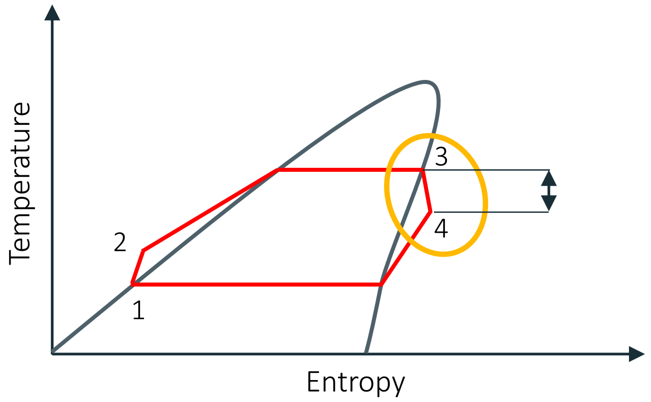


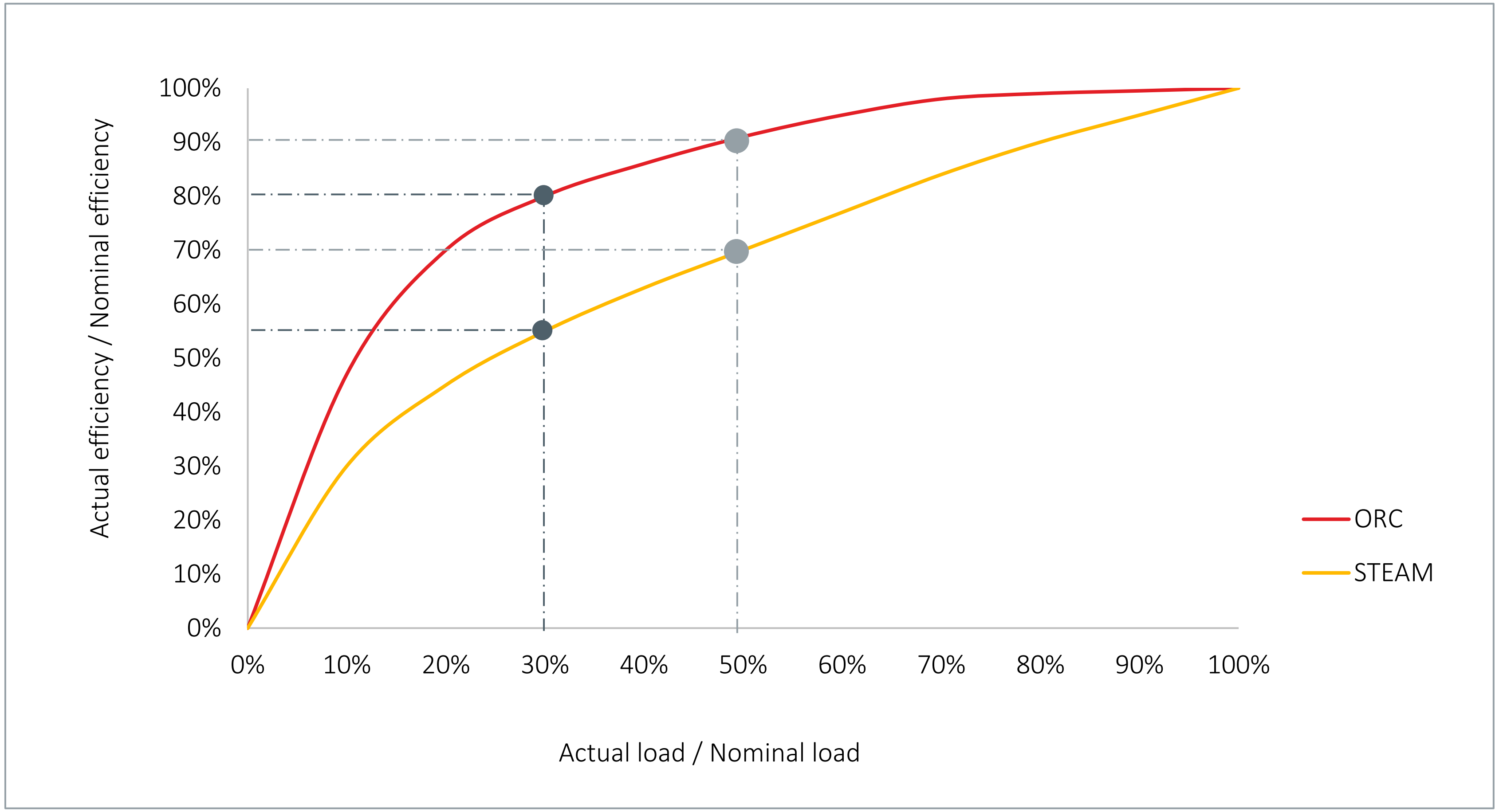

* ORC units can produce electric and/or mechanical power

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.

# THERMODYNAMIC CYCLE: ORC VS STEAM

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

# COMPARISON WITH STEAM TECHNOLOGY




50% PARTIAL LOAD

**ORC 90%**

STEAM 70%

30% PARTIAL LOAD

**ORC 80%**

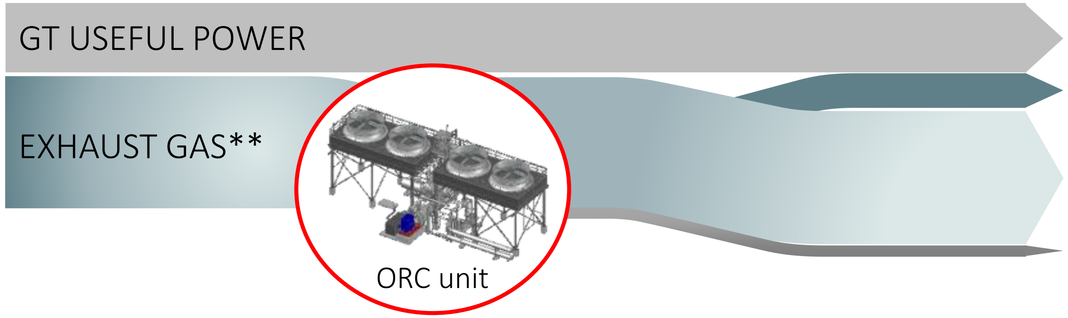
STEAM 55%

NOTE: steam turbine suffers partial load operation due to high risk of blade erosion.

# OVERALL PLANT PERFORMANCES

## GAS TURBINES

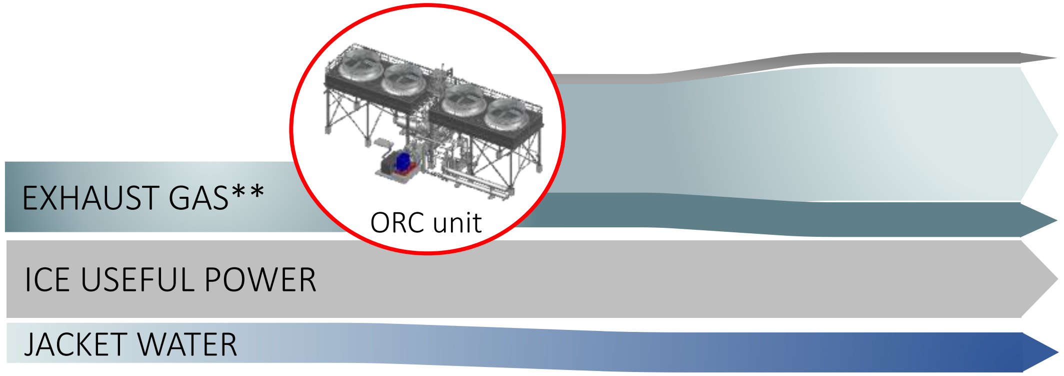
30÷40% ORC additional power*




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

## INTERNAL COMBUSTION ENGINES

10% ORC additional power*

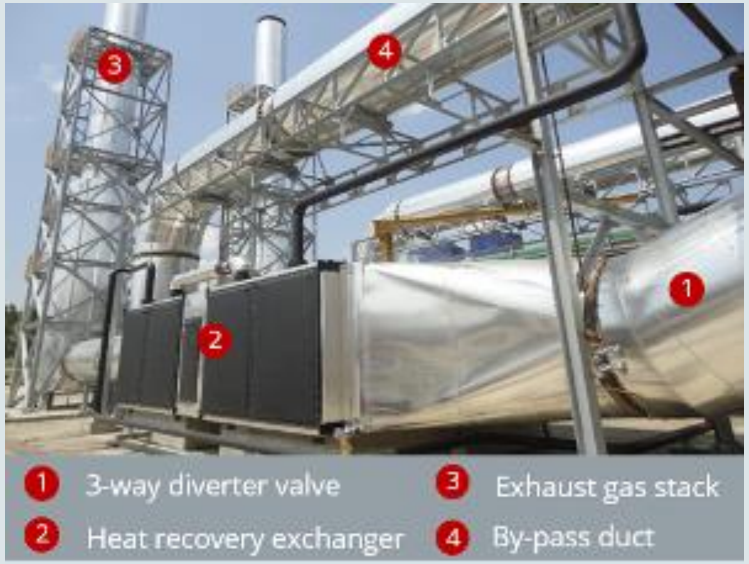


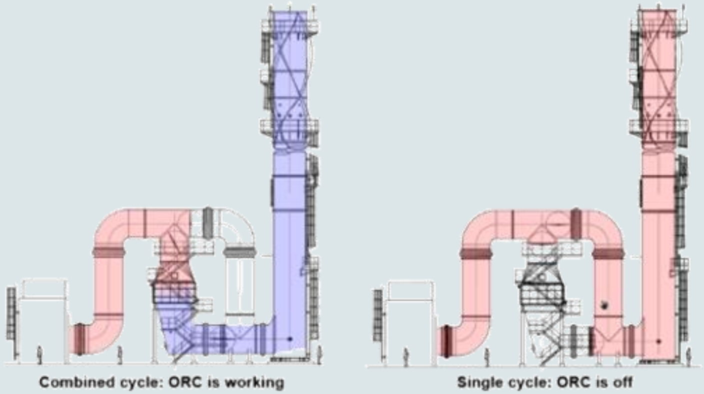

| | |
|---|---|
| 2% | Thermal losses |
| 80 ÷ 72% | Thermal power |
| 18 ÷ 26% | Useful power *** |

* 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.

# 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.



# NEW SOLUTION FOR COMBINED CYCLE POWER PLANTS

SIEMENS
Ingenuity for life
+
clean energy ahead
TURBODEN

Heat ReCycle by Siemens as integral solutions provider with Turboden ORC technology.

## Suitable for remote areas

thanks to its automated operation and high safety standards

## Affordable electricity

producing power with high efficiency

## Lower emissions

compared to other technologies typically used in desolated areas

## Water-free

allowing water to be used for people, not power

# REFERENCES

**400+**
POWER PLANTS

**50**
COUNTRIES

# TURBODEN REFERENCES IN COMBINED CYCLES

| PLANT | COUNTRY | START UP | ORC SIZE (MWe) | HEAT SOURCE |
|---|---|---|---|---|
| **TRANSGAS** | Canada | 2011 | **1** | Solar Centaur 40 gas turbine in gas compressor station |
| **UZTRANSGAZ** | Uzbekistan | 2021 | **1** | 3 GE LM 1600 gas turbines in gas compressor station |
| **GASCO** | Egypt | under construction | **24** | 5 X 30 MWe gas turbines (4 in operation, 1 in stand-by) in gas compressor station |
| **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 | under construction | **2 x 2.3** | 28 x 1.4 MWe Jenbacher engines + 4 x 1.2 MWe MWM engines – landfill gas |
| **ORTADOGU II** | Turkey | 2020 | **2.3** | 12 x 1.4 MWe Jenbacher engines – landfill gas |
| **BIOGASTECH** | Belgium | 2019 | **0.7** | 4 x 3.3 MWe Jenbacher gas engines |

# TRANSGAS

CUSTOMER:
TransGas

COUNTRY:
Canada

STATUS:
in operation since 2011

DESCRIPTION:
power generation from waste heat from Solar Centaur 40 gas turbine in a gas compressor station

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

GAS TURBINE PRIME POWER:
3.5 MWm

GAS TURBINE EFFICIENCY:
28%

# UZTRANSGAZ

CUSTOMER:
Uztransgaz

COUNTRY:
Uzbekistan

STATUS:
in operation since 2021

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

ORC ELECTRIC POWER:
1 MW - island mode operation. The ORC unit covers the compressor station captive consumption

FEATURES:
solution with air-cooled condenser, no water needed, containerized solution

# DAHSHOUR

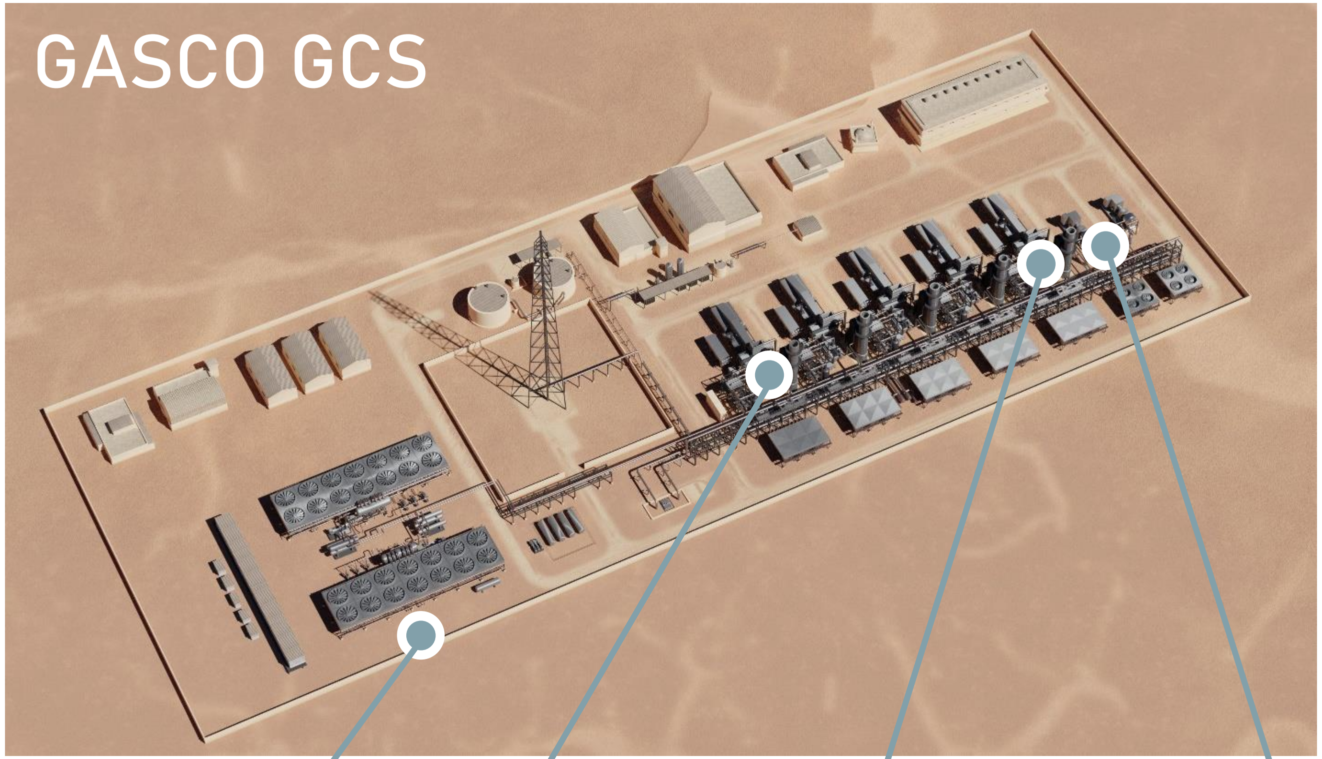
CUSTOMER:
GASCO

COUNTRY:
Egypt

STATUS:
under construction

DESCRIPTION:
power generation from waste heat from 5 simple cycle GTs (4 in operation 1 in standby) in gas compressor station.

ORC ELECTRIC POWER:
24+ MWe to feed 2 electrical motor driven compressors of 10 MW each that will empower compressor station pumping capacity.




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)

# CEREAL DOCKS


CUSTOMER:
Cereal Docks

COUNTRY:
Italy

STATUS:
in operation since 2012

DESCRIPTION:
power generation from exhaust gas of 1 x 7 MWe Wärtsilä diesel engine

ORC ELECTRIC POWER:
0.5 MW

HEAT CARRIER:
none – direct exchange

COOLING SYSTEM:
water cooled condenser + air coolers (closed water loop)

# HSY

CUSTOMER:
Helsinki Region Environmental Services Authority HSY

COUNTRY:
Finland

STATUS:
in operation since 2011

DESCRIPTION:
power generation from exhaust gas of 4 x 4 MWe MWM gas engines – landfill gas

ORC ELECTRIC POWER:
1.3 MW

HEAT CARRIER:
thermal oil

COOLING SYSTEM:
water cooled condenser + air coolers (closed water loop)

clean energy ahead

TURBODEN

MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP


OUR EXPERIENCE. YOUR POWER.