2016 BioCleantech Forum
TURBODEN ORC TECHNOLOGY: STATE-OF-THE-ART

clean energy ahead
TURBODEN®
a group company of MITSUBISHI HEAVY INDUSTRIES, LTD.

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Manager, Sales and Business Development North America

Ottawa, November 3rd, 2016

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Turboden has more than 35 Years of Experience…

- **TURBODEN** IS A **LEADING COMPANY** IN THE **DEVELOPMENT** AND **PRODUCTION** OF ORC TURBOGENERATORS
- **FOUNDED IN 1980**
- **PART OF MITSUBISHI HEAVY INDUSTRIES** (MHI) SINCE **2013**
- TODAY MORE THAN **330 PLANTS** IN **34 COUNTRIES**
- **500 MW** INSTALLED AND **8 MILLION OPERATING HOURS**

MITSUBISHI HEAVY INDUSTRIES, LTD.

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ORC Turbogenerators are Simple, Flexible and Reliable

- WORK AT LOW TEMPERATURES (90+°C)
- LOW O&M*
- SIMPLE
- NO NEED OF WATER
- HIGH FLEXIBILITY AND GOOD EFFICIENCY AT OFF DESIGN CONDITIONS
- AUTOMATIC AND CONTINUOUS OPERATION **
- RELIABILITY

* Few personnel required and no water treatment needed
** Simple start-stop procedures

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ORC: A Multi-Feed Technology

Biomass

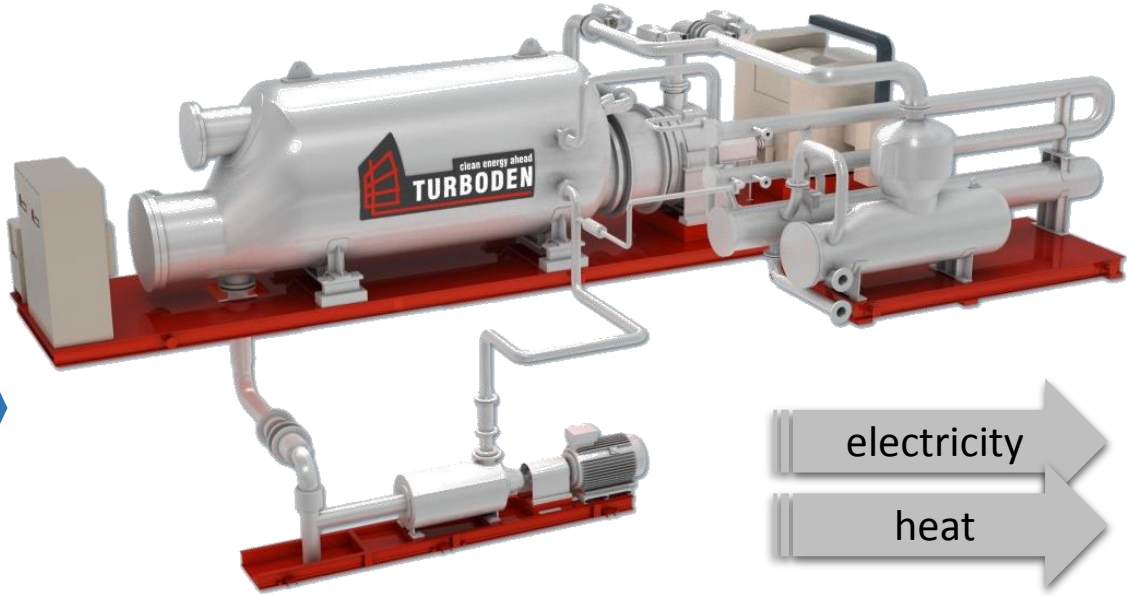
Heat recovery

Waste to energy

Geothermal

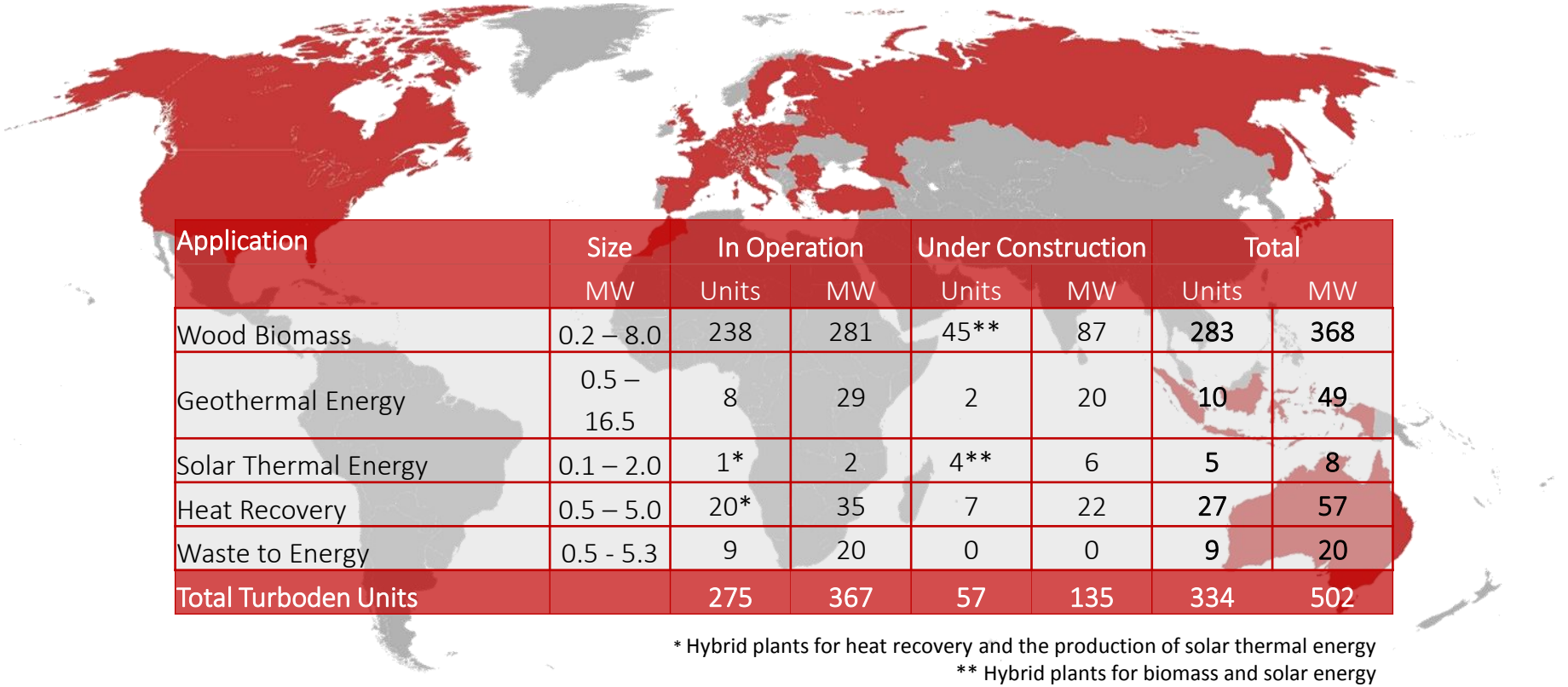
Solar

and others..



- Up to 20 MW electric per single shaft
- Modular solutions
- Suitable for distributed power generation and cogeneration

… and More than 330 Plants Installed Worldwide



Application	Size	In Operation		Under Construction		Total	
	MW	Units	MW	Units	MW	Units	MW
Wood Biomass	0.2 – 8.0	238	281	45**	87	283	368
Geothermal Energy	0.5 – 16.5	8	29	2	20	10	49
Solar Thermal Energy	0.1 – 2.0	1*	2	4**	6	5	8
Heat Recovery	0.5 – 5.0	20*	35	7	22	27	57
Waste to Energy	0.5 - 5.3	9	20	0	0	9	20
Total Turboden Units		275	367	57	135	334	502

* Hybrid plants for heat recovery and the production of solar thermal energy
** Hybrid plants for biomass and solar energy

Country	Total plants	Country	Total plants
Italy	94	Asia	11
Germany	82	Africa	1
Other Western European Countries	92	Americas	9
Eastern European Countries	44	Oceania	1

Date: August 2016

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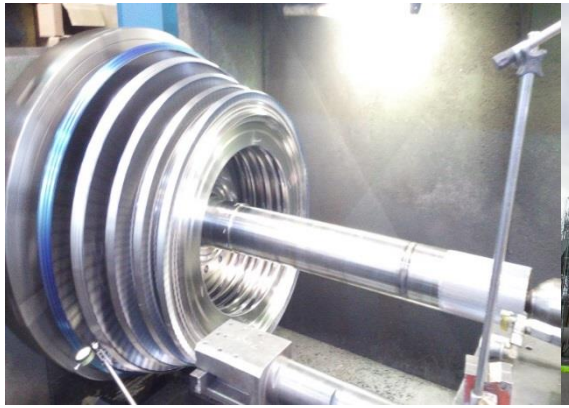
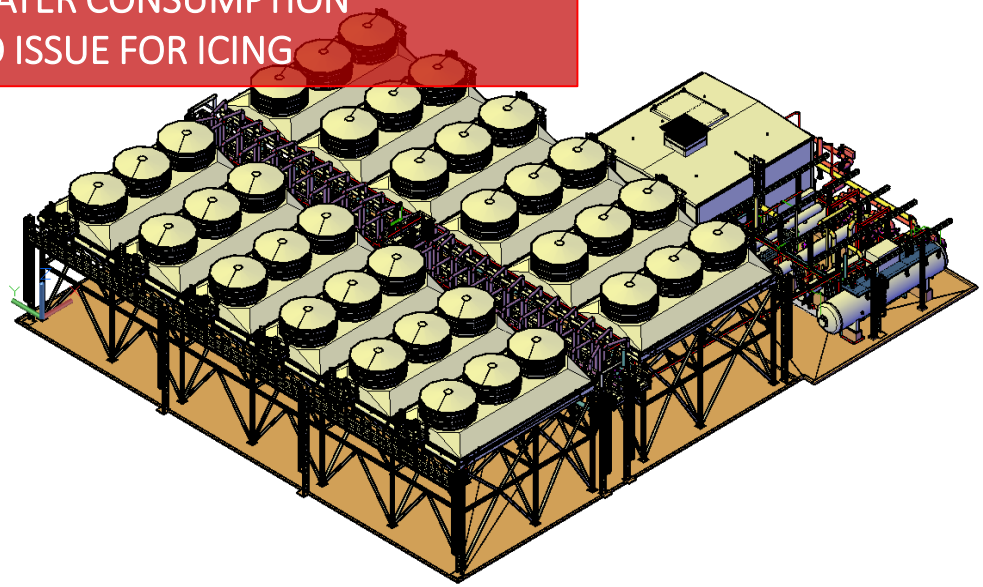
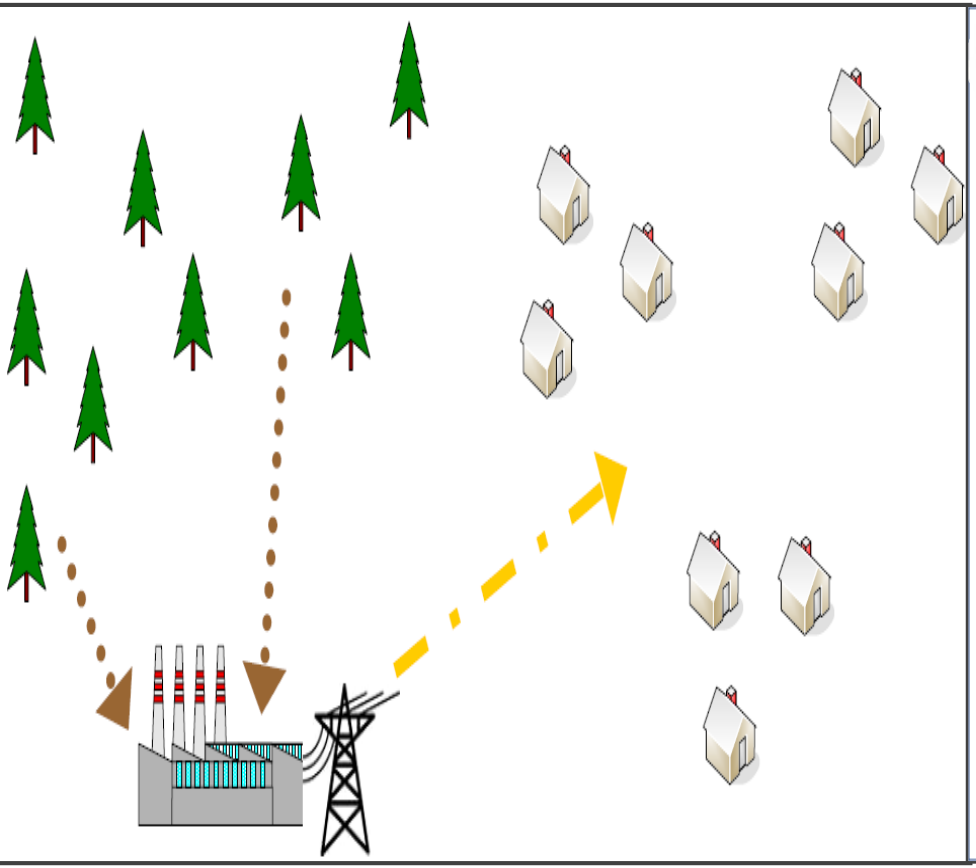
No Cooling Water Needed, No Icing

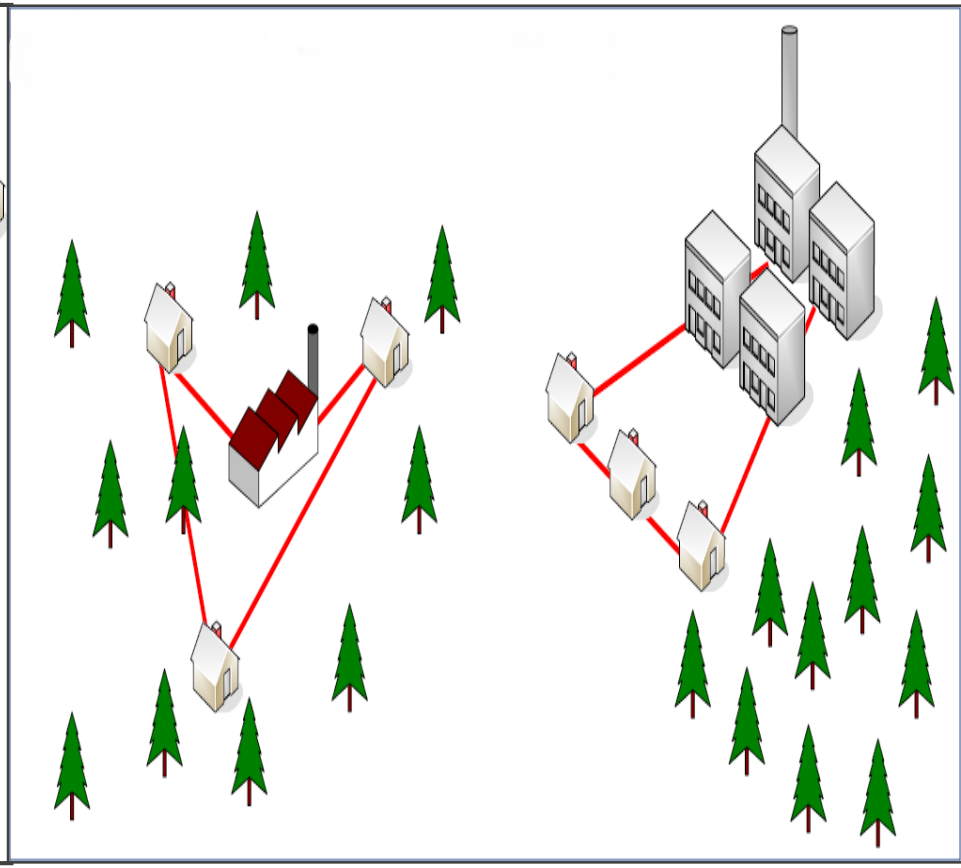


OVER 10 PLANTS ALREADY IN OPERATION
NO COOLING CIRCUIT NEEDED
NO WATER CONSUMPTION
NO ISSUE FOR ICING



Biomass Energy: Centralized vs Distributed Electric Power





Centralized

- Optimized Electric Efficiency
- Low total Energy Efficiency (< 40%; no use of heat)
- Higher Biomass Transport Cost & Transmission Losses

Distributed

- High Total Energy Efficiency (CHP)
- Higher Specific Investment Cost
- Low Biomass Transport Cost & Transmission Losses

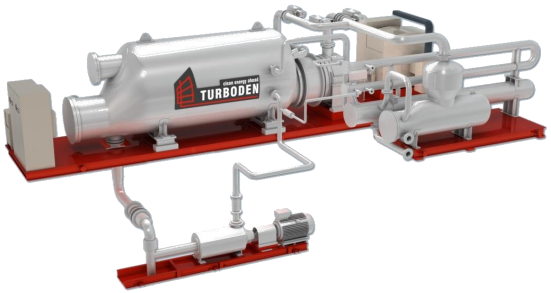
ORC for Cogeneration and District Heating

HEAT SOURCE

biomass combustion,
waste incinerator..

Biomass

Waste to energy



ELECTRIC POWER

DISTRICT HEATING

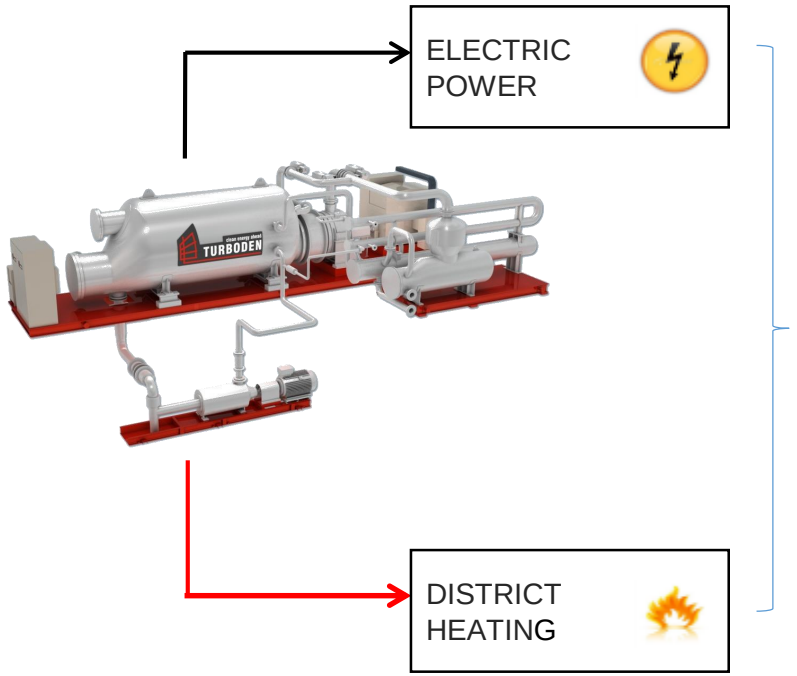
District Heating Example (grid connected)

Dalhousie University

- **Site:** Halifax, Nova Scotia, Canada
- **ORC Unit:** Turboden 10 CHP
- **Electric power:** 1 MW
- **Commissioning Date:** Expected Nov 2017

Project description

First ORC Combined Heat and Power application for a University Campus. ORC recovers Heat from a Biomass Thermal oil Boiler fed by Wood residuals and supplies both Electricity and Hot water for District Heating application.



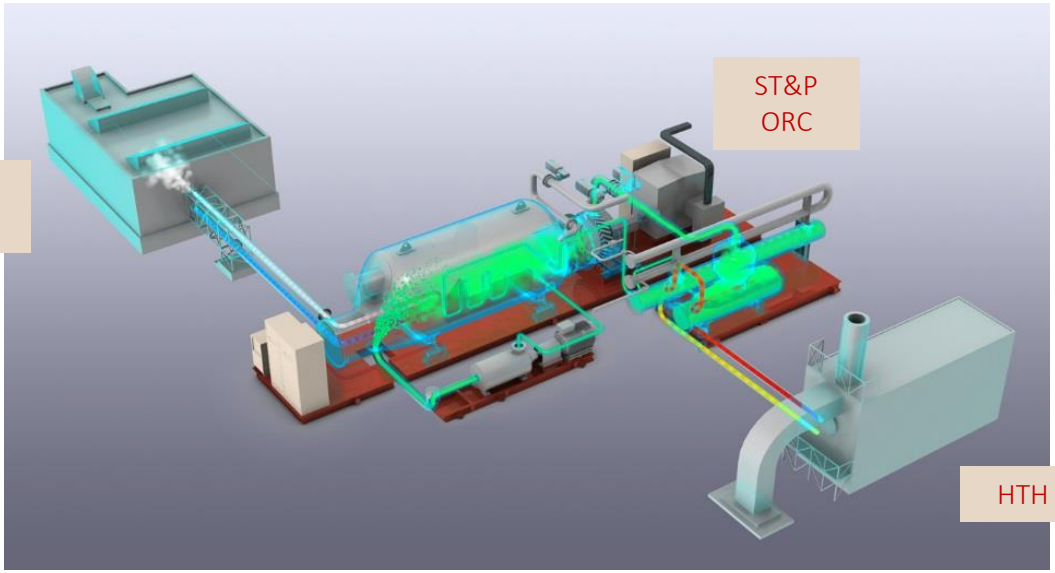
ORC Island Mode for Remote Communities

- Grid Code Analysis Requirement.
- Electrical stability study.
- Synchronous Electric Generator.
- ORC Start-Up (Black Start):
  - GENSETs are necessary to supply all the ancillaries
  - of the ORC
  - of the Heat Source (Biomass Boiler, Thermal oil pumps)
  - of the Heat Dissipation System (Cooling towers or Air Condenser)
  - It is necessary to synchronize GENSETs with the ORC after the ORC start-up
- ORC Start-Up (with presently installed generators):
  - Manage the overall Load Sharing with the Local Grid (a Droop strategy is Required)

Steam & Power ORC (1/4)

FUEL | POWER | STEAM

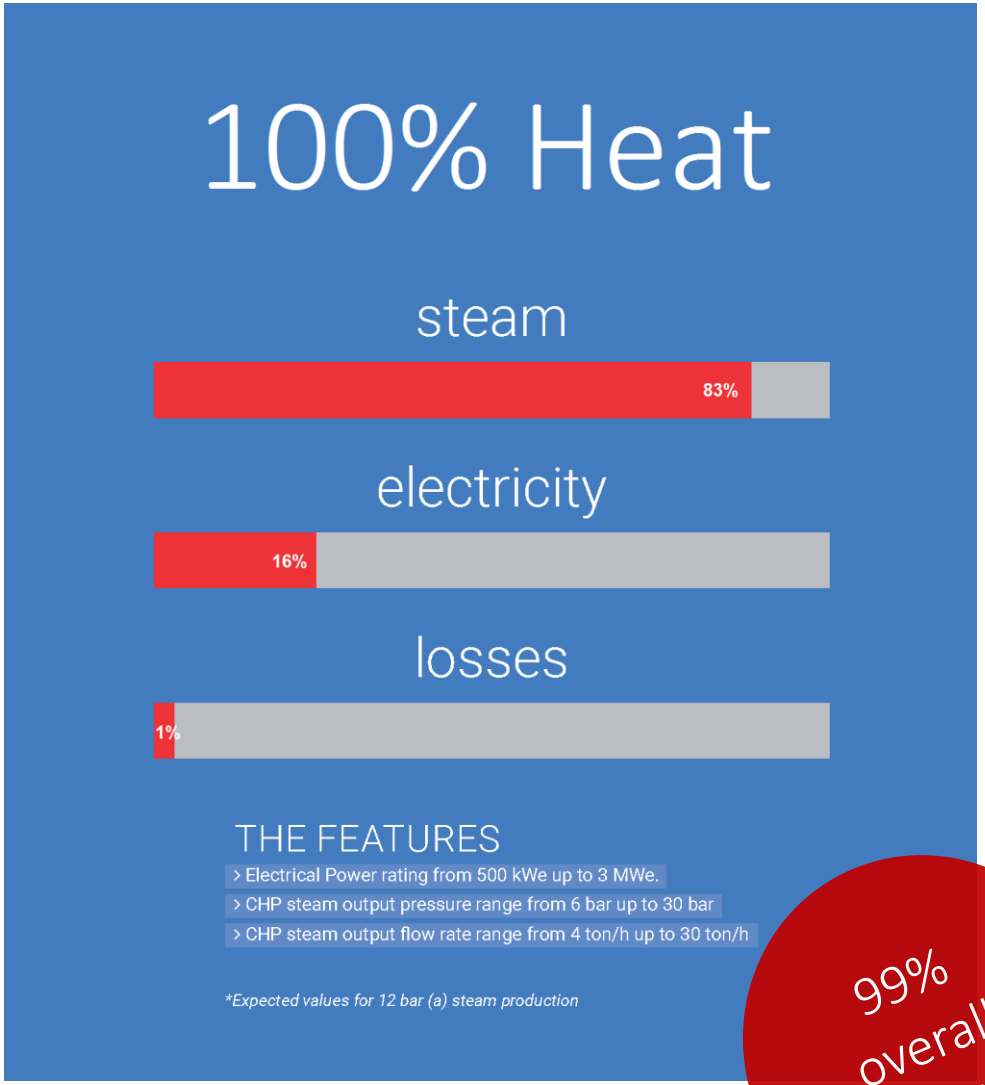
ST&P ORC technology can be applied for CHP, using a **Fuel (conventional or renewable)** to generate Electricity and Steam, directly exploitable in Manufacturing Processes.



ST&P Turnkey Solutions

Turboden proposes ST&P ORC system as a **turnkey CHP** system, together with Bono Sistemi, an Italian company, leader in the design and manufacturing of High Temperature thermal oil boiler.

Steam & Power ORC (2/4): Performance and Features



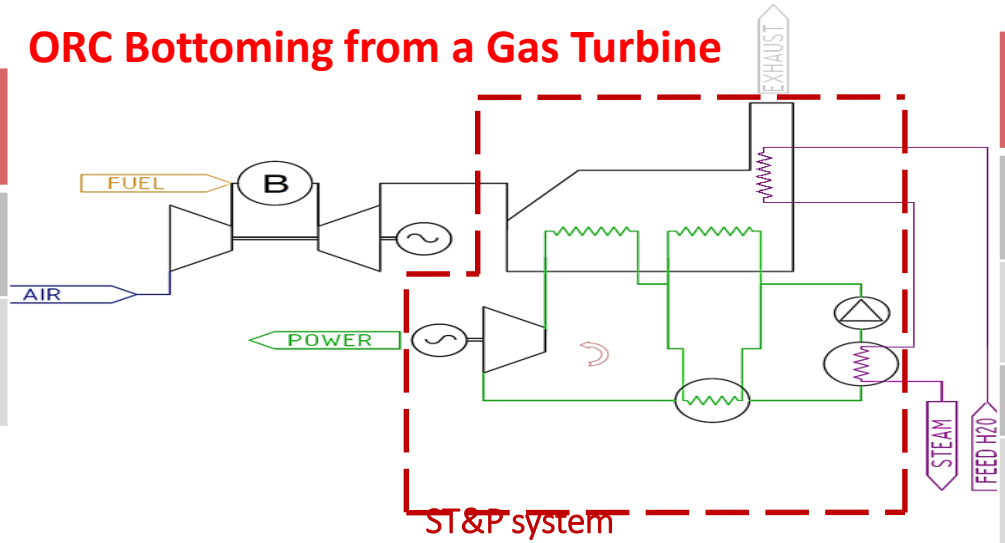
Steam & Power ORC Advantages

- High total Efficiency (99%).
- Focusing on Steam Output.
- High Availability.
- High Flexibility to Partial Load Operation down to 20%.
- Low O&M Cost.
- Fuel Flexibility.
- Modularity.
- Outdoor installation.
- Island Operation.
- Combined with other CHP technologies, if required

Steam & Power ORC (3/4): Configurations

GT + HRSG	
El. Efficiency	30 %
Steam Gen. Efficiency	52 %

ORC Bottoming from a Gas Turbine

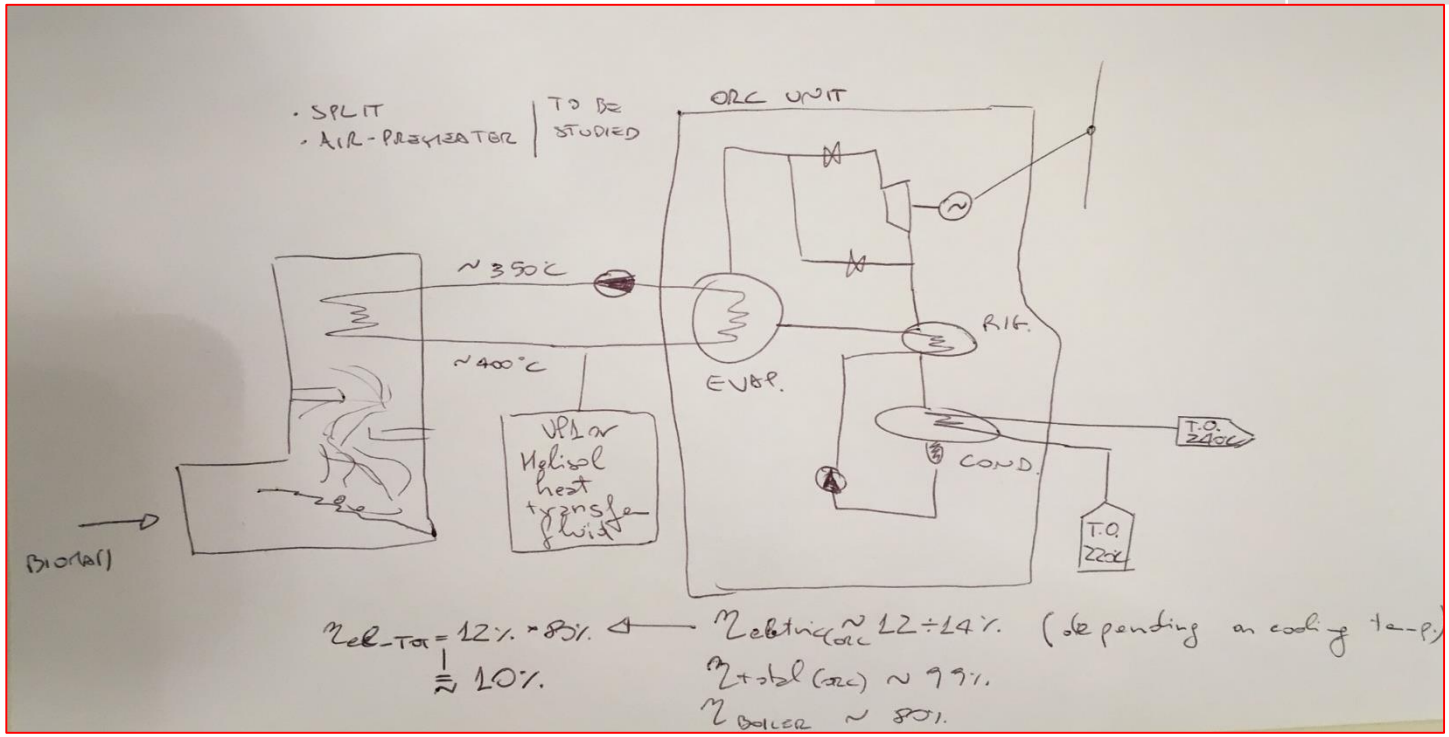


GT + ST&P	
Electrical Output	+15/20 %
Steam Output	-10/15%
Electrical Efficiency	35.5 %
Steam generation Efficiency	46 %

2 Thermal oil Cycles:

-1 for ORC Heat Source

-1 from the ORC to the Heat User (i.e. Kiln Dry Lumber)

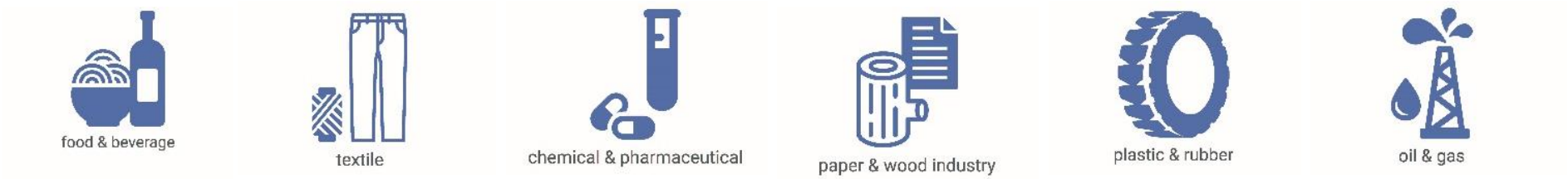


Steam & Power ORC (4/4): Manufacturing Process CHP

At Your Service

Steam & Power ORC system was conceived to satisfy energy requirements of many manufacturing processes requiring **Electricity** and relevant amount of **medium Pressure Steam.**

(or alternative high temperature heat carrier like thermal oil or pressurized water)



More Energy No Losses

Effective CHP systems satisfy directly the Thermal requirement of the **manufacturing process.** ST&P ORC does it, producing thermal energy in the form of **steam** and **minimizing losses**.

Just Steam & Power

ST&P ORC produces **Electricity & Steam without hot water to be exploited.**

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THANK YOU

FOR YOUR ATTENTION

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