clean energy ahead
TURBODEN

JCM THE JOINT CREDITING MECHANISM

MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

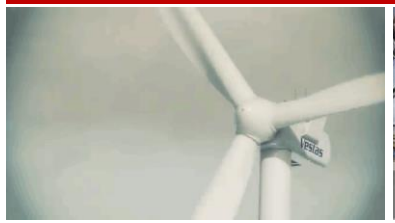
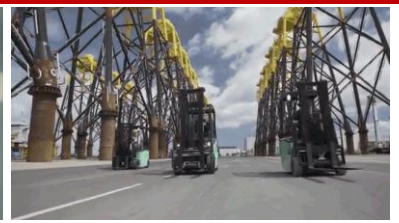
TURBODEN

ORC Technology development in Chilean market

ORC COGENERATION SYSTEM FROM YOUR GREEN FUEL.

TURBODEN IS A GROUP COMPANY OF MHI

MHI GROUP AT A GLANCE



POWER SYSTEMS

- Thermal Power Systems
- Nuclear Energy Systems
- Offshore Wind Power Systems
- Pumps
- Marine Machinery
- Compressors
- Aero Engines

$12.9 B NET SALES

INDUSTRY & INFRASTRUCTURE

- Engine & Energy
- Turbochargers
- Air-Conditioning & Refrigeration
- Automotive Thermal Systems
- Industry Instruments
- Machinery/Equipment
- Mechatronics Systems/ITS
- Metals Machinery
- Environmental Systems
- Chemical Plants
- Shipbuilding & Ocean Develop.
- Land Transportation Systems

$15.6 B NET SALES

AIRCRAFT, DEFENSE & SPACE

- Commercial Aircraft
- Mitsubishi Regional Jet (MRJ)
- Defense Aircraft
- Missile Systems
- Space Systems
- Special Vehicles
- Naval Ships
- Maritime & Space Systems

$6.3 B NET SALES

MITSUBISHI HEAVY INDUSTRIES, LTD.

One of the world's leading heavy machinery manufacturers, with consolidated sales of around $38 billion (in fiscal 2016).
Foundation July 7, 1884

83,000
EMPLOYEES WORLDWIDE

$38B
ANNUAL REVENUE

300
COMPANIES WORLDWIDE

31,783
PATENTS GLOBALLY

$1.3B
OPERATING INCOME

54%
SALES OUTSIDE JAPAN

MILESTONES

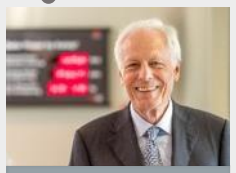
Prof. Mario Gaia makes experience in the field of ORC within his research group at Politecnico di Milano.

’60 - ‘70

1976

First prototype of a solar thermodynamic ORC.

Prof. Mario Gaia founds Turboden to design and manufacture ORC turbogenerators.



1980

‘90-2000

Turboden develops research projects in solar, geothermal and heat recovery applications.

First ORC biomass plant in Switzerland (300 kW).

1998

2000 - 09

Turboden installs ORC biomass plants, especially in Austria, Germany and Italy.

United Technologies Corp. (UTC) acquires the majority of Turboden’s quota. PW Power Systems supports Turboden in new markets beyond Europe.

2009

2013

MHI acquires the majority of Turboden. Italian quota-holders stay in charge of management.

More than 380 ORC plants in the world, more than 320 in operation.

2019

	1990	2000	2010	2019
ORC size developed	300 kW	1 - 2 - 4 MW	5 - 8 - 10 MW	17 MW
ORC plants number	1	100	220	380+

GLOBAL AND PROVEN EXPERIENCE

PLANTS:
384

COUNTRIES:
45

TOTAL CAPACITY:
630 MWe

CUMULATIVE OPERATION TIME:
15 million hours

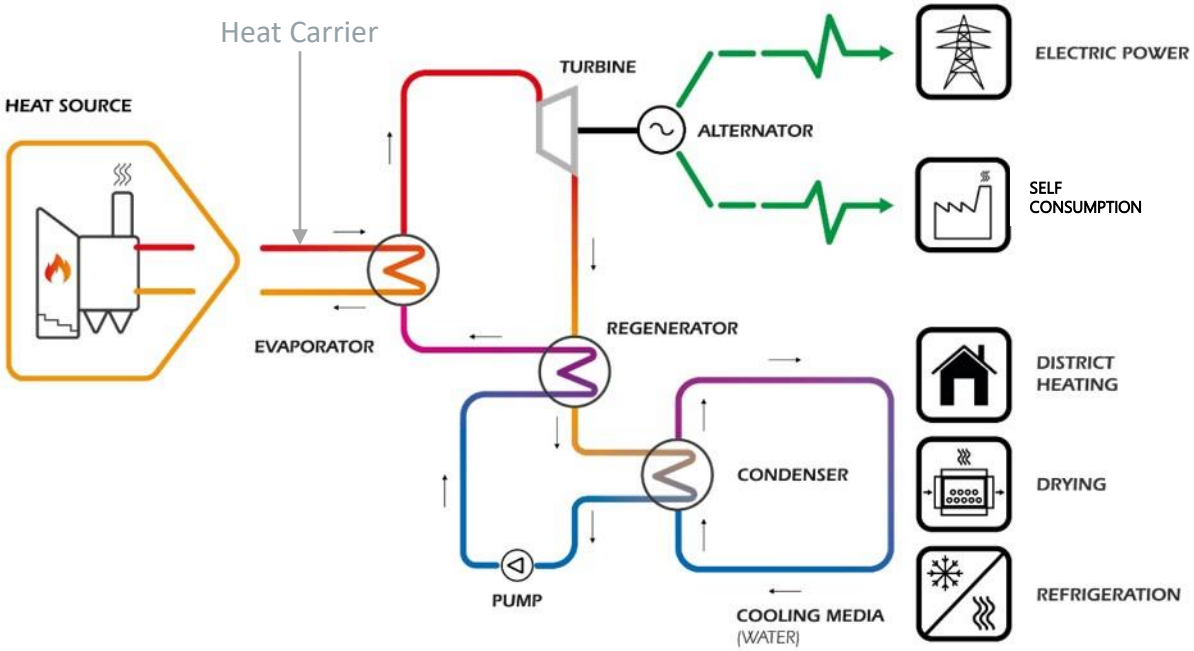
ENERGY GENERATED:
19 thousand GWh

AVERAGE AVAILABILITY:
98+%

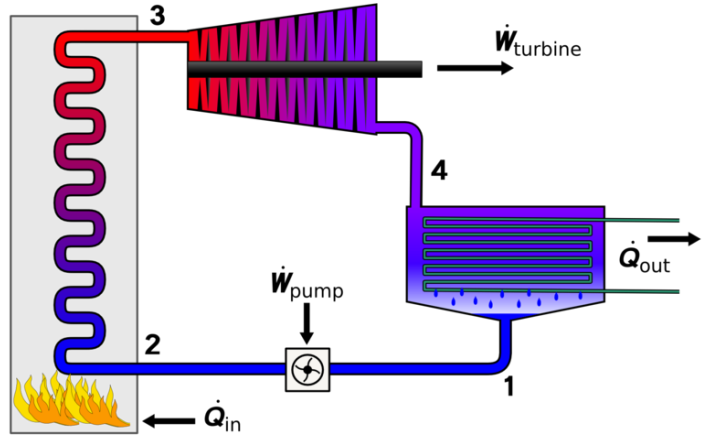
Last update: August 2019

ORC – WHAT IS IT

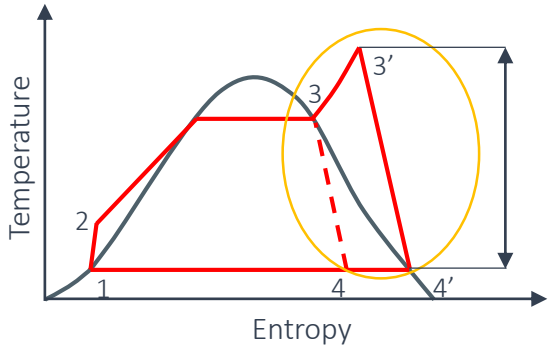
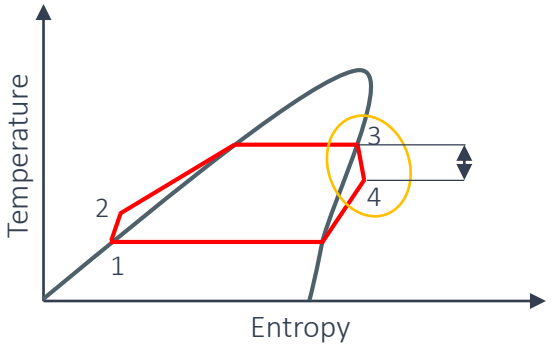
Organic **R**ankine **C**ycle



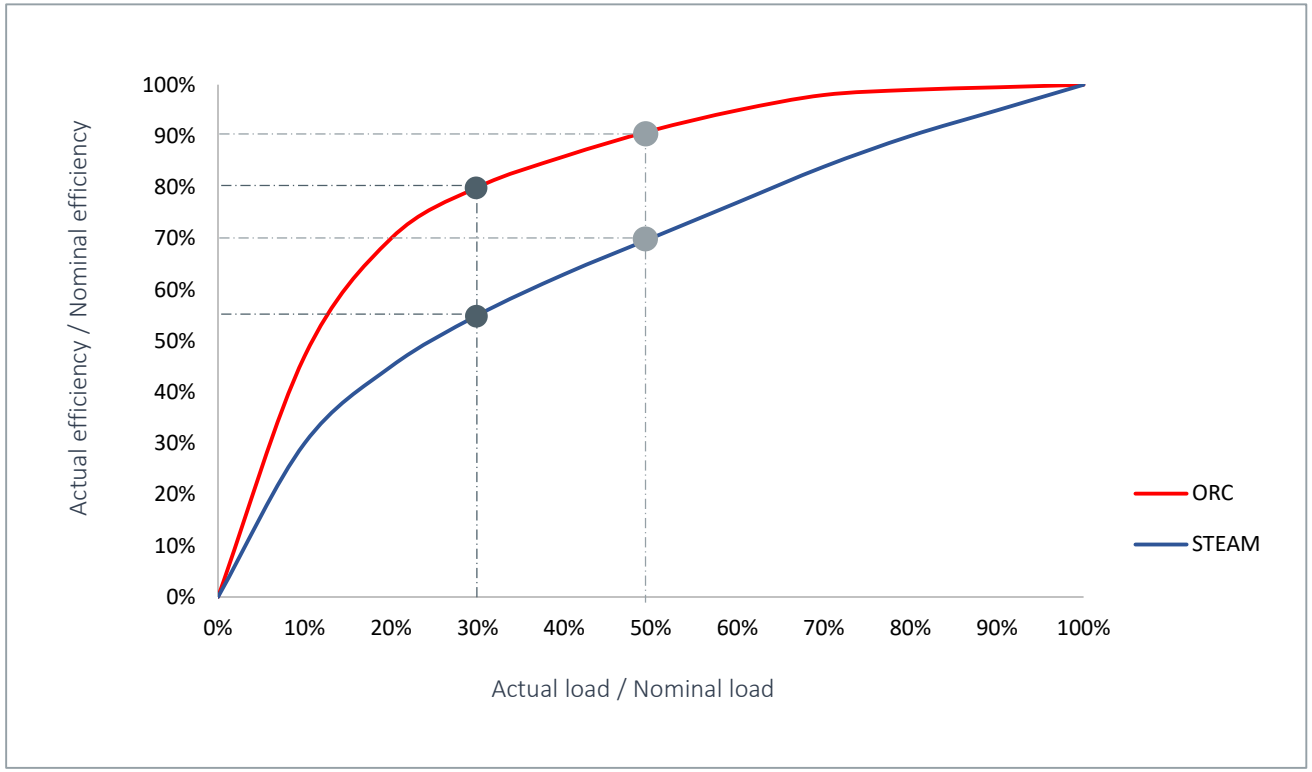
Steam Rankine Cycle



THERMODYNAMIC CYCLE: ORC VS STEAM

	STEAM RANKINE CYCLE (SRC)	ORGANIC RANKINE CYCLE (ORC)
Thermodynamic features and consequences	 ▪ High enthalpy drop ▪ High pressures and temperatures ▪ Superheating needed ▪ Risk of blade erosion	 ▪ Small enthalpy drop ▪ No supercritical pressure ▪ No need to superheat ▪ No risk of blade erosion
Operation and maintenance costs	▪ Water treatment required ▪ Highly skilled personnel needed ▪ Periodic major overhaul	▪ Water-free system ▪ Minimum personnel and 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%)

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.

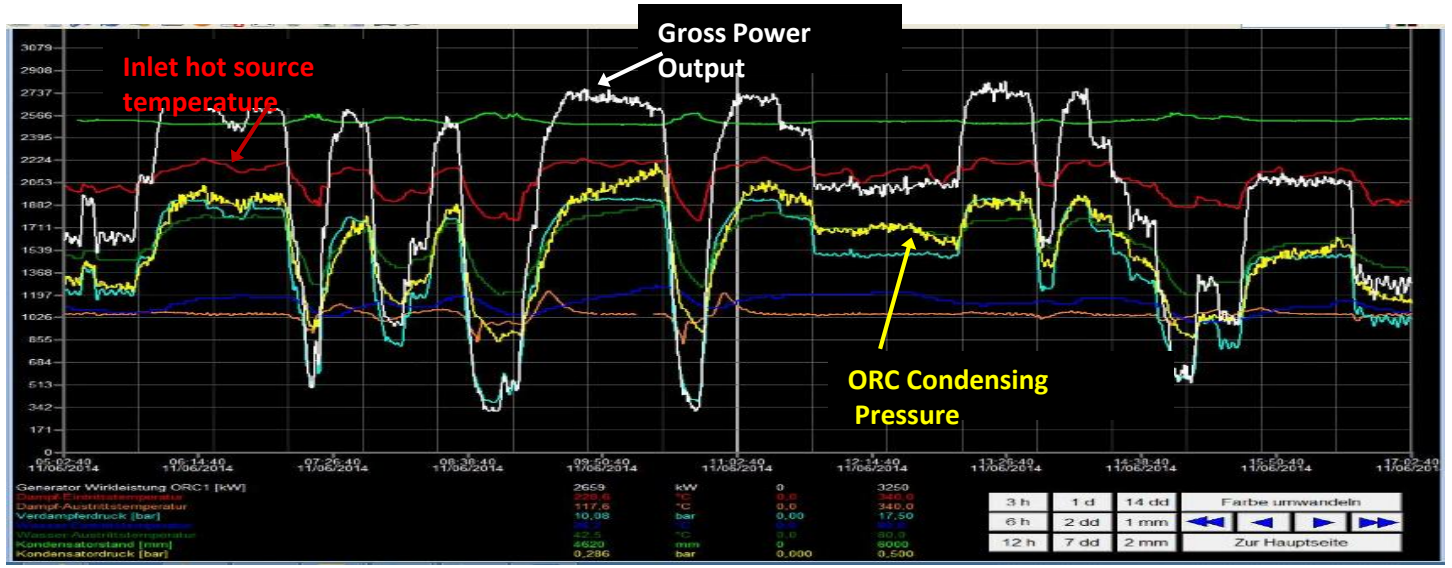
ORC FEATURES AND ADVANTAGES

Features

- High turbine efficiency (~ 85%)
- Low number of stages
- Low mechanical stress turbine (low peripheral speed, moderate temperature)
- No blades erosion (no liquid particles) & small or no corrosion in heat exchangers and piping
- Low turbine RPM

Operation advantages

- Simple start-stop procedures
- Automatic, unattended operation
- Quiet operation
- High Availability (> 98%)
- Turn-down to 10% and lower
- Minimum O&M requirements
- Long life



ORC OPERATION & MAINTENANCE

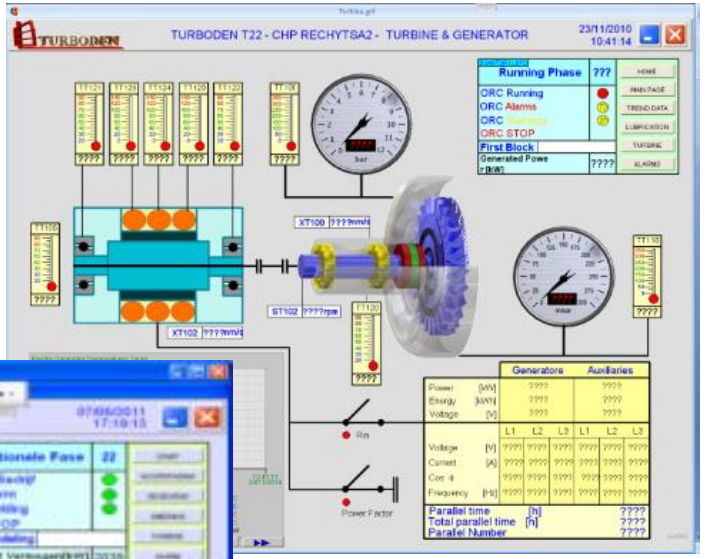
The **Turboden ORC modules are completely automatic** and this permit to minimize the quantity and the qualification of the labour required by the unit operation.

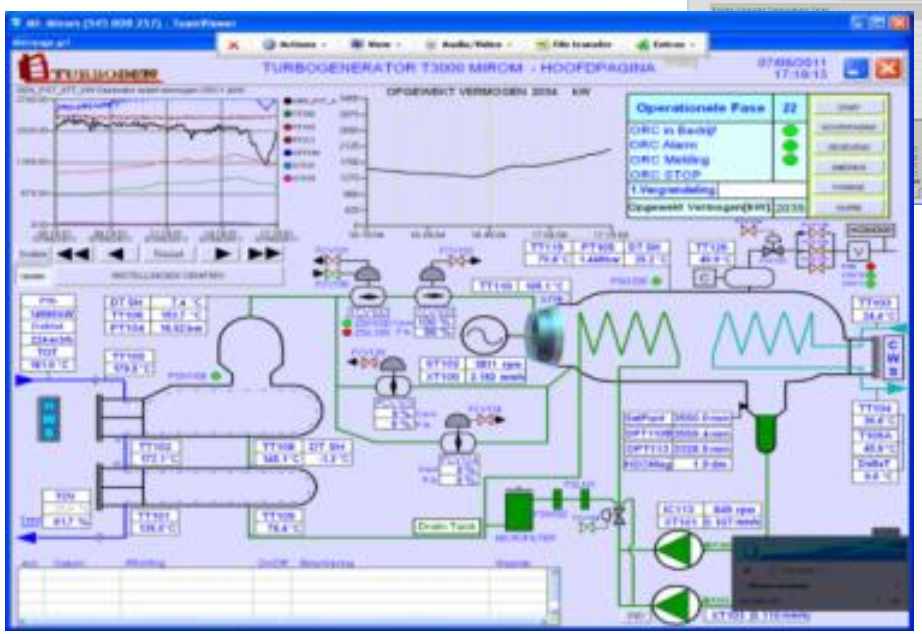
No Major Overhaul

Remote monitoring system

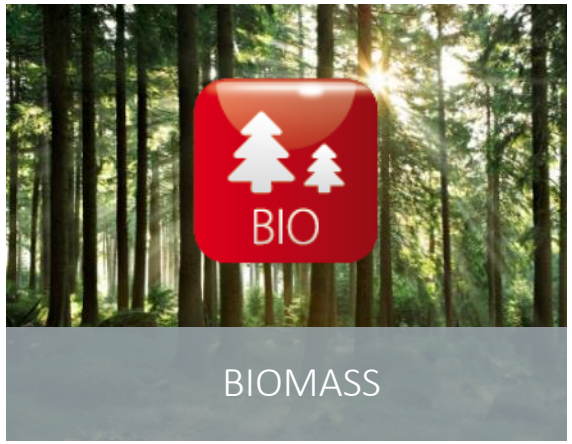
Turboden staff can:

- control the ORC working parameters
- make remote adjustments and troubleshoot
- optimize the ORC's performance
- give general technical support to customer operators



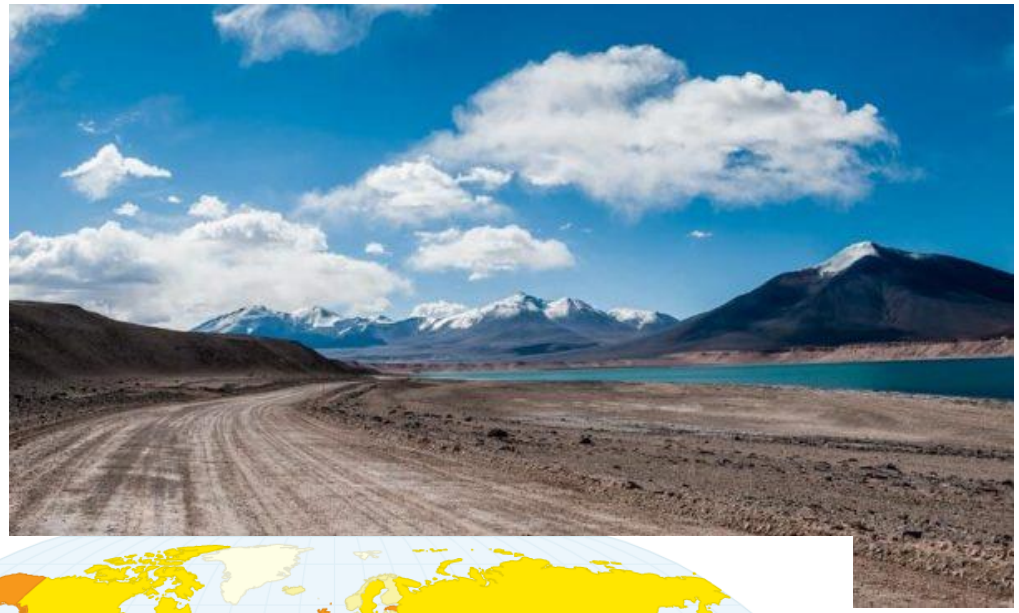


MAIN FIELDS OF APPLICATION



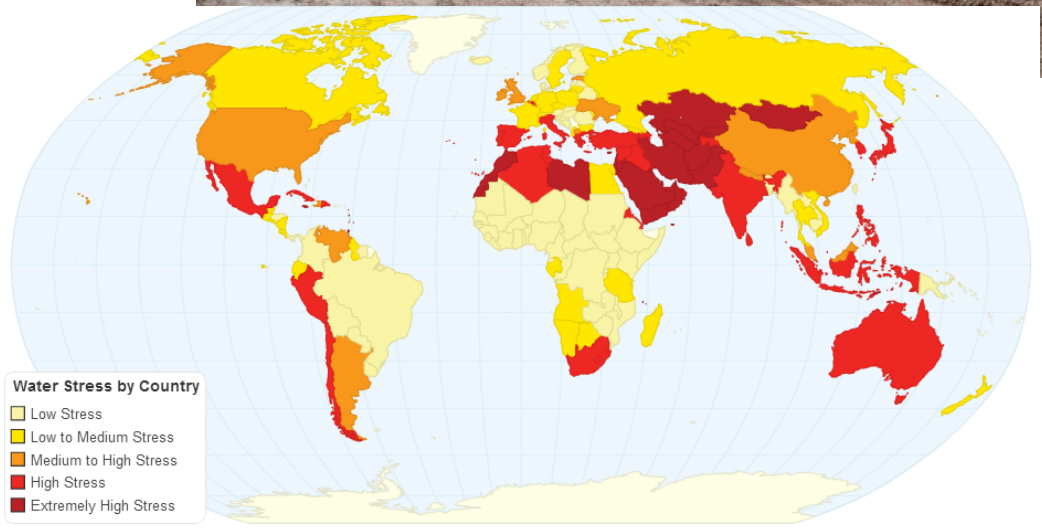
CHILE - FACING CLIMATE CHANGE

- Chile comply with 7 of the 9 conditions of vulnerability
- One of the ten countries most affected climate change
- Water scarcity
- Cities pollution
- Increasing energy demand



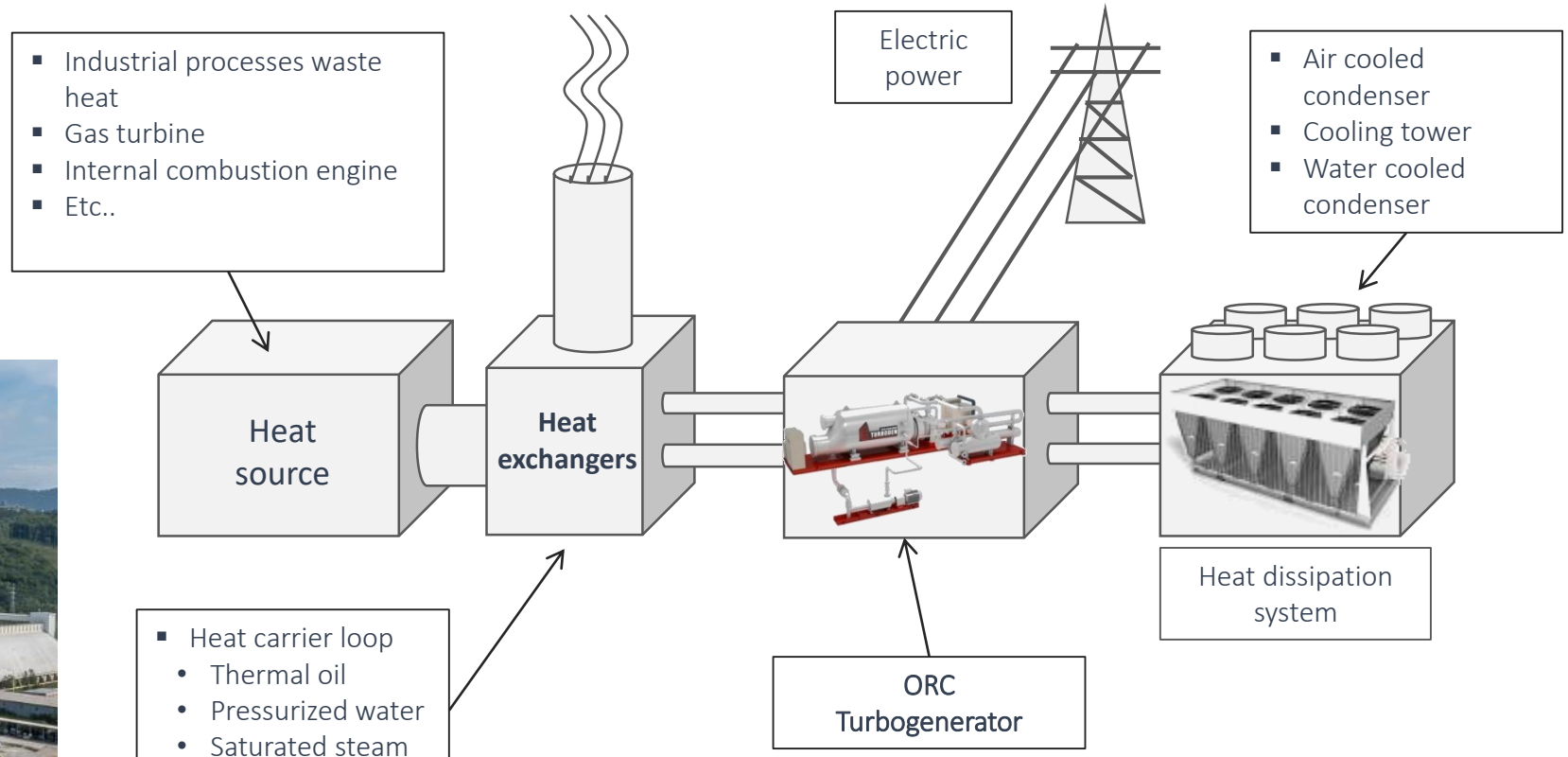
How can **ORC** technology contribute?

- **Water free power generation** plants (Biomass and Waste Heat Recovery)
- **CHP District heating cogeneration** plants (Biomass and Geothermal)
- **Low impact geothermal binary** plants
- **Large Heat Pumps**



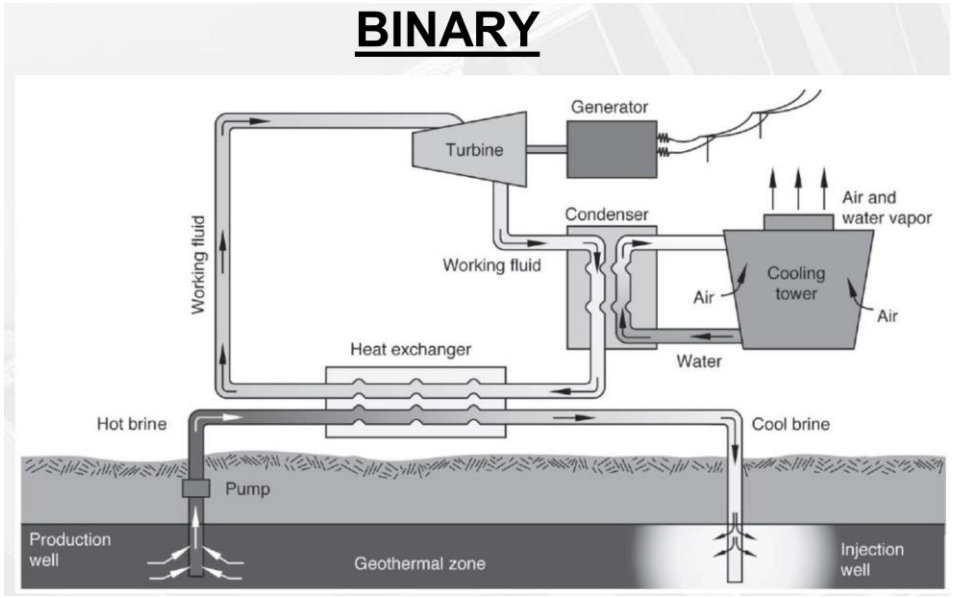
WASTE HEAT RECOVERY

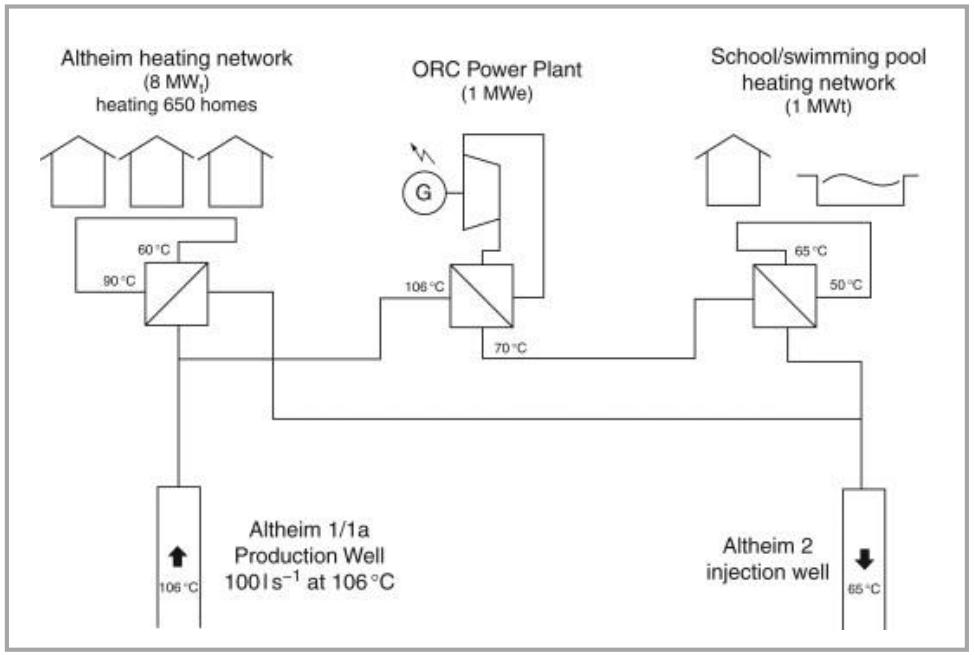
- Cement production
- Glass production
- Foundries
- Mining
- Internal combustion engines



GEOTHERMAL PLANTS

- Modular technology range size **from 1 MW up to 20 MW** per single shaft
- Capable to exploit both the separated hot brine & steam (**two phase flow**)
- **Full reinjection** of geothermal fluid is possible (with dry cooling)





POWER GENERATION FROM BIOMASS – CASE STUDY

CUSTOMER:
undisclosed

LOCATION:
Chile

ORC SIZE:
3.7 Mwe Gross

DESCRIPTION:
High efficiency ORC (HRS) to maximize the electrical production

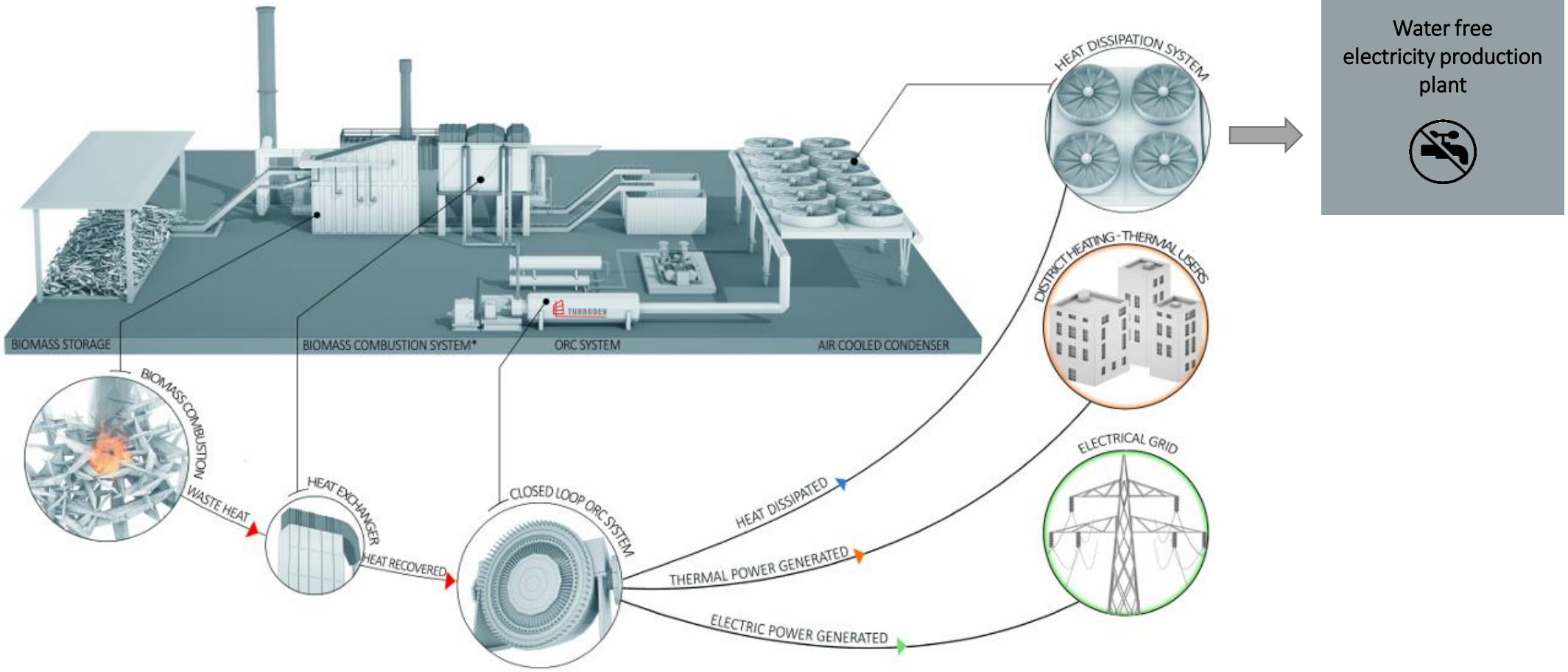
FUEL:
Rice Husk

HEAT CARRIER:
thermal oil

COOLING SYSTEM:
Air Cooled Condenser

ORC to provide power to the national grid

BIOMASS ORC PLANT



Water free electricity production plant

WHY CHOOSE ORC FOR ENERGY EFFICIENCY?

- **Generate profit** from leveraging a renewable source or waste heat
- **Reduce** specific **production cost** by decreasing energy demand
- **Improve** company **sustainability**
- **Reduce** CO_2 emissions

AN EXTENSIVE NETWORK OF INSTITUTIONAL RELATIONS

THE ORC CYCLE – HOW IT WORKS

clean energy ahead®
TURBODEN

MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

FIND OUT MORE

OUR EXPERIENCE. YOUR POWER.