Small Scale CHP Using the Organic Rankine Cycle

Case Studies from Europe

Ilaria Peretti
Manager, Sales and Business Development for North America

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Biomass – Fuels & Applications

**FUELS**

- Wood biomass:
  - sawdust
  - woodchips
  - bark
  - treated wood

- Other biomass:
  - dried sewage sludge
  - straw
  - green cuttings
  - rice husk

- Waste material

- Waste recycling wood

**APPLICATIONS**

- Timber drying in sawmills
- Saw dust drying in wood pellet factories
- Air pre-heating in MDF industry
- District heating networks
- Refrigeration / air conditioning

**CHP**

for cogeneration and/or trigeneration

**Efficiency up to 20%**
Why Distributed Biomass-Fueled CHP?

- Sustainable & renewable: CO₂ neutral and re-growing fuel
- Local energy source: no dependence on volatile global fossil fuel markets
- Local base-load electric power: relief for congested transmission lines
- Impact on economy: uses a local supply chain and keeps energy revenues local
- Clean technology: small plants - easier permit

Graph source: “Der biologische geschlossene Kreislauf” www.biomasseverband.it (April 2010)
Biomass Energy: Centralized Electric Power

- optimized electric efficiency
- low total energy efficiency (< 40%; no use of heat)
- higher biomass transport cost & transmission losses

Graph source: Neil Harrison: „Wood burns: an urban myth?“ Presentation held at „International Biomass Conference“, Portland, OR, 2009
Biomass Energy: Distributed CHP

- very high total energy efficiency (CHP)
- higher specific investment cost
- low biomass transport cost & transmission losses

Graph source: Neil Harrison: „Wood burns: an urban myth?” Presentation held at „International Biomass Conference“, Portland, OR, 2009
Modular ORC Units Layout

- Condenser
- Regenerator
- Electric generator
- Pre-heater
- Evaporator
- Electric cubicles
- Feed Pump
- ORC turbine
ORC Plants – Performances

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

- Gross electric efficiency: up to 20%
- Overall energy efficiency: 98%
Co-generation for district heating networks

For district heating networks:
- DH-Water temperature: 176 F to 203 F
- Need of increase incentives for CHP plants
- Need of optimization of existing power plant

- Hot water for district heating network
- Production of green energy
- Automatic operation
- Low operational costs:
  - ✓ no shift work needed
  - ✓ adapting to heat demand
Turboden ORCs for district heating networks

INPUT - Thermal Oil
Thermal Power Input: 17.54 MMBtu/hr
Inlet/outlet Thermal oil Temperature: 572/464 F

OUTPUT - Hot Water
Thermal Power to Hot Water circuit: 13.92 MMBtu/hr
Inlet/Outlet Hot Water Temperature: 140/176 F

PERFORMANCES
Electric Power: 1 MWe
Yearly operation hours: 8,000
Heat demand analysis

Diagram yearly cumulated thermal power

Base load of DH = ORC’s OUT-thermal power

- ORC all time at nominal load
- Highest efficiency, about 20%
- Electrical production full power
Co-generation for district heating networks

- ORC reliable technology for power production: highly reliable
- Cogenerative solution (also trigeneration - CCHP) since more than 30 years
- Distributed power generation
- Green energy production: reduced emissions and increased efficiency → incentives & funds
- Optimization of existing power plants and ORC automatic operation:
  - adapting to thermal demand
  - low operational costs

* Turboden ORC units can also be fitted with saturated vapor or superheated water
**Reference: Bioenergie Fernheizwerk Ritten**

**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 pics: 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 (srm)
- **Planned upgrade:** a second biomass boiler (55 MMBtu/hr total thermal power for about 400 customers)
CCHP – Combined Cooling Heating Power
Example in Public building - TV Studios

**Context / Special Feature**

A/ Television studios, Sky headquarter in Europe
- As Europe’s first Carbon neutral media company
- Space Area: 8,600 square feet, 113,000 cubic feet
- Thermal power: 5% heat the building, 50% to chiller and 45% as heating to a district heating loop around the campus
- Reason for Tri-generation: biomass-fuelled combined cooling and heating (CCHP) power plant, reducing the building’s carbon footprint by at least 20 percent
- Planning driven, achieving 20% reduction in carbon and 20% usage of Renewable Energy

B/ Specificity CCHP
- Fuel: biomass
- Type of biomass: waste clean wood
- Boiler supplier: VAS
- Thermal oil boiler capacity: 17.5 MMBtu/hr
- Cogeneration through ORC
- Cooling power produced by chiller
- Chiller supplier: Carrier (PWPS) / Sanyo

C/ Energy management due to:
- Natural air ventilation and wind turbine

**ORC characteristics:**
- **Model:** Turboden 10 CHP Split
- **Client:** Clearpower Limited
- **Start-up:** 4th quarter 2011
- **Localisation:** Osterley, West London, UK
- **Electric power generated:** 968 kW
- **Thermal power application:** space heating/cooling
- **Thermal power generated:** 14 MMBtu/hr
- **Water temperature:** 155-194 °F
Greenhouses

- Biomas powered boiler
- ORC
- Thermal oil
- Electric power
- Green cuttings
- Cold water
- Hot water

TURBODEN
Clean energy ahead
Example of greenhouses 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](http://www.tomstar.gbt-alperstedt.de)
Case study

Analysis of a cogenerative biomass plant
Turboden 22 CHP
## Analysis: Hypotheses

Turboden 22 CHP  
Fixed feed in tariff (15 c$/kWh)  
*Variable cost of biomass*

<table>
<thead>
<tr>
<th>INPUT PARAMETERS</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric energy cost</td>
<td>10 c$/kWh</td>
</tr>
<tr>
<td>Thermal energy cost</td>
<td>3 c$/kWh</td>
</tr>
<tr>
<td>Plant own consumption (ORC excluded)</td>
<td>250 kW</td>
</tr>
<tr>
<td>Interest rate</td>
<td>5 %</td>
</tr>
<tr>
<td>ORC maintenance costs</td>
<td>25,000 $/year</td>
</tr>
</tbody>
</table>
## Analysis: Hypotheses

<table>
<thead>
<tr>
<th>COGENERATION WITH TURBODEN 22 CHP</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal power at the furnace*</td>
<td>50</td>
<td>MMBtu/hr</td>
</tr>
<tr>
<td>Boiler thermal power</td>
<td>41.01</td>
<td>MMBtu/hr</td>
</tr>
<tr>
<td>Net electric power from ORC</td>
<td>2,207</td>
<td>kW</td>
</tr>
<tr>
<td>Thermal power to the grid (at 194 F)</td>
<td>32.76</td>
<td>MMBtu/hr</td>
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<tr>
<td>Portion of thermal energy sold**</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>Plant own consumption (estimation)</td>
<td>250</td>
<td>kW</td>
</tr>
<tr>
<td>Yearly biomass consumption***</td>
<td>36,000</td>
<td>tons</td>
</tr>
<tr>
<td>Net electrical power sold to the grid</td>
<td>1,957</td>
<td>kW</td>
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<tr>
<td>ORC cost</td>
<td>2,628,000</td>
<td>$</td>
</tr>
<tr>
<td>Total investment (estimation)</td>
<td>13,000,000</td>
<td>$</td>
</tr>
</tbody>
</table>

* Assuming 82% boiler efficiency
** Assuming 8,000 working hours a year, the overall thermal power produced results in 262,000 MMBtu per year; it is assumed that 50% (equivalent to 4,000 hours a year – i.e. 131,000 MMBtu per year) is sold and 50% dissipated
*** Assuming 17 MMbtu/ton biomass HHV
Example: with feed in tariff (15 c$/kWh)

Turboden 22 CHP

Payback Time (years)

Biomass Cost ($/ton)
Thank you for the attention!

Ilaria Peretti
Manager, Sales and Business Development for North America
ilaria.peretti@turboden.it