The Company and the Geothermal Applications
**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\(_e\) and water temperature above 100°C*.

* 212 °F
Binary Plant Schematic

No standard heat/cooling sources → highly customized solutions
Layout – Some Examples

TURBODEN 7 layout

TURBODEN 10 layout

Geothermal 5 MW Air-cooled

Geothermal 5 MW water-cooled
Tailor-made Solutions

- Hot water resource between 100°C and 200°C (212 – 392°F)
- Brine and steam bottoming cycles to flash steam plants
- Unit size up to 15 MW\textsubscript{el}
- Scalable for larger plants
- High cycle efficiency
- Enhanced cycle efficiency with two-level cycles
- Low O&M requirements
- Option to select non-flammable working fluids
- Typical delivery time (EXW): 11-13 months
Geothermal ORC Design

Main issues to consider

- Corrosion → special and costly materials for the heat exchangers
great influence on the cost of the unit
longer delivery period

- Scaling → limits in cooling the geothermal brine

- Fouling → removable covers and straight cleanable tubes

- Working fluid flammability: critical in urban areas & for insurance cost

- Cascade use / cogeneration: schemes, feasibility

- Vapor plume and need for makeup water in case of evaporative devices

- Larger footprint and noise emissions from the fans in case of air cooling
Evaluation of the proper Cooling System: wet Vs dry

**AVAILABLE**

**Evaporative towers**
- Smaller footprint
- Efficient in hot dry climate
- Higher own-consumption
- Fresh water consumption
- Chemical water treatment → operation cost, environment

**MAKE UP WATER**

**Air condensers**
- Larger footprint
- Efficient in cold climate
- Lower own consumption
- No water needed
- Virtually no environmental impact and operating costs

**NOT AVAILABLE**

**Critical issues**
- Investment costs: initial / overall
- Generated yearly output, linked to gross power and parasitic loads
Working fluid selection is influenced by many factors

Cost
Enthalpy drop & flow rate
Pressure levels
Environmental friendliness
Heat input curve
Cooling system
Flammability

Option to select a non flammable fluid

- Fluid flammability is critical in urban areas & for insurance costs
- Turboden identified and studied a number of fluids
- Turboden tested a non flammable fluid in Altheim, being used ever since
- Lab tests under way to check compatibility & behavior in wider range
- Possibility to place the unit inside a building or shelter (protection from atmospheric agents and mitigation of noise emissions)
Reference Plant - Sauerlach

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

**Customer:** Hochtief Energy Management GmbH  
**Site:** Dürrnhaar (München)  
**Start-up:** December 2012  
**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
Site: Kirchstockach (München)
Start-up: March 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 mbH  
**Site**: Traunreut (Bavaria)  
**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  
**Site:** Livorno, Italy  
**Start-up:** March 2012  
**Heat source:** hot water at 150°C nominal  
**Cooling device:** ‘dry & spray’ condenser  
**Total electric power:** 500 kW  
**Working fluid:** refrigerant (non flammable)
Reference Plant - Mirom

**Plant type:** heat recovery from pressurized water boiler in waste incinerator

**Customer:** MIROM, Spie Belgium SA

**Site:** Roeselare, Belgium

**Start-up:** April 2008

**Availability:** > 98%

**Heat source:** hot water at 180°C (return at 140°C)

**Cooling source:** water/air

**Total electric power:** 3 MW

**Net electric efficiency:** 16.5%

**Non-flammable working fluid:** to meet customer’s requirement
Early Demonstration Projects

Site: Kapisha, Zambia
Year: 1988
Heat source: Geothermal fluid at 88°C
Total electric power: 2 x 100 kW

Plant type: geothermal – experimental for Enel
Site: Castelnuovo di Val di Cecina, Italy
Year: 1992
Heat source: Geothermal fluid at 114°C (return at 102°C)
Cooling source: water/air
Total electric power: 1.3 MW
Net electric efficiency: 9%
EU Funded Demonstration Projects

**Plant type:** geothermal low enthalpy, coupled with a geothermal district heating system  
**Site:** Marktgemeinde, Altheim, Austria  
**Start-up:** March 2001  
**Heat source:** hot water at 106°C  
**Cooling source:** cold water from a nearby river (cooling temperature 10/18°C)  
**Design electric power:** 1 MW (normally operated by the owner at ~ 500 kW)

**Plant type:** geothermal, 1st EU operating plant on EGS (Enhanced Geothermal System)  
**Site:** Soultz-sous-Forêts, Alsace, France  
**Start-up:** June 2008  
**Heat source:** hot water at 180°C  
**Cooling source:** air  
**Total electric power:** 1.5 MW  
**Net electric efficiency:** 11.5%

**Plant type:** geothermal low enthalpy, coupled with a geothermal district heating system  
**Site:** Simbach – Braunau, German-Austrian border  
**Start-up:** August 2009  
**Cooling source:** air/water  
**Design electric power:** 200 kW
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

EPC capability *
Full Power Plant EPC
Single point responsibility
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