Turboden: ORC Solutions for Cogeneration and District Heating

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Workshop on Energy Efficiency in Buildings and Advanced District Heating

Kiev, 23 March 2015
More than 30 Years in ORC

- 1980 – Prof. Mario Gaia founds Turboden to design and manufacture ORC turbogenerators
- Turboden installs 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 – 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
- MHI acquires the majority of Turboden. Italian quotaholders stay in charge of management

- 1976 – First prototype of a solar thermodynamic ORC
- 2000-2009
- 2009-2013
- 2013...
- 2015...

More than 300 plants in 32 countries and 410 MW installed
## Turboden ORC Plants in the World

<table>
<thead>
<tr>
<th>Application</th>
<th>Size (MW)</th>
<th>Plants (MW)</th>
<th>Countries</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biomass</strong></td>
<td>0.2 - 8</td>
<td>218</td>
<td>• Germany (74)</td>
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<td></td>
<td></td>
<td>• Italy (68)</td>
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<td>• Austria (29)</td>
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<td>• Poland (11)</td>
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<td>• Other (75)</td>
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<tr>
<td><strong>Waste to Energy</strong></td>
<td>0.5 – 5.3</td>
<td>7</td>
<td>• France (2)</td>
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<tr>
<td></td>
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<td>• Italy (2)</td>
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<td></td>
<td>• Belgium (1)</td>
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<td></td>
<td></td>
<td></td>
<td>• Other (4)</td>
</tr>
<tr>
<td><strong>Heat Recovery</strong></td>
<td>0.5 - 7.0</td>
<td>16</td>
<td>• Italy (10)</td>
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<td></td>
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<td>• Germany (4)</td>
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<td>• Romania (2)</td>
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<td>• Other (8)</td>
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<tr>
<td><strong>Geothermal</strong></td>
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<td>6</td>
<td>• Germany (4)</td>
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<td>• Austria (1)</td>
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<td>• Italy (1)</td>
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<td></td>
<td></td>
<td></td>
<td>• Other (3)</td>
</tr>
<tr>
<td><strong>Solar Thermal Power</strong></td>
<td>0.6 - 2</td>
<td>3</td>
<td>• Italy (3)</td>
</tr>
</tbody>
</table>

**Total Turboden Plants**: 0.2 - 8 MW, 247 plants, 55 under construction

Last update: March 2015
Turboden ORC applications and advantages

**Advantages**

- Low temperatures
- Simple start up procedures
- High availability
- Partial load operation down to 10% of nominal power
- Low operation&maintenance requirements

**ORC units**: from 200 kW to 15 MW
ORC significant advantages *versus* steam turbine

**Thermodynamic features**

- High enthalpy drop
- Superheating needed
- Risk of blade erosion
- Small enthalpy drop
- No need to superheat
- No risk of blade erosion

**Operation and maintenance costs**

- Water treatment required
- Highly skilled personnel
- High pressures and temperatures
- Non oxidizing working fluid
- Minimum personnel
- Completely automatic

**Other features**

- Convenient for plants > 10 MWe
- Low flexibility
- Lower performances at partial load
- High flexibility and good performances at partial load
- Well proven in industrial heat recovery
ORC for cogeneration and district heating

HEAT SOURCE
biomass combustion, waste incinerator...

HEAT CARRIER
(thermal oil, hot water, saturated steam)

ELECTRIC POWER

ORC (Organic Rankine Cycle)

DISTRICT HEATING

hot water

Biomass

Waste to energy

ORC for cogeneration and district heating

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Turboden ORC in biomass (cogeneration, trigeneration, buildings)

By applications:
- sawmill and wood industry
- pellet
- CCHP*
- district heating
- panel industry
- power only

By sizes:
- 0.2 - 1 MW
- 1-2 MW
- 2-3 MW
- > 3 MW

BIOMASS REFERENCES:
- Cogeneration (Combined Heat and Power - CHP) 227
- CCHP in buildings 5
- Other 25
- TOTAL 257

* Combined Cooling Heating Power
Ludwigsburg (Germany)

Model: T2000

Started up: November 2009

Fuel: Wood chips & Green cuttings

Electric power generated: 2.100 kWe

Thermal power application: **district heating**

Thermal power generated: 9,85 MWth

Water temperature: 60 - 90° C

Context / Special Feature

Power to district heating: 12,6 MWth

Yearly **CO₂ savings**: 18.000 tons

Km of district heating: about **20 km**

Customers served: about 200

Biomass storage for 2.000 m3

Employees: 2, working mainly for wood logistics
Example of District Heating application

Ostrow Wielkopolski (Poland)

Model: T1500
Started up: September 2007
Fuel: Wood chips
Electric power generated: 1,750 kWe
Thermal power application: district heating
Thermal power generated: 8,2 MWth
Water temperature: 60 - 85° C

Context / Special Feature
Total heat capacity production: about 100 MWth
- 4 coal fired boilers (12 MWth each)
- 2 nat gas boilers (15 MWth each, peak load)
- 1 gas turbine (5,2 Mwel + 11,6 Mwel)
- 1 new thermal oil heater for ORC: 10 MWth

Shut-off of fifth coal fired boiler
Km of district heating: about 50 km
Example of district heating application

Varna, Bozen (Italy)

Model: T800
Started up: December 2008
Electric power generated: **800 kW**
Thermal use: **district heating**
Water temperature: 60 - 90 °C
Trigeneration - Combined Cooling Heating Power (CCHP) in buildings

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

Flow diagram:
- Thermal oil from BIOMASS to BIOMASS POWERED BOILER
- Hot water from ORC to DISTRICT HEATING
- Cold water from COOLING SYSTEM to ORC
- Cold water from BIOMASS POWERED BOILER to ORC
Example of CCHP in buildings - Offices and TV Studios

West London (UK)

Model: Turboden 10 CHP Split
Client: Clearpower Limited
End user: B SKY B
Started up: November 2011
Fuel: waste clean wood
Electric power generated: 964 kW
Thermal power application: space heating/cooling
Thermal power generated: 4142 kW
Water temperature: 75-90 °C

Context / Special Feature
Television studios Sky headquarter in Europe
Space Area: 800 m2, 3200m3
Thermal power: 5% heat the building, 50% to chiller, 45% as heating to a district heating loop around the campus
Reduction of the building’s carbon footprint: 20%
Thermal oil boiler capacity: 5140 kW
Cogeneration through ORC
Cooling power produced by chiller
Example of CCHP in buildings – 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: 7851 kW
Water temperature: 55-95 °C

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: 9790 kW
Cogeneration through ORC
Cooling power produced by chiller
Example of CCHP in buildings – Hotel and resort

Arlamow (Poland)

Model: Turboden 14 CHP Split
Client: Arlamow Hotel
Started up: February 2012
Fuel: virgin wood chips
Electric power generated: 1236 kW
Thermal power application: building heating/cooling
Thermal power generated: 5438 kWth
Water temperature: 80-95 °C

Context / Special Feature
Cooling devices: absorption chillers
Heating as hot water for hotel: 2,7 MWth
Examples of Waste to Energy applications

**Mirom - Belgium**

Heat recovery from **pressurized water** boiler in **waste incinerator**

*Retrofit of existing municipal solid waste incinerator with district heating system*

*Site*: Roeselare, Belgium

*Started up*: In operation since April 2008

*Source*: hot water at 180°C (back at 140°C)

*Cooling source*: air coolers

*ORC electric power*: 3 MW

*Net electrical efficiency*: 16.5%

*Availability*: >98%

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**Waste Gasifier – ITC Turkey**

Heat recovery from **exhaust gas** from the **waste gasifier**

*Site*: Ankara (Turkey)

*Start up*: First unit in operation since February 2014, second unit under construction

*Heat carrier*: thermal oil

*ORC electric power*: 2 ORC units of 5.5 MW each

*ORC efficiency*: up to 25% (power only)
Recovery of waste heat from industrial processes currently dissipated in the atmosphere

**ORC in heat recovery from industrial processes**

- **Industrial process**
- **Exhaust gases**
- **Heat exchanger**
- **Organic Ranking Cycle**
- **Civil and industrial thermal user**

- Cement industry
- Glass industry
- Steel industry
- etc.

**Electric energy**

**Thermal energy**
Reference papers & articles

Papers on biomass


Articles on BSkyB and Heathrow plants


• http://www.clearpower.ie/case-studies/bioenergy-solutions/case-study-2


• http://www.theengineer.co.uk/channels/policy-and-business/business-briefs/bskyb-and-heathrow-select-turboden-for-chp-plants/1012490.article

• http://professionalservices.morgansindall.com/projects/energy-infrastructure-project-uk/
Thank you for your attention!

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Back up slides
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.

Over 30 Years of Experience

1984 – 40 kW\(_{\text{el}}\) ORC turbo-generator for a solar plant in Australia

1987 – 3 kW\(_{\text{el}}\) ORC turbo-generator for a biomass plant in Italy

1988 – 200 kW\(_{\text{el}}\) ORC geothermal plant in Zambia

2008 – 3 MW\(_{\text{el}}\) ORC turbo-generator for heat recovery on a waste incinerator in Belgium

2009 – First 100 plants and first installed 100 MW\(_{\text{el}}\)

2010 – First plant overseas

2014 – Over 280 ORC plants in the world
Mitsubishi Heavy Industries is one of the world’s leading heavy machinery manufacturers, with consolidated sales of over $32 billion (in fiscal 2013).

**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.
Turboden ORC Plants in the World

**Biomass**
- In operation: 206
- Under construction: 44
- Total: 250

**Heat Recovery**
- In operation: 16
- Under construction: 6
- Total: 22

**Geothermal**
- In operation: 6
- Under construction: 2
- Total: 8

**Solar**
- In operation: 6
- Under construction: 2
- Total: 8

**Waste to Energy**
- In operation: 2
- Under construction: 2
- Total: 2


Update September 2014
The turbogenerator uses the hot temperature thermal oil to pre-heat and vaporize a suitable organic working fluid in the evaporator (8→3→4). The organic fluid vapor powers the turbine (4→5), which is directly coupled to the electric generator through an elastic coupling. The exhaust vapor flows through the regenerator (5→9) where it heats the organic liquid (2→8). The vapor is then condensed in the condenser (cooled by the water flow) (9→6→1). The organic fluid liquid is finally pumped (1→2) to the regenerator and then to the evaporator, thus completing the sequence of operations in the closed-loop circuit.
Why High Molecular Mass Working Fluid Instead of Water?

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

Organic Fluid
- Very large flow rate
- Larger diameter turbine
- No wear of blades and metal parts
Turboden strong points

R&D
- Participation in national & EU research programs
- Cooperation with EU Universities and Research Centres
- Thermodynamic cycle optimization
- Working fluid selection & testing
- Thermo-fluid-dynamic design and validation
- Implementation & testing of control/supervision software
- Many patents obtained

Sales/marketing
- Pre-feasibility studies: evaluation of technical & economical feasibility of ORC power plants
- Customized proposals to maximize economic & environmental targets

Design
- Complete in-house mechanical design
- Proprietary design and own manufacturing of ORC optimized turbine
- Tools
  - Thermo-fluid-dynamic programs
  - FEA
  - 3D CAD-CAM
  - Vibration analysis

Operations & manufacturing
- Outsourced components from highly qualified suppliers
- Quality assurance & project management
- In-house skid mounting to minimize site activities

Aftermarket service
- Start-up and commissioning
- Maintenance, technical assistance to operation and spare parts service
- Remote monitoring & optimization of plant operation
**Biomass**

Cogeneration plants with Turboden ORC can produce heat and electrical power from biomass with high efficiency and user friendly operation. The generated power usually ranges between 200 kW and 15 MW electric.
Biomass - sources and applications

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

Heat Consumers
- District Heating networks
- Timber drying in sawmills
- Sawdust drying in wood pellet factories
- MDF/PB Producers
- Refrigeration
- Greenhouses
- Wine industry
District Heating Networks

WITHOUT ORC

BIOMASS

BIOMASS POWERED BOILER

HEAT USER
cold water

hot water

WITH ORC

BIOMASS

BIOMASS POWERED BOILER

HEAT USER

Electric power
cold water

Thermal oil

hot water

ORC
Sawmills

TRUNKS → SELECTION → BARKING → PROCESSING

PRODUCT ← PACKAGING ← DRYING

BARKING PROCESSING

bark sawdust

cold water

hot water

Electric power

Thermal oil

BIOMASS POWERED BOILER

ORC

Sawmills

TRUNKS → SELECTION → BARKING → PROCESSING

PRODUCT ← PACKAGING ← DRYING

BARKING PROCESSING

bark sawdust

cold water

hot water

Electric power

Thermal oil

BIOMASS POWERED BOILER

ORC
Wood Pellet Production

- **BARKING**
- **CHIPPING**
- **MILLING**
- **SELECTION/SORTING**
- **AIR COOLING/DEDUSTING**
- **BELT DRYER**
- **PELLET MAKING PRESS**
- **DEDUSTING/SELECTION/REFINING**

**Suitable granulometry**
- UR 40%
- UR < 13%

**Power Sources**
- **Biogas**
- **Thermal Oil**
- **Electric Power**

**Cooling and Water**
- Suitability of water and gas (hot, cold, and thermal)

**Additional Processes**
- **TRUNKS**
- **Wood Pellet Production**
- **Pellet Ready to Be Packaged**
Figure: Proposed scheme for MDF plant with ORC cogeneration unit
Greenhouses

- Green cuttings
- Thermal oil
- Electric power
- Cold water
- Hot water

Biomass Powered Boiler

Greenhouses

Thermal Oil

O.R.C.
Reference projects - biomass for district heating

Biogenera SrL
Site: Calenzano, Florence (Italy)
Start-up: October 2009
Electric power generated: 800 kW
Thermal use: district heating
Water temperature: 70 - 90 °C
Example of District Heating applications

Zatec (Czech Republic)

Model: T1500 CHP Split

Started up: August 2010

Fuel: Wood chips

Electric power generated: 1.862 kWel gross

Context / Special Feature
Thermal power application: municipal district heating of Žatec
Thermal power generated: 7.851 kWth
Water temperature: 60 - 90° C
Example of cogenerative application

Rechytsa in Belarus – GG & GT

Model: 2 x TD 22
End user: GOMELENERGO
Start-up: June 2011
Localisation: Rechytsa – Belarus
Fuel: peat briquettes, wood chips
Electric power generated: 2 x 2200kWe
Thermal power application: district heating
Thermal power generated: 19 MWth
Water temperature: 60 - 90°C
Boiler supplier: Polytechnik

Context / Special Features

- Biomass-fueled thermal oil boiler: 2 x 12 MW thermal oil output power
- 2 x Turboden 2,2 MWe units: el. capacity 4,4 MWe
- Heat users: District heating
Reference projects Canada and USA

**Nechako Green Energy** (a subsidiary of Nechako Lumber)
- **Site:** Sawmill in Vanderhoof, BC, Canada
- **ORC Unit:** Turboden 22 CHP
- **Started up:** February 2013
- **Electric power generated:** 2 MW
- **Thermal power application:** hot water temperature (60-90 °C) for future belt dryer connection

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**West Fraser Timber**
- **2 Sites:** Chetwynd and Fraser Lake, BC, Canada
- **ORC Unit:** 4 x units Turboden 65 HRS (high efficiency - up to 26 %)
- **Electric power generated:** 13 MW each site (total of 26 MW)
- **Status:** Fraser Lake site in operation since November 2014, Chetwynd site under construction

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**Client: Manning Diversified Forest Products Ltd**
- **Site:** Manning, Alberta, Canada
- **ORC Unit:** Turboden 32 HRS (high efficiency - up to 26 %)
- **Electric power generated:** 3 MW
- **Started up:** February 2015

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**Client: Athens Energy LLC**
- **Site:** Athens – Maine, USA
- **ORC Unit:** Turboden 80 HRS
- **Electric power generated:** 8 MW
- **Status:** Under Construction
Heat Recovery
Turboden ORC can produce electricity by recovering heat from industrial processes, reciprocating engines and gas turbines. The power of Turboden turbogenerators in this application generally ranges between 200 kW and 15 MW electric.
Reference projects – heat recovery from industrial processes

**Cement industry**
Holcim Romania

Heat source: exhaust gas @ 360°C (PH) and hot air @ 250 °C (CC)
ORC electric power: ~ 4 MWe
Started up: July 2012 (4,200 working hours)
Availability: >98%

**Glass industry**
AGC Glass Europe

Heat source: gas @ 500°C from glass production process
Heat carrier: thermal oil
Cooling: water condenser + air-coolers
ORC electric power: 1.3 MWe
Started up: March 2012

**Steel industry**
NatSteel – TATA Group - Singapore

Heat source: exhaust gas from LFO combustion, @ 400 from Billet reheating furnace at steel rolling mill
Direct exchange between exhaust gas and working fluid
ORC electric power: 0.7 MWe
Started up: February 2013
WHAVES project (2013 – 2015)

Waste Heat Valorisation for more Sustainable Energy Intensive Industries

“successor” of the projects H-REII (2010-2012)
H-REII DEMO (2012-2014)

Objectives

- **Standardize** heat recovery systems from steel production process with ORC technology
- **Disseminate** results to other industrial sectors
- **Promote innovative funding models** of heat recovery from industrial processes
Low heating value gas turbine

- Russian Oil & Gas company
- Flare Gas: 3.5 MWe
- ORC Power: 1.8 MWe
- Burner + thermal oil circuit
- Start up: Q3 2014

**Heat recovery – Oil & Gas application**

- Boilers
- Gas turbine*

**Heat exchanger**
- Thermal oil

**Organic Rankine Cycle**
- 25% efficiency

- Cooling tower
- Water cooled condenser
- Air cooled condenser

Exhaust gases of flare gas burners in petrochemical plants

* Low heating value gas turbine
Heat recovery from Gas Turbines

Gas Compressor Station – Trans Gas

Heat recovery from Solar CENTAUR gas turbine in a Gas compressor station in Canada.
Gas turbine prime power: 3.5 MWe
Gas turbine efficiency: 28%
ORC electric power: 1 MWe
General contractor: IST
Final client: TransGas
Started up: November 2011

Gas Compressor Station

Heat recovery from Solar TITAN 130 gas turbine in a Gas Turbine Power Plant (GTPP) in Russia (Moscow region).
Gas turbine prime power: 15 MWe
Gas turbine efficiency: 30%
ORC electric power: 3 MWe direct exchange cogenerative solution
ORC thermal power 15 MWth for hot water at 90°C
General Contractor: Energo development LCC
Final Client: Polympex
Expected start up: Q4 2014
Example: heat recovery on open cycle gas turbines exhaust gases

Example: waste heat recovery projects in Saudi Arabia

<table>
<thead>
<tr>
<th>Facility</th>
<th>Saved energy ktoe/year</th>
<th>Saved CO₂ ktons/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas pipeline</td>
<td>80</td>
<td>430</td>
</tr>
<tr>
<td>Oil pipeline</td>
<td>45</td>
<td>240</td>
</tr>
<tr>
<td>Oil extraction - sea water injection facilities</td>
<td>85</td>
<td>450</td>
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<tr>
<td></td>
<td>210</td>
<td>1’120</td>
</tr>
</tbody>
</table>

* Referred to the gas turbine shaft power output

SOURCE: internal estimates, websites, press clippings
Example: exploitation of associated gas (currently flared)

Example: flare gas exploitation in Nigeria (2009)

- Nigeria overall
  - Saved energy: 1'530 ktoe/year
  - Saved CO₂: 8'170 ktons/year

- Shell’s footprint in Nigeria
  - Saved energy: 215 ktoe/year
  - Saved CO₂: 1’150 ktons/year

SOURCE: internal analysis on GE Flare Gas reduction Recent global trends and policy considerations
A huge potential resides in waste heat recovery on Oil & Gas infrastructures

Reference case:

**Germany Gas Transmission System Operator**

28 Gas Compressor Stations on 11,550 km network (1)

- Capacity factor considered: 45% (2)
- Total mechanical drive installed capacity: 990 MW

Equivalence power considered: 445 MW

- ORC recovery factor: 30%
- ORC potential: 135 MWe

- Equivalent operating hours: 6,000 h/y (3)
- Energy savings: 800 GWhe → 48 M€/y (4)
  or 208 million cubic meter of natural gas (5)
- Emission avoided: 320,000 t CO₂/y (6)

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(1) Source ENTSOG Ten Year Network Development Plan 2011-2020
(2) Assuming 3 gas turbine per site. Average power: 1 nominal (100%) + 1 partial load (35%) + 1 backup (0%)
(3) Assuming seasonal fluctuations in GCS operation, ORC availability > 95%
(4) Assuming an electricity value of 60 €/MWh
(5) Assuming a consumption of 260 mc of natural gas per MWh of power generated
(6) Assuming an average emission factor of EU power generation plants of 400 t CO₂ per GWh (source IEA 2013)
Geothermal
ORC technology is particularly suitable for the exploitation of medium to low enthalpy sources. Cost-effective solution with power output up to 15 MW_{el} and water temperature above 100°C\(^*\).

\(*\ 212 \degree F\)
New generation of geothermal Turboden plants

Turboden geothermal plants offer the following **key features**:

*Since the very beginning…*
- Maximum electrical efficiency (evaluation of all the possible thermodynamic cycles)
- Flexibility in fluid choice (matching the customer’s needs)
- High reliability and availability guarantee

*…to the new generation*
- Flexibility in district heating coupling
- Grid supporting by power regulation
- Stability during the low voltage ride through
- Island mode capability
Geothermal CHP: Different Possible Schemes

- In Parallel (Altheim, Simbach-Braunau)
- In Series (cascade uses, New Mexico)
- From the Condensation Heat (classic cogeneration concept)

Turboden standard ORC combined to district heating networks: more than 100 customers among Municipal Companies, Multi-utilities, private investors.
Reference Plant - Sauerlach

**Plant type:** Two-level cycle geothermal unit  
**Customer:** SWM - StadtWerke München (public utilities company)  
**Location:** Bavaria, Germany  
**Start-up:** February 2013  
**Accepted:** November 2013  
**Heat source:** geothermal fluid at 140 °C  
**Cooling device:** air condensers  
**Total electric power:** 5+ MW\textsubscript{el} plus 4 MW\textsubscript{th} decoupling for district heating  
**Working fluid:** refrigerant 245fa (non flammable)

*Off grid mode capable*
Reference Plant - Dürrnhaar

Customer Name: Hochtief Energy Management GmbH
Location: Dürrnhaar (München), Germany
Start-up: December 2012
Accepted: December 2013
Heat source: geothermal fluid at 138 °C
Total electric power: 5.6 MW
Scope of supply: EPC contract for the complete ORC unit, including the Air Cooled Condenser and the geothermal balance of plant
Reference Plant - Kirchstockach

Customer: Hochtief Energy Management GmbH
Location: Kirchstockach (München), Germany
Start-up: March 2013
Accepted: November 2013
Heat source: geothermal fluid at 138 °C
Total electric power: 5.6 MW
Scope of supply: EPC contract for the complete ORC unit, including the Air Cooled Condenser and the geothermal balance of plant
Reference Plant - Traunreut

**Customer:** Geothermische Kraftwerksgeellschaft Traunreut GmbH  
**Location:** Bavaria, Germany  
**Status:** under construction  
**Heat source:** geothermal fluid at 118 °C  
**Total electric power:** 4.1 MW  
**Total thermal power:** 12 MW (to the district heating)  
**Scope of supply:** Supply of the complete ORC unit, including the Air Cooled Condenser and control system of geothermal site
Reference Plant - Enel supercritical

- **Plant type**: geothermal prototype with supercritical cycle
- **Customer**: Enel Green Power
- **Location**: Livorno, Italy
- **Started-up**: March 2012
- **Heat source**: hot water at 150 °C nominal
- **Cooling device**: ‘dry & spray’ condenser
- **Total electric power**: 500 kW<sub>el</sub>
- **Working fluid**: refrigerant (non flammable)
Turboden Geothermal key features

Geothermal energy from Turboden’s ORC is the energy of the next generation as:

- it has **zero emissions** (binary cycle with total reinjection)
- it is high **predictable** (small seasonal and daily trends)
- it can work both in **island mode** or connected to the grid
- it can support the grid (different possible power regulations)
- it can remain stable during the Low Voltage Right Trough (**LVRT**)
- it can be connected to a **district heating**
- It has maximum electric efficiency (total flexibility in the choice of the working fluid and of the thermodynamic cycle)
- it starts from **100 °C**
Turboden + MHI: Ranges of Application

- **Stability limit for ORC fluid**
- **HIGH ENTHALPY GEOTHERMAL ORC**
- **MEDIUM TO LOW ENTHALPY ORC**
- **STEAM TURBINE**

- High cost for steam plant
- Size too small
- Temperature too low
Every geothermal resource is unique. Turboden has experienced the possible solutions to exploit efficiently the geothermal variable temperature heat source, by selecting the optimum fluid and cycle configuration.
Early Demonstration Projects

Location: **DAL – Kapisya, Zambia**
Year: 1988
Heat source: Geothermal fluid at 88°C
Total electric power: 2 x 100 kW

Location: **Castelnuovo Val di Cecina, Italy**
Year: 1992
Heat source: Geothermal fluid at 114°C
Total electric power: 1.3 MW

Plant type: geothermal low enthalpy, coupled with a geothermal district heating system

Location: **Marktgemeinde, Altheim, Austria**
Started up: March 2001
Heat source: hot water at 106°C
Cooling source: cold water from a nearby river (cooling temperature 10/18°C)

Plant type: geothermal, 1st EU operating plant on EGS (Enhanced Geothermal System)
Location: **Soultz-sous-Forêts, Alsace, France**
Started up: II quarter 2008
Heat source: hot water at 180°C
Total electric power: 1.5 MW

Plant type: geothermal low enthalpy, coupled with a geothermal district heating system

Location: **Simbach – Braunau, German-Austrian border**
Started up: III quarter 2009
Heat source: hot water at 80°C
Design electric power: 200 kW