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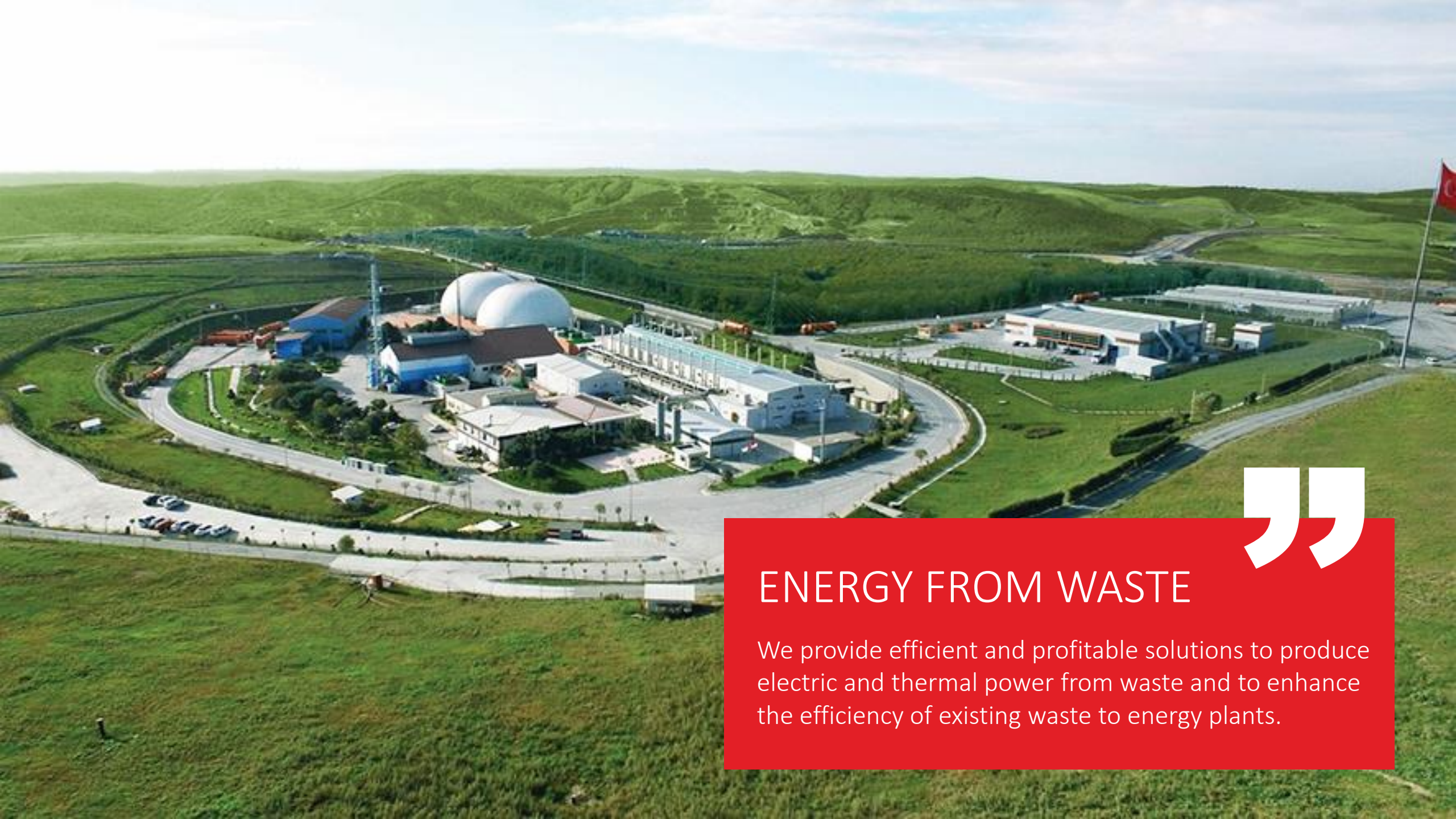
# TURBODEN
# WASTE TO ENERGY

Cod. 15-COM.P-7-rev.19

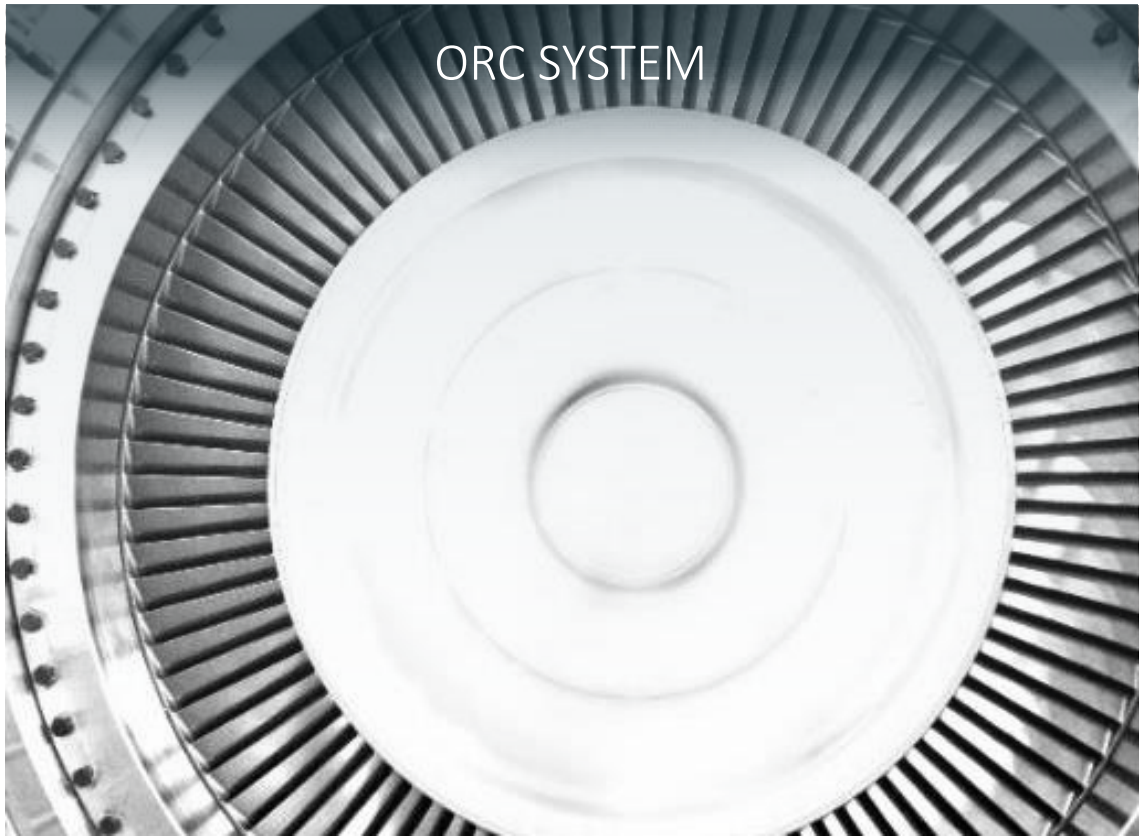
TURN YOUR WASTE INTO USEFUL POWER

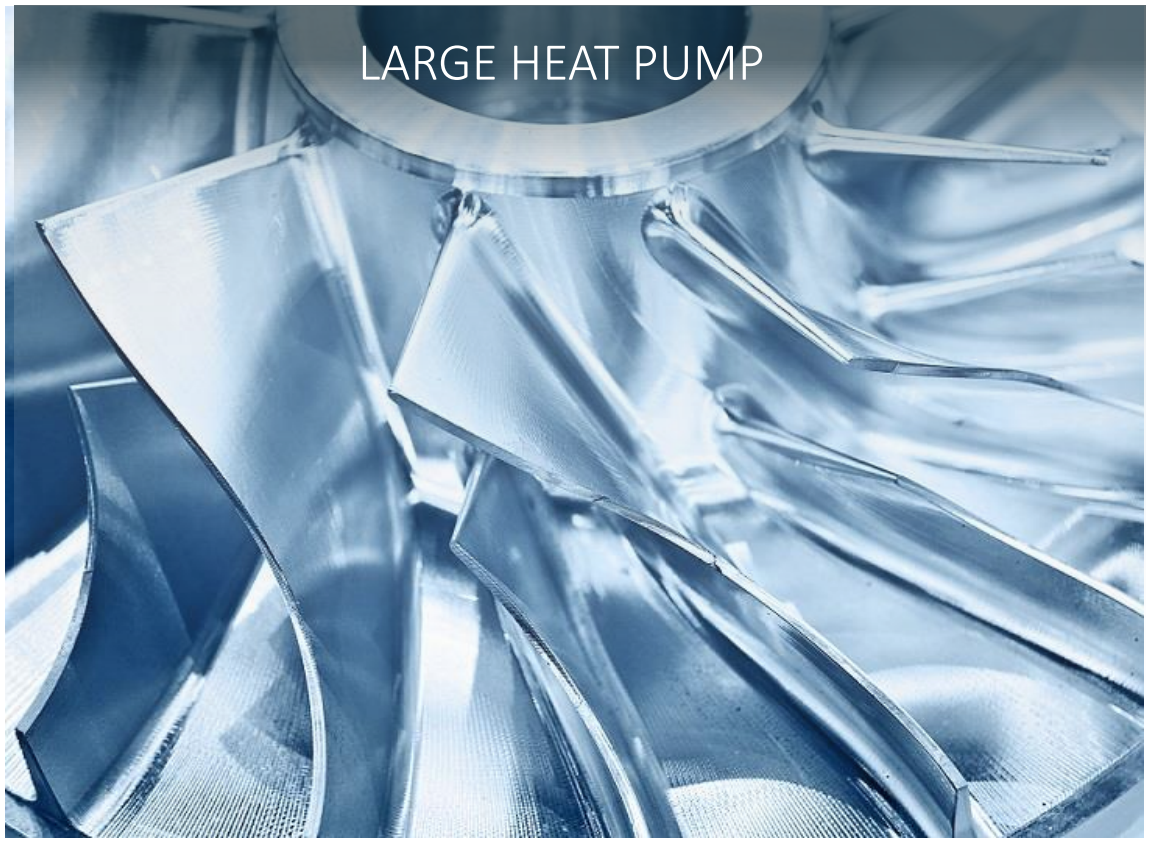


# ENERGY FROM WASTE

We provide efficient and profitable solutions to produce electric and thermal power from waste and to enhance the efficiency of existing waste to energy plants.

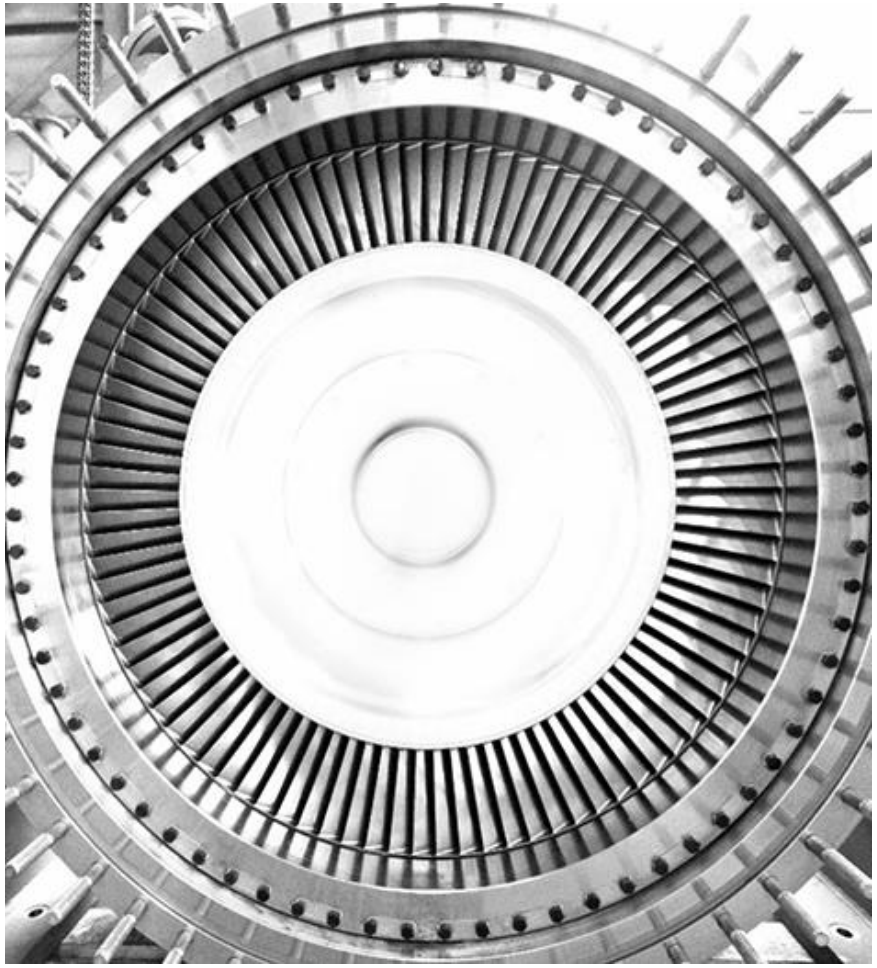
# OUR PRODUCTS




Designed for decarbonization.

# ORC SYSTEM



Turboden Organic Rankine Cycle (ORC) systems are profitably used to produce electric and thermal power from **various kind of waste**.
Depending on waste quantity, characteristics, specific projects' requirements and regulations, the best thermal conversion technology available in the market is selected.
The generated power ranges up to **20 MW electric** per single shaft.

## WHY CHOOSE ORC FOR AN EFFICIENT WASTE TO ENERGY?

- To divert waste from landfilling
- To valorise waste and improve circular economy
- To generate low-carbon heat and green power
- To generate profit
- To reduce fossil fuel consumption and GHG emissions
- To improve sustainability and combat climate change

# TURBODEN ENERGY FROM WASTE POWER PLANTS

**25 plants**

Energy from Waste

- 40+ years experience
- Global presence in 50 countries
- Tailor-made EPC solutions
- High availability (98%)
- Customized after-sales service

Last update: April 2022

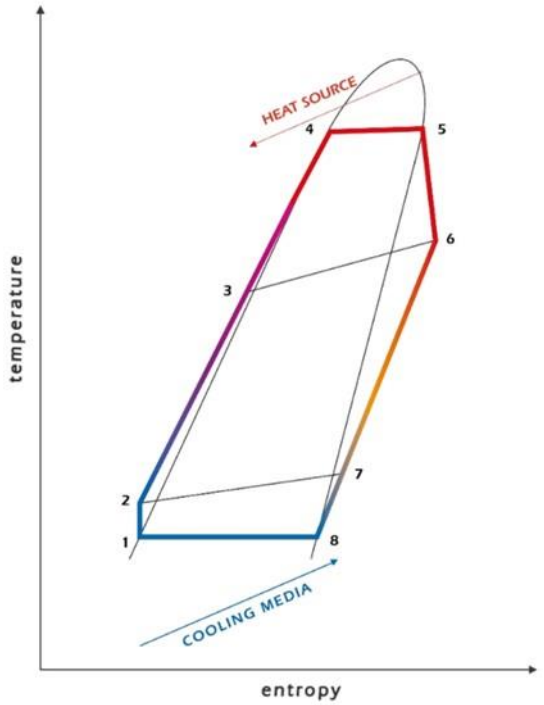
# THE ORC CYCLE – HOW IT WORKS

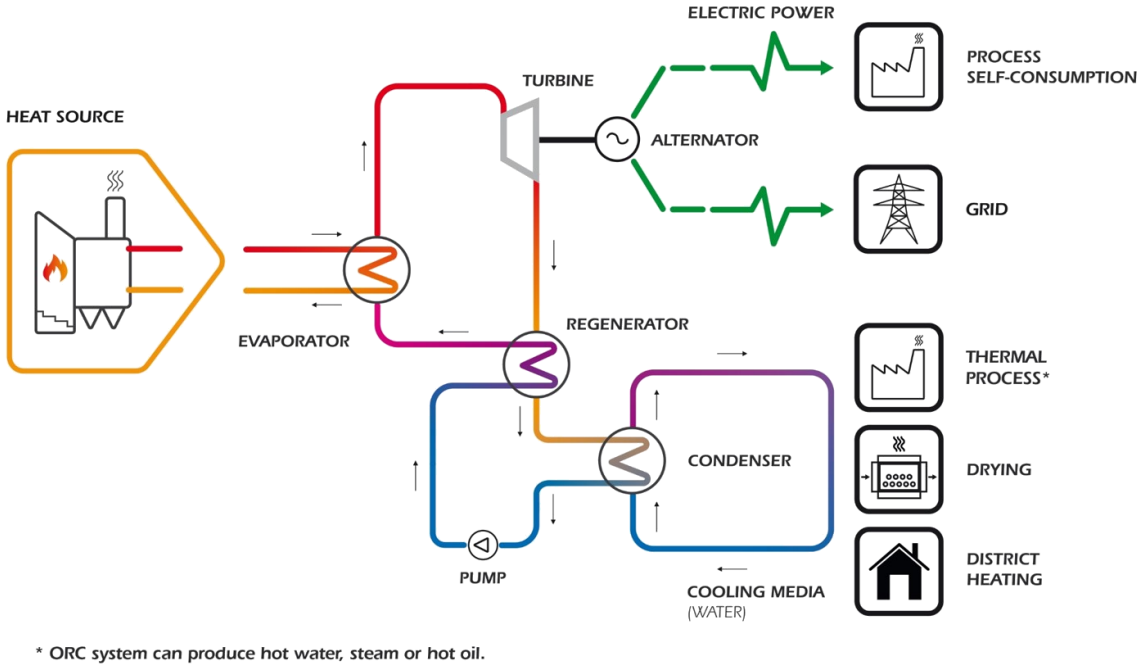
The ORC turbogenerator uses medium-to-high temperature thermal media to preheat and vaporize a suitable organic working fluid in the evaporator (4>5).

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.

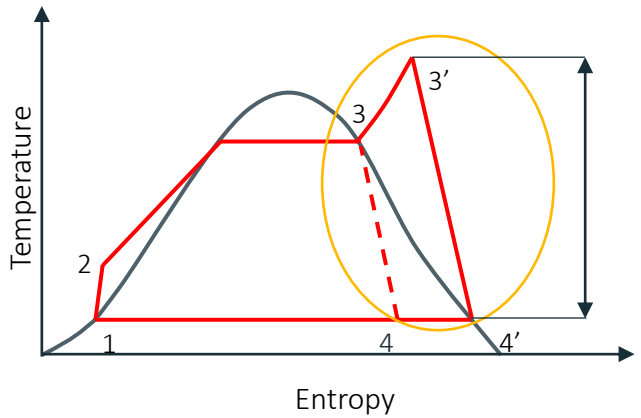
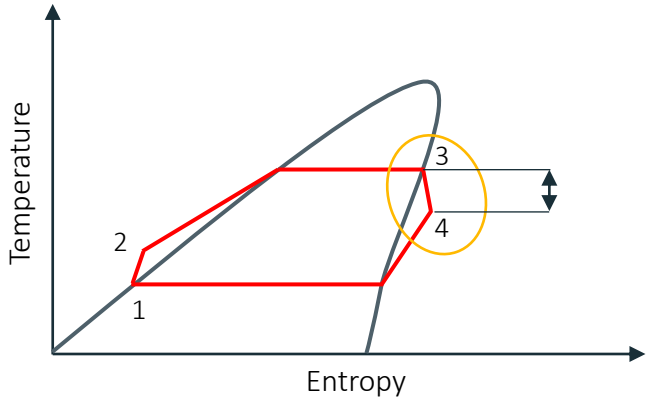


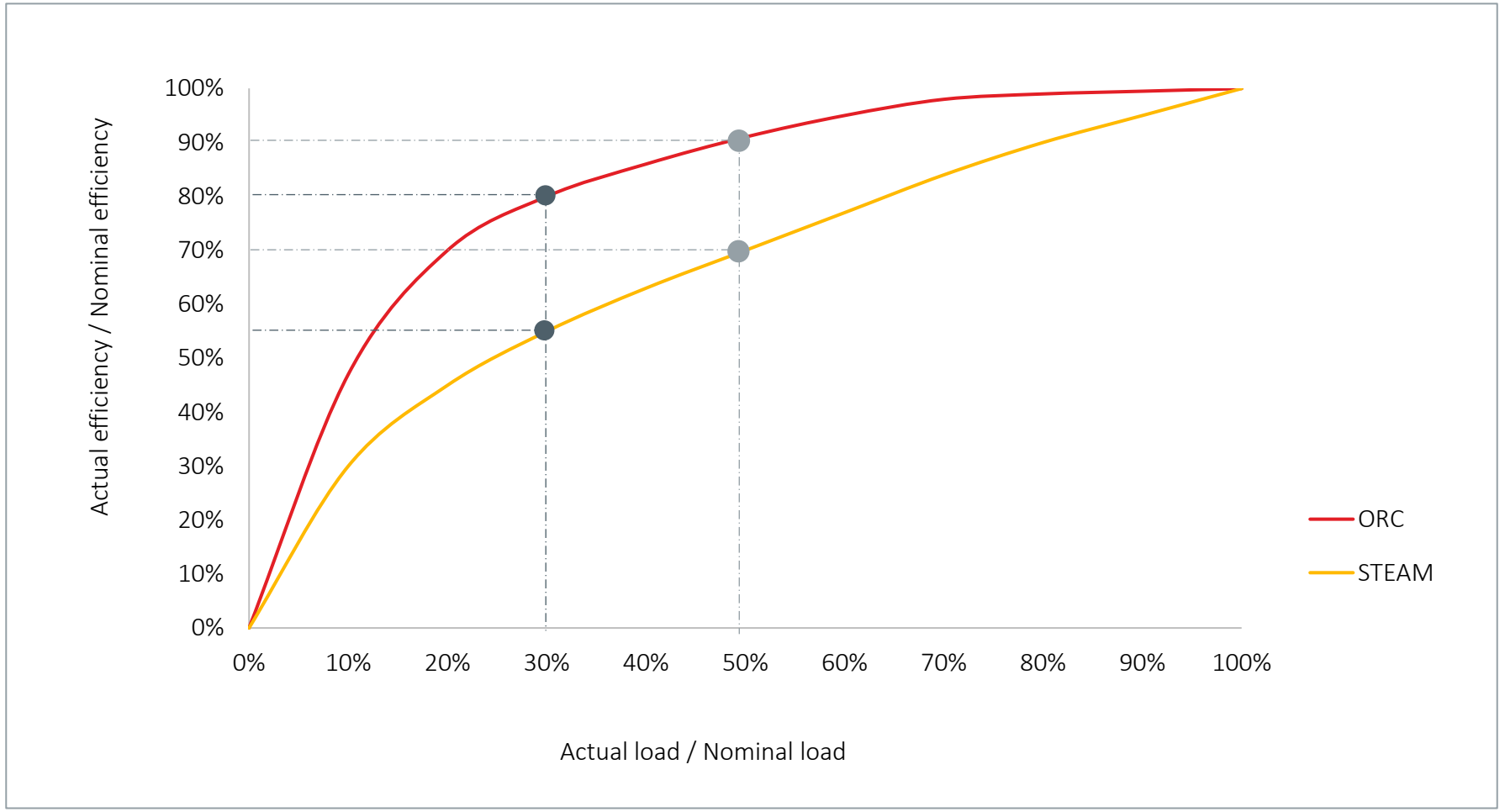

The heat is transferred to the ORC working fluid by means of an intermediate circuit or directly via the exhaust gases in direct exchange systems. The media used in the intermediate circuits are thermal oil, saturated steam or superheated water.

TURBODEN energy plants often use thermal oil as the heat transfer medium. Thermal oil has significant advantages compared to steam or hot water, particularly it can be heated at atmospheric pressure up to temperatures of over 300°C with mineral oils, or 400°C with synthetic oils.

# 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 stages 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%

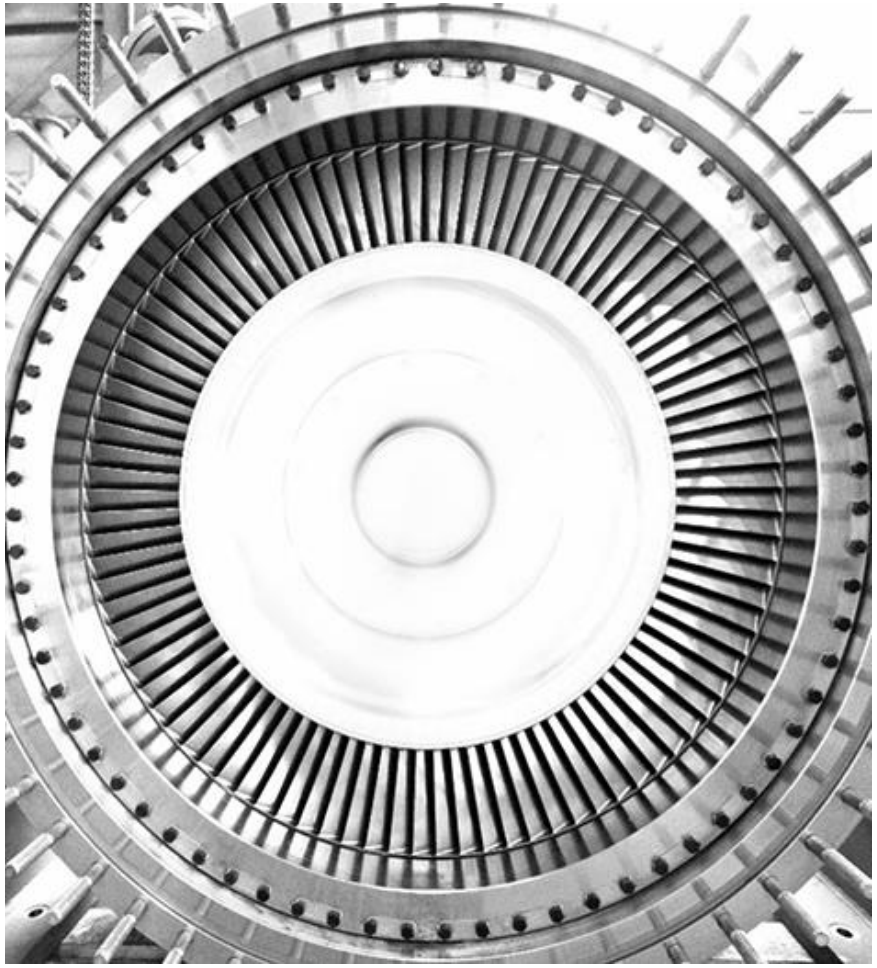
30% PARTIAL LOAD

**ORC 80%**

STEAM 55%

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

# ORC SYSTEM FEATURES



## Simplicity

- ✓ Remote monitoring and automatic operation, no personnel needed
- ✓ 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

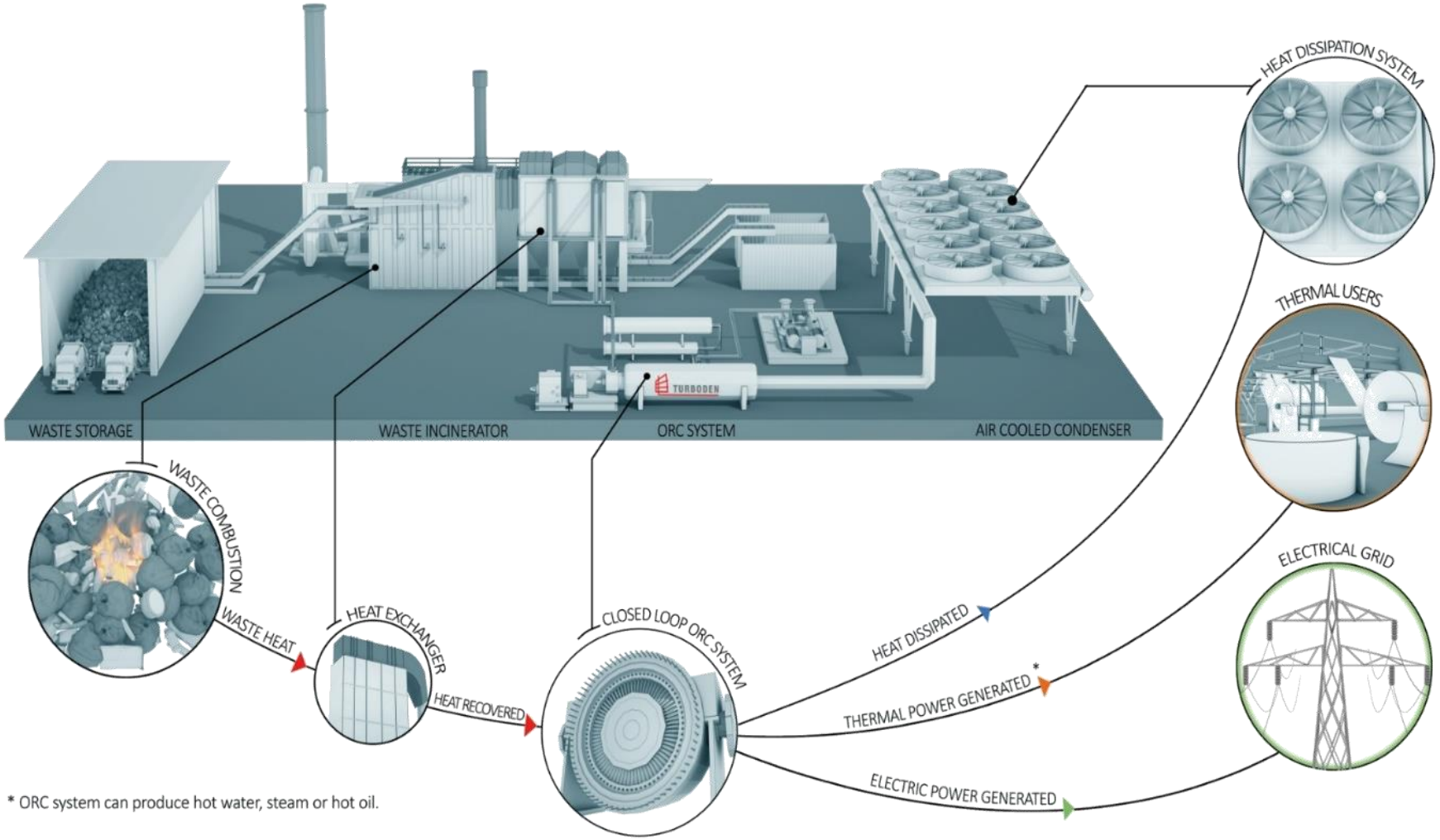
## Dependability

- ✓ High availability
- ✓ Long life (> 25 years)
- ✓ Proven technology - 40 years experience

## Sustainability

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

# DECENTRALIZED WASTE TO ENERGY



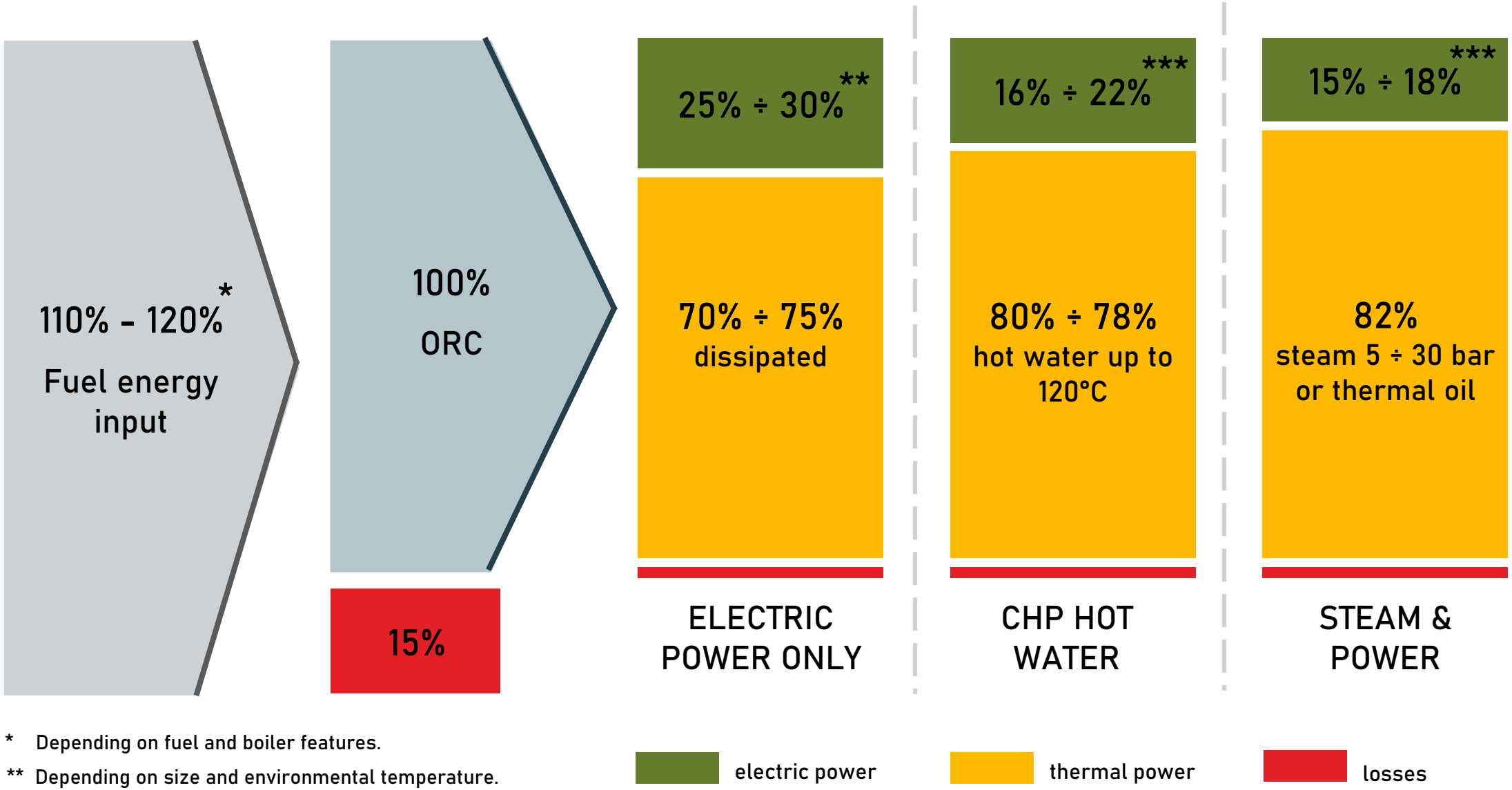

Turboden ORC systems generate **power and heat** by recovering heat from a primary waste thermal treatment such as:

- incineration
- gasification
- pyrolysis

The heat transfer medium can be:

- thermal oil
- saturated steam
- hot water

# THREE MAIN POSSIBLE SCHEMES




* Depending on fuel and boiler features.

** Depending on size and environmental temperature.

*** Depending on heat output temperature.

# FIELDS OF APPLICATIONS

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# DECENTRALIZED WTE

- The best thermal treatment is selected for each case
- Flexibility to cope with waste quantity & quality fluctuations
- Easy operation and maintenance
- From 5,000 to 200,000 TPY of waste treated
- From 500 kWe to 40 MWe of power generation
- Up to 30% ORC electrical efficiency

Main type of waste

- MSW, SRF, RDF
- Industrial waste
- Hazardous waste
- Medical waste
- C&D waste
- Food waste
- Pulp & Paper
- Tiers

# WHY DECENTRALIZED EFW?

## ADVANTAGES

EFW <200,000 tpy

- Small footprint with low impact on landscape and environment
- Easy and quick to obtain planning, permits and grid connection
- Low impact on road transport as waste is treated locally
- Low carbon heat and green power are used locally
- Facilitate public acceptance as it brings direct benefits to local communities
- High availability to mitigate financial risk and increase investment returns
- High efficiency at partial load to cope with waste variations and maximize energy
- Avoid waste landfilling and fight climate change
- Reduction of GHG emissions to increase sustainability

# SOLID WASTE REFERENCES

| PLANT | COUNTRY | START UP | DESCRIPTION | ORC POWER (MWe) |
|---|---|---|---|---|
| AGRIVIS | Italy | 2005 | CHP - MSW Incineration plant | 0.5 |
| THE CORPORATION OF THE CITY OF LONDON | Canada | 2021 | Electric power - MSW fluidized bed incineration plant | 0.6 |
| VEOLIA PROPRETÉ RHIN-RHÔNE | France | 2015 | Electric power - waste incineration plant | 0.7 |
| TERRAVERDE ENERGY | Italy | under construction | Electric power - gasification of RDF | 1 |
| PPM PROMONT BYDGOSZCZ | Poland | 2018 | Electric power - waste incineration plant | 1.2 |
| undisclosed | Turkey | 2020 | Electric power - gasification of RDF and biomass | 12.8 |
| SASU ALCEA, SECHE ENVIRONNEMENT | France | 2014 | Electric power - waste incineration plant | 2.7 |
| MIROM ROESELARE | Belgium | 2008 | Electric power - waste incineration plant | 3 |
| ITC-KA | Turkey | 2014 | Electric power - MSW gasification | 2 x 5.3 |
| undisclosed | Taiwan | 2021 | Electric power - RDF incineration plant | 10 |

# POWER FROM INDUSTRIAL WASTE GASIFIER

CUSTOMER:
ITC, Turkey

ORC ELECTRIC POWER:
2 x 5.3 MW

STATUS:
in operation since 2014

DESCRIPTION:
waste gasification generates synthesis gases which are burnt into two thermal oil boilers of 20 MWth each.

Two ORC units, one for each boiler, are fed with thermal oil to generate power with at 25% electrical efficiency.

WASTE:
industrial and medical waste

FEATURES:
high efficiency at partial loads to cope with waste fluctuation and maximize energy production

# DECENTRALIZED ENERGY FROM WASTE

CUSTOMER:
undisclosed, Turkey

ORC ELECTRIC POWER:
13 MW

STATUS:
in operation since 2020

DESCRIPTION:
two-stage gasification of waste and heat recovery by a thermal oil boiler to feed the ORC for power generation at high efficiency. ORC working fluid is cooled down by air cooled condensers.

WASTE:
2/3 RDF, 1/3 biomass
120,000 ton/year

CUSTOMER:
undisclosed, Taiwan

ORC ELECTRIC POWER:
9 MW

STATUS:
in operation since 2021

DESCRIPTION:
waste incinerator with a thermal oil boiler to recover the heat and feed the ORC for power generation. ORC working fluid is cooled down by a water condenser and air coolers.

WASTE:
80% RDF-3 + RDF-5* + 20% TDF (waste tires)
6,000 ton/month

# ENERGY FROM INDUSTRIAL WASTE

CUSTOMER:
SABA, Poland

ORC ELECTRIC POWER:
1.2 MW

STATUS:
in operation since 2018

DESCRIPTION:
waste is incinerated in a rotary kiln and heat is recovered by a thermal oil boiler to feed the ORC for power generation. ORC working fluid is cooled down by a water condenser and air coolers.

WASTE:
plastic and hospital waste

CUSTOMER:
Terraverde, Italy

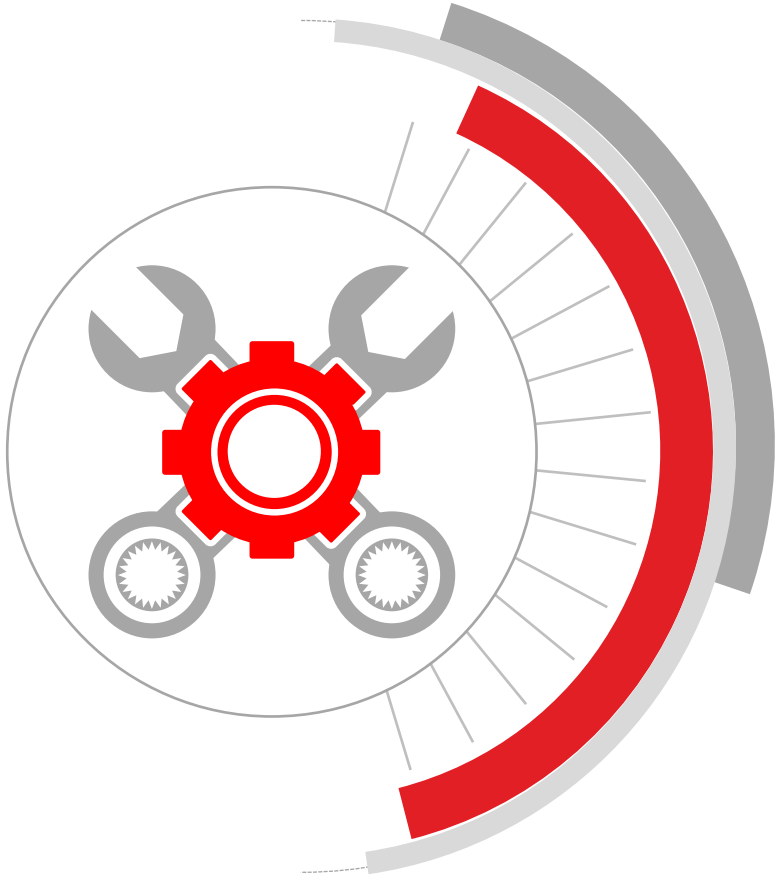
ORC ELECTRIC POWER:
1.2 MW

STATUS:
under construction

DESCRIPTION:
the heat released by the gasification of waste is recovered by a thermal oil boiler to feed the ORC for power generation. ORC working fluid is cooled down by a water condenser and air coolers.

WASTE:
RDF (refused-derived fuel)

# REVAMPING OF EXISTING ENERGY FROM WASTE



ORC is a breakthrough technological solution **to increase the overall efficiency of existing Waste to Energy** by converting unused heat streams to power.

While offering attractive economical returns, such solutions will help WtE plant to reduce their environmental footprint and to develop a more sustainable business.

Applying ORC solutions within the WtE facilities also helps to achieve the R1 status as defined by 2008/98/EC.

## ORC RECOVERS ENERGY FROM FOLLOWING WASTE HEAT STREAMS:

- Exhaust gases from existing open cycle incinerators
- Surplus heat from existing recuperators

# REVAMPING OF EXISTING ENERGY FROM WASTE

CUSTOMER:
SPIE Belgium / MIROM Roeselare, Belgium

ORC ELECTRIC POWER:
3 MWe

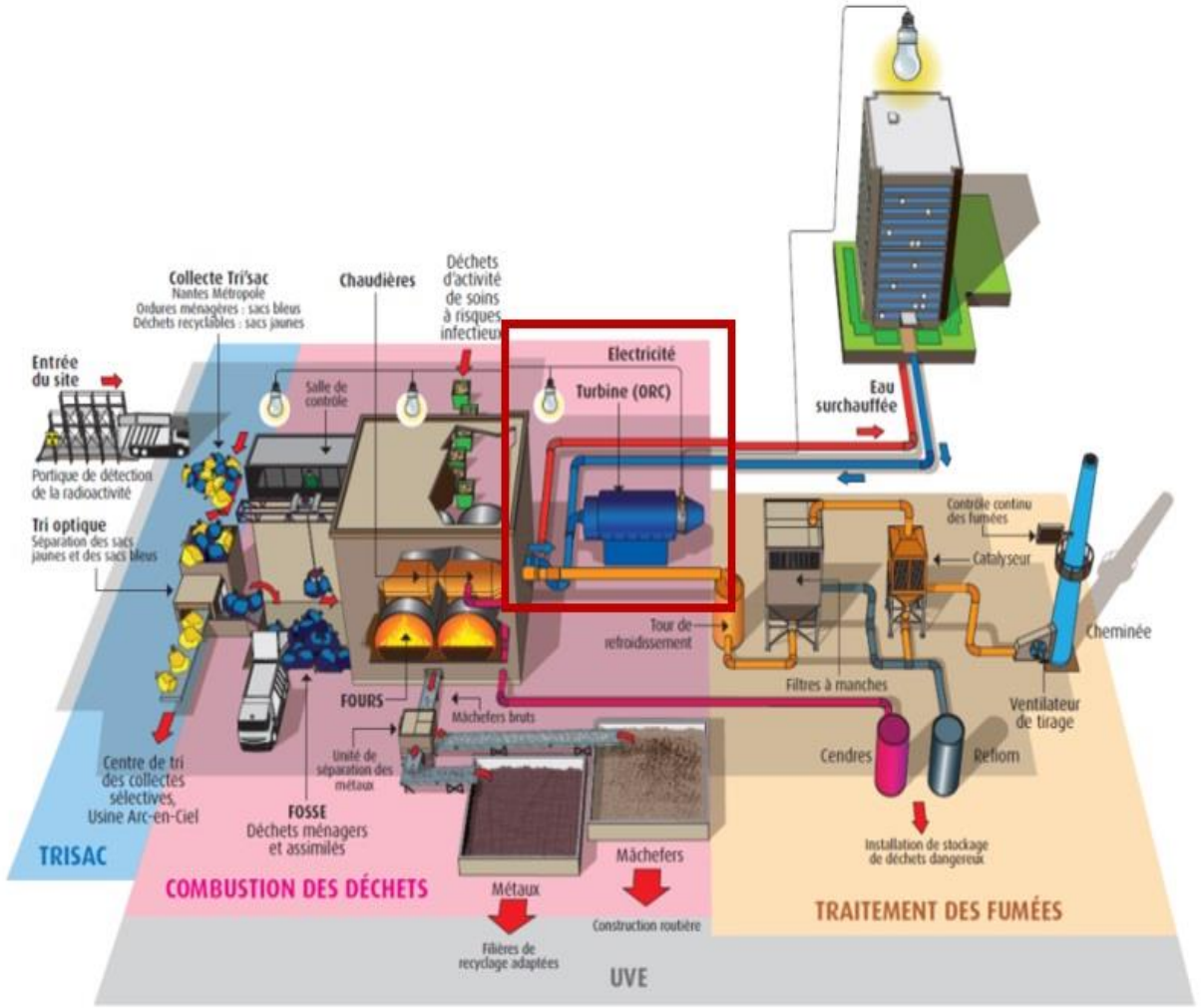
STATUS:
in operation since 2008

DESCRIPTION:
the existing urban waste incinerator (62,000 t/y MSW plant) has two hot water boilers (8 MWth each) to feed the district heating network. The ORC is installed in parallel to the district heating network to exploit the surplus thermal power, available especially in warm seasons. The electric power produced by the ORC is sold to the grid.

FEATURES:
Exceptional ORC performances are recorded in fluctuating conditions.

HEAT CARRIER:
hot water at 180°C

# ENHANCE EFW ELECTRICAL EFFICIENCY




CUSTOMER:
Sasu Alcéa, Groupe Séché Environnement, France

ORC ELECTRIC POWER:
2.7 MW

STATUS:
in operation since 2014

DESCRIPTION:
the existing urban waste incinerator has a hot water boiler to feed the district heating network.

The ORC turbogenerator is installed in parallel to the district heating network and exploits the surplus thermal power, available especially in warm seasons. The electric power produced by the ORC is exported to the grid.

Overall efficiency of the WTE plant is increased.

HEAT CARRIER:
superheated water at 150°C

# SEWAGE SLUDGE

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SLUDGE MONO-INCINERATION is a proven, clean and sustainable way to treat and valorize sludge in order to:

- Avoid sludge landfilling
- Solve sludge disposal issues and costs
- Recover Phosphorous from incineration ashes

ENERGY RECOVERY from incineration is a great opportunity to:

- Valorize sludge to generate low-carbon heat and green energy
- Generate profit reducing energy bills
- Reduce use of fossil fuel and GHG emissions
- Increase business sustainability

# SEWAGE SLUDGE REFERENCES

| PLANT | COUNTRY | START UP | DESCRIPTION | ORC POWER (MWe) |
|---|---|---|---|---|
| undisclosed | Japan | 2022 | Electric power - sewage sludge incineration plant | 1 |
| ALBANY COUNTY SEWER DISTRICT | USA | 2013 | Electric power - sewage sludge incineration plant | 1 |
| SUEZ INTERNATIONAL | Romania | under construction | Electric power - sewage sludge incineration plant | 1.2 |
| undisclosed | Japan | under construction | Electric power - sewage sludge incineration plant | 1.3 |

# SLUDGE TO POWER

CUSTOMER:
Albany County Sewer District, USA

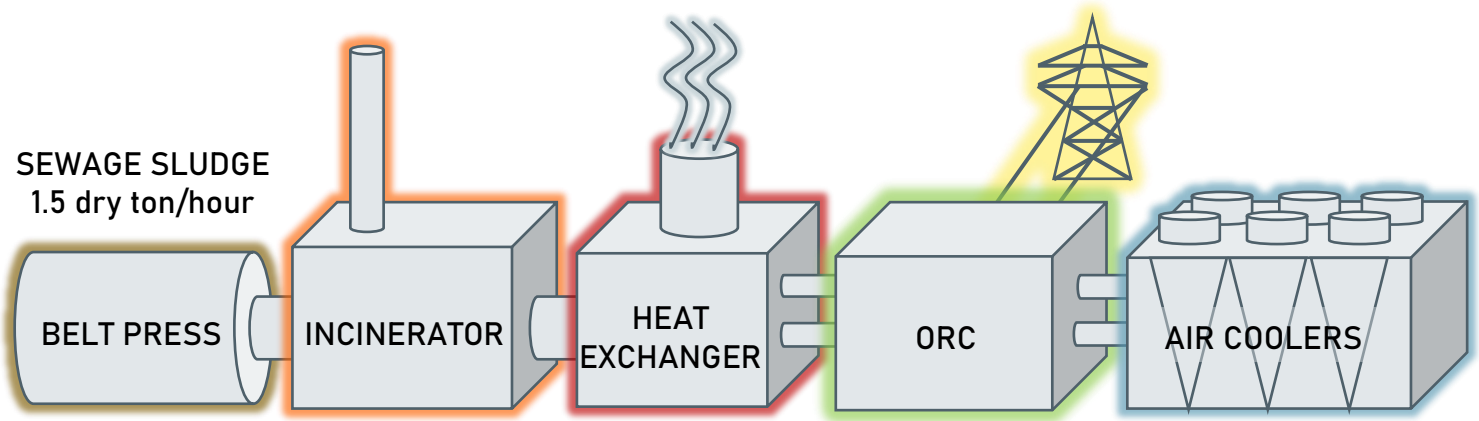
ORC ELECTRIC POWER:
1 MW

STATUS:
in operation since 2013

DESCRIPTION:
in a waste water treatment plant, the heat from sludge incinerator is recovered by a thermal oil boiler to feed the ORC for power generation. ORC working fluid is cooled down by water condenser and air coolers.

FEATURES:
The WWTP process and sludge production allow 106 hours/week of operations. ORC flexibility and easy start up & stop procedures facilitate weekly batches.

WASTE:
1.5 tons of dry sewage sludge per hour



# POWER FROM SLUDGE INCINERATOR

CUSTOMER:
Suez International, Romania

ORC ELECTRIC POWER:
2 x 0.6 MW

STATUS:
under construction

DESCRIPTION:
2 fluidized bed combustors are employed to burn sewage sludge and the heat is recovered by 2 oil boilers. Two ORC units, one each boiler, are fed with hot oil to generate power at maximum efficiency. ORC working fluid is cooled down by water condenser and air coolers.

WASTE:
dewatered sewage sludge

CUSTOMER:
undisclosed, Japan

ORC ELECTRIC POWER:
1 MW

STATUS:
in operation since 2022

DESCRIPTION:
sludge is burnt in a bubbling fluidized bed combustor and the heat is recovered by a thermal oil boiler to feed the ORC for power generation at high efficiency. ORC working fluid is cooled down by a water condenser and air coolers.

WASTE:
300 ton/day of dewatered sludge (25% DS) – 15 MW

# ANIMAL WASTE

Wet biomass landfilling or agricultural use, are not possible because of smells, dirt, soil contamination and other challenges.

COMBUSTION OR GASIFICATION are proven, clean and sustainable solutions to:

- Avoid landfilling and solve issues related to manure storage
- Eliminate the high costs for waste disposal
- Recover nutrients such as P and K from the ashes

ENERGY RECOVERY is a great opportunity to:

- Generate low-carbon heat and green power to use locally
- Generate profit reducing energy bills
- Increase business sustainability

Type of waste

- Animal manure and slurry
- Dairy industry waste
- Animal by-products

# ORC IN POULTRY FARMS

There are 2 possible options depending on the type of waste available:

## CHICKEN MEAT PRODUCTION

**CHICKEN LITTER**

A mixture of feces of chicken and «bedding» biomass matter (e.g. rice straw or sawdust)

with a **humidity level lower than 40%.**

**ELECTRIC POWER ONLY**

## CHICKEN EGGS PRODUCTION

**CHICKEN MANURE**

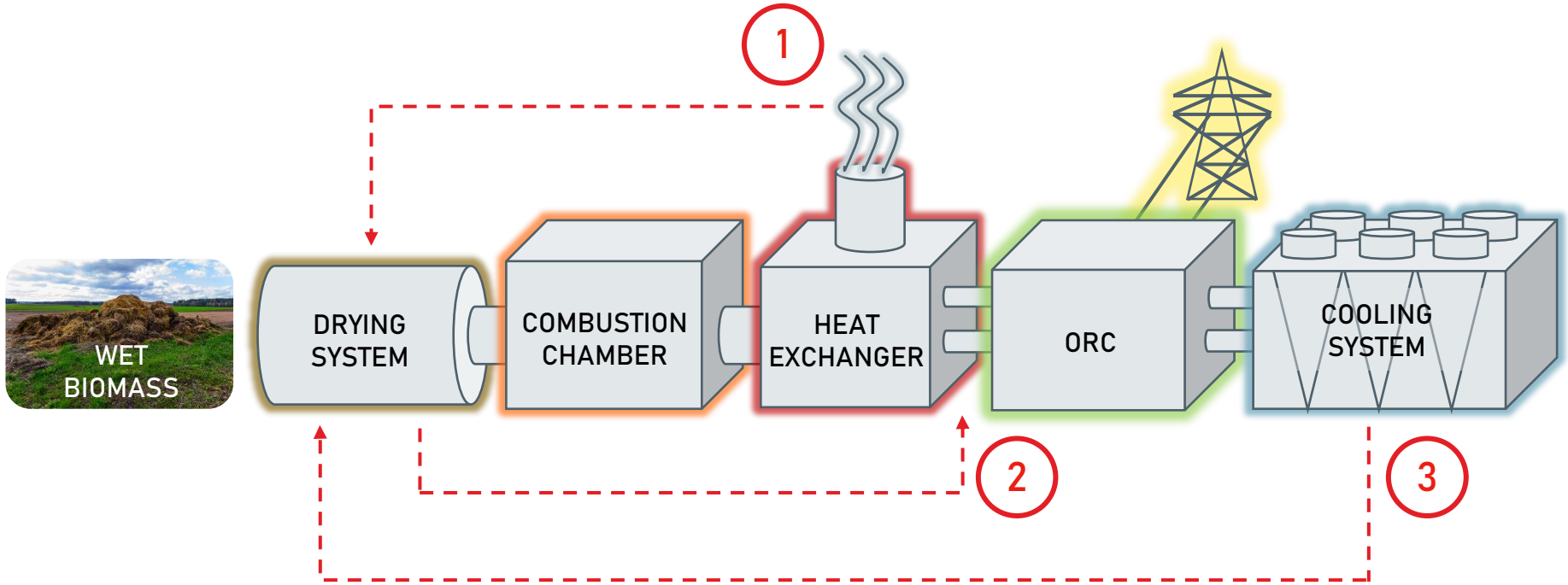
A mixture of feces of chicken with a

**humidity level of about 70 - 80%.**

**COMBINED HEAT AND POWER**

# CHP CONFIGURATION

Wet biomass, such as chicken manure, cannot reach combustion temperatures (above 850°C) without the use of auxiliary fuel (i.e. natural gas, dry biomass), which is a big operational cost. The best solution is to lower the humidity level before incineration, using a drying system. The heat used in the drying system could be sourced in different part of the process:




1. Exhaust gases after thermal oil or steam heat exchanger (between 200°C to 300°C).
2. High enthalpy thermal oil or steam before the turbo expander.
3. Low enthalpy heat at turbine condenser (hot water 70°C to LP steam).

# WET WASTE REFERENCES

| PLANT | COUNTRY | START UP | DESCRIPTION | ORC POWER (MWe) |
|---|---|---|---|---|
| GÜRES TAV. ÜRETIM PAZ. TIC. A.Ş. | Turkey | 2018 | CHP - chicken litter combustion | 2.3 |
| BGB ENERJI YATIRIM A.Ş | Turkey | 2020 | Electric power - broiler manure gasification | 2.3 |

# CHP IN AN EGG PRODUCTION FACILITY

CUSTOMER:
Güres Tav. A.Ş., Turkey

ORC ELECTRIC POWER:
2.3 MW

STATUS:
in operation since 2018

DESCRIPTION:
The layer manure is pre-dryed and then burnt in a Fluidized Bed Combustor. Heat is recovered by an oil boiler to feed the ORC with 11 MWth. ORC co-generates electricity and 70°C hot water. Hot water is used for the heating of the cages and in a belt dryer to dry the manure before combustion. Power generated is used on site and partially exported to the grid.

WASTE:
400 ton/day layer manure, 75% humidity (about 20% humidity after drying)

CUSTOMER:
BGB Enerji Yatırım A.Ş., Turkey

ORC ELECTRIC POWER:
2.3 MW

STATUS:
in operation since 2020

DESCRIPTION:
The power plant at BGB facility transforms about 100 ton/day of broiler manure into pellet, and then from pellet into electric power by employing a Fixed Bed Gasification system. The 9 MWth produced by the gasification feeds an ORC unit that generates 2.3 MWe being used on site and partially exported to the grid. Cooling system is by air-coolers.

WASTE:
100 ton/day chicken manure (mainly broiler), <30% humidity

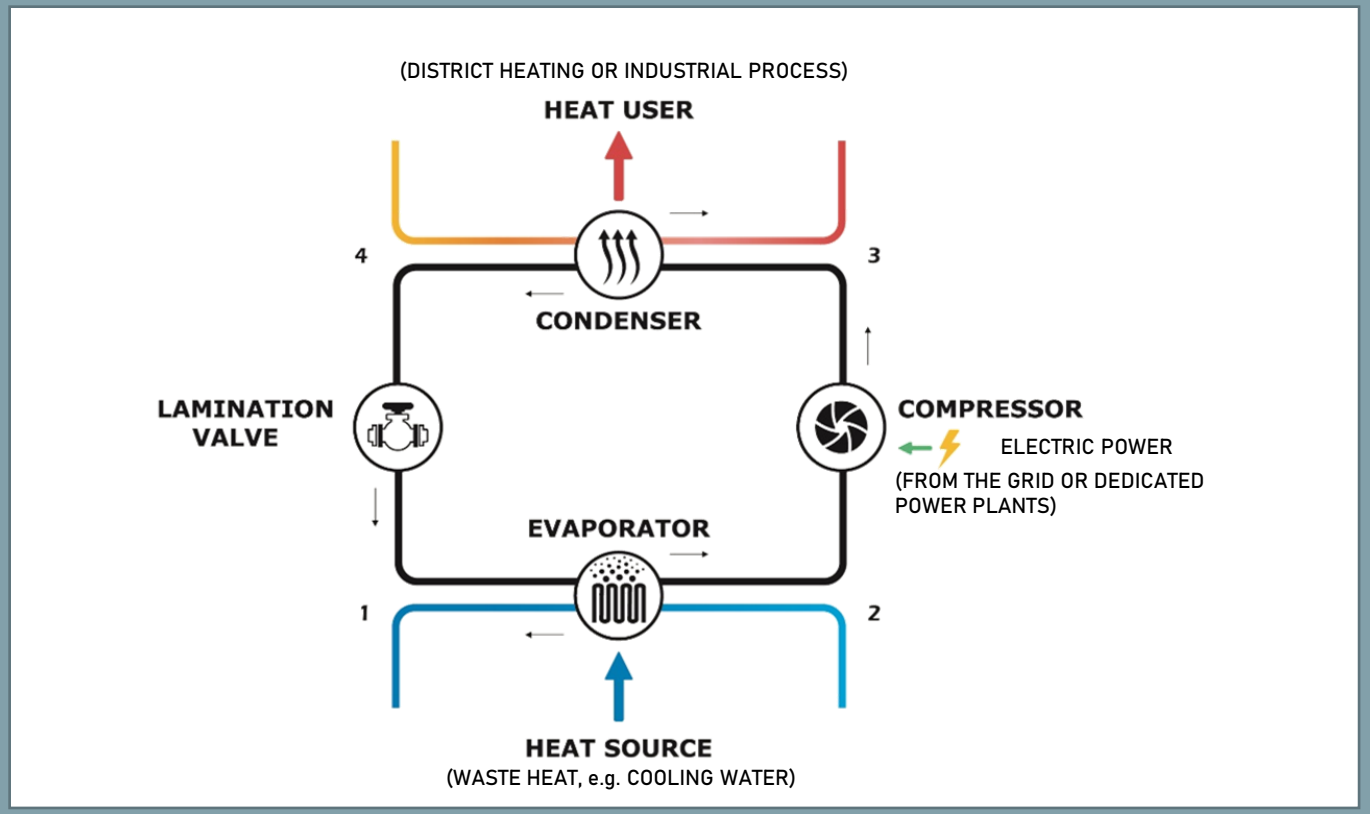
# LARGE HEAT PUMP

Large Heat Pumps are utility-scale heating plants that supply large quantities of higher temperature heat exploiting a colder energy source like mid-low temperature cooling water or process water streams. Large heat users, such as district heating networks, can benefit from this clean energy source, otherwise wasted.

## KEY POINTS

- Large-scale: output from 3 MWth to 30 MWth per unit
- High-temperature lift (ΔT up to 80°C and more)
- High-temperature output: above 100°C, including steam generation
- Benefits from Turboden's experience with a variety of waste to energy projects

# LARGE HEAT PUMP SCHEMATIC

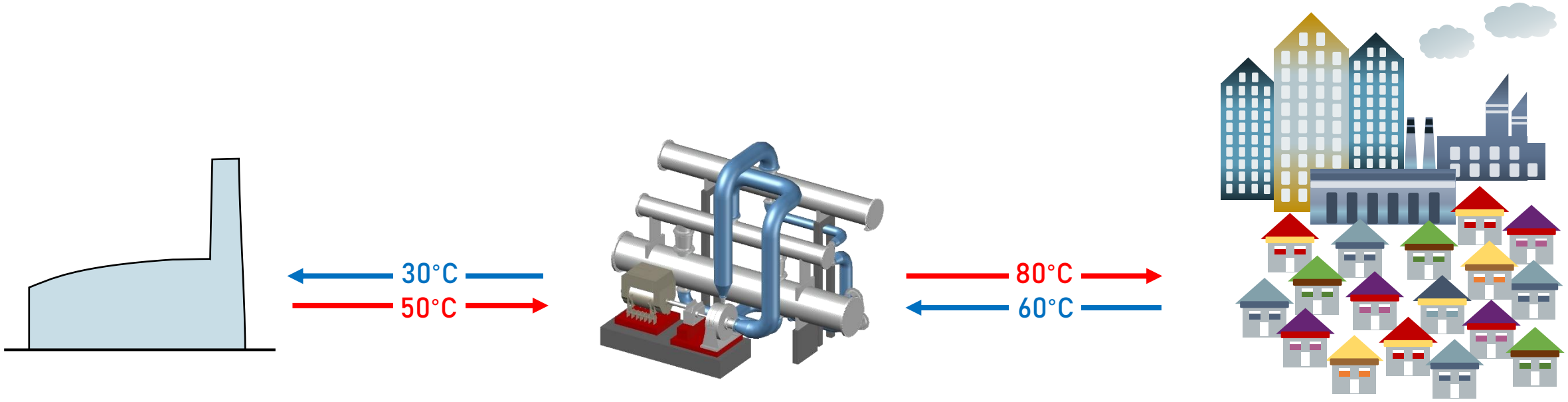



## HEAT SOURCES

- Cooling water in flue gas abatement systems
- Jacket water from gas engines
- Drying of sludge or animal manure
- Other processes or cooling water in large WTE plants

# CASE STUDY: WASTE TO ENERGY PLANT

Pollutant abatement in flue gas through quenching and recovery of heat (from condensate): projects of this kind are becoming common in Northern Europe (e.g. Scandinavia) and there is a vast potential for replication.



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