Biomass CHP Systems using Organic Rankine Cycle from Europe to North America

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What we do: ORC turbogenerators

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

ORC solution from 300 kW to 15 MW
Basic ideas behind the technology

High efficiency and ease of operation for community size plants (up to 15 MW)

**Compact solution:** shop pre-assembled and delivered to the installation site

**Working fluid:** suitable organic fluid to optimize performances even at low temperatures.
Advantages of Turboden ORC vs Steam turbines

ORC: a technology for significant O&M savings

Steam Rankine Cycle

- High enthalpy drop
- Superheating needed
- Risk of blade erosion
- Water treatment required
- Specialized personnel needed
- High pressures and temperatures
- Convenient for plants > 10 MW
- Low flexibility
- Lower performances at partial load

Organic Rankine Cycle (ORC)

- Small enthalpy drop
- No need to superheat
- No risk of blade erosion
- Non oxidizing working fluid
- Minimum personnel and O&M\(^{(1)}\)
- Automatic/self regulated\(^{(2)}\)
- High flexibility and good performances at partial load
- More than 250 references worldwide in biomass plants

(1) Standard maintenance: 2-3 days per year
(2) Fast start-stop procedure (about 20 min.), partial load operation (down to 10% of nominal load)
One of the key points in the success of ORC technology is the capability to adapt to load variation easily and quickly.

"Flexible and Automatic"

Part load operation down to 10% of nominal load.
Mantains 90% of cycle efficiency down to 50% of loading.

Turboden ORC units automatically adapt the cycle at the ambient temperature variations.

**Cooling water temperature effect on cycle efficiency**

**ORC Partial Load Efficiency**

- Gross electric efficiency
- Water outlet temperature from condenser [°C]
- Actual Load / Nominal Load

- Design Point

Flexible and Automatic
ORC Plants – Performance in CHP

- **100%** Thermal power from thermal oil
- **78%** Thermal power to heat users
- **20%** Gross electric power
- **2%** Thermal losses (insulation and generator losses)

- **Gross electric efficiency:** up to 20%
- **Overall energy efficiency:** 98%
Turboden ORC Application in CHP

Biomass fuels

- Wood biomass: sawdust, woodchips, bark, treated wood
- Other biomass: dried sewage sludge, green cuttings, rice husks, vinasse and vine cuttings, wood industry waste material etc...
- Other organic waste material

Heat Consumers

- District Heating networks
- Timber drying in sawmills
- Saw dust drying in wood pellet factories
- Pannel Board (OSB/MDF) Producers
- Air pre-heating in MDF industry
- Refrigeration (Tri-generation)
- Wine industry
- Greenhouses
Turboden References in Biomass and in CHP

299 Turboden ORC plants in the World

255 plants in Biomass in 32 countries

By Applications:

- **128 CHP District heating**
  - From 300 kW to 3 MW

- **109 CHP in wood industry** (Sawmills, pellet industry, MDF, OSB, etc.) and agroindustry (rice husks, etc.)
  - From 200 kW to 6 MW

- **5 CCHP (trigeneration) in public buildings** (Combined Cooling Heating & Power)
  - From 600 kW to 1.8 MW

- **13 Power only**
  - From 600 kW to 13 MW

80% of Turboden plants are Biomass CHP

January 2015
Our CHP plants in Europe

Austrian business model

- Small villages (mountain area) → distributed generation
- Thermal energy needed (district heating)
- Biomass of good quality available on site (sawmill waste wood, forest thinning, etc.)
- No needs of certified steam engineer
- Emphasis on renewables

Ideal conditions for small/middle size (300 kW÷3 MW) ORC CHP biomass power plants

Austria is the best European example of biomass utilization, with 13% of the energy needs covered by this source. Around 20% of households have heat and hot water from biomass.

Biomass CHP ORC units in Europe

<table>
<thead>
<tr>
<th>Country</th>
<th>Units</th>
</tr>
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<tbody>
<tr>
<td>Germany</td>
<td>73</td>
</tr>
<tr>
<td>Italy</td>
<td>59</td>
</tr>
<tr>
<td>Austria</td>
<td>30</td>
</tr>
<tr>
<td>Latvia</td>
<td>12</td>
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<tr>
<td>Spain</td>
<td>7</td>
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<td>etc...</td>
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First Germany and later Italy followed the successful Austrian model, thanks also to:

- High price of electricity
- Incentive for renewable energy (feed-in tariffs)

Strong growth of this market between 2005 and 2010
North American market - Canada

CANADA

Features/conditions

- Huge biomass potential 😊
- Competitive biomass cost 😊
- Long experience with thermal oil systems 😊 (many Konus systems in wood industry, etc.)
- Thermal energy needed 😊
- Strong interest in renewables 😊
- Forest industry important role 😊
- Low specific investment cost required 😞
- Low electricity price 😞

Key driver

- Minimum skilled personnel required
- Automatic, unattended operation
- Remote operator assistance provided
- High availability (>98%)
- Low O&M required

Lower OPEX

Advantage over the steam cycle especially at remote location or with high skilled personnel costs

7 plants in operation: 32 MW installed (6 are Biomass based)
(1 Biomass CHP plant under construction: 3 MW)
Reference in Pellet Application

**Model:** Turboden 30 CHP  
**Customer:** Canadian Forest Products (Canfor)  
**Start-up:** under construction, expected start-up QIV 2015  
**Location:** Chetwynd, BC, Canada  
**ORC electric power:** 3 MW  
**ORC thermal power:** 49.5 MMBtu/hr  
**Water temperature:** 158/230 F  
**Biomass boiler:** 60 MMBtu/hr  
**Pellet production capacity:** 100,000 t/y
**ORC characteristics:**

- **Model:** Turboden 8 CHP
- **Client:** Bioenergie Fernheizwerk Ritten coop
- **Start-up:** December 2008
- **Localisation:** Renon (BZ) – Italy
- **Fuel:** Wood chips
- **Electric power generated:** 990 kW
- **Thermal power application:** district heating
- **Thermal power generated:** 15 MMBtu/hr
- **Water temperature:** 140/194 F

**Context / Special Feature**

- **Total heat capacity production:**
  - 1 thermal oil biomass boiler: 17 MMBtu/hr
  - 1 gasoil boiler for consumption peak: 13.65 MBtu/hr
- **Separated district heating water circuit**
- **district heating:** about 10 miles (main root)
- **Nr. of customers on the grid:** about 250
- **Biomass storage for 7,000 cubic meter**
- **Planned upgrade:** a second biomass boiler (55 MMBtu/hr total thermal power for about 400 customers)
CCHP – Combined Cooling Heating Power

Biomass

Biomass Powered Boiler

Orc

Electric Power

District Heating

Cooling System

Absorption Chiller

Cold Water

Hot Water

Use in Public Building, Hotel, …

Thermal Oil

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Reference in UK, Heathrow Airport

Heathrow, London

Model: Turboden 18 CHP Split
Client: Morgan Sindall plc/Heathrow Airport
Started up: May 2014
Fuel: waste clean wood
Electric power generated: 1862 kW
Thermal power application: space heating/cooling
Thermal power generated: 26.8 MMBtu/hr
Water temperature: 131-203 F

Context / Special Feature
London main airport
Space Area: 20,000 m2, 100 000,m3
Thermal power: 75% heat and 25% to chiller
Thermal usage: heat and cooling to Terminals T2a and T2b, heat only to Terminal T5
Reduction of the building’s carbon footprint: 40%
Thermal oil boiler capacity: 33.4 MMBtu/hr
Cogeneration through ORC
Cooling power produced by chiller
Reference in Greenhouse Application

Context / Special Feature
Model: Turboden 18 CHP
Client: AGO AG - TOMSTAR
Start-up: December 2006
Localisation: Alperstedt, Germany
Fuel: Virgin wood chips
Electric power generated: 1,784 kW
Thermal power application: greenhouse heating
Thermal power generated: 26.73 MMBtu/hr
Water temperature: 140/194 F
Boiler supplier: Mawera

Context / Special Feature
Business: Vine tomatoes greenhouse
Greenhouse size: 1 MM square feet
Yearly production: 4,800 ton
Nominal thermal power: 27 MMBtu/hr
CO₂ saving: 14,000 ton/year
Website: www.tomstar.gbt-alperstedt.de
Proposed Business Plan for Biomass CCHP in US - Open for Discussion -

**Input data**

- Biomass CCHP (Trigeneration) Power Plant in Buildings (Hospital, Airport, Data Center, Campus, Prison etc).

**Project features**

- Biomass Fuel: Wood residual
- ORC unit proposed: Turboden 22 CHP

**Electric power output (net)**

- 2,000 kW

**ORC electric efficiency**

- ~ 20 %

**Thermal power output**

- 9,500 kW (50% used for the heating system and 50% for the cooling system to feed an absorption chiller)

**Thermal efficiency**

- ~ 80 %

**Biomass consumption**

- ~ 5 tons/hr

**Cooling water temperature (in/out)**

- 140/194 F

**Annual operating hours**

- 8,000

**Amount of investment estimation**

- ORC + Thermal oil Boiler: 8,500 kUSD
- BoP (engineering, civil work, contingency): 1,500 kUSD
- Overall CAPEX: 10,000 kUSD
- OPEX (ORC - BoP O&M): 80 kUSD

**CO₂ avoided**: 30,000 ton/year (from thermal and electrical production)

**Electricity price sensitivity analysis**

<table>
<thead>
<tr>
<th>Electricity price (c$/kWh)</th>
<th>PBT (years)</th>
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<tbody>
<tr>
<td>5</td>
<td>3.8</td>
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<tr>
<td>6</td>
<td>3.7</td>
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<td>7</td>
<td>3.5</td>
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<td>12</td>
<td>2.9</td>
</tr>
<tr>
<td>12.5</td>
<td>2.8</td>
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FIT in California
Over 30 years of experience in ORC turbogenerators

- **’60-’70**
  - 1976 – First prototype of a solar thermodynamic ORC

- **1980-1999**
  - 1980 – Prof. Mario Gaia founds Turboden to design and manufacture ORC turbogenerators
  - Turboden develops research projects in solar, geothermal, and heat recovery applications
  - 1998 – First ORC biomass plant in Switzerland (300 kW)

- **2000-2009**
  - Turboden installs CHP ORC biomass plants, especially in Austria, Germany, and Italy
  - Turboden plans to enter new markets, with focus on North America
  - First heat recovery applications

- **2009-2013**
  - 2009 – Turboden achieves 100 plants sold
  - United Technologies Corp. (UTC) acquires the majority of Turboden's quota. PW Power Systems supports Turboden in new markets beyond Europe
  - UTC exits the power market forming strategic alliance with Mitsubishi Heavy Industries
  - PW Power Systems becomes an MHI group company

- **2013…**
  - MHI acquires the majority of Turboden. Italian stockholders stay in charge of management
  - Today – About 300 ORC plants in 32 countries
Thank You for your attention!
Questions?

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