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Turboden Geothermal Applications

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Over 30 Years of Experience

’60-’70

- Prof. Mario Gaia makes experience in the field of ORC within his research group at *Politecnico di Milano*
- 1976 – First prototype of a solar thermodynamic ORC

1980-1999

- 1980 – Prof. Mario Gaia founds Turboden to design and manufacture ORC turbogenerators
- Turboden develops research projects in solar, geothermal and heat recovery applications
- 1998 – First ORC biomass plant in Switzerland (300 kW)

2000-2009

- 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

2009-2013

- **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

2013…

- **MHI acquires the majority of Turboden. Italian quotaholders stay in charge of management**
- **Today - Over 250 ORC plants in the world, 200 in operation**

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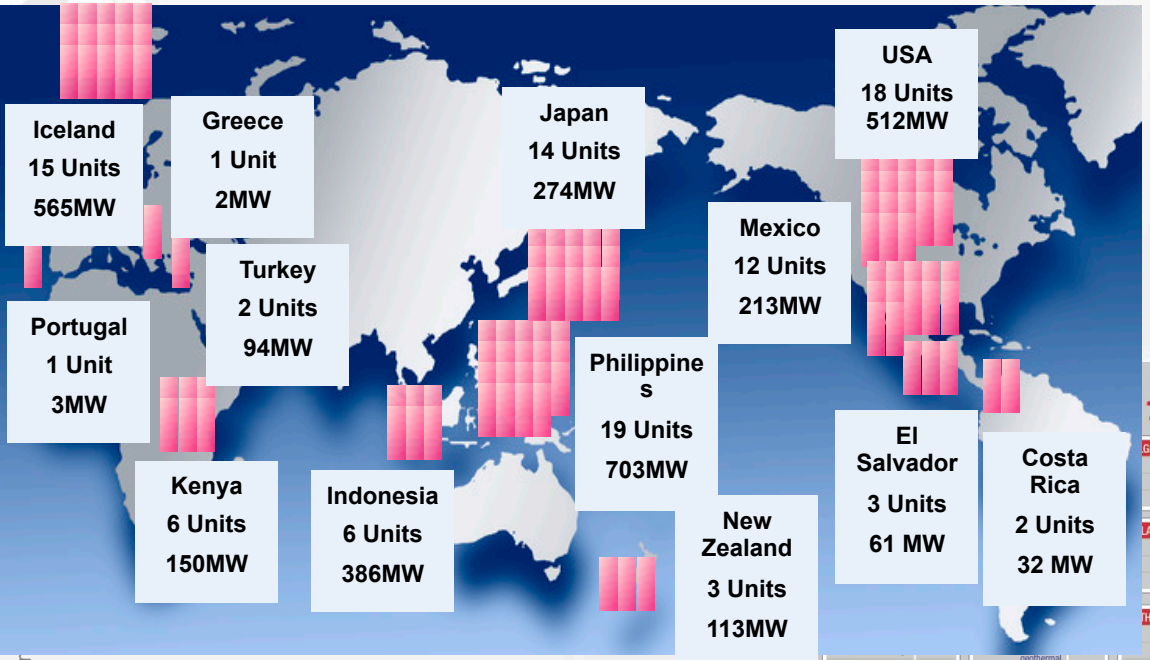
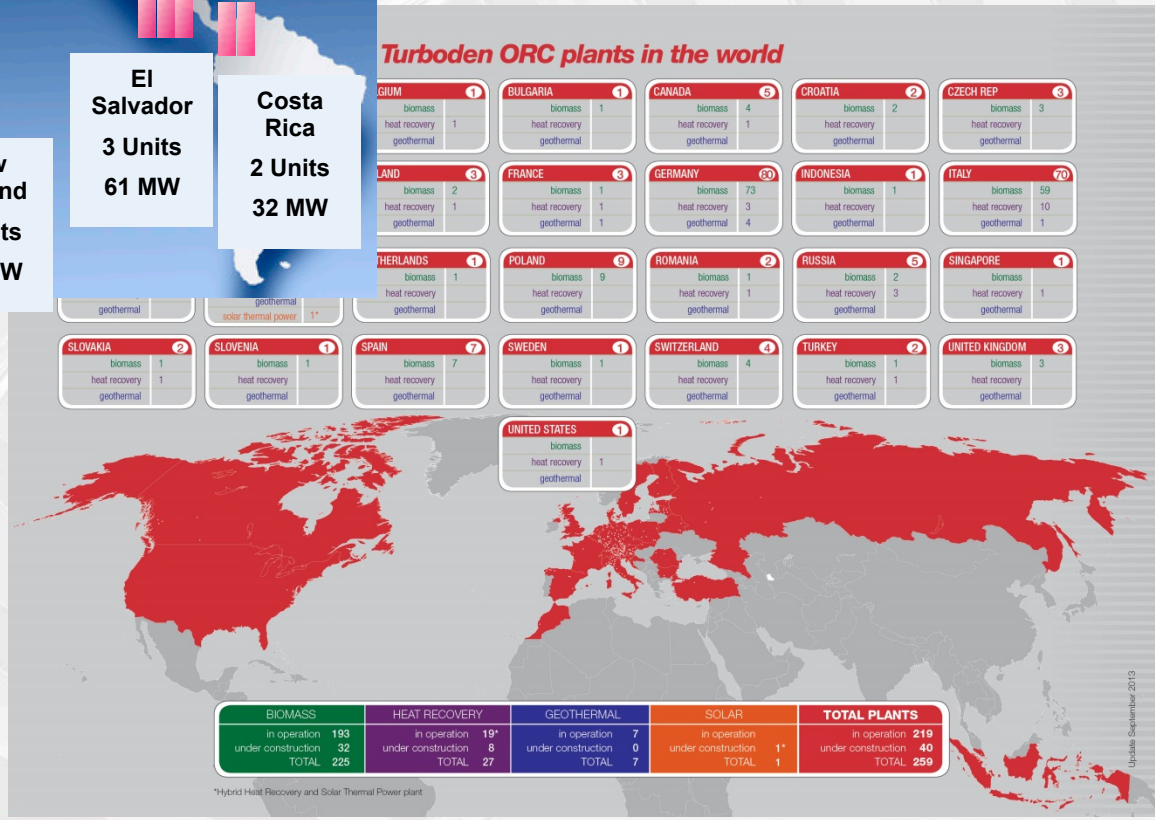
Turboden – a Group Company of MHI



Mitsubishi Geothermal Power Plants supply record:

- Total Output: 3.108 MW
- Total Units: 103 Units



Turboden ORC Plants supply record:

- Total Output: 335 MW
- Total Units: 259 Units
- Total Geothermal: 28,5 MW

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Optimized Solutions to speed up the geothermal growth

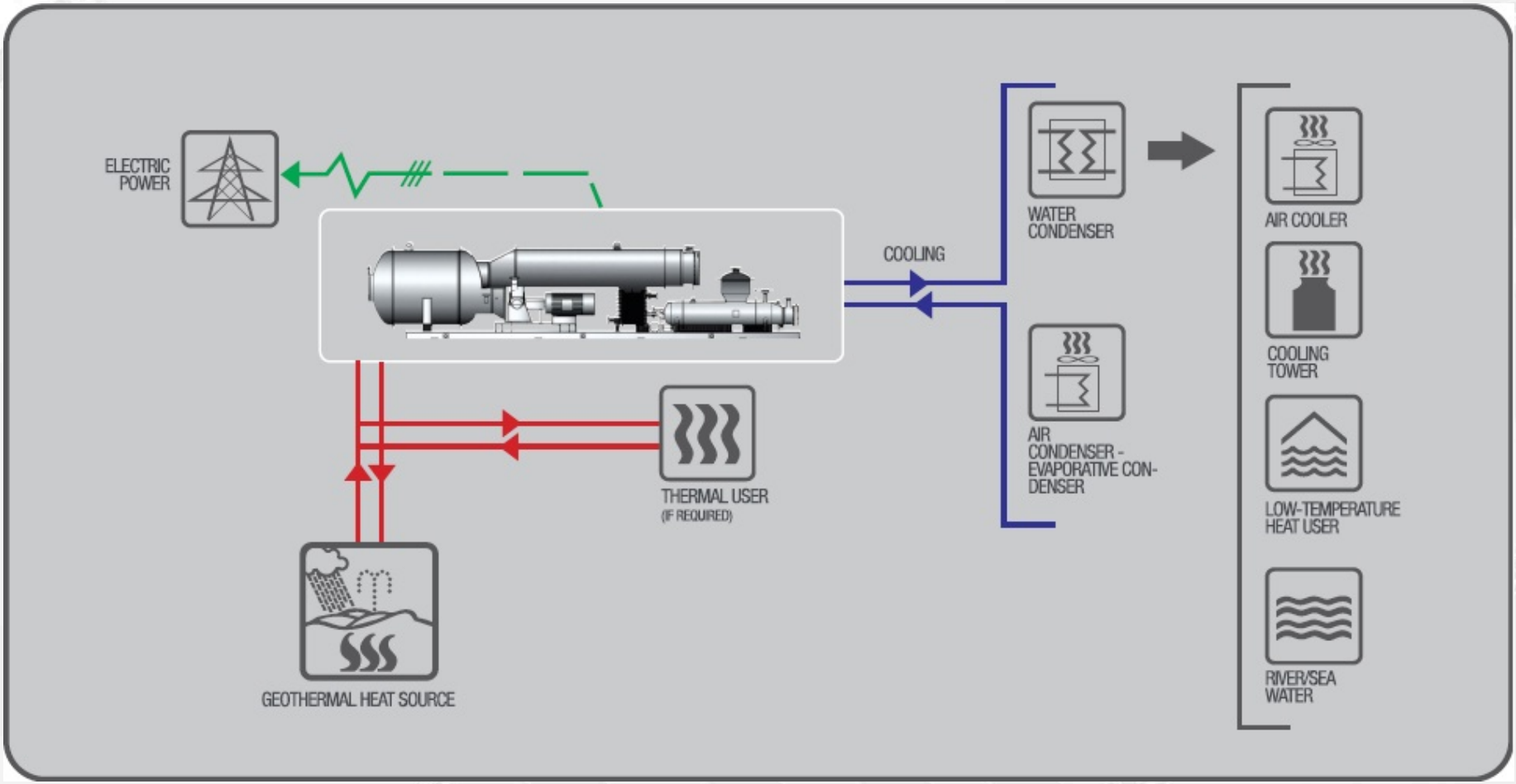
SPEED UP THE GROWTH …

- Support the Developer at early stage
- Hot water resource between 100°C and 200°C
- Hybrid solutions coupled to steam plants
- Unit size up to 15 MW_{el} - Scalable for larger plants
- High cycle efficiency / Off grid capability
- Air or Water cooling
- Cogenerative Heat & Power solutions
- Wide selection of working fluids (also non-flammable)
- Typical delivery time: 11-13 months

…SUSTAINABLE GROWTH

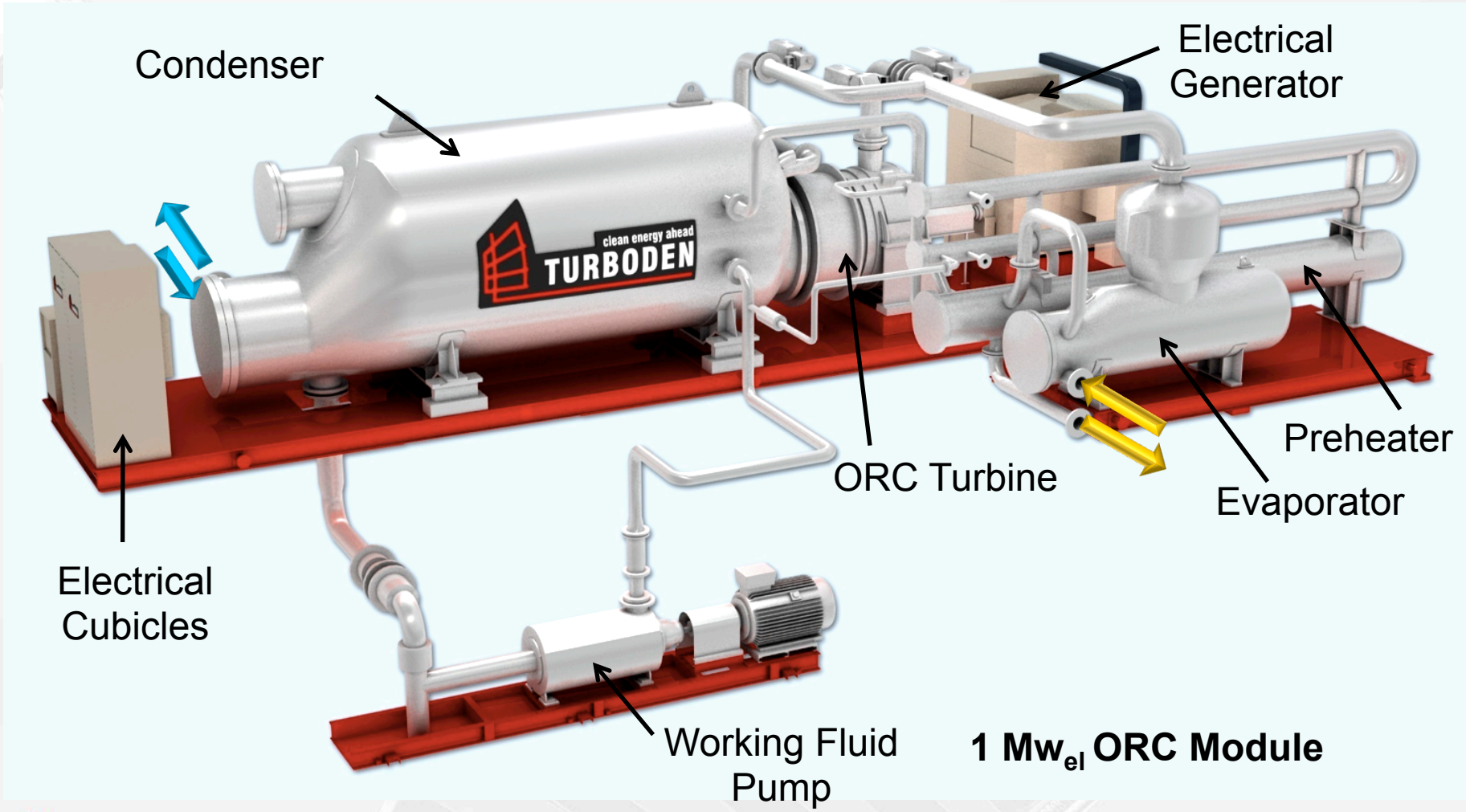
- Low O&M requirements / Reliability
- Commissioning and start-up + Training
- Service maintenance + 24/7 remote assistance

Binary Plant Schematic



No standard heat/cooling sources → highly customized solutions

ORC – how it works?



Hot Resource (geothermal water / steam)

Cold Resource / Cogeneration

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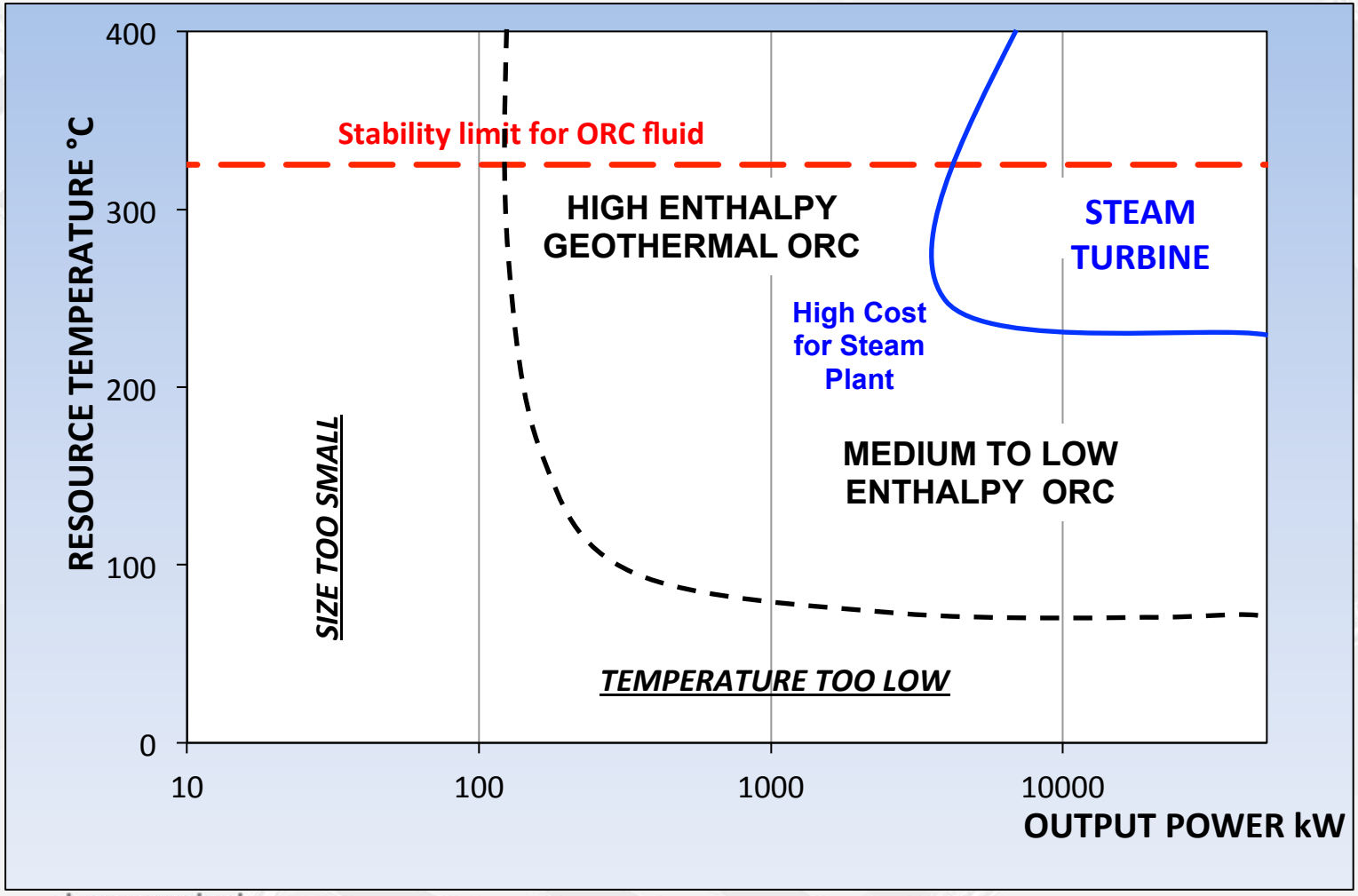
Turboden + MHI: Ranges of Application



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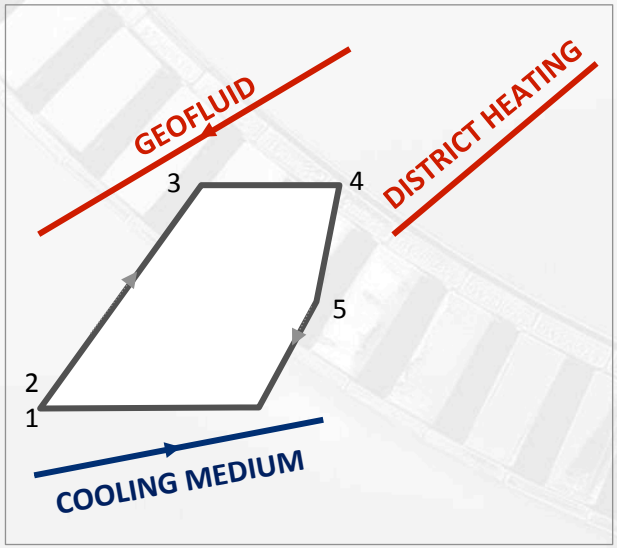
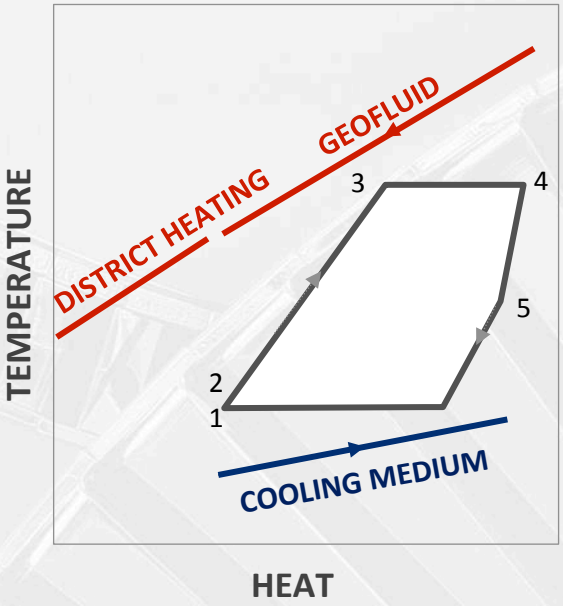
Geothermal Plant Video

Geothermal CHP: Different possible schemes

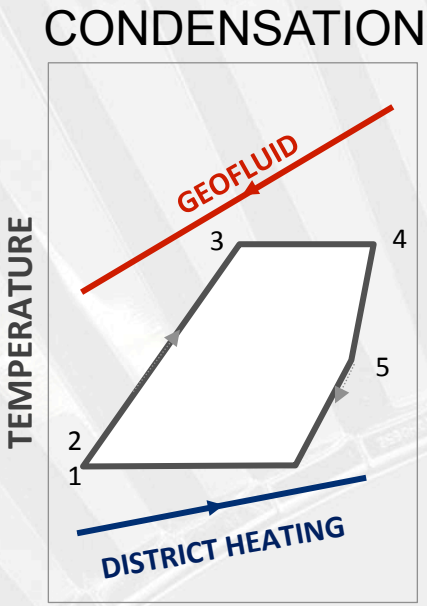
PARALLEL



CASCADE



CONDENSATION



- In Parallel (Traunreut, Altheim, Simbach-Braunau)
- In Series (cascade uses)
- From the Condensation Heat (classic cogeneration concept, LowBin)
- 2-Level Cycle Heat Decoupling – mixed parallel / cascade (Sauerlach)

Existing Geothermal District Heating Systems can be improved!

Turboden Geothermal Plants in Bavaria

Kirchstockach:
5,6 MWel

Dürrnhaar:
5,6 MWel

Sauerlach:
5,6 MWel + 4 MWth

Reference Plant - Sauerlach

Plant type: Two level cycle geothermal unit

Customer: SWM - StadtWerke München (public utilities company)

Location: Bavaria, Germany

Started-up: February 2013

Heat source: geothermal fluid at 140°C

Cooling device: air condensers

Total electric power: 5+ MW_{el} plus 4 MW_{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)

Heat source: geothermal fluid at 138°C

Total electric power: 5,600 kW

Started-up: December 2012

Scope of supply: EPC contract for the complete ORC unit, including the Air Cooled Condenser and the geothermal balance of plant

5.6 MWe geothermal ORC Turboden plant for Hochtief Energy Management. Dürrnhaar – Munich, Germany – 2012

Reference Plant - Kirchstockach

Customer Name: Hochtief Energy Management GmbH

Location: Kirchstockach (München)

Heat source: geothermal fluid at 138°C

Total electric power: 5,600 kW

Started-up: March 2013

Scope of supply: EPC contract for the complete ORC unit,
including the Air Cooled Condenser and the geothermal balance of plant

Foto www.ottaviotomasini.it — 5.6 MWe geothermal ORC Turboden plant for Hochtief Energy Management, Kirchstockach – Munich, Germany – 2013

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Reference Plant - Traunreut

Customer Name: Geothermische Kraftwerksgesellschaft Traunreut mbH

Location: Traunreut (Bavaria)

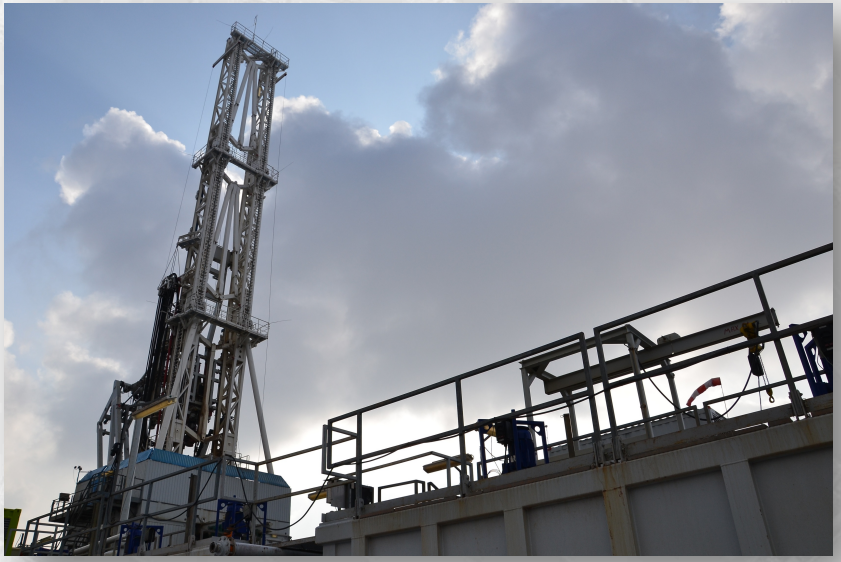
Heat source: geothermal fluid at 118°C

Total electric power: 4,100 kW

Total thermal power: 12,000 kW (to the District Heating)

Status: Under Construction

Scope of supply: Supply of the complete ORC unit,
including the Air Cooled Condenser and control system of geothermal site



Reference Plant – Turboden / MHI

Plant type: Brine + Steam ORC geothermal unit

Start-up: Q1 2015

Heat source: geothermal brine / steam 140°C → Conditions very similar to Italy

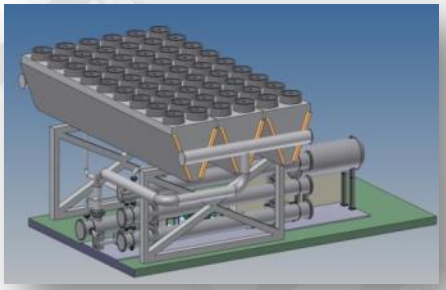
Cooling device: air condensers

Total electric power: 5+ MW_{el}

Working fluid: n-pentane

Last order awarded / new reference under construction

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_{el}

Working fluid: refrigerant (non flammable)

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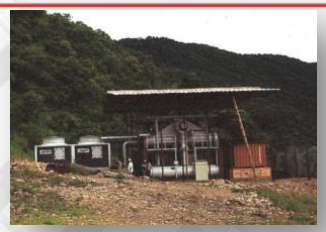
Early Demonstration Projects



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

LOW-BIN GEOTHERMAL POWER

Germany – Italy: comparative analysis

Driver	Germany	Italy
Political willingness	Boost since 2000	National Energy Strategy: insufficient relevance
EU obligations (Dir. 2009/28/CE)	2020 Geothermal target: Additional ~ 300 MW (no tradition, deep drilling, no steam)	2020 geothermal target: Additional ~200 MW (tradition since early '900, shallow drilling, dry/ flash steam)
Incentive scheme	250€/MWh for 20 years +50 €/MWh if stable EGS	159€/MWh (register) – 230€/MWh (50MW) ~3% total incentive RES/year … After 2015?
Timing	2007 projects – 2010 contracts – 2012 start-up (3-6 months authorization)	Pilot project - MiSE Regional regulations No guideline, no homogeneity
Mineral risk management	Helped by public intervention	Barrier against development
Finance	Financially structured subjects	Pre-authorization phase with own resources Risky investments
Technological development	Leading element in the RES policy	Geothermal since early '900. ORC "cross" technology (biomass, HR, CSP)
Industrial boost (export)	Leading element in the RES policy	Made in Italy: excellence in all the supply chain (exploration, drilling, power block, management)
Training Information	More social acceptability and dissemination: wiki «geothermie» pag .17	Inadeguate information and hostility: wiki «geotermia» pag. 1

Proposals for the Italian context

- More valorization of national technology: to boost the industrial system
- How to improve D.M. 6/07/2012: e.g. extension of incentive tariffs until 2020 (stability for investment)
- To develop financial scheme for investments (e.g. EIB funds)
- Support/public guarantee for pre-investment phase
- Training and information campaign
- More valorization for the Italian export
- R&D support for geothermal technology

Back-up slides

Come and visit the next International Geothermal Summit in Essen, Germany

12 – 14 November

Foto www.ottaviotomasini.it 5.6 MWe Geothermal ORC Turboden Plant for Hochtief Energy Management. Kirchstockach - Munich, Germany - 2013

Geothermal Energy is sustainable!

Turboden will support the Growth!

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Thank you for your kind attention!

Joseph Bonafin – Sales Manager Geothermal

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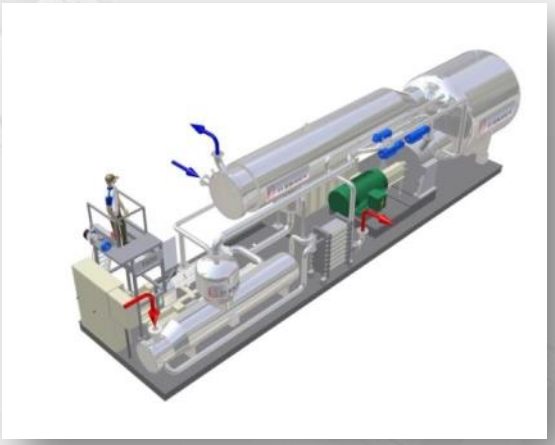
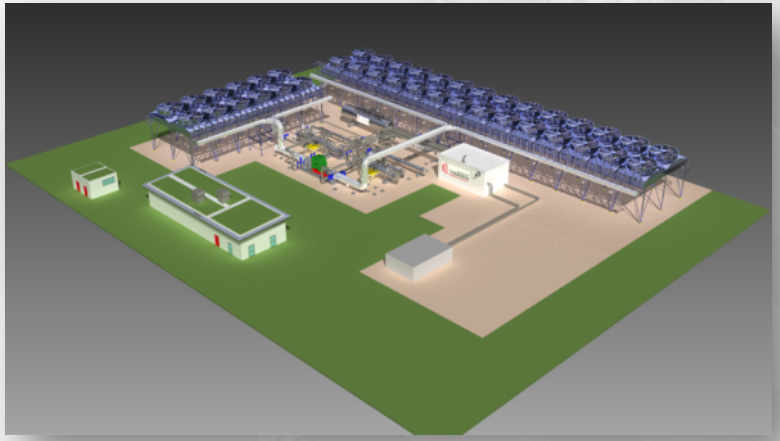
Layout – Some Examples

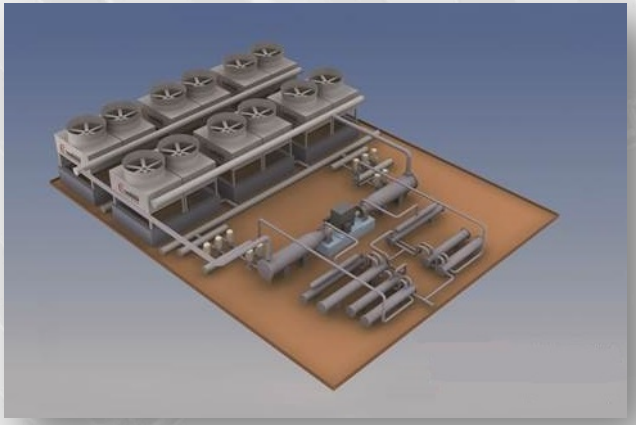


TURBODEN 7 layout

TURBODEN 10 layout



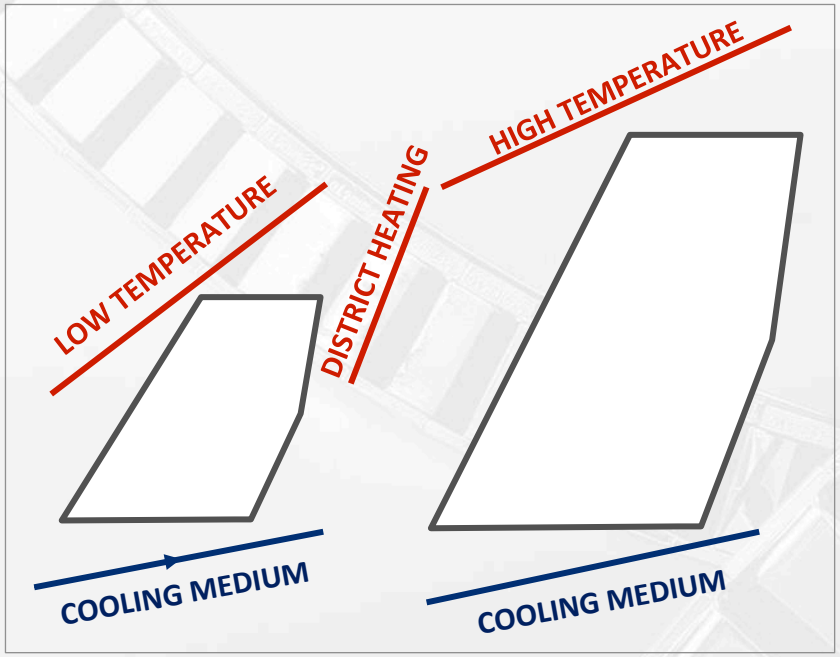
Geothermal 5 MW Air-cooled



Geothermal 15 MW Water-cooled

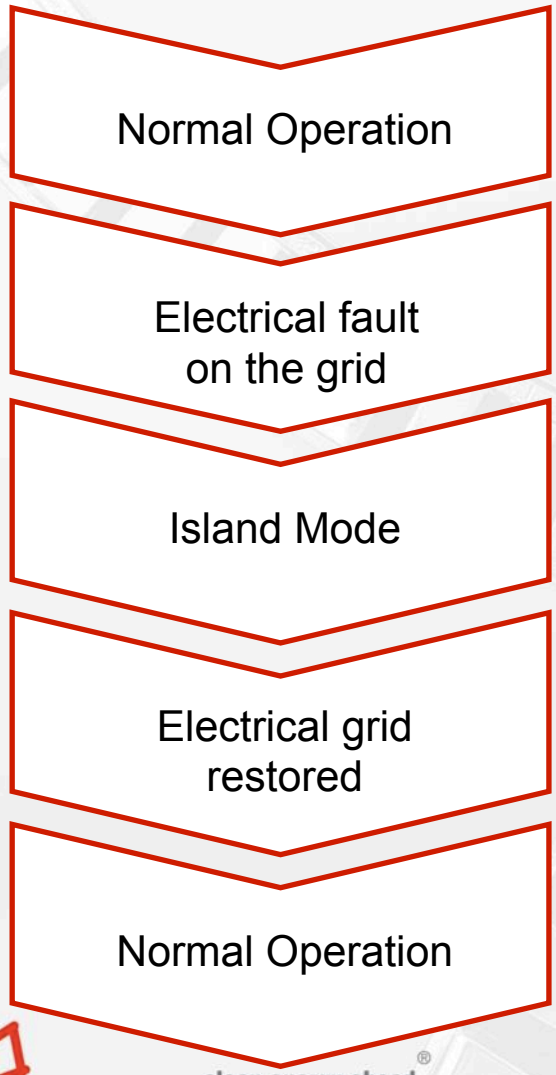
Geothermal CHP: Different possible schemes

HEAT DECOUPLING WITH 2 LEVEL CYCLE



- Sauerlach → 4 MW nominal heat coupling
- Duerrnhaar → “blind flanges”, possible future development
- Kirchstockach → “blind flanges, possible future development

ORC on island mode



In case of **electrical fault on the grid** outside the main circuit, can be required to keep the ORC operating on island mode (feeding the local auxiliaries).

Main advantages of this capability are:

- avoid start and stop of the geothermal pump, involving less stress to the pumps and wells
- Keep the plant ready for quick re-synchro to the grid
- Increase availability of the district heating

The main issue of this process is related to the switch on and off on the island operating mode, since it is required both **fine** and **fast** regulation.

Sauerlach geothermal plant is designed to automatically **switch from normal operation to island operation**.

During the island operation the **power generated by the turbines** (P turbine) has to be **equal to the power required** by the electrical loads of the plant (P island).

Turboden strength points

R&D	Sales/marketing	Design	Operations & manufacturing	Aftermarket service
• 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	• Pre-feasibility studies: evaluation of technical & economical feasibility of ORC power plants • Customized proposals to maximize economic & environmental targets	• 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	• Outsourced components from highly qualified suppliers • Quality assurance & project management • In house skid mounting to minimize site activities	• Start-up and commissioning • Maintenance, technical assistance to operation and spare parts service • Remote monitoring & optimization of plant operation