

POWER
GENERATION

WASTE TO ENERGY

Turboden S.p.A.

A Group Company of  MITSUBISHI HEAVY INDUSTRIES

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.



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

Energy from Waste

- [illegible]



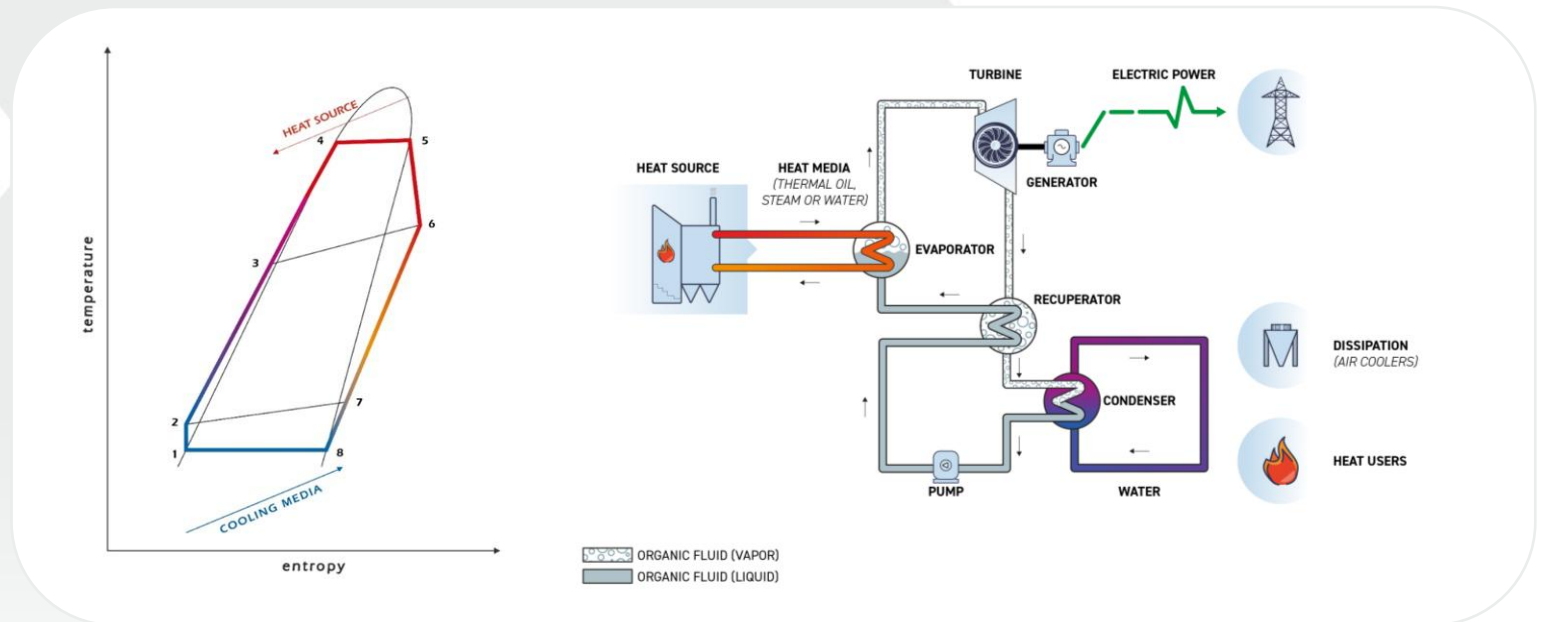
The ORC Cycle – How It Works

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.

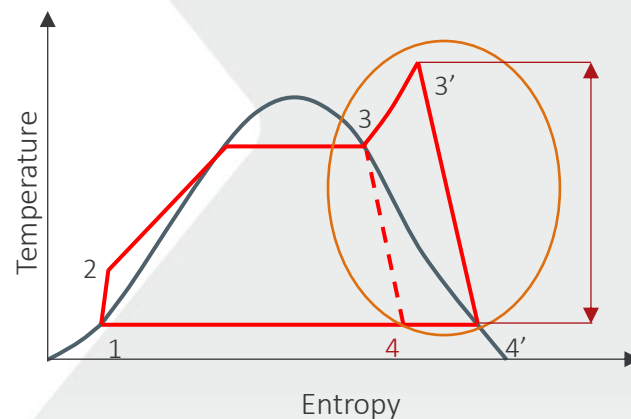


The heat is transferred to the ORC working fluid by means of an intermediate circuit or directly via the exhaust gases in direct exchange systems. The media used in the intermediate circuits are thermal oil, saturated steam or superheated water.

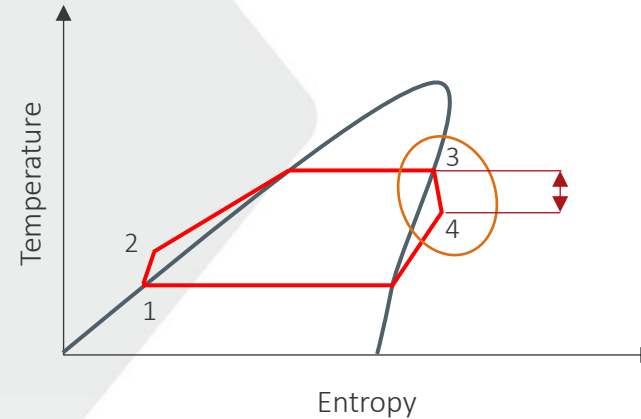
TURBODEN energy plants often use thermal oil as the heat transfer medium. Thermal oil has significant advantages compared to steam or hot water, particularly it can be heated at atmospheric pressure up to temperatures of over 300°C with mineral oils, or 400°C with synthetic oils.

Thermodynamic Cycle: ORC vs Steam

STEAM RANKINE CYCLE

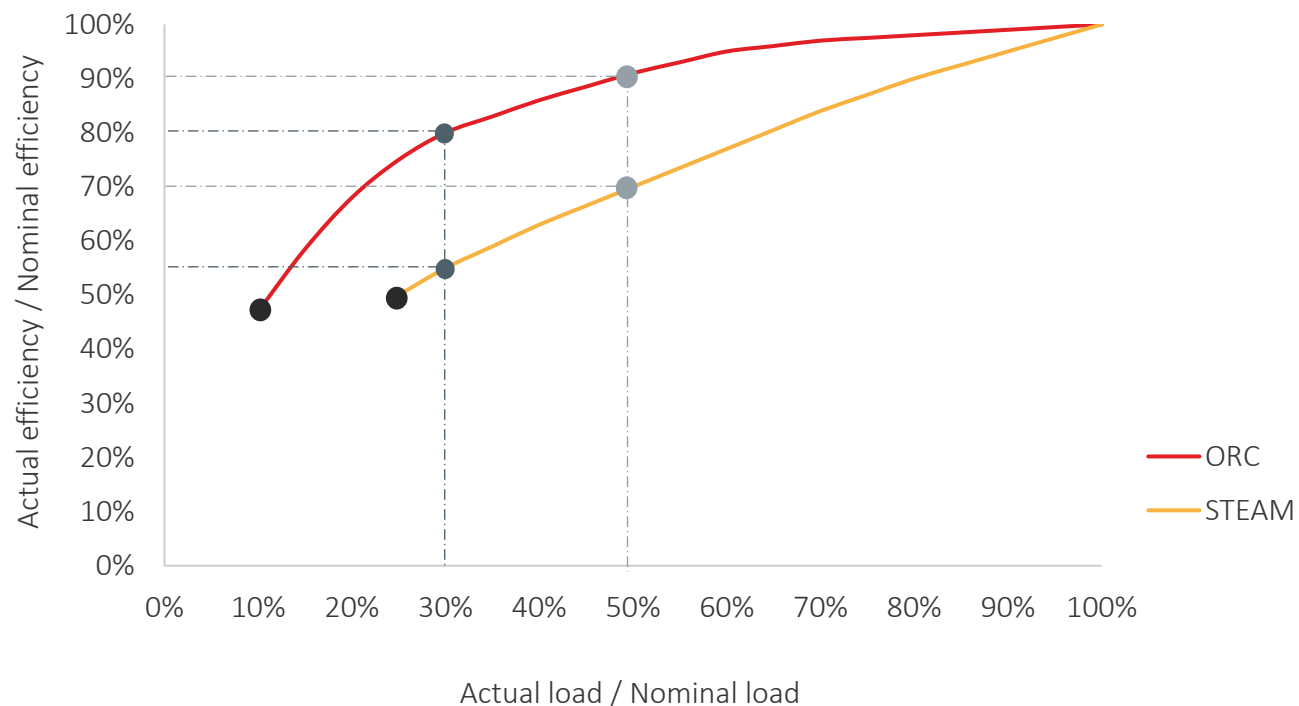


ORGANIC RANKINE CYCLE



Thermodynamic features and consequences	▪ Superheating needed ▪ Risk of blade erosion due to possible liquid formation during the expansion ▪ High enthalpy drop – turbine with high stages number	▪ No need to superheat ▪ No risk of blade erosion thanks to dry expansion in the turbine ▪ Small enthalpy drop -turbine with low stage number
Operation and maintenance costs	▪ Water treatment required ▪ Highly skilled personnel needed ▪ Periodic major overhaul	▪ Water-free system ▪ Minimum 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%)

Partial load behaviour



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

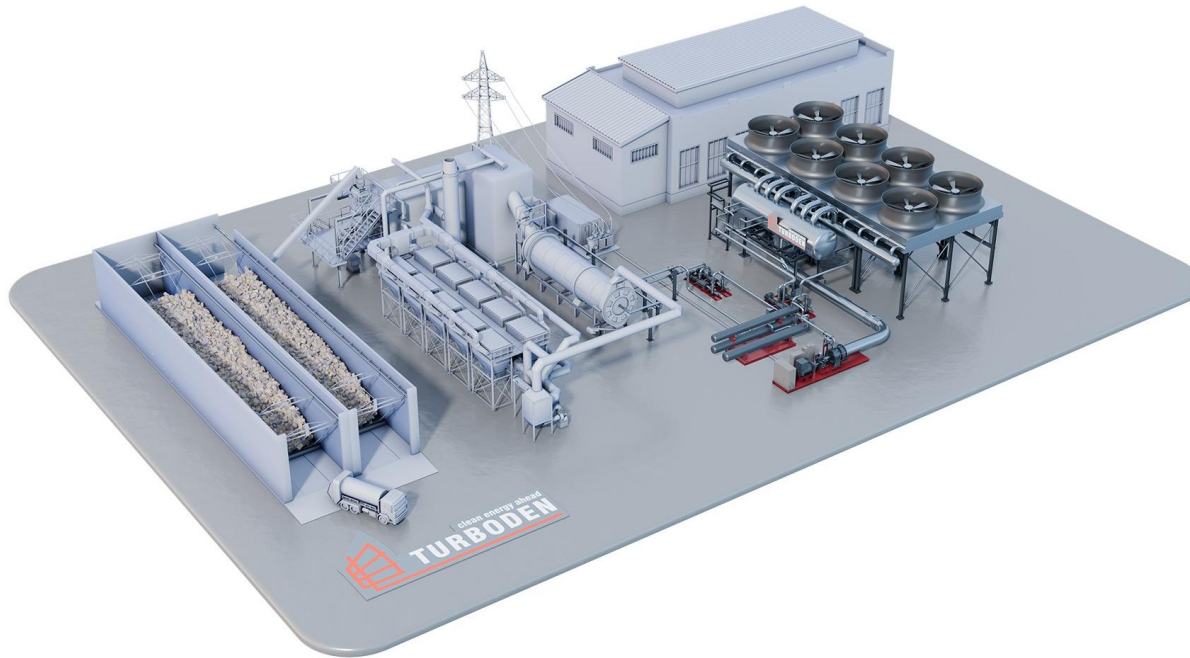
Dependability

- High availability
- Long life (> 25 years)
- 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 CO₂ emissions

Decentralized Waste to Energy



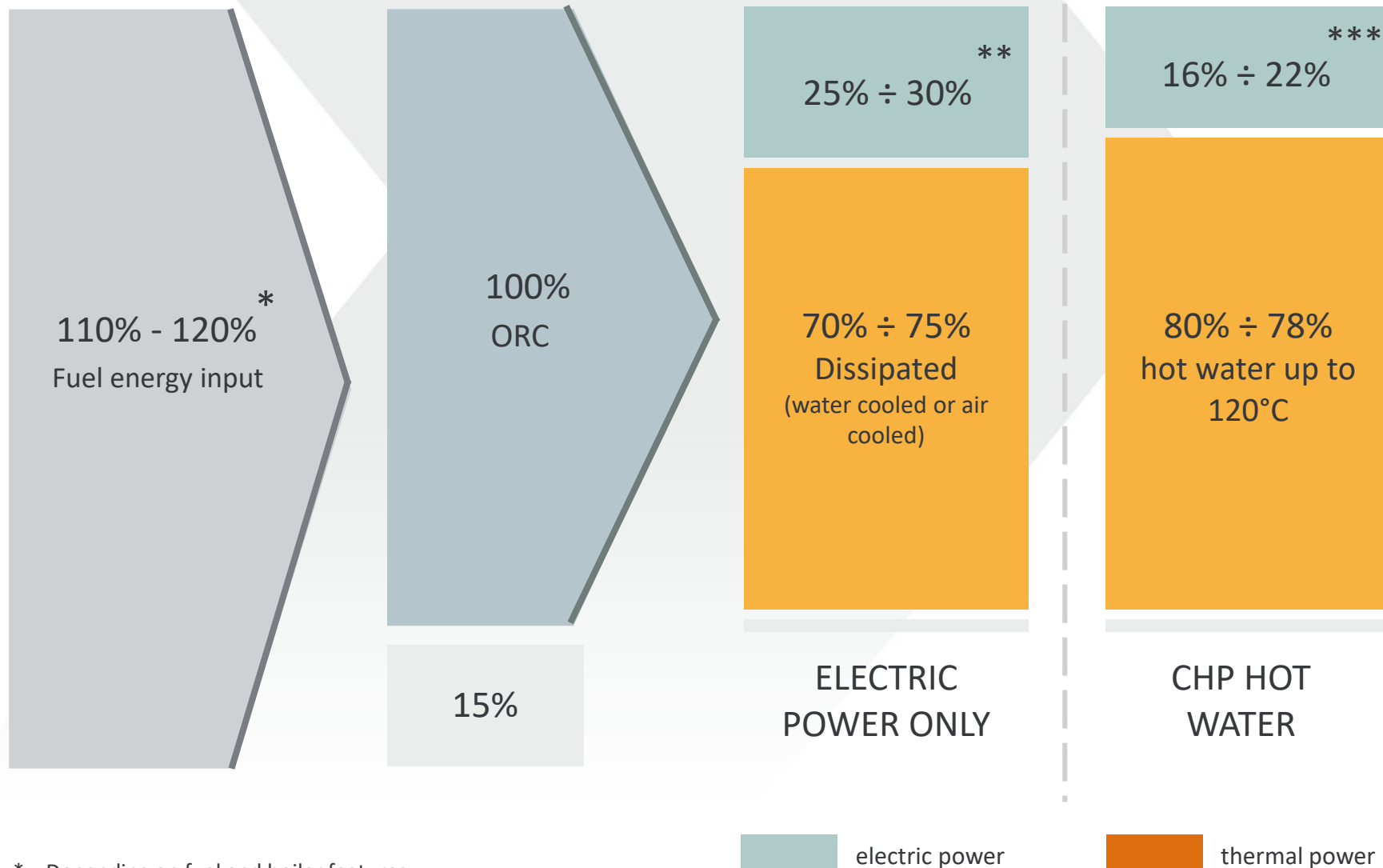
Turboden ORC systems generate **power and heat** by recovering heat from a primary waste thermal treatment such as:

- **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.

Field of Applications



SOLID WASTE



SEWAGE SLUDGE



ANIMAL WASTE

Solid Waste



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 PROPRIÉTÉ 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

Solid Waste References

PLANT	COUNTRY	START UP	DESCRIPTION	ORC POWER (MWe)
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
NOVALUX ENERGY SOLUTIONS Ltd/ALLIUM ENERGY	United Kingdom	2023	Electric power production from refused derived fuel	1.3
AB INDUSTRY S.A.	Poland	2024	Electric power production from hazardous waste incineration	1.5
RENEWABLE ASSET Ltd	United Kingdom	2025	Electric and thermal power production from refuse derived fuel	2.4
EKO GARB OOD	Bulgaria	under construction	Electric power production from municipal waste	9.1
UNDISCLOSED	Spain	under construction	Electric and thermal power production from refuse derived fuel	3.5

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



Power from Waste Combustion

- **CUSTOMER:** Renewable Asset Ltd
- **ORC ELECTRIC POWER:** 2,4 MWe
- **STATUS:** in operation since 2025
- **DESCRIPTION:** The Waste To Energy Renewable Asset Ltd project is a 3 t/h SWIP plant commissioned at Brooke Energy in Exeter (UK), developed by Turboden in partnership with BIANNA, converting RDF and solid waste into energy through ORC technology.
- **WASTE:** RDF (Refuse Derived Fuel)
- **FEATURES:** It integrates a HORIZON+ thermal oil boiler patented by BIANNA and an ORC unit water cooled; it is CHP-ready for future district heating connection, and stands out for efficiency, compactness, and compliance with UK environmental regulations.



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

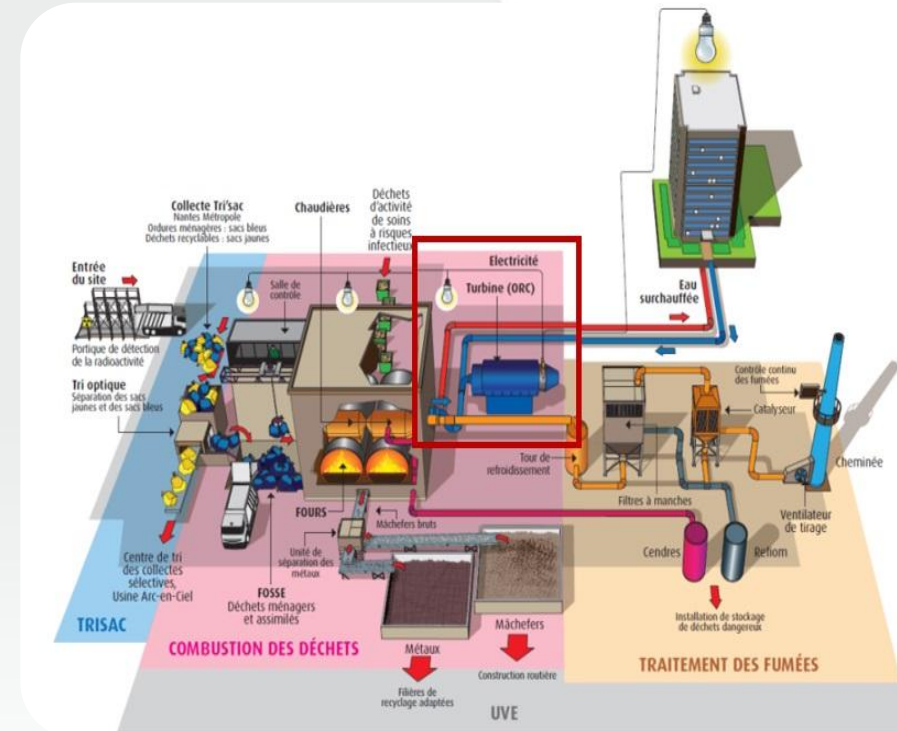
Revamping of Existing Energy from Waste

- **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 Sèché 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



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:

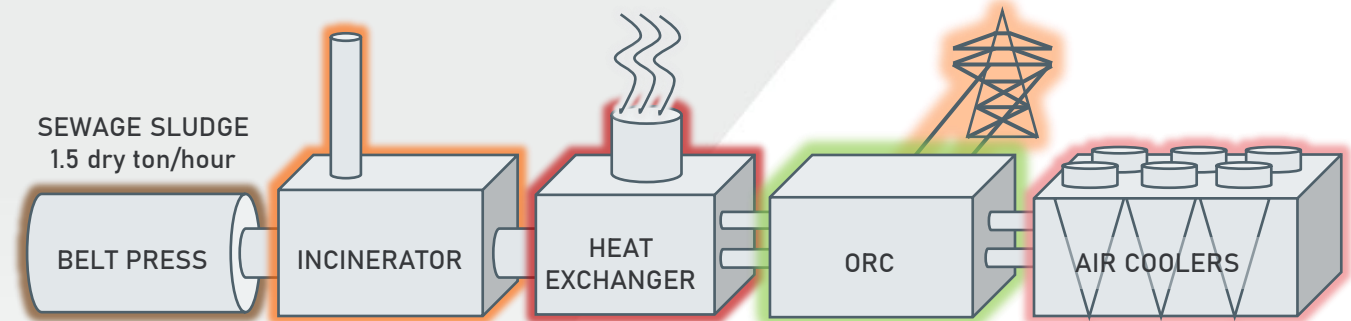
- Valorize sludge to generate low-carbon heat and green energy
- Generate profit reducing energy bills
- Reduce use of fossil fuel and GHG emissions
- Increase business sustainability

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

Main 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

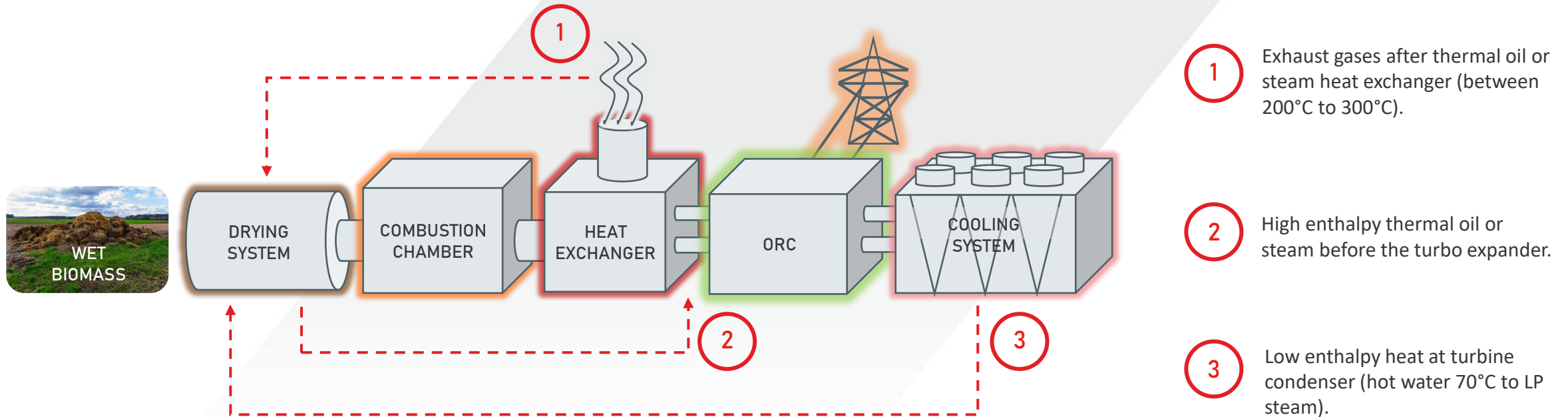
A mixture of feces of chicken with a **humidity level of about 70 - 80%**



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:



Wet Waste References

PLANT	COUNTRY	START UP	DESCRIPTION	ORC POWER (MWe)
GÜRES TAV. ÜRETİM PAZ. TIC. A.Ş.	Turkey	2018	CHP - chicken litter combustion	2.3
BGB ENERJİ 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-dried 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





www.turboden.com

Turboden S.p.A.

A Group Company of  **mitsubishi heavy industries**

MOVE THE WORLD FORWARD  **mitsubishi
heavy
industries
group**