The experience of Turboden in the region

Francesca Ettorre – Institutional Relations Department

Hungary, Budapest, 21-24 June 2016
About Us

Turboden is a leading European company in development and production of ORC (Organic Rankine Cycle) turbogenerators. This state-of-the-art equipment generates heat and power from renewable sources and heat recovery in industrial processes.

The company was founded in 1980 in Milan by Mario Gaia, Associate Professor at Politecnico di Milano, teaching Thermodynamics, Renewable Energy and specifically studying ORC systems. At present Prof. Gaia is Honorary Chairman. A number of his former students are key persons in the Company and the whole Company is permeated by innovative and research oriented spirit.

Turboden has always had a single mission: to design ORC turbogenerators for the production of heat and electrical power from renewable sources, while constantly striving to implement ORC technical solutions.

In 2009, Turboden became part of UTC Corp., a worldwide leader in development, production and service for aero engines, aerospace drive systems and power generation gas turbines, to develop ORC solutions from renewable sources and waste heat worldwide.

In 2013 UTC exits the power market forming strategic alliance with Mitsubishi Heavy Industries.

In 2013 Mitsubishi Heavy Industries acquires from UTC Pratt & Whitney Power Systems (now PW Power Systems, Inc.) and the affiliate Turboden.

Today Turboden S.r.l. and PW Power Systems, Inc. are MHI group companies to provide a wider range of products and services for thermal power generation systems.

35 Years of Experience

1980 - Founded by Mario Gaia, professor at Politecnico di Milano

1998 – First ORC biomass plant in Switzerland (300 kW)

1990's – First ORC projects in solar, geothermal and heat recovery applications

2000's - ORC biomass plants in Europe

2009 - United Technologies Corp. (UTC) acquires the majority of Turboden’s quotas. PW Power Systems supports Turboden in new markets beyond Europe. **100 plants sold**

2013 - MHI acquires the majority of Turboden. Italian shareholders stay in charge of management

Today - Over 300 plants in the world, **240 in operation**, 200 employees, ~100 M€ turnover (2012)
What we do

Turboden designs, develops and maintains turbogenerators based on the Organic Rankine Cycle (ORC), a technology for the combined generation of electric power and heat from various renewable sources, particularly suitable for distributed generation.

➢ **Turboden solutions** from 200 kW to 15 MW electric per single unit
## Turboden ORC a proven worldwide experience

More than 8 million hours of operation cumulated and 7.800 GWh produced

### Application

<table>
<thead>
<tr>
<th>Application</th>
<th>Size</th>
<th>Plant in Operation</th>
<th>Under Construction</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MW</td>
<td>no.</td>
<td>MW</td>
<td>no.</td>
</tr>
<tr>
<td>Solid Biomass</td>
<td>0.2 - 6.5</td>
<td>234</td>
<td>274.1</td>
<td>45</td>
</tr>
<tr>
<td>Geothermal</td>
<td>0.5 – 16.5</td>
<td>7</td>
<td>27.8</td>
<td>3</td>
</tr>
<tr>
<td>Solar thermal power</td>
<td>0.1 – 2.0</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Heat Recovery</td>
<td>0.5 – 9.0</td>
<td>20</td>
<td>35.3</td>
<td>6</td>
</tr>
<tr>
<td>Waste to Energy</td>
<td>0.5 - 5.3</td>
<td>9</td>
<td>20.3</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total Turboden Plants</strong></td>
<td><strong>260</strong></td>
<td><strong>342.7</strong></td>
<td><strong>55</strong></td>
<td><strong>122.3</strong></td>
</tr>
</tbody>
</table>

### Country

<table>
<thead>
<tr>
<th>Country</th>
<th>Plants</th>
<th>Country</th>
<th>Plants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>91</td>
<td>Balkans</td>
<td>12</td>
</tr>
<tr>
<td>Germany</td>
<td>82</td>
<td>Baltics</td>
<td>20</td>
</tr>
<tr>
<td>Austria</td>
<td>31</td>
<td>CIS</td>
<td>11</td>
</tr>
<tr>
<td>Eastern Europe</td>
<td>21</td>
<td>Rest of the world</td>
<td>47</td>
</tr>
</tbody>
</table>

Strong Turboden experience in the biomass field

Copyright © – Turboden S.r.l. All rights reserved

Last Update: May 2016
Turboden ORC in biomass application

By application

- District heating
- sawmill and wood industry
- pellet
- CCHP*
- panel industry
- power only

By size

- 0.2 - 1 MW
- 1-2 MW
- 2-3 MW
- > 3 MW

* Combined Cooling Heating Power

BIOMASS REFERENCES

<table>
<thead>
<tr>
<th>Description</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combined Heat and Power (CHP)</td>
<td>158</td>
</tr>
<tr>
<td>CCHP* in buildings</td>
<td>5</td>
</tr>
<tr>
<td>Other</td>
<td>116</td>
</tr>
<tr>
<td>TOT.</td>
<td>279</td>
</tr>
</tbody>
</table>
ORC Plant in a Process of Cogeneration from Biomass

FUELS

- Wood biomass
- Other biomass (green cuttings, cotton residues, rice husk, etc.)
- Waste material

Turboden ORC units can also be fed with saturated vapor or superheated water.
Cogeneration with ORC for district heating: some references

Ludwigsburg (Germany)
Started up: November 2009
Fuel: wood chips & green cuttings
Electric power generated: 2.1 MW
Thermal power generated: ~ 10 MW
Water temperature: 60° - 90° C

Ostrow Wielkopolski (Poland)
Started up: September 2007
Fuel: wood chips
Electric power generated: ~ 1.8 MW
Thermal power generated: ~ 8 MW
Water temperature: 60° - 85° C

Rechytsa (Belarus)
Started up: June 2011
Fuel: peat briquettes, wood chips
Electric power generated: 2 x 2.2 MW
Thermal power generated: 19 MW
Water temperature: 60° - 90° C

Heat to 20 km local district heating
Heat to 50 km municipal district heating
Power production from agricultural residues

Pavia (Italy)
Started up: December 2006
Fuel: rice husk
Electric power generated: 600 kW
Thermal power generated: 2.8 MW
Thermal use: parboiled rice production

General Santos (The Philippines)
Under construction
Fuel: corn cob/rice husk (210 ton/day)
Electric power generated: ~ 5 MW
Thermal power generated: 25 MW

Bursa (Turkey)
Started up: May 2015
Fuel: olive husk gasified in a proper gasifier coupled with a thermal oil boiler
Electric power generated: 250 kW
Thermal power generated: 1 MW
Thermal use: industrial process (treatment of black water)

Same concept applicable to countries with large availability of straw (Ukraine..), cotton residues (Uzbekistan..) and other agricultural residues
Greenhouses

- Greenhouses
- BIOMASS POWERED BOILER
- ORC
- Electric power
- Cold water
- Hot water
- Tomatoes greenhouse heating

Turboden reference

Alperstedt - Germany
Fuel: wood chips
Electrical production: ~ 2 MW
Thermal power: ~ 8.2 MW
Thermal use: greenhouses heating
Start-up: December 2006
Wood Pellet Production

TRUNKS → BARKING → CHIPPING → MILLING → SELECTION/SORTING → BELT DRYER → PELLET READY TO BE PACKAGED

Biomass powered boiler → Thermal oil → ORC → Electric power

Suitable granulometry UR 40%

Pellet → PELLET MAKING PRESS → DEDUSTING/SELECTION/REFINING

Suitable granulometry UR < 13%

Wood Pellet Production Turboden reference

Novska - Croatia
Fuel: wood chips
Electrical production: 999 kWe
Thermal power: 4 MWth
Thermal use: drying belt in pelletization process
Start-up: February 2014
Sawmills

TRUNKS → SELECTION → BARKING → PROCESSING

PRODUCT ← PACKAGING ← DRYING

Biomass powered boiler

Thermal oil

ORC

Electric power

bark → sawdust

cold water

hot water

Turboden reference

Vrbovsko - Croatia
Fuel: wood chips
Electrical production: **1.8 MWe**
Thermal power: **7.8 MWth**
Thermal use: timber drying kilns
Start-up: May 2016
MDF Panels production

**Gebze (Turkey)**

Client: Kastamonu Entegre
Started up: November 2014
Fuel: waste biomass from the process
Electric power generated: **955 kW**
Thermal power generated: **5.5 MW**
Thermal power application: **industrial process (production of MDF panels)**
Trigeneration or Combined Cooling Heating Power (CCHP)

- BIOMASS
- BIOMASS POWERED BOILER
- ORC
- ELECTRIC POWER
- DISTRICT HEATING
- COOLING SYSTEM
- USE IN PUBLIC BUILDING, HOTEL, ...

Thermal oil

Hot water

Cold water

Cold water
CCHP reference plants in buildings

Television studios Sky, West London (UK)
- Started up: November 2011
- Fuel: waste clean wood
- Electric power generated: ~ 1 MW
- Thermal power generated: ~ 4.2 kW
- Thermal power application: space heating/cooling

Heathrow Airport, London
- Started up: May 2014
- Fuel: waste clean wood
- Electric power generated: 1.8 MW
- Thermal power generated: 7.8 MW
- Thermal power application: space heating/cooling

Hotel and resort, Arlamow (Poland)
- Started up: February 2012
- Fuel: virgin wood chips
- Electric power generated: 1.3 MW
- Thermal power generated: 5.4 MW
- Thermal power application: 2.7 MWth heating as hot water for hotel
Conclusion: turning residues into local resources

- Valorization of local resources in the agricultural and agribusiness sectors
- Diversification of energy mix
- Development of a local supply chain & job creation
- Towards an effective zero waste and circular economy
Thanks for your attention

Francesca Ettorre – francesca.ettorre@turboden.it
+39 030.3552.001

Visit us at:
Turboden website: www.turboden.eu
Official YouTube Channel: https://www.youtube.com/user/TurbodenItaly
Back up slides
Turboden – a Group Company of MHI

Mitsubishi Heavy Industries is one of the world’s leading heavy machinery manufacturers, with consolidated sales of over $33 billion (in fiscal 2014).

Foundation July 7, 1884

**Energy & Environment**

Providing optimal solutions in the energy-related fields of thermal power, nuclear energy and renewable energy in different environmental areas and for chemical plants & other industrial infrastructures elements.

**Machinery, Equipment & Infrastructure**

Providing a wide range of products that form the foundation of industrial development, such as machine tools, material handling, construction machinery, air-conditioning and refrigeration systems.

**Commercial Aviation & Transport Systems**

Delivering advanced land, sea and air transportation systems, including civilian aircraft, commercial ships and transit networks.

**Integrated Defense & Space Systems**

Providing advanced land, sea and air defense systems, including naval ships, defense aircraft, launch vehicles and special vehicles, as well as space-related services.
Organic Rankine Cycle: concept

**Cycle**
- it is a thermodynamic cycle

**Rankine**
- it is theoretically given by 2 isobar and 2 adiabatic thermodynamic transformations

**Organic**
- it exploits an organic working fluid

**The principle** is based on a turbogenerator working as a normal steam turbine to transform thermal energy into mechanical energy and finally into electric energy through an electric generator. Instead of the water steam, the ORC system vaporizes an organic fluid, characterized by a molecular mass higher than water, which leads to a slower rotation of the turbine and to lower pressure and erosion of the metallic parts and blades.

**Efficiency**: 98% of incoming thermal power is transformed into electric power (around 20%) and heat (78%), with extremely limited thermal leaks, only 2% due to thermal isolation, radiance and losses in the generator. The electric efficiency obtained in non-cogeneration cases is much higher (more than 24% of the thermal input).
Water vs High Molecular Mass - Working Fluid

- **Water**
  - Small, fast moving molecules
  - Metal parts and blade erosion
  - Multistage turbine and high speed with mechanical stress

- **High molecular mass fluid**
  - Large flow rate
  - Larger diameter turbine with high efficiency of the turbine (85-90%)
  - No wear of blades and metal parts
  - Slow rotation speed and few stages (2-6)
ORC provides significant advantages as compared to steam

### Thermodynamic features and consequences
- High enthalpy drop
- Superheating needed
- Risk of blade erosion
- Small enthalpy drop
- No need to superheat
- No supercritical pressure
- No risk of blade erosion

### Operation and maintenance costs
- Water treatment required
- Highly skilled personnel needed
- High pressures and temperatures in the cycle
- Non-oxidizing working fluid with no corrosion issues
- Minimum personnel and O&M (1)
- Completely automatic (2)
- No blow down
- High flexibility and good performances at partial load
- High availability (average >98%)
- Possibility to work at low temperatures (90+°C)

### Other features
- Convenient for large plants and high temperatures
- Low flexibility with significantly lower performances at partial load
- Minimum personnel and O&M (1)
- Completely automatic (2)
- No blow down
- High flexibility and good performances at partial load
- High availability (average >98%)
- Possibility to work at low temperatures (90+°C)

(1) Standard maintenance: 2-3 days per year
(2) Fast start-stop procedure (ca. 20 min), partial load operation (down to 10% of nominal load)