

TURBODEN

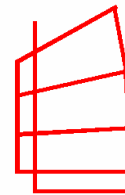


Turboden ORC Systems by Mario Gaia

Strasbourg, 14.09.06: “Electricity Generation from Enhanced Geothermal Systems”



Workshop5
14-16 September 2006



TURBODEN

Turboden yesterday

Established in 1980 with the aim to design and manufacture turbines and turn-key turbogenerator units based on the Organic Rankine Cycle (ORC). Turboden pioneered the use of Silicone fluid in ORC.



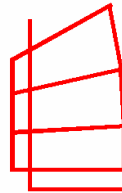
1984: A 40 kWel ORC turbogenerator for a solar application in Perth, Australia



1987: A 3 kWel ORC turbogenerator biomass CHP plant in Milan



Workshop5
14-16 September 2006



TURBODEN

Turboden yesterday

Early ORC units for geothermal applications.



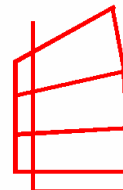
DAL – Kapisya (Zambia) – 1988
2 X 100 kWel
Geothermal source: 88 °C



Enel Castelnuovo Val di Cecina
1,3 MWel
Geothermal source: 114 °C



Workshop5
14-16 September 2006

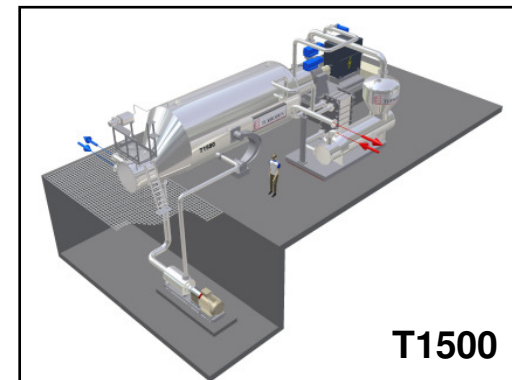
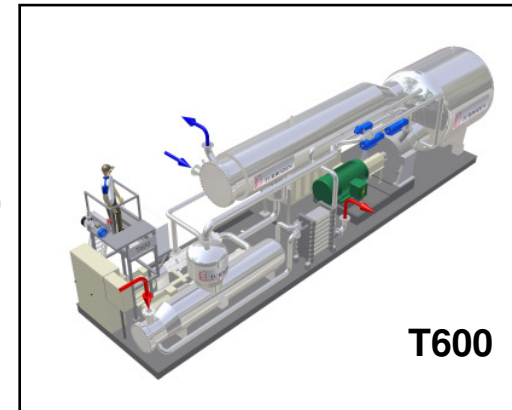


TURBODEN

Turboden today

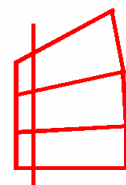
Turboden is the leading supplier of ORC plants in Europe

- ❑ 44 units in operation for a total installed power of more than 44,000 kW (capacities between 500 and 1500 kW)
- ❑ 20 units under construction (capacities between 200 and 2000 kW)
- ❑ Vast majority of applications in Austria and Germany for renewable biomass CHP plants
- ❑ Other applications:
 1. Geothermal (Altheim)
 2. Waste incineration
 3. Heat recovery





Workshop5
14-16 September 2006



TURBODEN

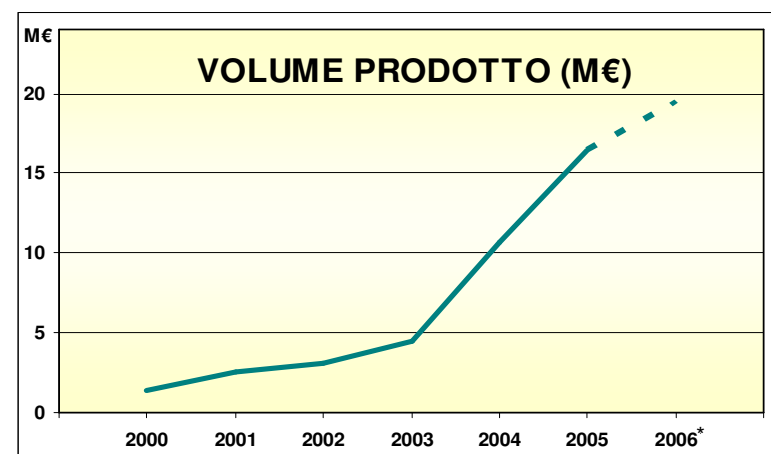
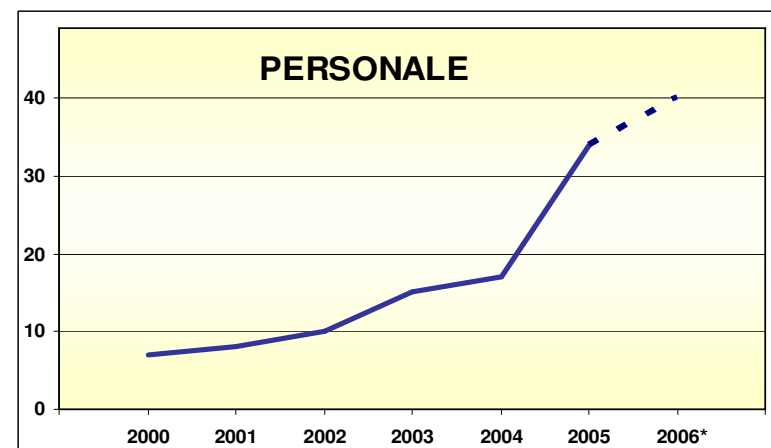
Turboden Today

Personnel **40 persons** (1/09/2006)

**Production
Volume:** **15.8 million €** (2005)

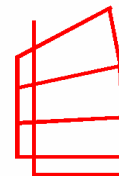
Equity **> 2 million €** (31/12/2005)

Order Backlog **23 million €** (1/09/2006)





Workshop5
14-16 September 2006

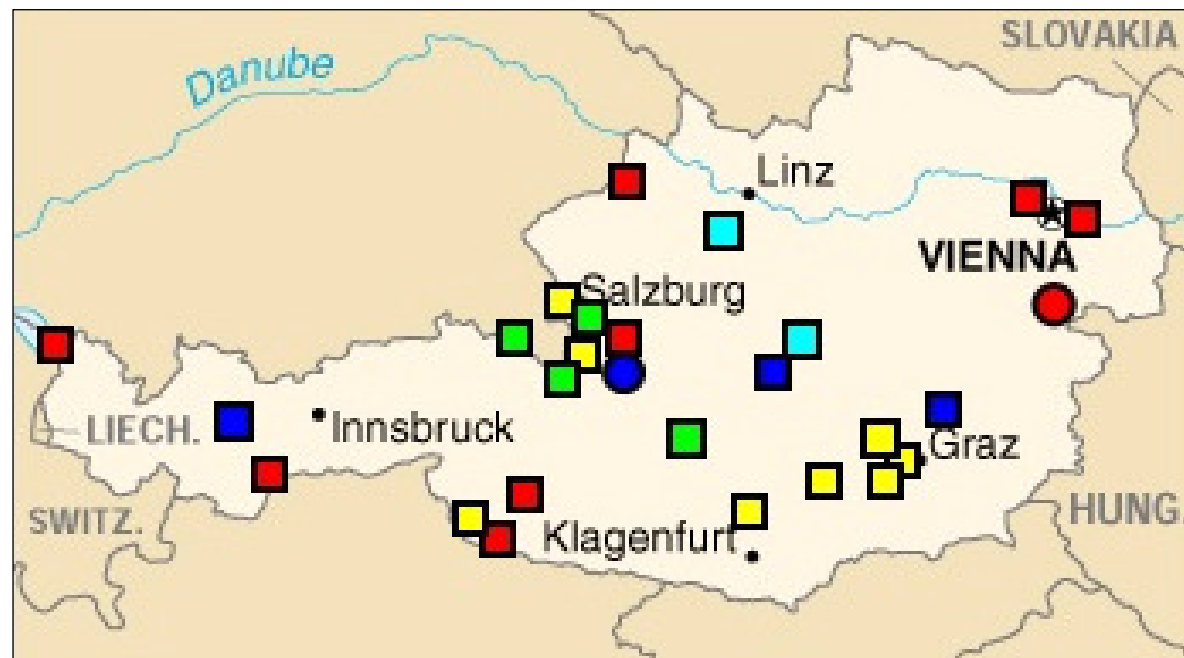


TURBODEN

Turboden today

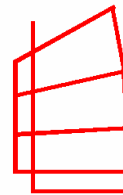


**Austria: 25 Turboden ORC plants in operation,
2 under construction**





Workshop5
14-16 September 2006



TURBODEN

Turboden today



Austria: Leoben, 3 T1500-CHP units

Start up: March 2005

Total electric power: 4,8 MW

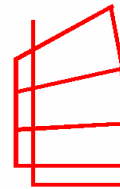
Customer: BIOMASSE-KWK-LEOBEN

Heat use: Drying of sawmill timber
and saw dust for pellets production





Workshop5
14-16 September 2006



TURBODEN

Turboden Today



**Germany: 10 Turboden ORC plants in operation,
14 under construction**



Under construction

In operation

4	2	T500
2	2	T600
2	1	T800
1	2	T1100
4	3	T1500
1		T2000

Turboden today

Geothermal Energy : Altheim Plant

Start up: November 2000

Total electric power: 1 MW

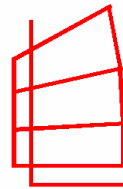
Customer: Marktgemeinde Altheim

Heat source: Geothermal Water at
106°C





Workshop5
14-16 September 2006



TURBODEN

Turboden Today

Turboden achievements in biomass based ORC plants are the result of:

- High efficiency:
 - a) axial proprietary design turbine
 - b) cycle/working fluid optimized for specific site conditions
- Reliability:
 - a) Moderate pressure and temperature cycle
 - b) Directly coupled low rpm turbine
 - c) Simple operation & maintenance
- Closeness to client: technical assistance support including remote monitoring



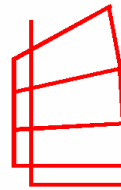
Turboden Today

Turboden is committed to extend ORC technology applications

- Bio-oil & Biogas
- Solar
- Internal combustion engine exhaust gases
- Industrial process (cement, metals, glass, etc)



Workshop5
14-16 September 2006



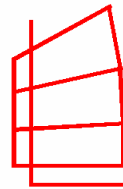
TURBODEN

Turboden Research & Development

- R & D for continuous product improvement,
- heavily committed to Research for future ORCs in heat recovery, biofuel, solar and geothermal applications
- partner of the LOW-BIN European Program with ambitious targets in low temperature / low power geothermal sources



Workshop5
14-16 September 2006



TURBODEN

Turboden in geothermal energy

Non flammable fluids

- Fluid flammability is a significant factor in urban areas & involves higher insurance costs
- Turboden identified and studied a number of fluids
- Turboden tested in the Altheim plant, in collaboration with the owner of the plant (Commune of Altheim), a non flammable fluid suitable for geothermal applications. The plant is now working with this fluid.

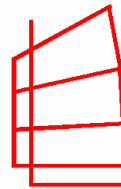
Name of the fluid: Solkatherm

Manufacturer: Solvay

- Turboden and Solvay collaborate for further applications
- Laboratory tests are under way for a general understanding of the fluid compatibility and behaviour



Workshop5
14-16 September 2006



TURBODEN

Turboden in geothermal energy

Characteristics of Altheim fluid

An azeotropic mixture

- HFC 365 mfc: Hydrofluorocarbon
- PFPE : Perfluoro-poliether

Boiling point: 35,6 °C

Critical point: 177,5 °C

Molecular weight: 184,5 °C

Thermal stability: up to 225 °C

Excellent turbine fluid-dynamics

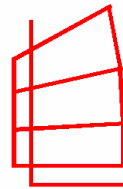
Good heat transfer properties

Low viscosity

Non flammable



Workshop5
14-16 September 2006

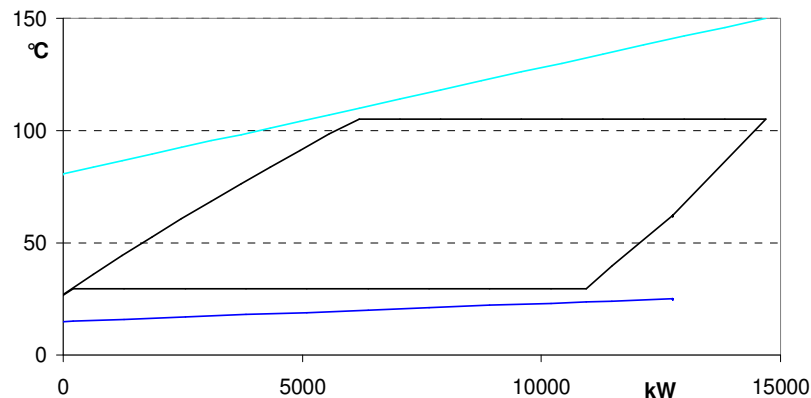


TURBODEN

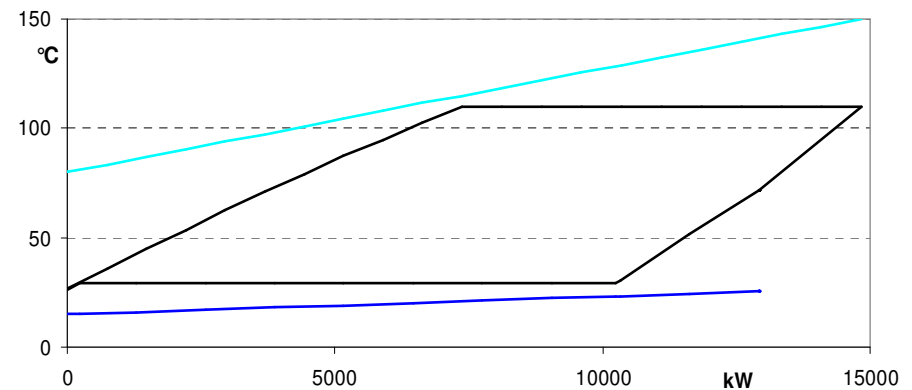
Turboden in geothermal energy

Comparison of Pentane and Solkatherm azeotrope cycles

Temperature vs Exchanged thermal power diagrams



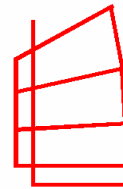
Pentane



Solkatherm



Workshop5
14-16 September 2006



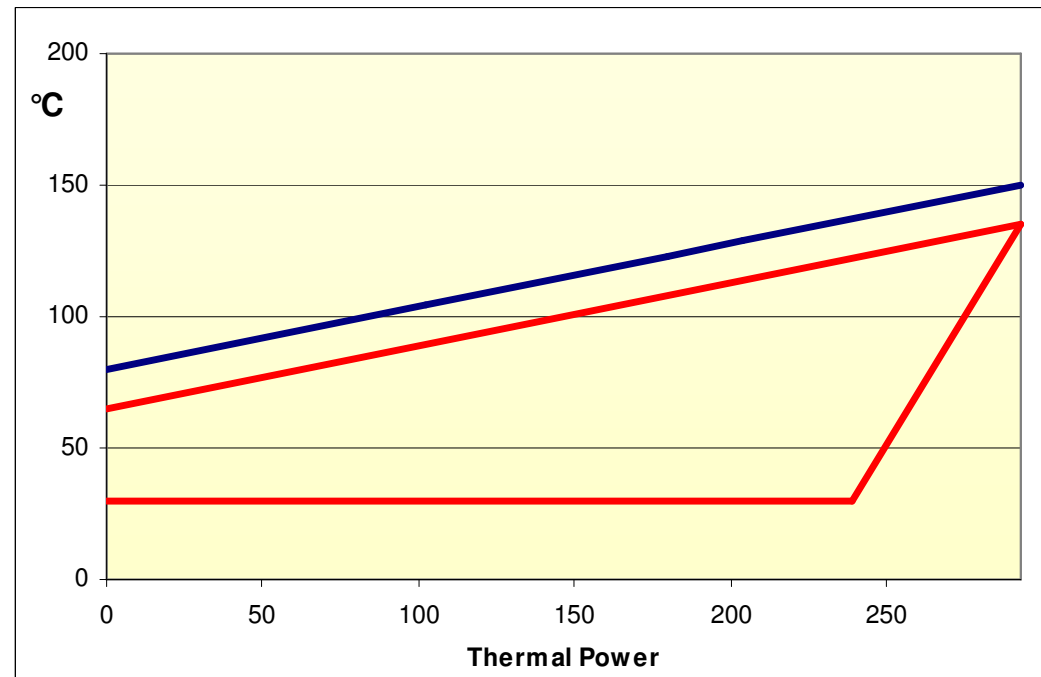
TURBODEN

- ☐ Most geothermal applications are for the liquid dominated systems
- ☐ Preferably the geothermal fluid is maintained in liquid phase

Hence it is important to exploit efficiently the variable temperature heat source

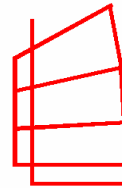
Ideal (Lorentz Cycle)

— Geothermal Fluid
— Ideal Lorentz Cycle

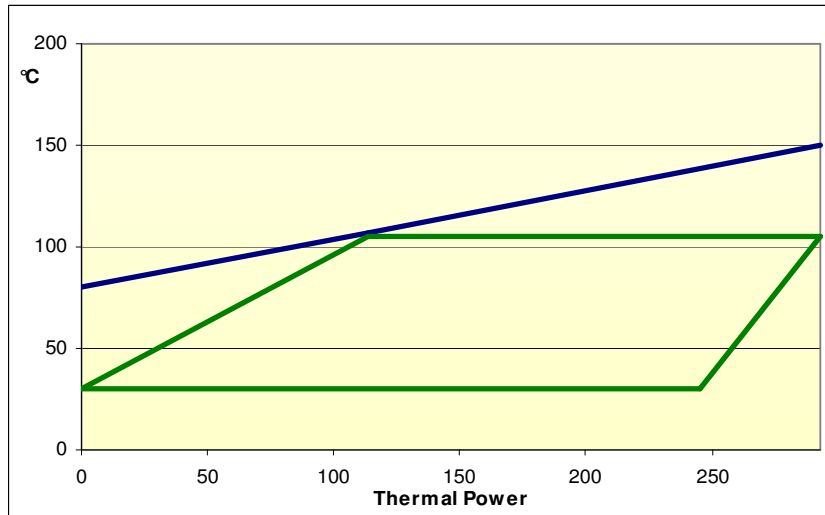




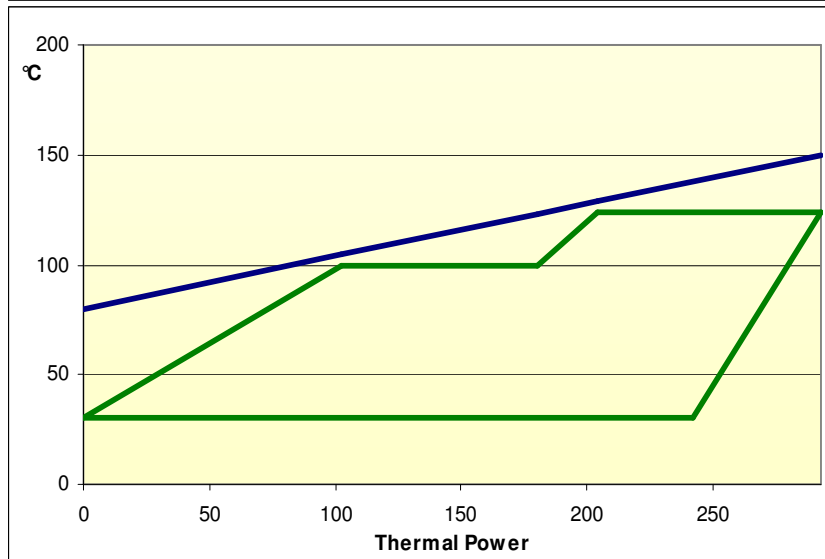
Workshop5
14-16 September 2006



TURBODEN



ORC: single evaporation pressure level

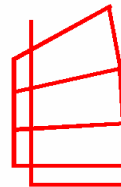


ORC: two evaporation pressure levels

— Geothermal Fluid
— Organic Fluid



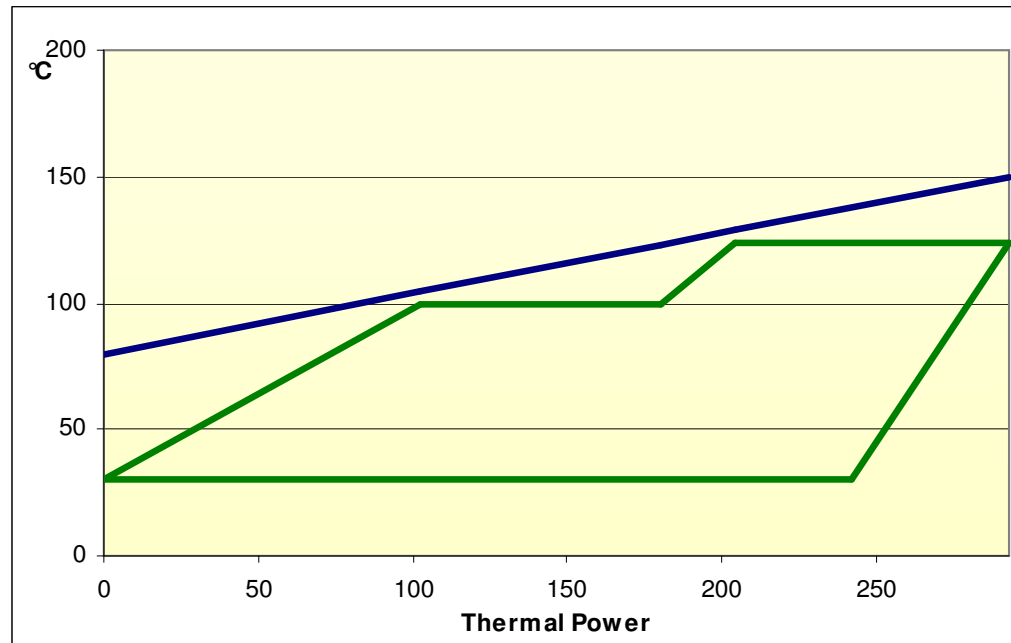
Workshop5
14-16 September 2006



TURBODEN

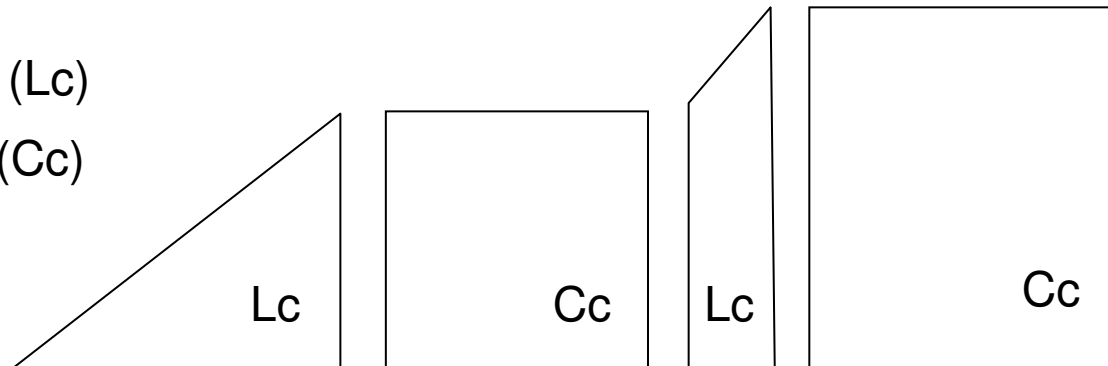
ORC: two evaporation pressure levels

— Geothermal Fluid
— Organic Fluid



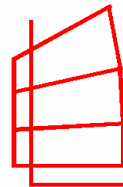
Equivalent to:

- ❑ 2 Lorentz ideal cycles (Lc)
- ❑ 2 Carnot Ideal cycles (Cc)



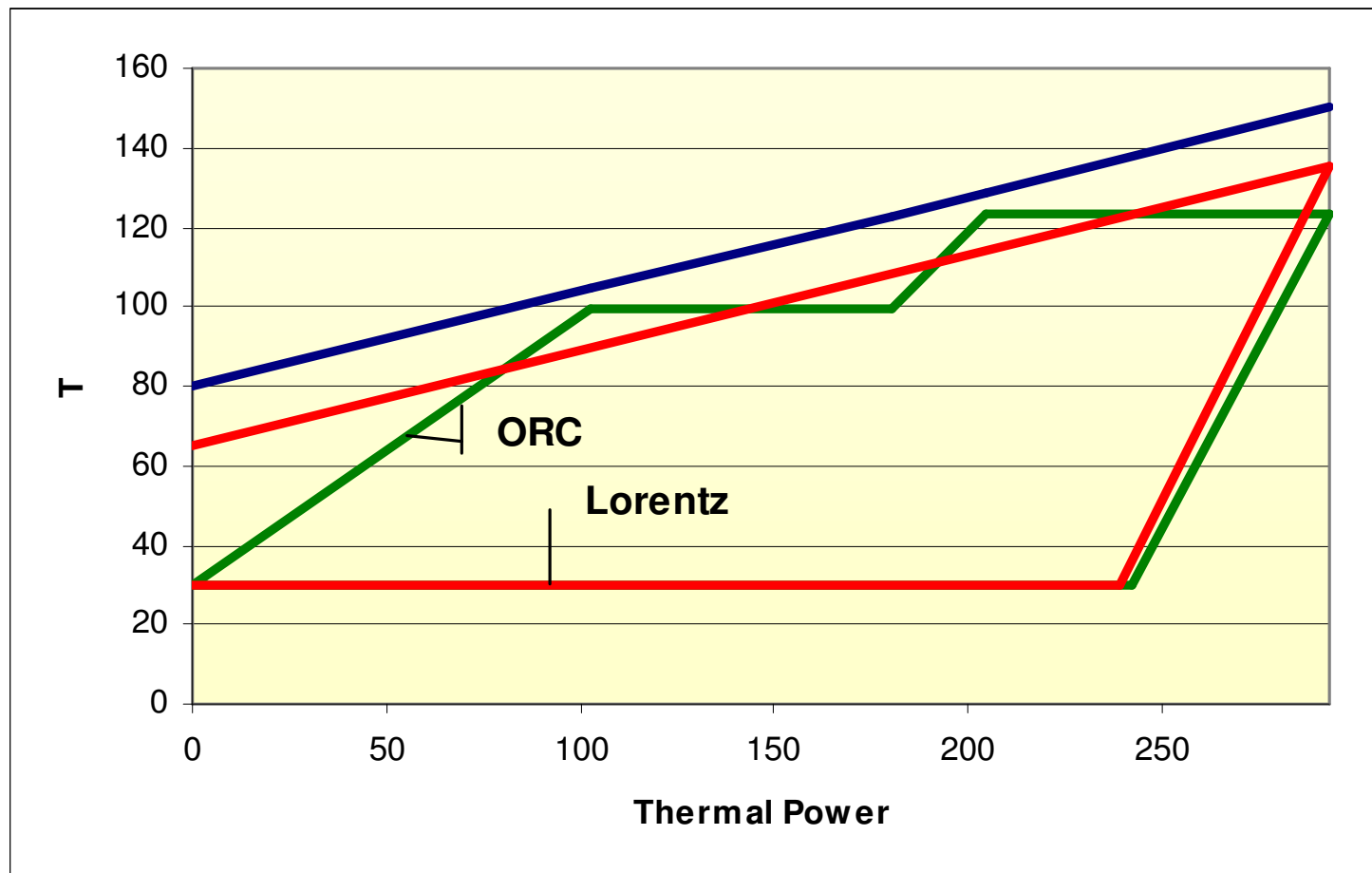


Workshop5
14-16 September 2006



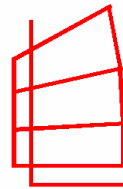
TURBODEN

Comparison for a given heat exchanger surface



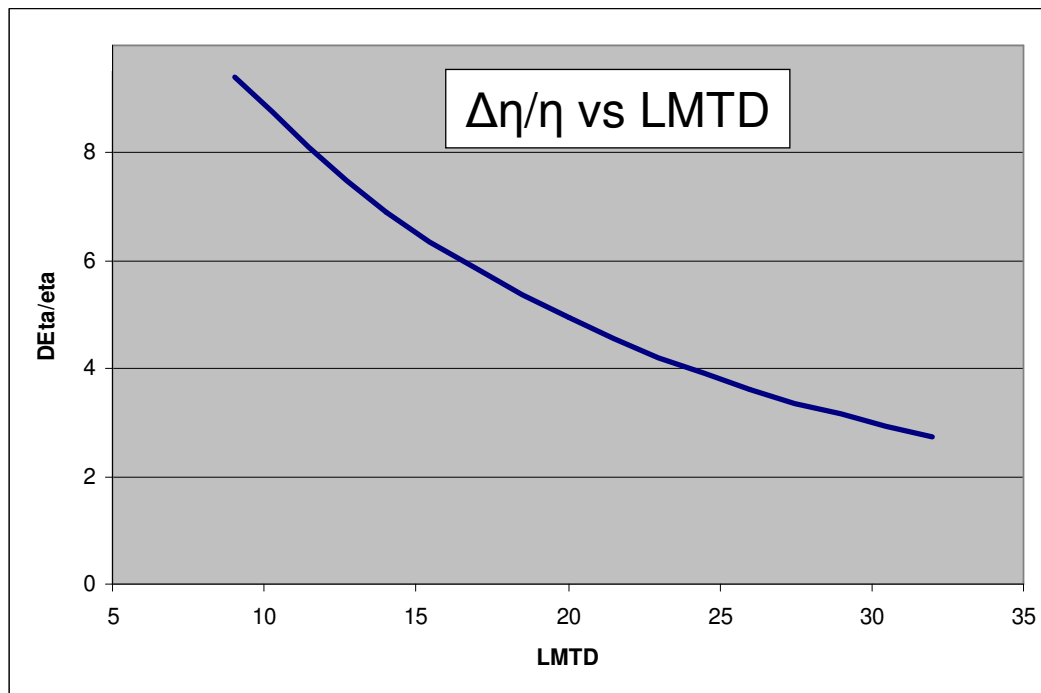


Workshop5
14-16 September 2006



TURBODEN

Power lost due to non-ideal heat input curve Vs temperature difference in the geothermal fluid heat exchanger



Only a few percent of efficiency are lost when passing from ideal input curve to the actual ORC input curve



Turboden in geothermal energy

ORC technical advantages

- Low toxicity profile
- Very high turbine efficiency
- Low mechanical stress of the turbine, due to the low peripheral speed
- Low RPM of the turbine allowing the direct drive of the electric generator without reduction gear
- No erosion of blades, due to the absence of moisture in the vapour nozzles

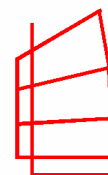


Conclusions

- ❖ The ORC technology is a good option with further growth potential for low / medium scale geothermal applications
- ❖ We believe that Turboden ORCs are in a good position to exploit this potential

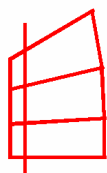


Workshop5
14-16 September 2006



TURBODEN

Thank you!



TURBODEN

V.le Stazione, 23 - 25122 Brescia - I

Visit our web site: www.turboden.it

E-mail: info@turboden.com

Phone: +39.030.3772341

Fax: +39.030.3772346