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TURBODEN

MOVE THE WORLD FORW>RD MITSUBISHI HEAVY INDUSTRIES GROUP



BIOMASS ORC SYSTEM
from green fuel to clean power

POWER GENERATION

Turboden S.p.A.
A Group Company of MITSUBISHI HEAVY INDUSTRIES

High-Efficiency ORC Biomass Power for Clean and Renewable Energy

Since its foundation Turboden has been committed to delivering efficient and reliable cogeneration solutions from renewable sources.

Organic Rankine Cycle (ORC) biomass power plants efficiently produce clean electricity and heat from a wide range of biomass fuels, including wood, agricultural residues, and industrial byproducts. With flexible, environmentally friendly systems capable of generating up to 40 MW per turbine, they support sustainable and renewable power generation.



The Organic Rankine Cycle Technology



Turboden Organic Rankine Cycle (ORC) plants produce electric power and heat with high efficiency and automatic operation by using any kind of biomass, from virgin wood to organic residues from various production processes.

KEY POINTS

- Large range size up to 20 MWe per single shaft
- Generate profit by valorizing a renewable source
- Provide a reliable source of power also for island mode operation
- Reduce specific production cost by decreasing energy demand
- Improve company sustainability
- Reduce CO2 emissions

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Turboden Biomass Unit Design

CHP SOLUTIONS (low and high temperature cogeneration)

Turboden units generate Combined Heat and Power (CHP) solution - providing either hot water or higher temperature heat medium (e.g. saturated steam or thermal oil). Alternatively, Turboden can provide also electric power only solutions.

POWER-ONLY	CHP
Electrical efficiency up to 30%	Electrical efficiency up to 22%



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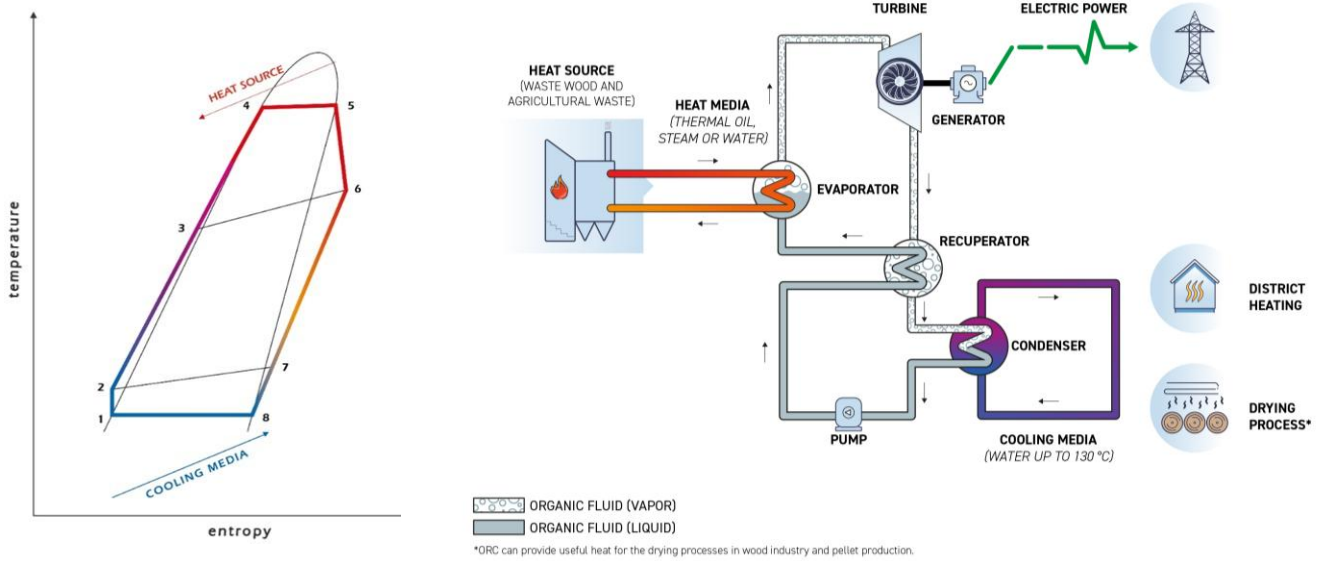
The ORC Closed-Loop Cycle – How It Works

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).

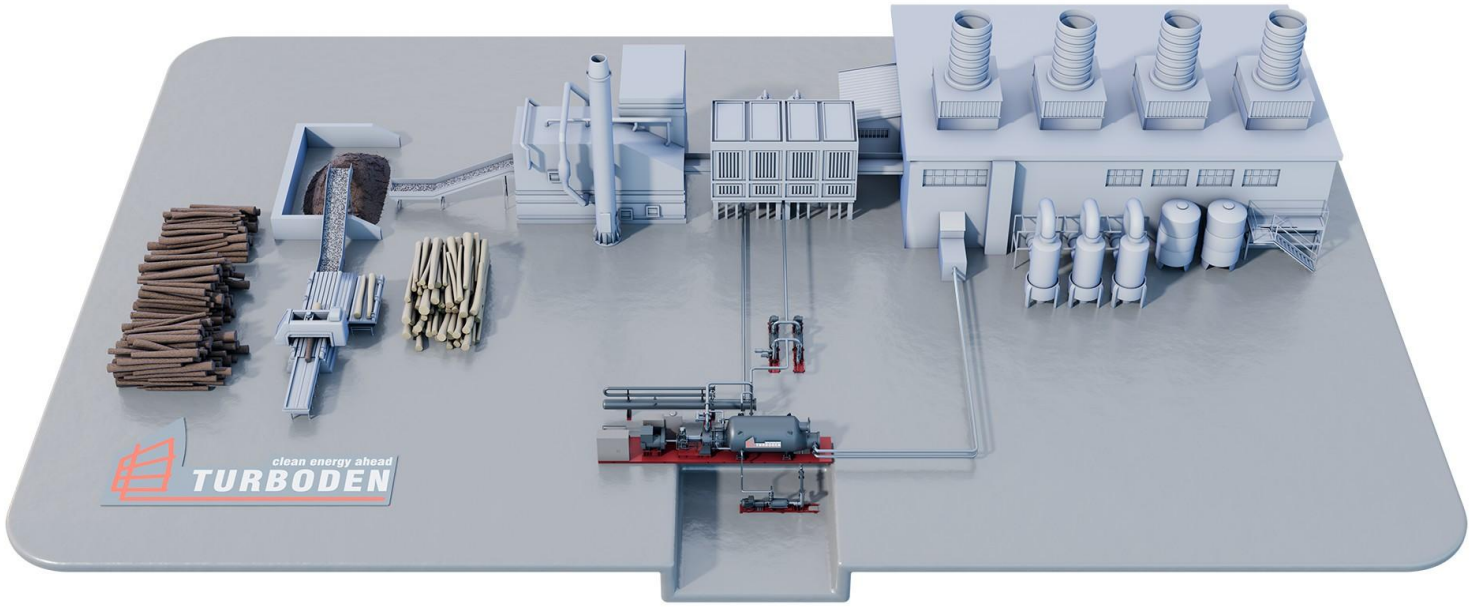
The organic working fluid is then pumped (1>2) into the regenerator and evaporator, thus completing the closed-cycle operation.



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Example of a Biomass ORC plant



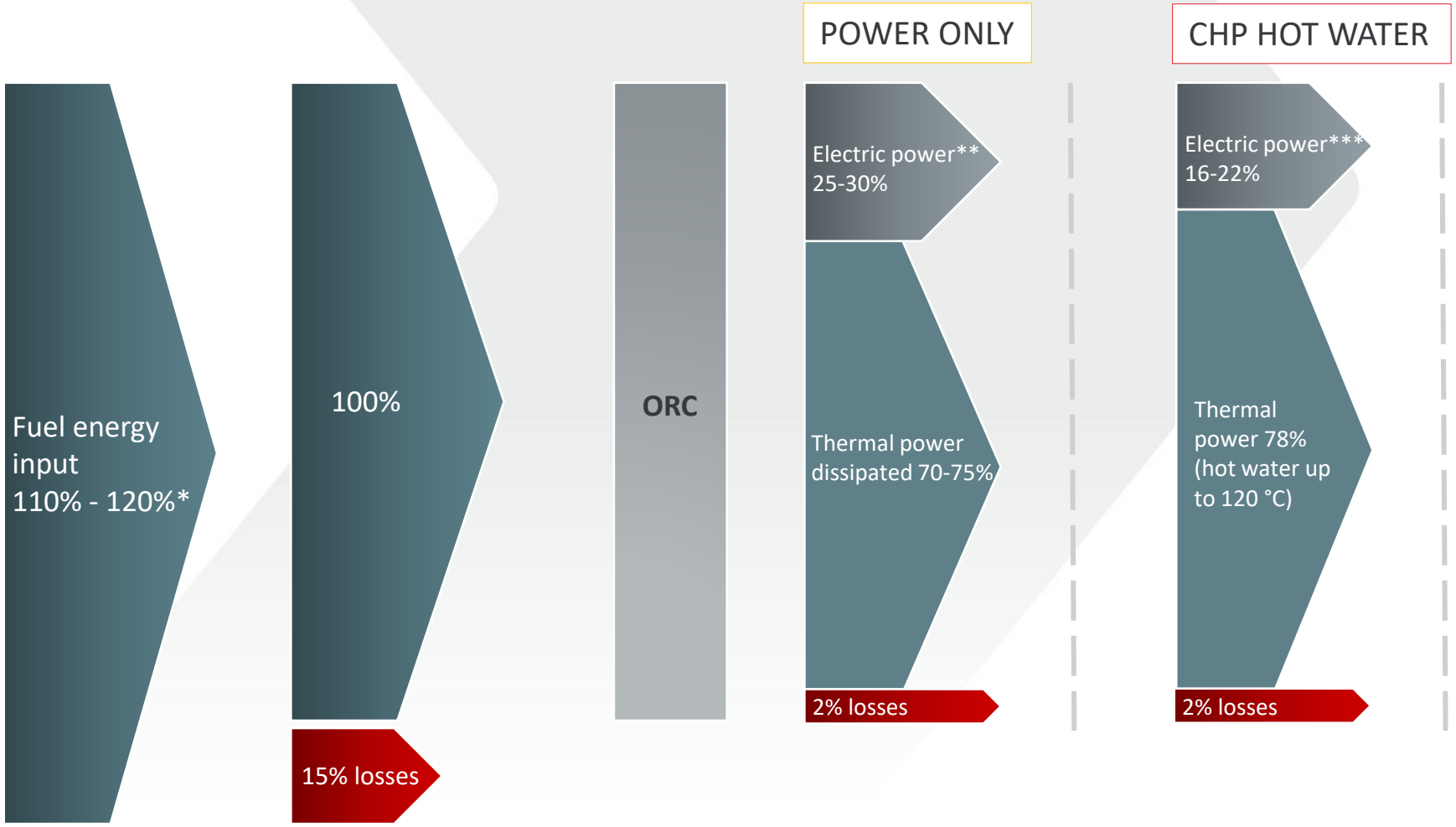
*In alternative to more traditional combustion systems, gasification and pyrolysis solutions may be applied.

THE ORC HEAT TRANSFER FLUID

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

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Three Main Possible Schemes



* Depending on fuel and boiler features

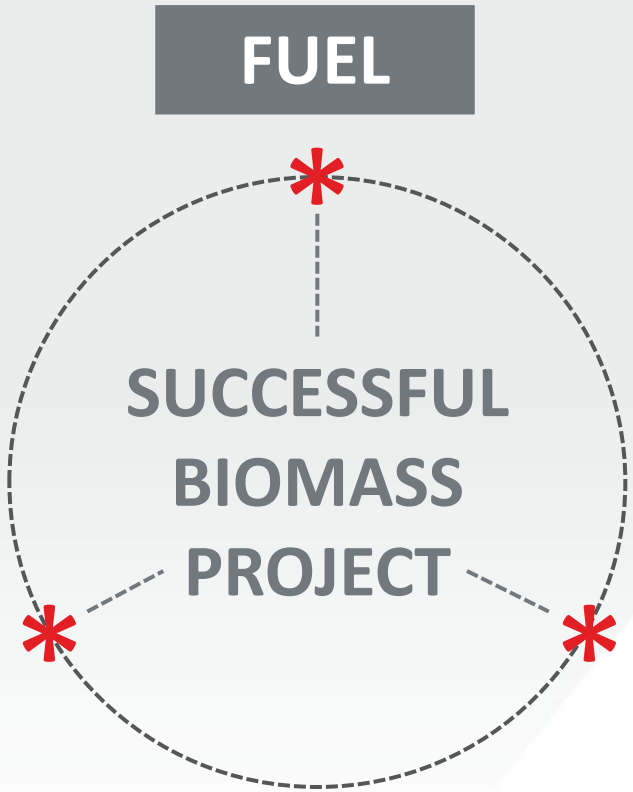
** Depending on size and environmental temperature

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Key Successful Factors

FUEL AVAILABILITY AT AN AFFORDABLE COST IN THE LONG RUN MINIMIZING TRANSPORT COSTS



A HEAT USER TO VALORIZE THE CO-GENERATED HEAT (CHP configuration is more efficient and remunerative than a power – only one)

HIGHT ENERGY VALUE (renewable incentives, PPA, feed-in tariffs, green certificates, etc.) **AND RELIABLE SOURCE OF ELECTRICITY IN ISLAND MODE SYSTEMS**

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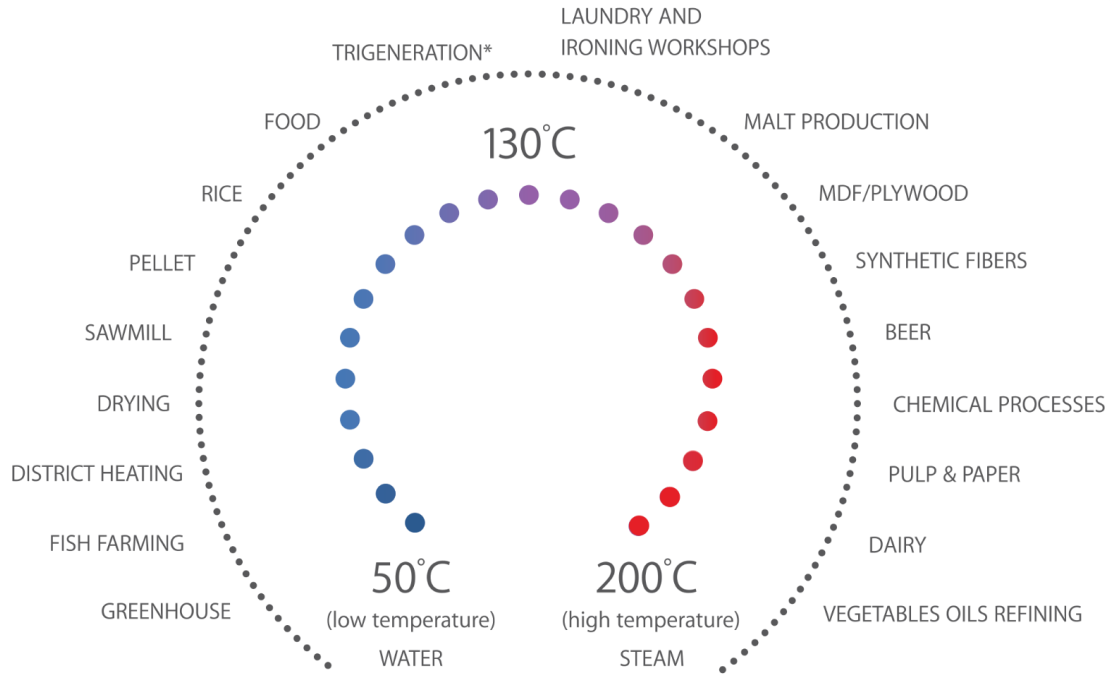
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Main Applications

TYPICAL FUELS

- sawmill residues or by-products
- bark
- wood dust and chips
- pellet
- furniture waste
- particle board screen dust
- recycled wood waste
- olive pomace and pits
- bruning & trimmings
- barley dust
- malt dust
- rice husks
- almond shells
- sunflower husks
- coffee husks and spent ground
- corn cobs
- coconut shells and husks
- empty fruit bunches
- palm kernel shells
- cotton gin waste, stalks
- Paper
- SAGD
- Biochart

HEAT USERS



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Exemple of Successful Projects

	SAWMILL, WOOD-BASED PANEL	RICE, CEREALS, FOOD PROCESSING	DISTRICT HEATING	PELLET AND CHARCOAL PROD.	POWER ONLY
	98 plants	**8** plants	**170** plants	**44** plants	**20** plants
Fuel	Wood residues (e.g. bark, sawdust, etc.) from sawmill production process.	Rice husks, corn cobs, recovered locally from the rice/cereals processing industry.	Various depending on geographical area (typically wood chips).	Wood residues (e.g. bark, sawdust, etc.) from pellet and charcoal production process.	Various depending on geographical area.
Power	Used to feed internal auxiliaries; it can also be used to sustain island operation.	Used to feed internal auxiliaries; it can also be used to sustain island operation.	Incentives as a renewable source. Also used partly to power internal users.	Used to feed internal auxiliaries.	Incentives as a renewable source.
Heat	Fully used in drying chambers as hot water or low-pressure steam.	Used for rice processing as hot water or steam, cereal drying.	Used to feed the heating network.	Used as hot water for wood drying in the process.	No use.
Note	Fuel generated as by-product by the industry, heat and electricity valorized internally by the same industry.	Fuel produced as by-product by the facility, heat and electricity valorized internally by the same industry.	Fuel collected from various sources, heat sold to the local district heating network, electricity partly used internally, and the rest sold to the grid.	Fuel generated as by-product by the facility, heat and electricity valorized internally by the same industry.	Fuel collected from various sources, electricity sold to the grid. Business model viability subject to biomass price fluctuation.

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CHP in Wood Industry

- **CUSTOMER**: Stia Holzindustrie
- **COUNTRY**: Austria
- **STATUS**: in operation since 1999
- **ORC SIZE**: 0.5 MWe
- **DESCRIPTION**: CHP in a wood factory (wooden flooring and panels)
- **FUEL**: wood residues
- **HEAT CARRIER**: thermal oil
- **WATER TEMPERATURE (IN/OUT):** 60 - 90 °C

Longest Turboden ORC in operation

Almost 100 plants integrated with wood industries



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Power Generation in Sawmill

- **CUSTOMER**: West Fraser Mills
- **COUNTRY:** Canada
- **STATUS:** in operation since 2014 – 2015
- **ORC SIZE:** 26 MWe (4 x 6.5 MWe)
- **DESCRIPTION:** power only in two large sawmills
- **FUEL:** residues from sawmill process (mainly bark)
- **HEAT CARRIER:** thermal oil
- **WATER TEMPERATURE (IN/OUT):** 24 - 34°C

The largest lumber producer in North America

More than 80 plants for sawmills worldwide

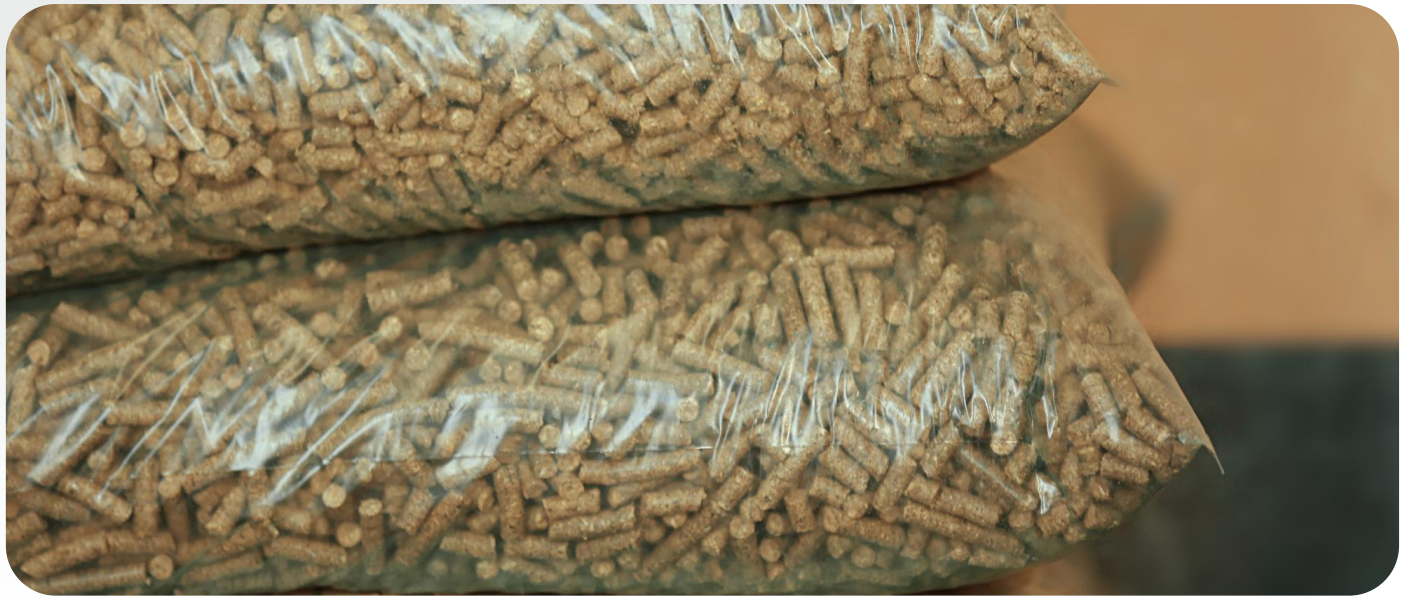


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CHP in Pellet and Briquette Production Plant

- **CUSTOMER:** JAF Madeiras - JOSE AFONSO & FILHOS S.A.
- **COUNTRY:** Portugal
- **STATUS:** in operation from June 2026
- **ORC SIZE:** 3 MWe
- **DESCRIPTION:** CHP - Pellet and briquette production
- **FUEL:** barks and branches
- **HEAT CARRIER:** Thermal oil
- **WATER TEMPERATURE (IN/OUT):** 60 - 85 °C



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CHP in the Wood-Based Panel Industry

- **CUSTOMER:** Kastamonu Entegre Ağaç Sanayi ve Ticaret Anonim Şirketi
- **COUNTRY:** Turkey
- **STATUS:** in operation since November 2023
- **ORC SIZE:** 13.6 MWe
- **DESCRIPTION:** Electric and thermal power production from wood waste combustion
- **FUEL:** wood by-products
- **HEAT CARRIER:** Thermal oil
- **WATER TEMPERATURE (IN/OUT):** 100 - 70°C



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CHP in the Wood-Based Panel Industry

- **CUSTOMER:** Tableros Hispanos
- **COUNTRY:** Spain
- **STATUS:** in operation from June 2026
- **ORC SIZE:** 3.6 MWe
- **DESCRIPTION:** CHP – Particle Board wood panels
- **FUEL:** wood by-products
- **HEAT CARRIER:** Thermal oil
- **WATER TEMPERATURE (IN/OUT):** 80 - 100 °C



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CHP in the Wood-Based Panel Industry

- **CUSTOMER:** Künkel
- **COUNTRY:** France
- **STATUS:** in operation since October 2020
- **ORC SIZE:** 1.4 MWe
- **DESCRIPTION:** CHP - Pallet blocks production
- **FUEL:** wood by-products
- **HEAT CARRIER:** Thermal oil
- **WATER TEMPERATURE (IN/OUT):** 70 - 90 °C



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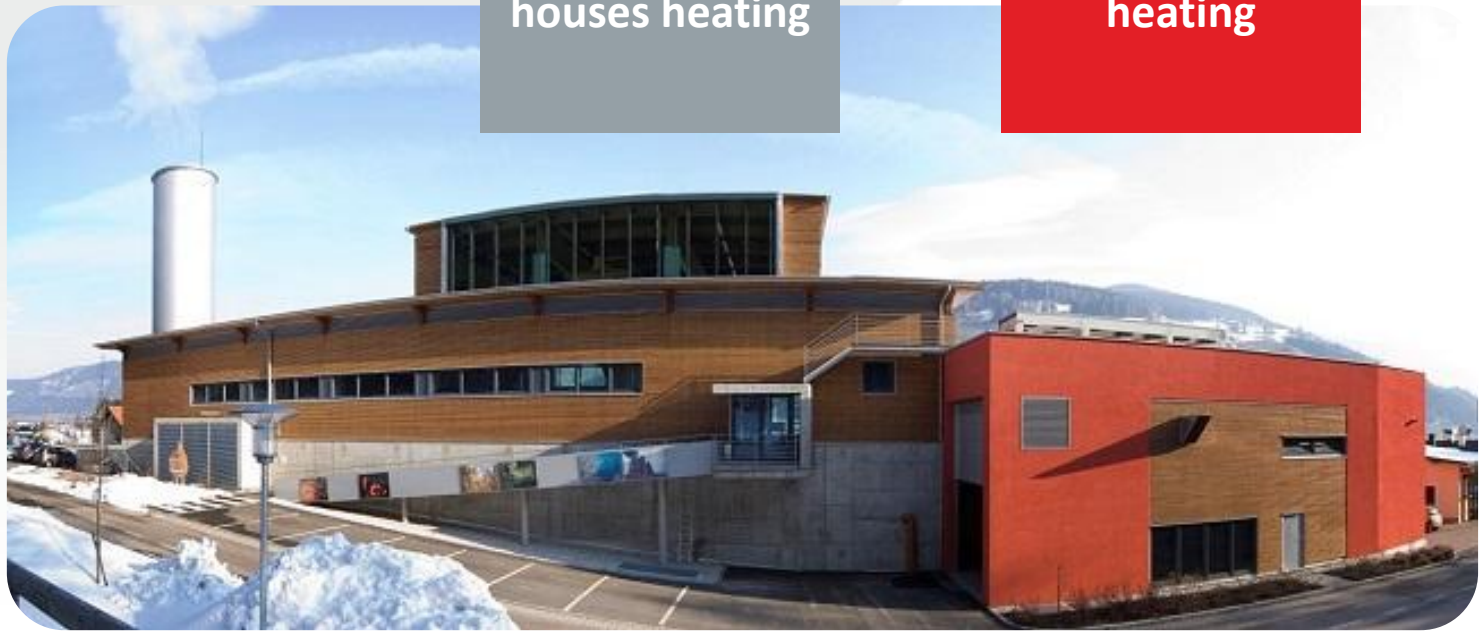
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CHP for District Heating Networks

- **CUSTOMER:** Fernheizwerk Toblach-Innichen
- **COUNTRY:** Italy
- **STATUS:** in operation since December 2003
- **ORC SIZE:** 1.5 MWe
- **DESCRIPTION:** CHP for the district heating network
- **FUEL:** wood chips
- **HEAT CARRIER:** thermal oil
- **WATER TEMPERATURE (IN/OUT):** 60 - 80 °C

Renewable energy for houses heating

170 plants for district heating



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Power Generation in the Agri-Food Industry

- **CUSTOMER / END USER:** ACC Renewable Resources LLC / Rice Hull
- **COUNTRY:** California, USA
- **STATUS:** in operation since June 2022
- **ORC SIZE:** 3.6 MWe
- **DESCRIPTION:** Electric power only with air cooled condenser (no water consumption)
- **FUEL:** rice husk
- **HEAT CARRIER:** thermal oil

Different kind of fuels: rice, cereal, production waste, etc.

Profitable management of agro residues



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Power Generation in the Agri-Food Industry

- **CUSTOMER:** Sobono
- **COUNTRY:** The Philippines
- **STATUS:** in operation since December 2017
- **ORC SIZE:** 5.5 MWe
- **DESCRIPTION:** CHP in a farm for cereals dryers
- **FUEL:** rice husk
- **HEAT CARRIER:** thermal oil
- **WATER TEMPERATURE (IN/OUT):** 40 - 80 °C

Efficient exploiting of different kind of waste

Island mode operation



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Selected Customers















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