TOWARDS INDUSTRY DECARBONIZATION

RANKINE CYCLE FOR HEAT AND POWER GENERATION

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MORE HEAT OUT OF HEAT


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INTRODUCTION
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OVER 40 YEARS OF
A VIABLE SUSTAINABILITY

Turboden (a group company of Mitsubishi Heavy Industries) is an Italian firm and a global leader in the design, manufacturing, and maintenance of **Organic Rankine Cycle (ORC) systems**, highly suitable for distributed generation, which produce electric and thermal power exploiting multiple sources.

Thanks to its long experience in the energy efficiency sector, today Turboden expands its solutions offering with **gas expanders** and **large heat pumps**.

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TURBODEN IS A GROUP COMPANY OF MHI

MHI BUSINESS DOMAINS

TURBODEN

Energy Systems

Main Businesses

- Gas & steam power systems*
- Nuclear power systems
- Compressors
- Aero engines
- Marine machinery

* Includes GTCC, steam power and air quality control system

42,4%

Plants & Infrastructure Systems

Main Businesses

- Commercial ships
- Engineering
- Environmental systems
- Metals machinery
- Machinery systems

16.7%

REVENUE $32B

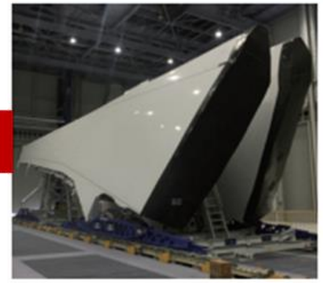
Logistics, Thermal & Drive Systems

Main Businesses

- Material handling systems
- Engines
- Turbochargers
- HVAC systems
- Automotive air conditioners

25.3%

Aircraft, Defense & Space



Main Businesses

- Commercial aircraft
- Defense aircraft
- Missile systems
- Naval ships
- Special vehicles (tanks)
- Maritime systems (torpedoes)
- Space systems

15.6%

Ca. 80,000 EMPLOYEES WORLDWIDE

$32B ANNUAL REVENUE

300 COMPANIES WORLDWIDE

Ca. 26,000 PATENTS GLOBALLY

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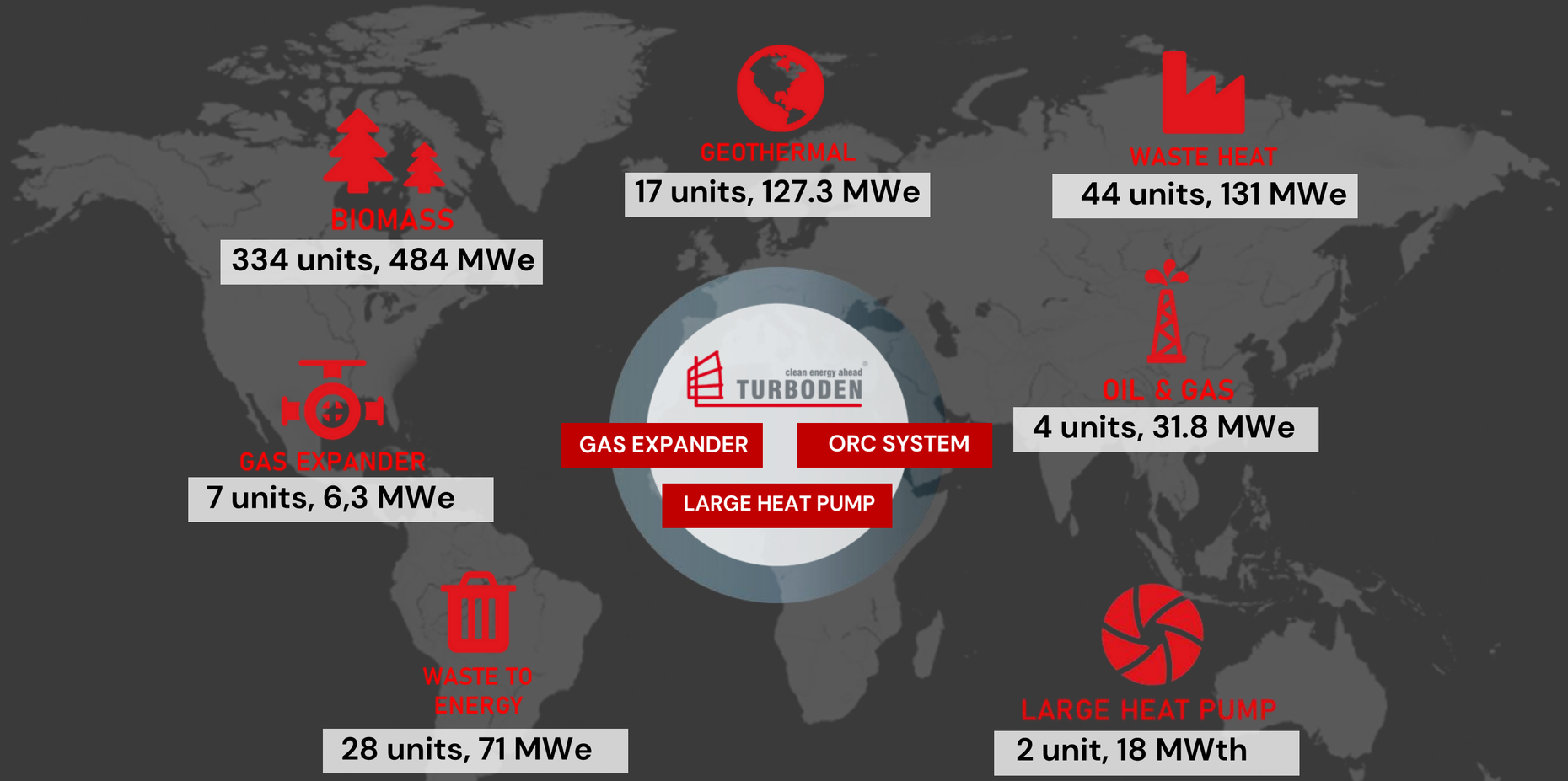
GLOBAL AND PROVEN EXPERIENCE



Experience in over
50
countries

With
430+
plants

Power generated
25 thousand
GWh

Cumulative operation time
20 million
hours

Last update: May 2023

* including two hybrid power plants

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OUR PRODUCTS

Designed for decarbonisation.

ORC SYSTEM

GAS EXPANDER

LARGE HEAT PUMP

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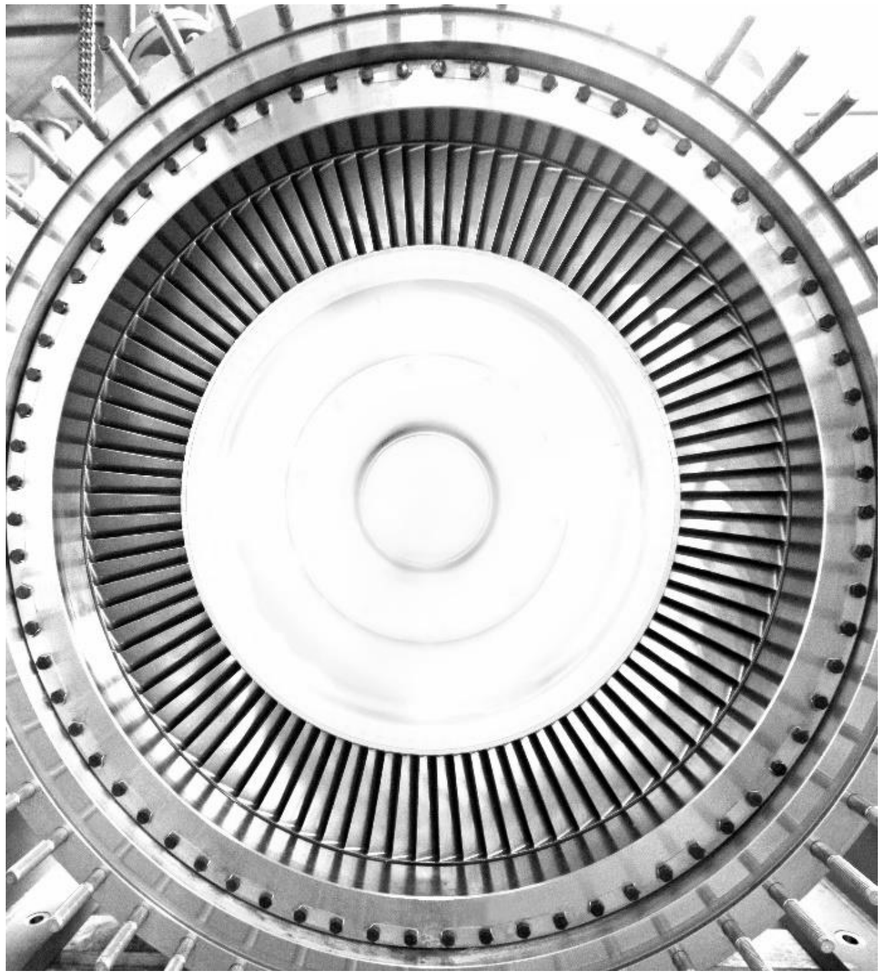
ORC SYSTEM



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

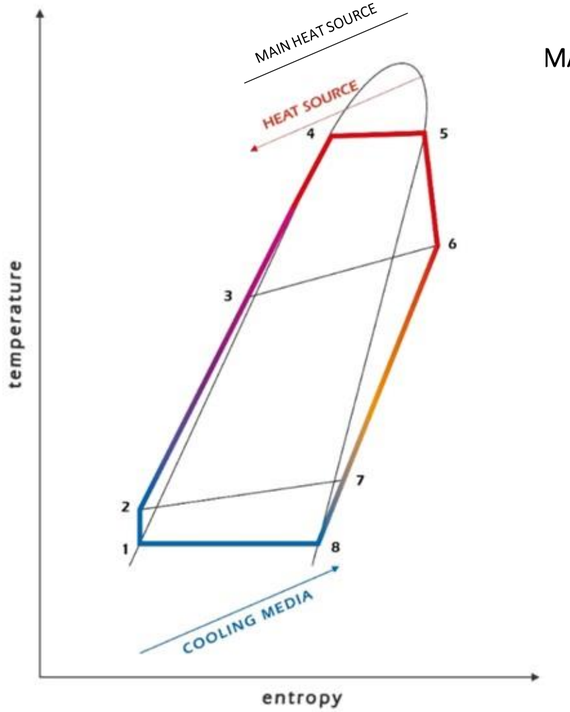
THE ORC CYCLE – HOW IT WORKS

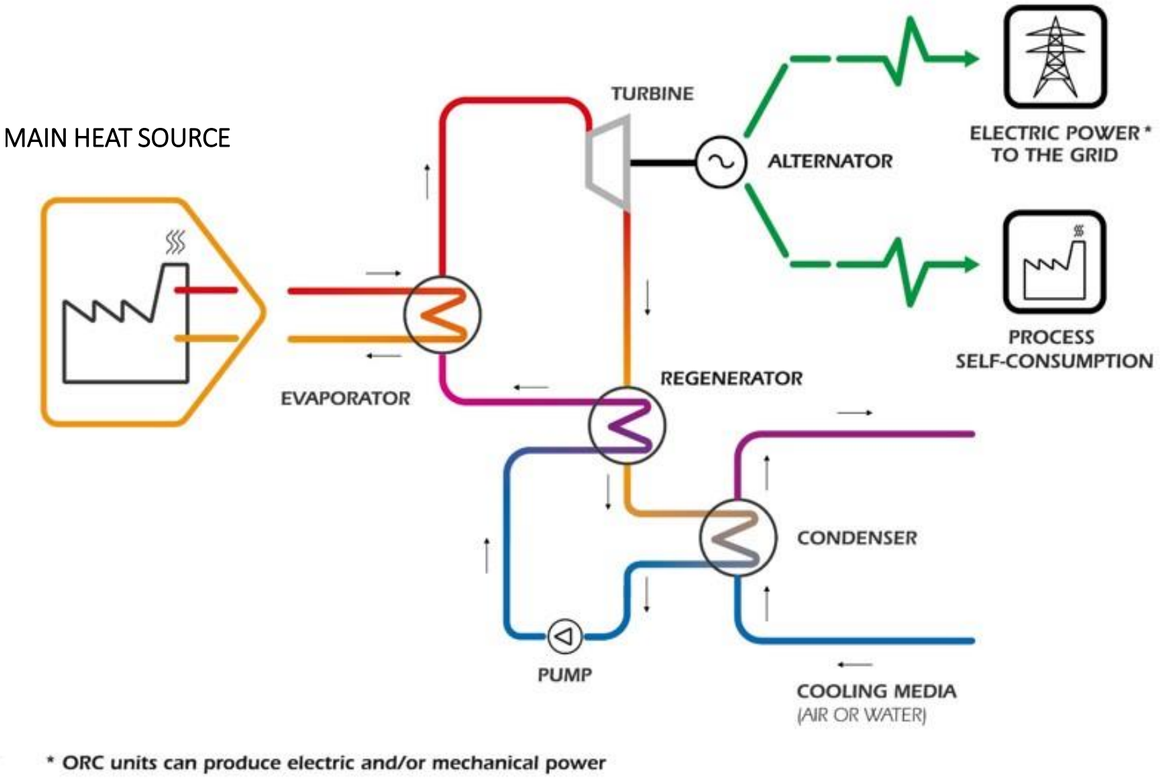
The ORC turbogenerator uses medium-to-high temperature thermal oil to preheat and vaporize a suitable organic working fluid in the evaporator (4>5).

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.



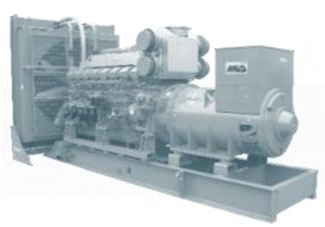


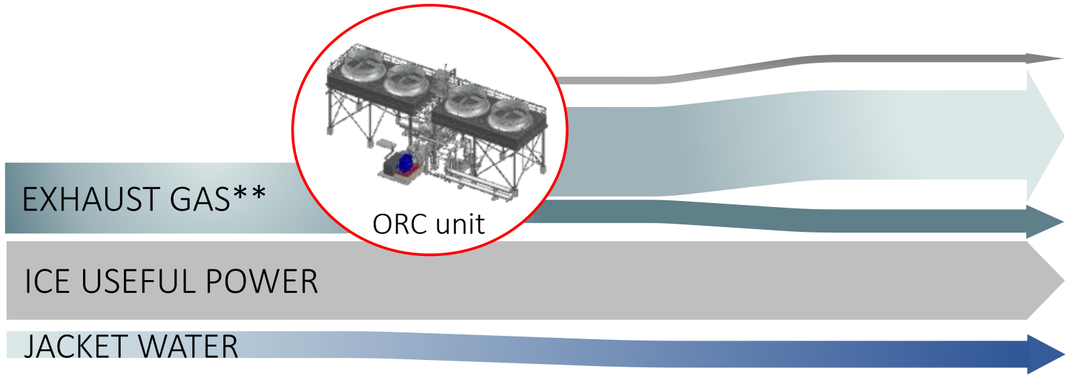
The waste heat from production process is transferred to the ORC working fluid by means of an intermediate circuit or directly via the exhaust gases in direct exchange systems. The media used in the intermediate circuits are thermal oil, saturated steam or superheated water.

OVERALL PLANT PERFORMANCES

INTERNAL COMBUSTION ENGINES

10% ORC additional power*





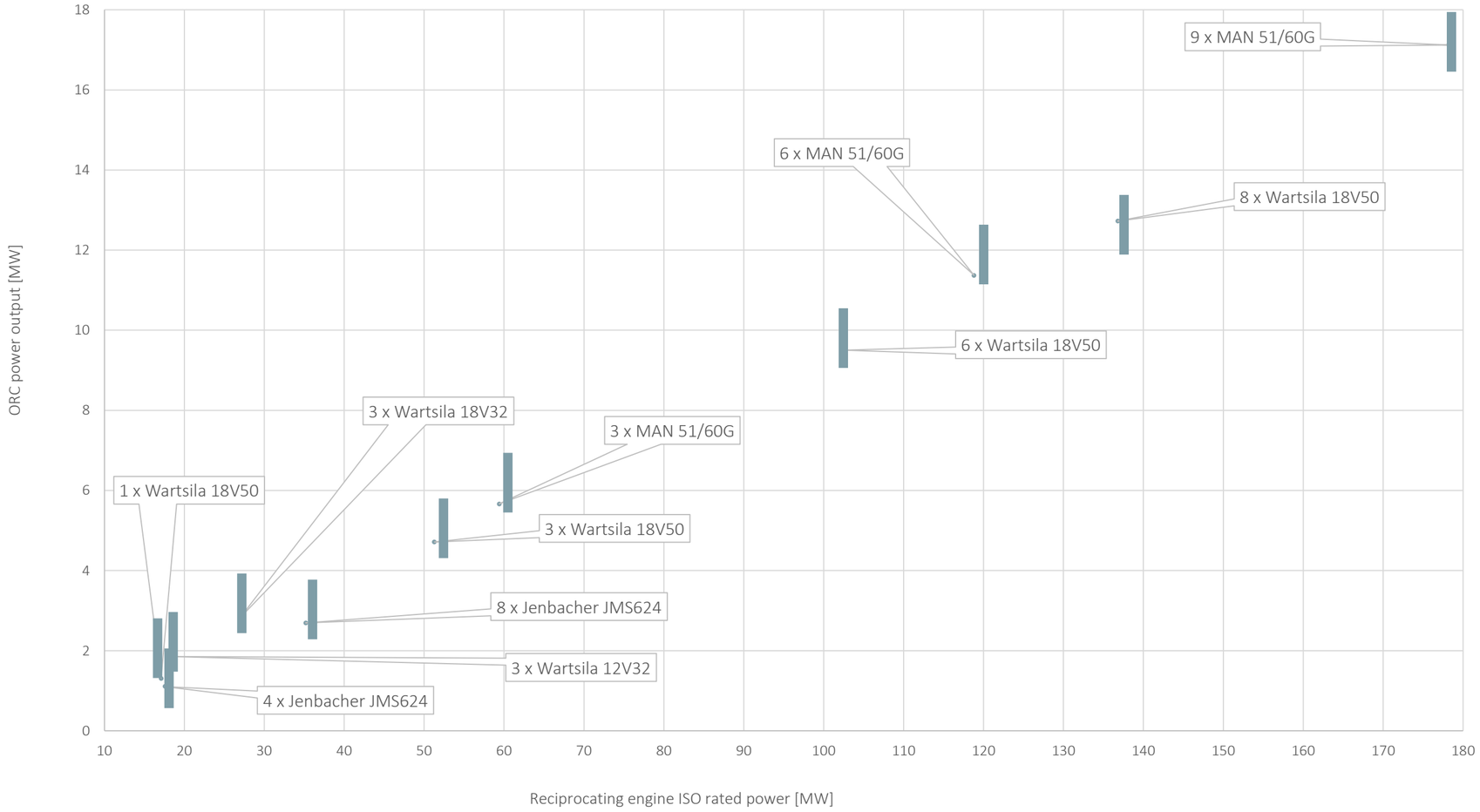
2%	Thermal losses
80 ÷ 72%	Thermal power
18 ÷ 26%	Useful power ***

* 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.

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.



COMPATIBILITY WITH DIFFERENT FUELS ENGINES

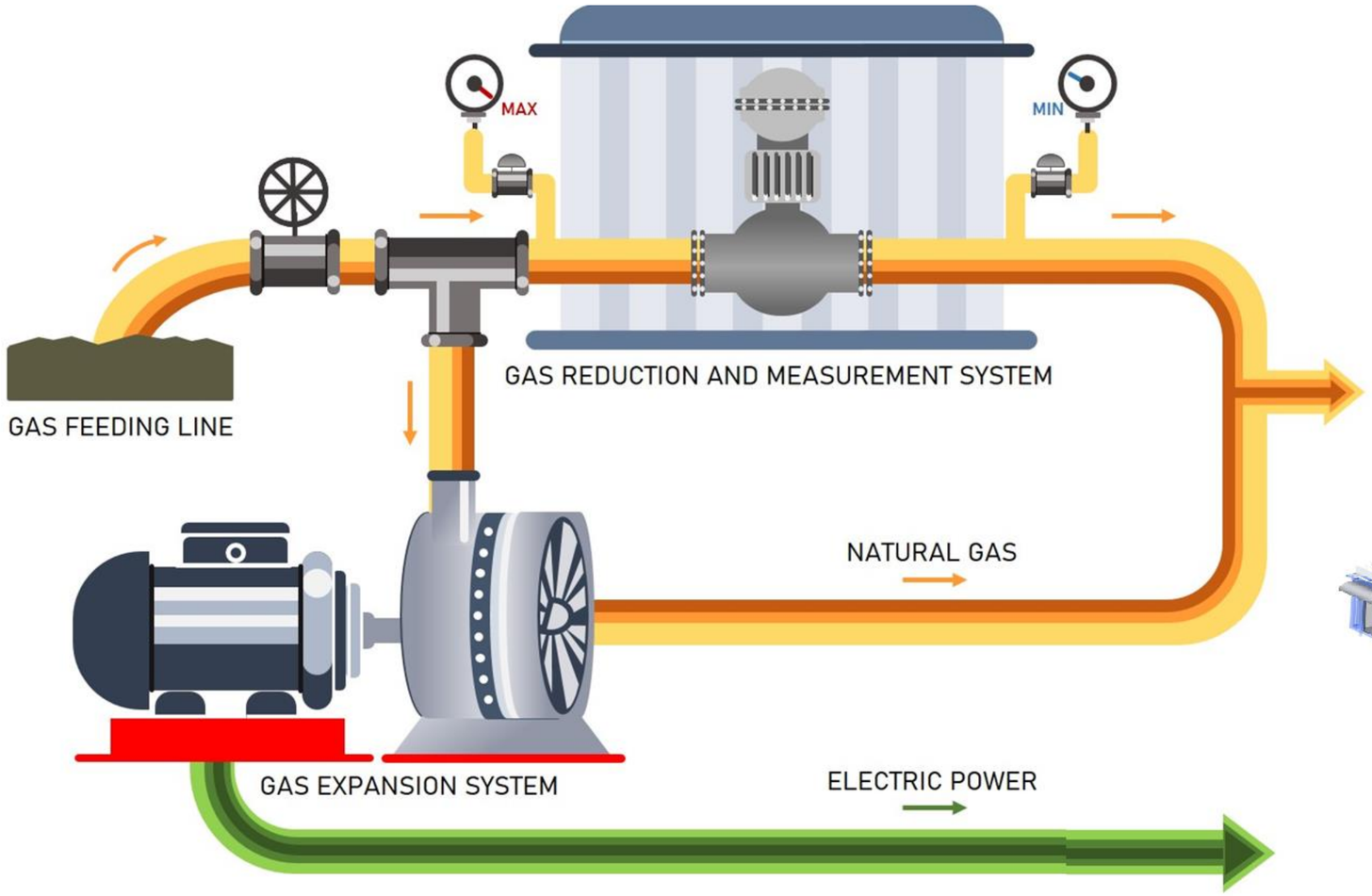
GAS EXPANDER

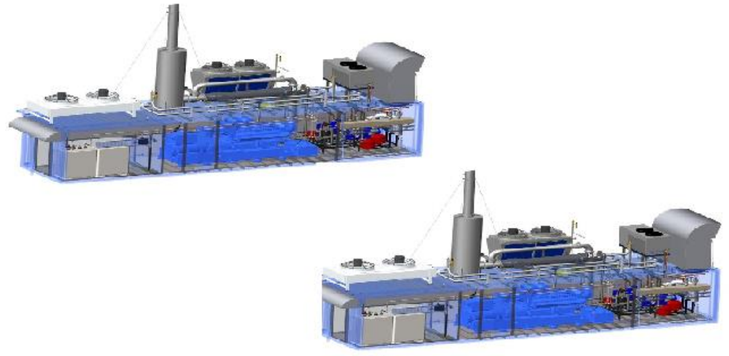
Turboden gas expander is an alternative solution to standard lamination valves, aimed at enhancing the energy efficiency of gas-intensive industries (or industrial parks). It produces clean electricity by exploiting gas pressure drop, otherwise wasted, from the delivery level to the one required by the industrial process. The decarbonised electricity is then delivered to the factory, reducing the associated costs.

KEY POINTS

- Design based on 40+ years of experience, leveraging Mitsubishi Heavy Industries support
- Profit generation while reducing the gas pressure
- Improvement of industry green footprint
- Unmanned installations, thanks to specific technology features
- Over 60 Turboden turbine models within the 400+ power plants fleet

GAS EXPANDER CONFIGURATION





CHP GAS ENGINES PLANT

LARGE HEAT PUMPS

Large Heat Pumps are utility-scale heating plants that supply large quantities of high-temperature heat exploiting a colder energy source that would otherwise be wasted, e.g. through cooling towers. Hence, industrial processes or district heating networks can benefit from this new higher-grade heat source.

KEY POINTS

- **Large-scale:** output from **5 MW** to **50 MW** per unit
- **High lift** (ΔT up to 100°C and more)
- **High-temperature output**: above 200°C, **Steam generation**
- **Heavy duty** – industrial design
- **Natural refrigerants** working fluid

REFERENCES LARGE HEAT PUMPS

Steel Mill

IN OPERATION

- **CUSTOMER**: ORI Martin SpA
- **LOCATION**: Italy
- **CONFIGURATION**: Thermal power generation from furnace cooling water to produce hot water for district heating
- **LHP THERMAL POWER OUTPUT**: 6 MW
- **FEATURES**:
- Heat source: 75-70°C
- Heat Sink: 65→120°C
- Thermal power delivered: 6MWt
- COP: 8,2-5 (depending on the operation)

Pulp&Paper

UNDER CONSTRUCTION

- **CUSTOMER**: Undisclosed
- **LOCATION**: Europe, Nordic
- **CONFIGURATION**: Steam generation generation from cold water cooling water to produce steam for process. Sinergy of LHP with MVR. Sinergy with MCO for compressor implementation.
- **LHP THERMAL POWER OUTPUT**: 12 MW
- **FEATURES**:
- Heat source: 17-8°C
- Heat Sink: 100→175°C
- Thermal power delivered: 12 MWt superheated steam
- COP: 2

FEED / Studies / Tenders

ONGOING

- **Several project in different industrial fields are under discussion.**
- CCUS
- Refineries
- Petrochemical
- Chemical
- Pulp&paper
- Process industry
- District heating
- Diaries
- Food&beverage
- Pharma
- Etc…

THANK YOU – GRACIAS!

OUR EXPERIENCE. YOUR POWER - NUESTRA EXPERIENCIA. TU POTENCIA

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BACK UP

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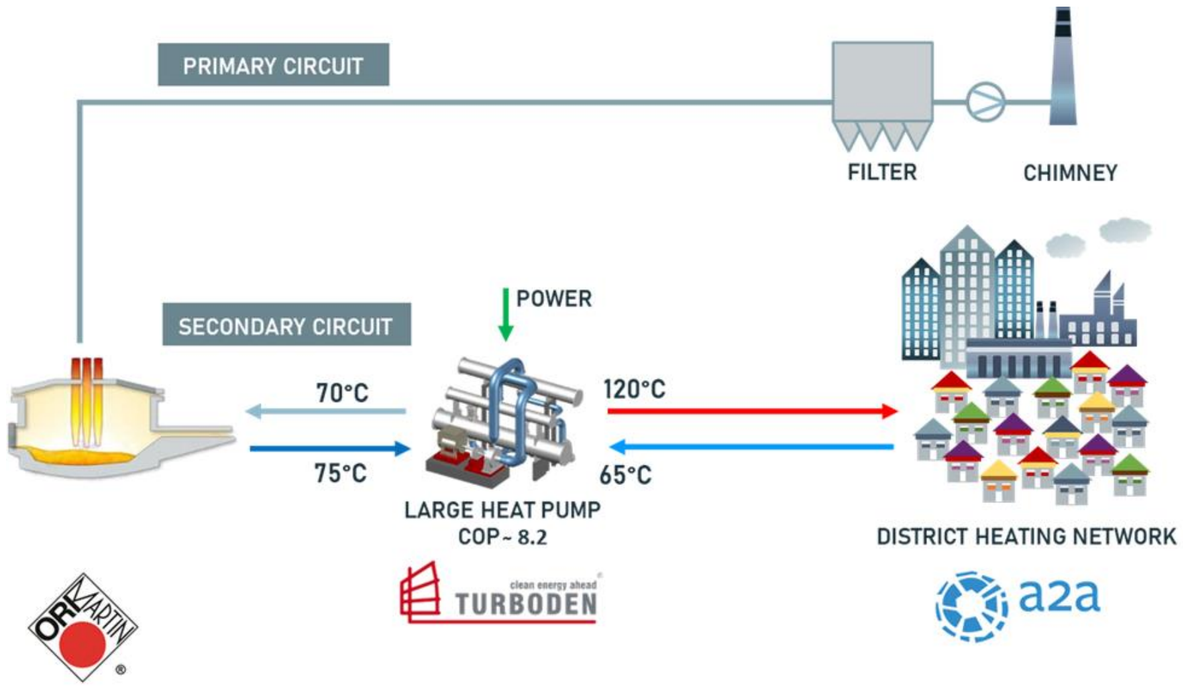
REFERENCE CASE: STEEL MILL PRODUCTION

Heat from the cooling of the steelmaking process can be upgraded through a LHP and used for district heating instead of being wasted, i.e. dissipated through cooling towers.



PROJECT FEATURES

- Industrial application: Steel Mill plant
- Country: Italy
- Status: start up 2023
- Size: 6 MWth
- Temperature: 120°C

TECHNICAL FEATURES

- Turboden scope: EP
- Delivery: pressurized water 120°C to District Heating
- Centrifugal compressor from Turboden
- LHP working fluid: R1233zd

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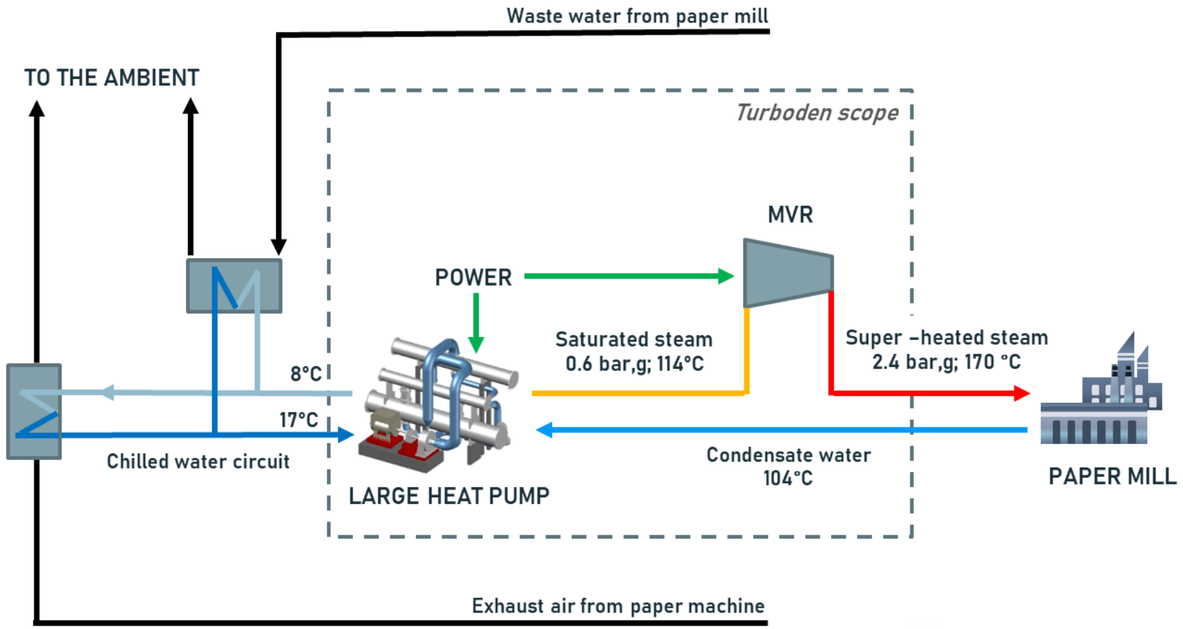
REFERENCE CASE: DECARBONIZE PULP&PAPER INDUSTRY



PROJECT FEATURES

- Industrial application: Pulp & Paper
- Country: Northern Europe
- Status: under construction
- Size: 12 MWth
- Temperature: 170°C

TECHNICAL FEATURES

- Turboden scope: EPC (LHP + MVR)
- Delivery: Steam @2.4 bar,g (superheated at 170 °C)
- Centrifugal compressor from MHI
- LHP working fluid: Isobutane