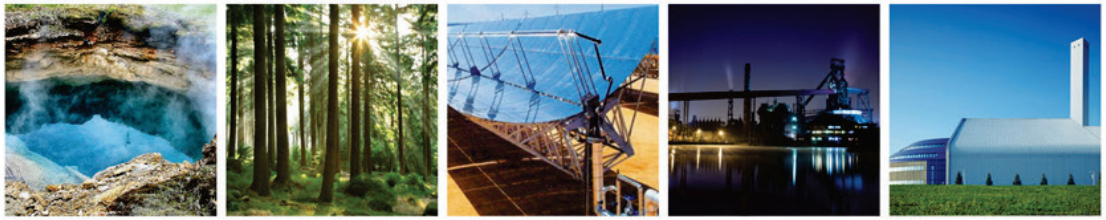
Opportunities for ORC Technology in Oil and Gas Fields



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a group company of MITSUBISHI HEAVY INDUSTRIES, LTD.

Clotilde Rossi di Schio

Dallas, 19-20 May

SMU | GEOTHERMAL LABORATORY

LLOYD'S REGISTER · LRQA
ISO 9001

Doc.: SMU_Turboden_Mitsubishi

Update: 18/05/2015

Turboden ORC – fields of application

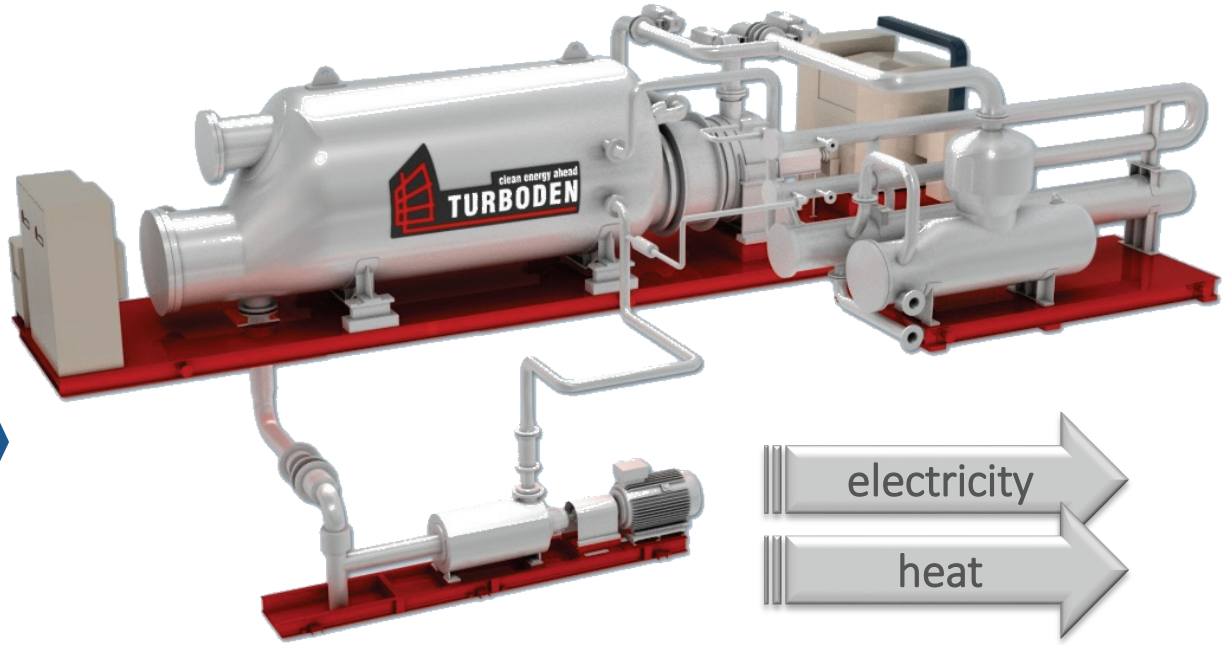
Biomass

Heat recovery

Waste to energy

Geothermal

Solar



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

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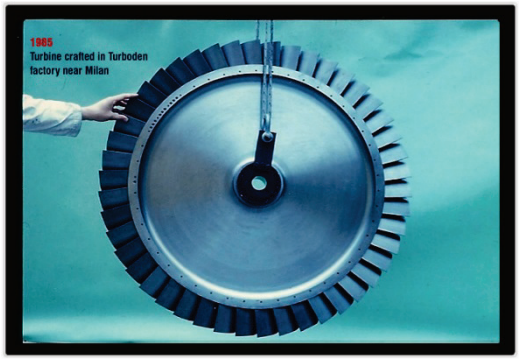
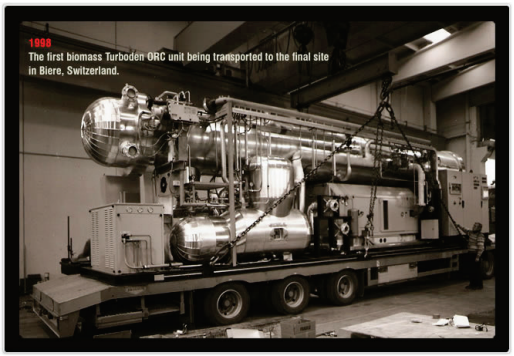
35 Years of Experience



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

MITSUBISHI HEAVY INDUSTRIES, LTD.

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

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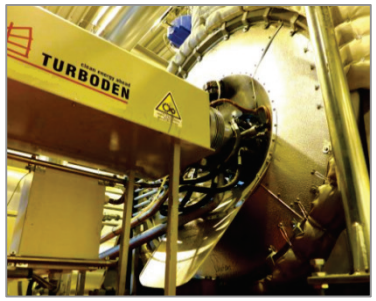
Organic Rankine Cycle: concept



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).

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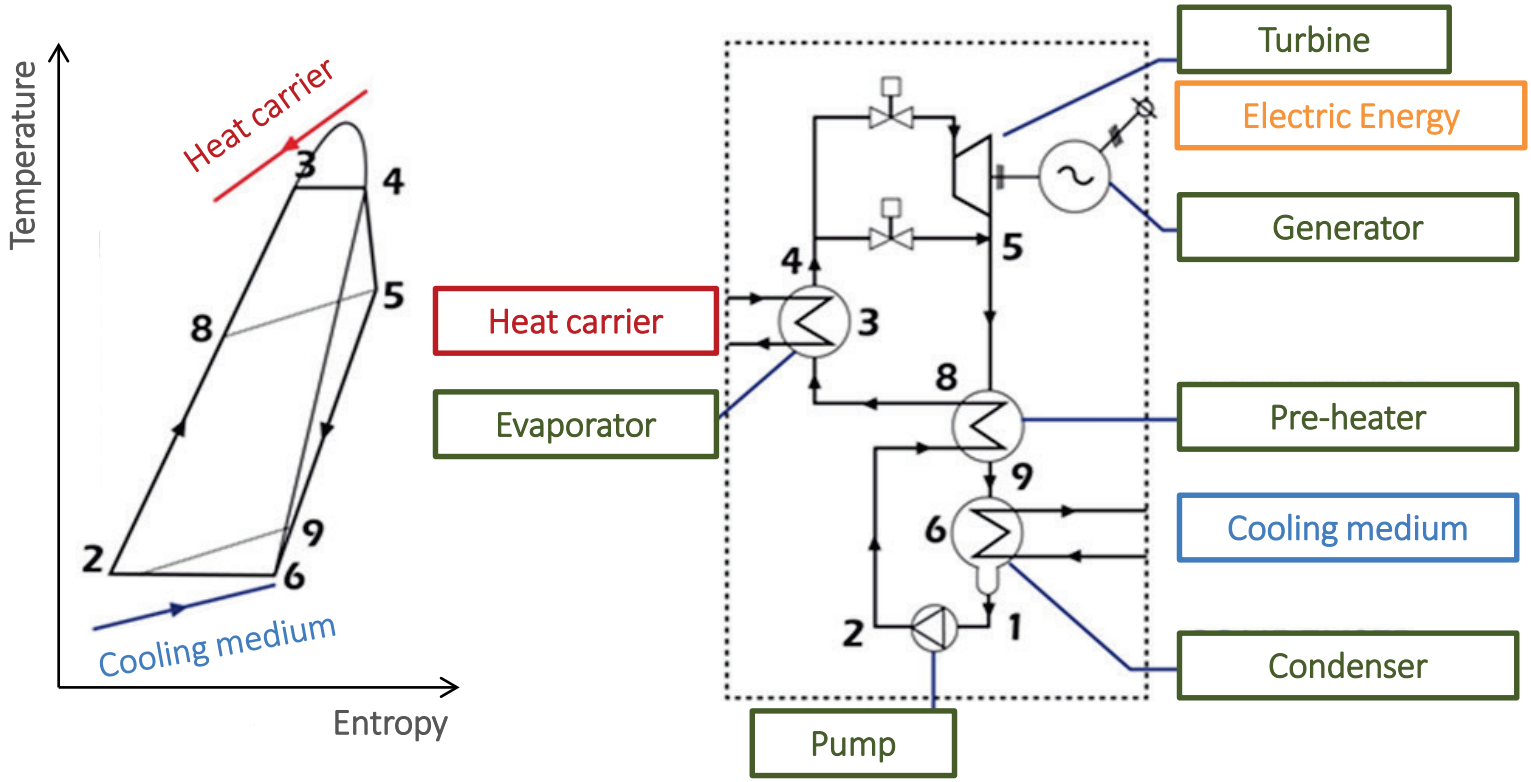
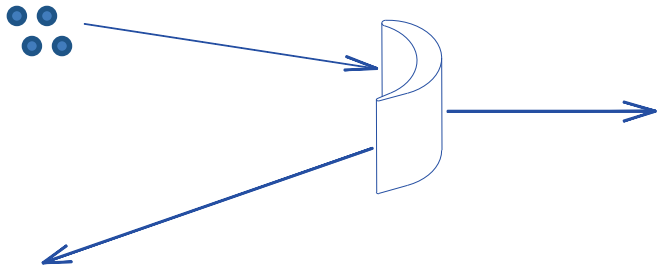
Organic Rankine Cycle: Thermodynamics

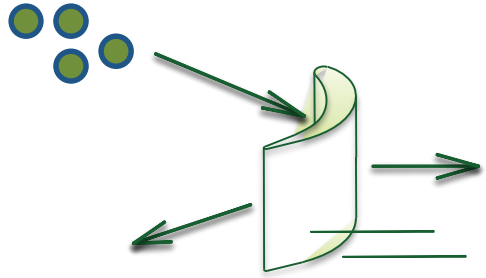


Water vs High Molecular Mass - Working Fluid



Water

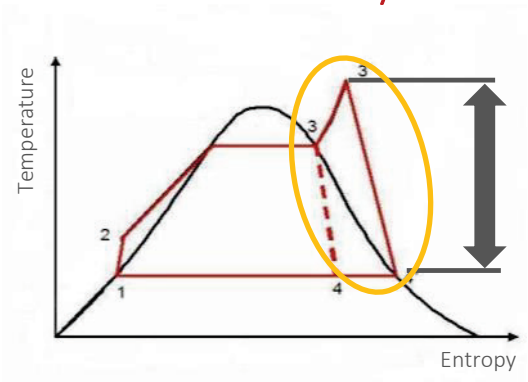
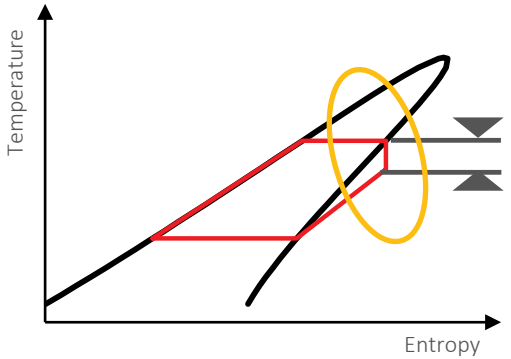
- Small, fast moving molecules
- Metal parts and blade erosion
- Multistage turbine and high speed with mechanical stress



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)

Traditional Rankine Cycle vs. Organic Rankine Cycle

	Steam Rankine Cycle	Organic Rankine Cycle (ORC)
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 • Completely automatic
Other features	• Convenient for large plants and high temperatures • Low flexibility with significantly lower performances at partial load	• High flexibility and good performances at partial load • High availability (average >98%) • Possibility to work at low temperatures (90+°C)

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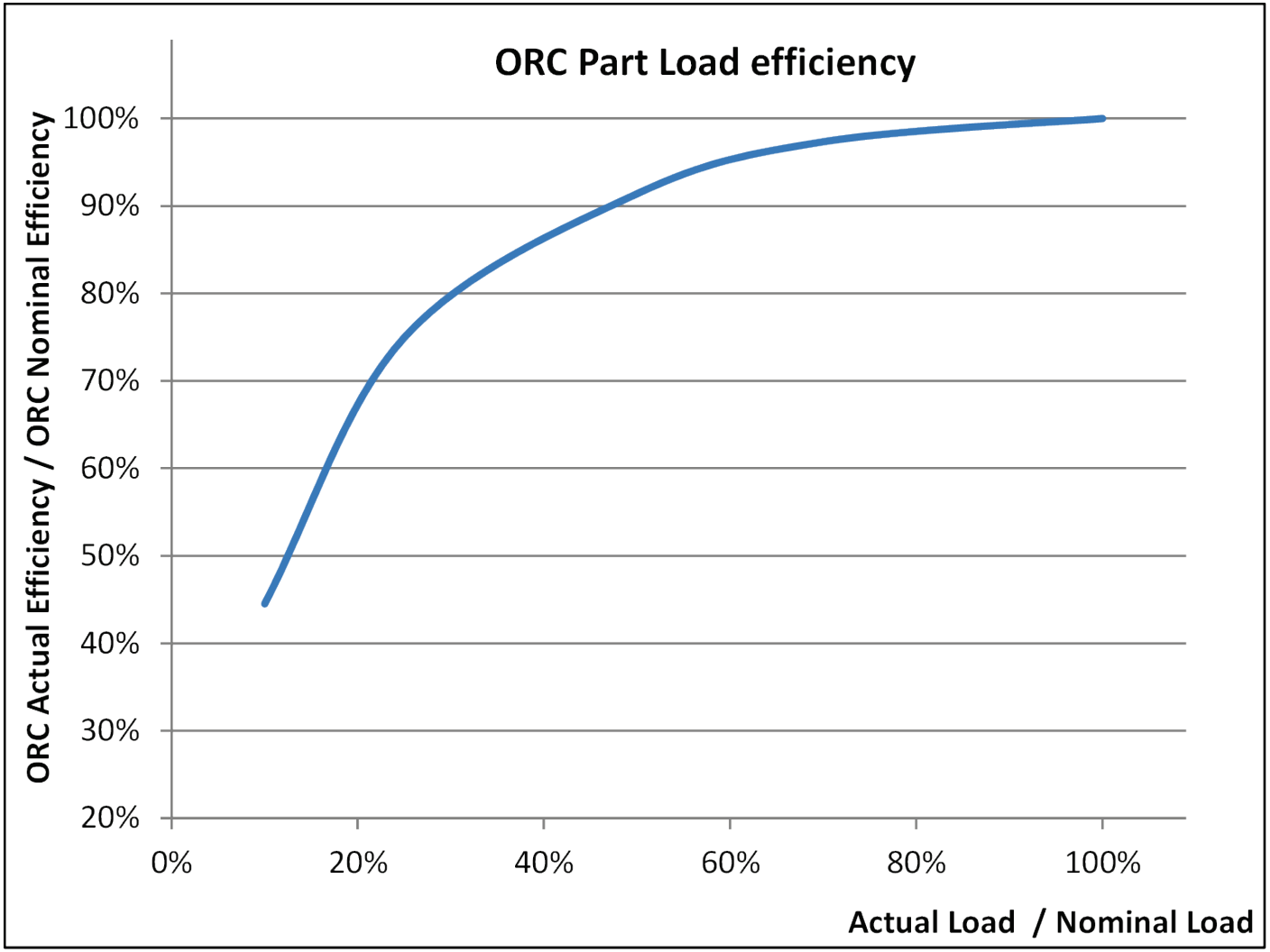
ORC performance at partial load



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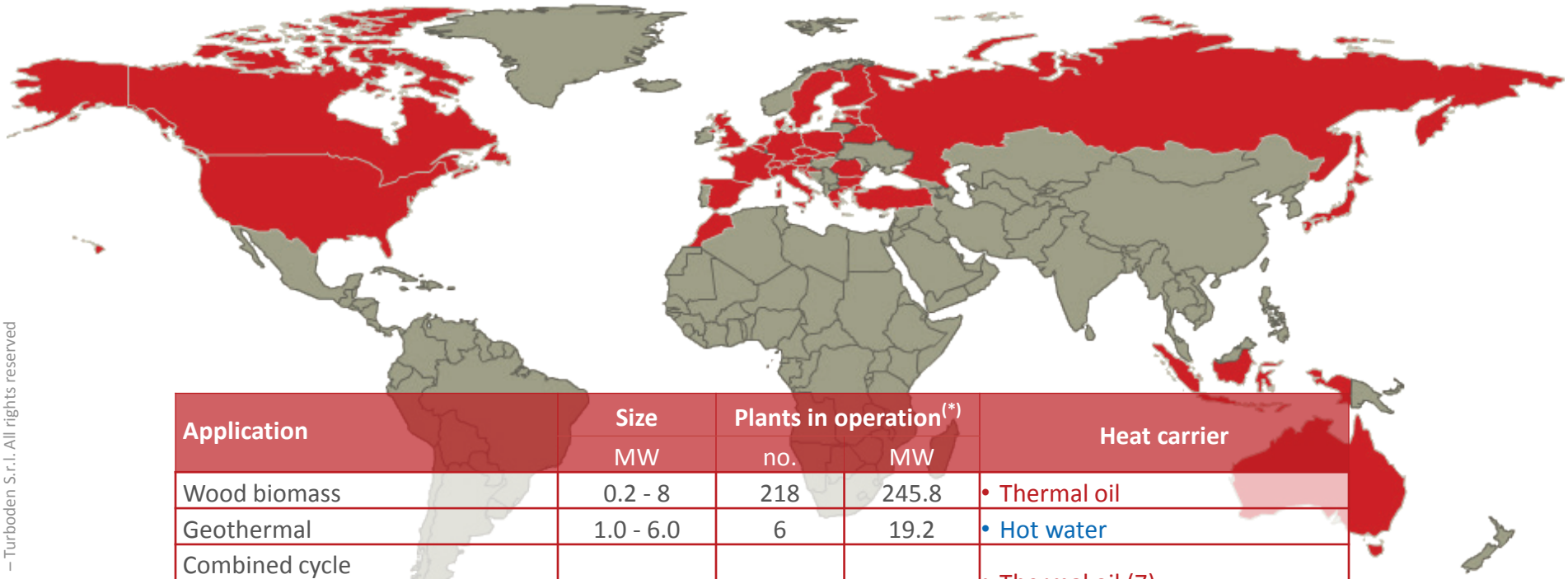
Turboden references



Application	Size	Plants in operation(*)		Heat carrier
	MW	no.	MW	
Wood biomass	0.2 - 8	218	245.8	• Thermal oil
Geothermal	1.0 - 6.0	6	19.2	• Hot water
Combined cycle (bottoming of gas turbines or reciprocating engines)	0.5 - 4.5	9	10.5	• Thermal oil (7) • Direct heat exchange (2)
Industrial heat recovery (cement, glass, steel, etc.)	0.5 - 7.0	7	16.5	• Thermal oil (5) • Saturated steam (1) • Direct heat exchange (1)
Waste to energy	0.5 - 6.0	7	14.3	• Thermal oil (6) • Hot water (1)
Total Turboden plants		**247**	**306.3**	

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(*) Other 58 plants are under construction

Last update: April 2015

ORC finds several applications in the Oil&Gas sector

A. Hot water from exhausted oil wells

B. Gas turbines exhaust gas

Gas compressor stations, natural gas liquefaction, gas storage, etc.

C. Associated Petroleum Gas (APG)

D. Refinery hot streams

Distillation columns, Oil/Gasoline/Kerosene production, etc.

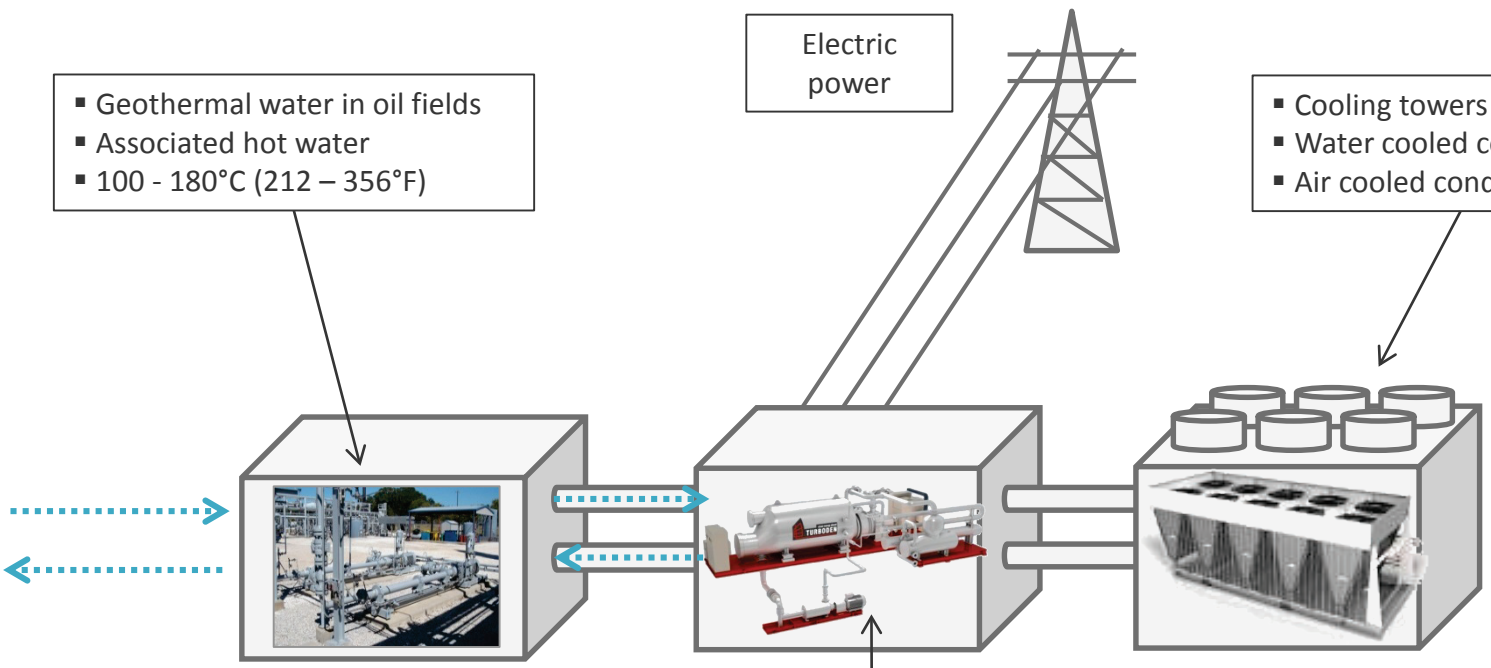
Oil&Gas applications

Ⓐ Hot water from exhausted oil wells

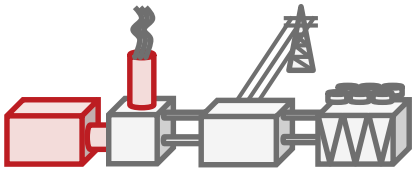
- Geothermal water in oil fields
- Associated hot water
- 100 - 180°C (212 – 356°F)

Electric power

- Cooling towers
- Water cooled condensers
- Air cooled condensers



Organic Rankine Cycle
Efficiency up to 16%



Turboden references

31 MW in 9 geothermal plants

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References – Geothermal

6 references in operation, 19 MW installed

Sauerlach

Customer: SWM - StadtWerke München (Munich multi-utility)
Site: Sauerlach, Germany
ORC size: 5.6 MWe + 4 MWth to district heating
Start up: January 2013
Scope of supply: Complete ORC supply, air condenser includes

Dürrnhaar

Customer: Hochtief Energy Management GmbH
Site: Dürrnhaar (München), Germany
ORC size: 5.6 MWe
Start up: December 2012
Scope of supply: full EPC for ORC, air condenser and BOP

Kirchstockach

Customer: Hochtief Energy Management GmbH
Site: Kirchstockach (München), Germany
ORC size: 5 MWe
Start up: January 2013
Scope of supply: full EPC for ORC, air condenser and BOP

Key factors:

- **Close to the Munich urban area (<10 km)**
- Coupled with urban **district heating network**
- Possibility to work **on island mode** (Sauerlach)
- **Medium enthalpy: 140°C (284°F)**
- **Non-flammable** working fluid
- **Small area covered** due to houses in the nearby
- **Turboden supply all the components** except geothermal pump an circuit

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References – Low temperature water

Waste to energy – Mirom, Belgium

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

Customer: MIROM

Location: Roeselare, Belgium

Source: hot water at 180C – 356F (back at 140C – 284F)

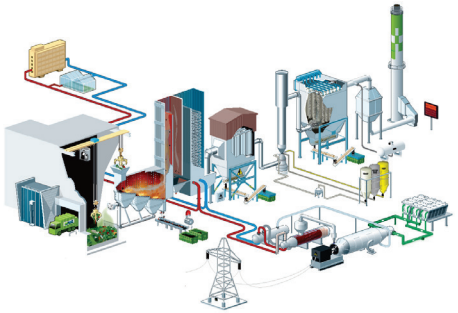
Cooling source: air coolers

ORC electric power: 3 MW

Electrical efficiency: 16.5%

Availability: >98%

Start up: Q2 2008



Waste to energy – Séché, France

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

Customer: Séché Environnement Usine - Alcea

Location: Nantes, France

Source: hot water at 200C – 392F

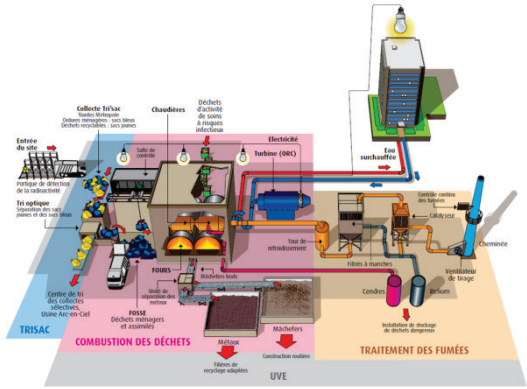
(back at 130C – 266F)

Cooling source: air coolers

ORC electric power: 2.4 MW

Electrical efficiency: 16.5%

Start up: Q3 2014



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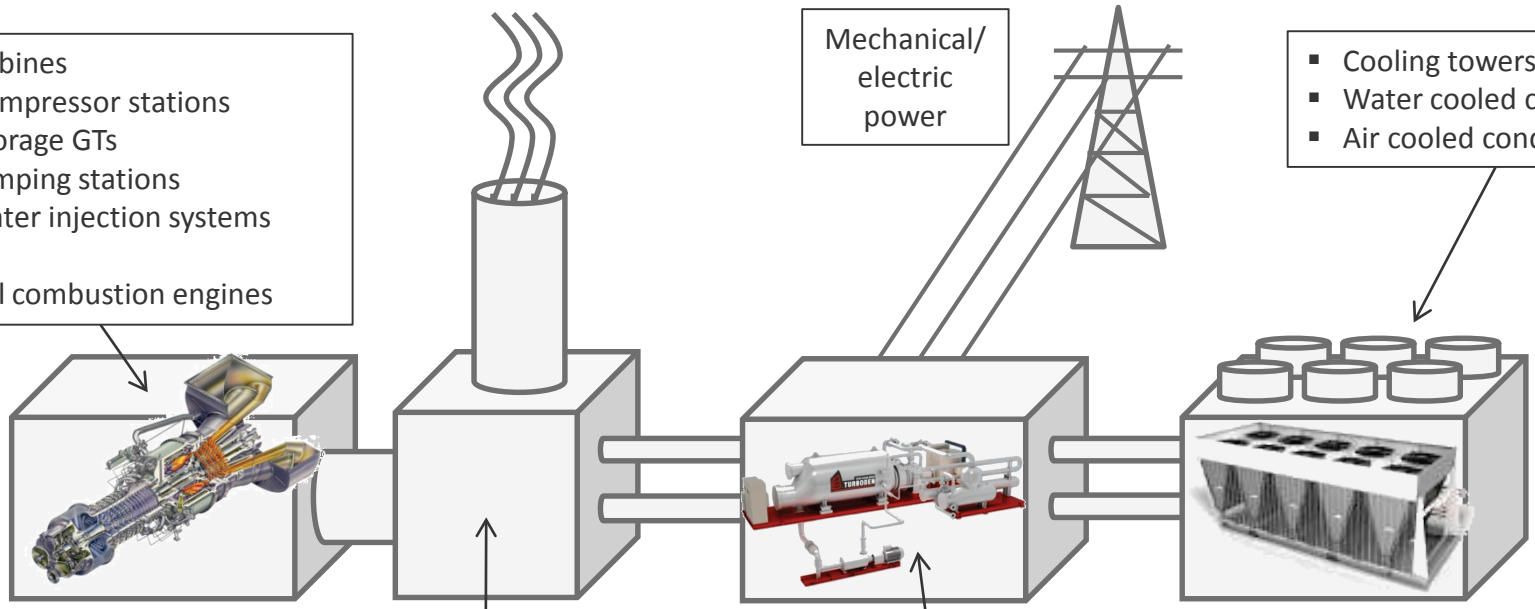
Oil&Gas applications

Ⓑ Gas turbines exhaust gas

- Gas turbines
  - Gas compressor stations
  - Gas storage GTs
  - Oil pumping stations
  - Sea water injection systems
  - …
- Internal combustion engines

Mechanical/ electric power

- Cooling towers
- Water cooled condensers
- Air cooled condensers

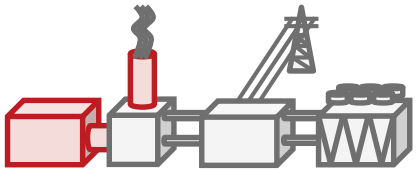


Heat exchanger
- Direct exchange
- Thermal oil

Organic Rankine Cycle
25 ÷ 35% additional power (1)

Turboden References

- **TransGas – Canada**
  GT power: 3.5 MWe
  ORC power: **1 MWe**
  Thermal oil circuit
  Start up: Q4 2011
- **Polympex – Russia**
  GT power: 25 MWe
  ORC power: **3 MWe**
  CHP th. power: 15 MWth
  Direct Exchange
  Start up: Q4 2014



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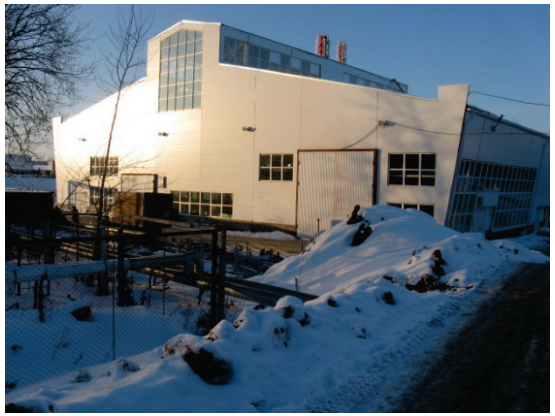
(1) Percent of the prime mover nominal power

Turboden reference – APG exploitation

© Associated Petroleum Gas (APG)



Site: Perm, Russia

Customer/End user: LabNT/LUKoil

Status: started up in June 2012

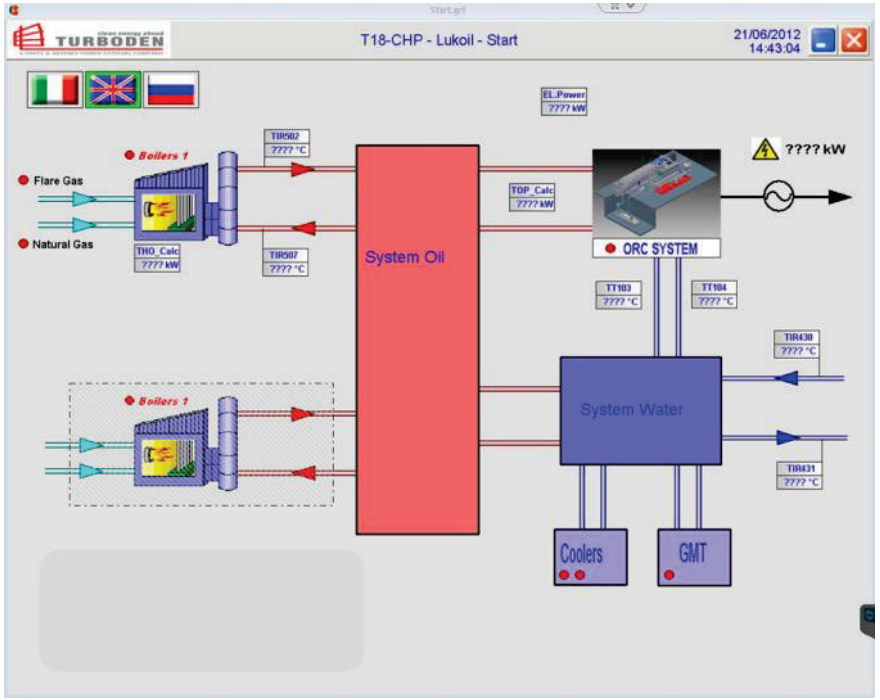
Heat source: flare gas burning (boiler designed to burn gas with a minimum lower calorific value of 4,500 kcal/Nm3

Heat source temperature: thermal oil at 300 °C

Inlet/Outlet water temperature: 65/95 °C (149/203°F)

Electric power: ~1.8 MW

Net electric efficiency: ~18%



Project description

Flare gas from oil extraction wells is burned to heat up thermal oil which is used to feed up an ORC CHP unit. The electricity produced reduces the plant consumptions, whereas the hot water produced is exploited in oil refinery processes including warming up of refined products to be pumped.

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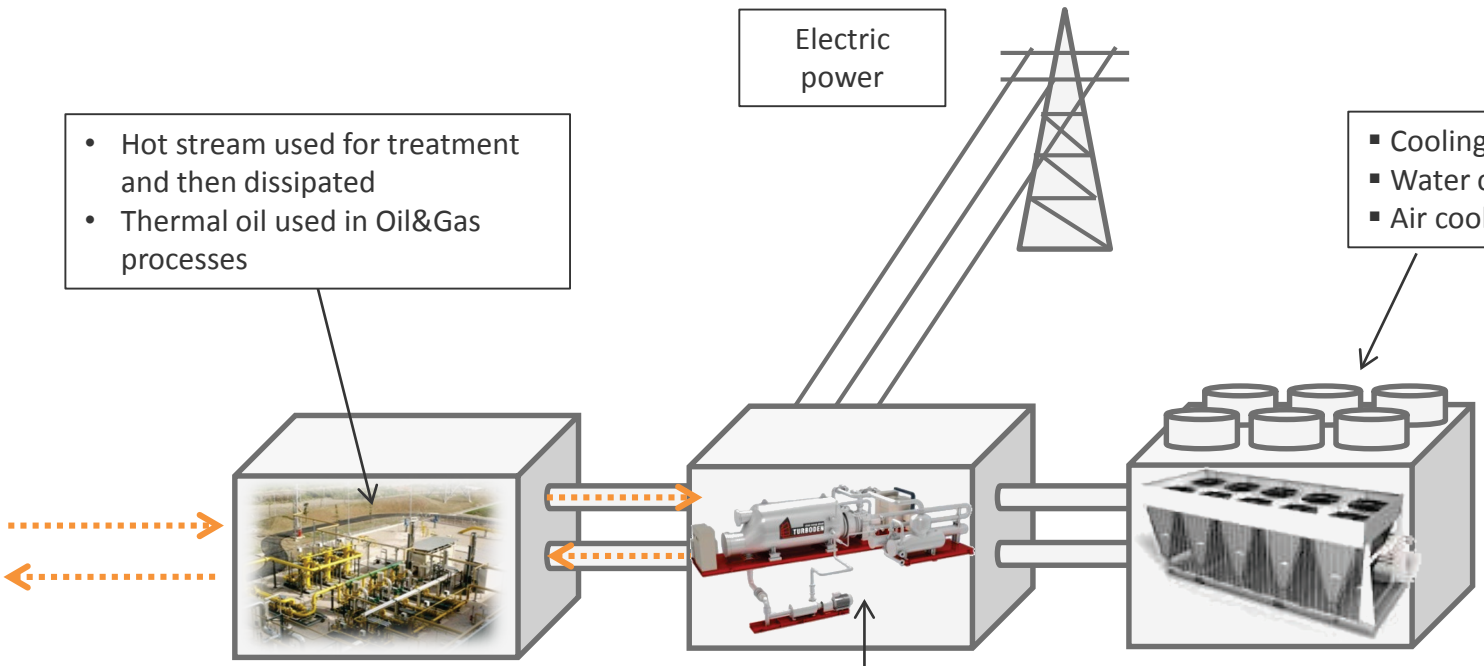
Oil&Gas applications

Ⓓ Refinery hot streams

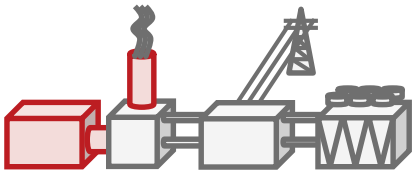
Electric power

- Hot stream used for treatment and then dissipated
- Thermal oil used in Oil&Gas processes

- Cooling towers
- Water cooled condensers
- Air cooled condensers



Organic Rankine Cycle
Efficiency up to 25+% (1)



Turboden case study

Thermal oil power: 53 MWth
ORC electric power: 10 MW

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(1) Heat carrier temperature above 300°C

Thank you!

For further information:
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