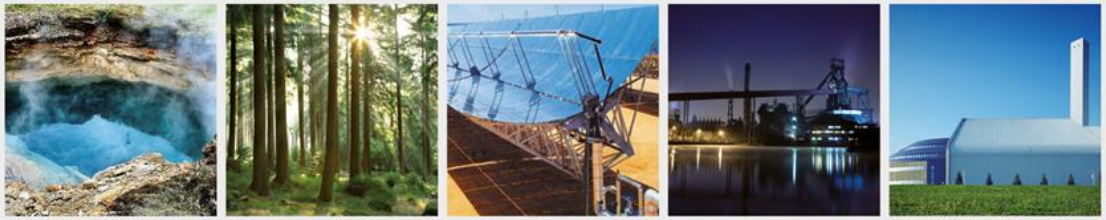
European Technology
Deep Geothermal
& Innovation Platform

European Technology Deep Geothermal & Innovation Platform

Turboden experience in geothermal application



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a group company of MITSUBISHI HEAVY INDUSTRIES, LTD.

Marco Baresi – Institutional Relations

Brussels, 6th April 2016

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 320 plants in the world, **265 in operation**, 200+ employees, ~ 70 M€ turnover (2015)

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What We Do

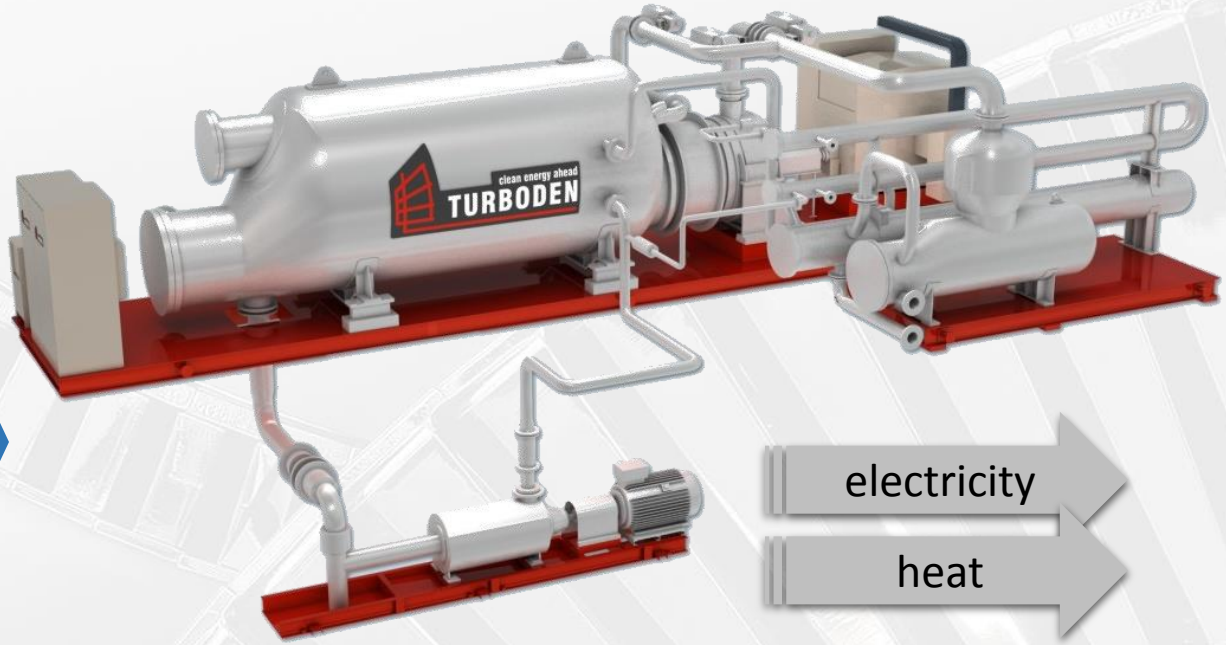
Biomass

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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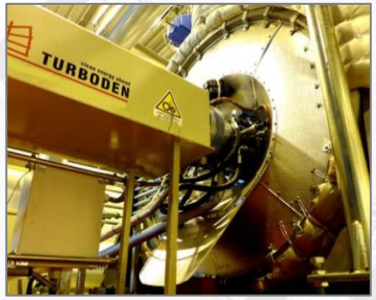
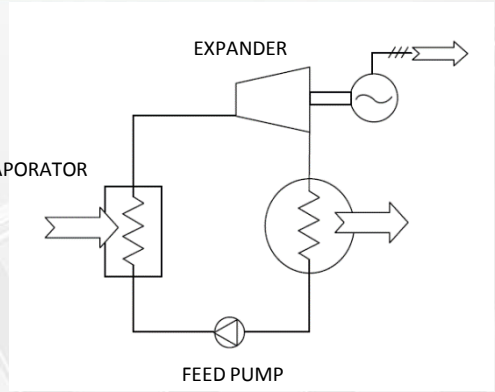
Organic Rankine Cycle: concept

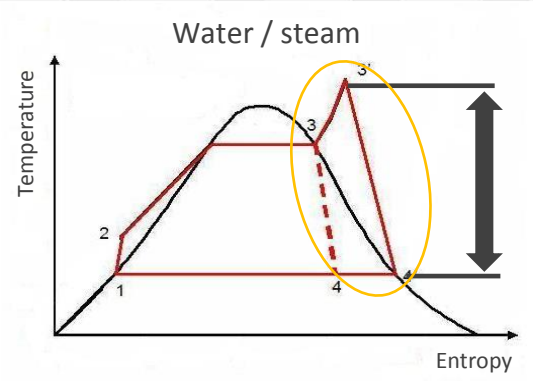


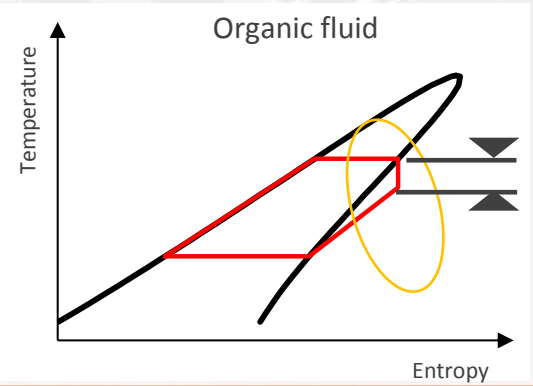
Cycle	it is a thermodynamic cycle
Rankine	it is theoretically given by 2 isobar and 2 adiabatic thermodynamic transformations
Organic	it exploits an organic working fluid

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).

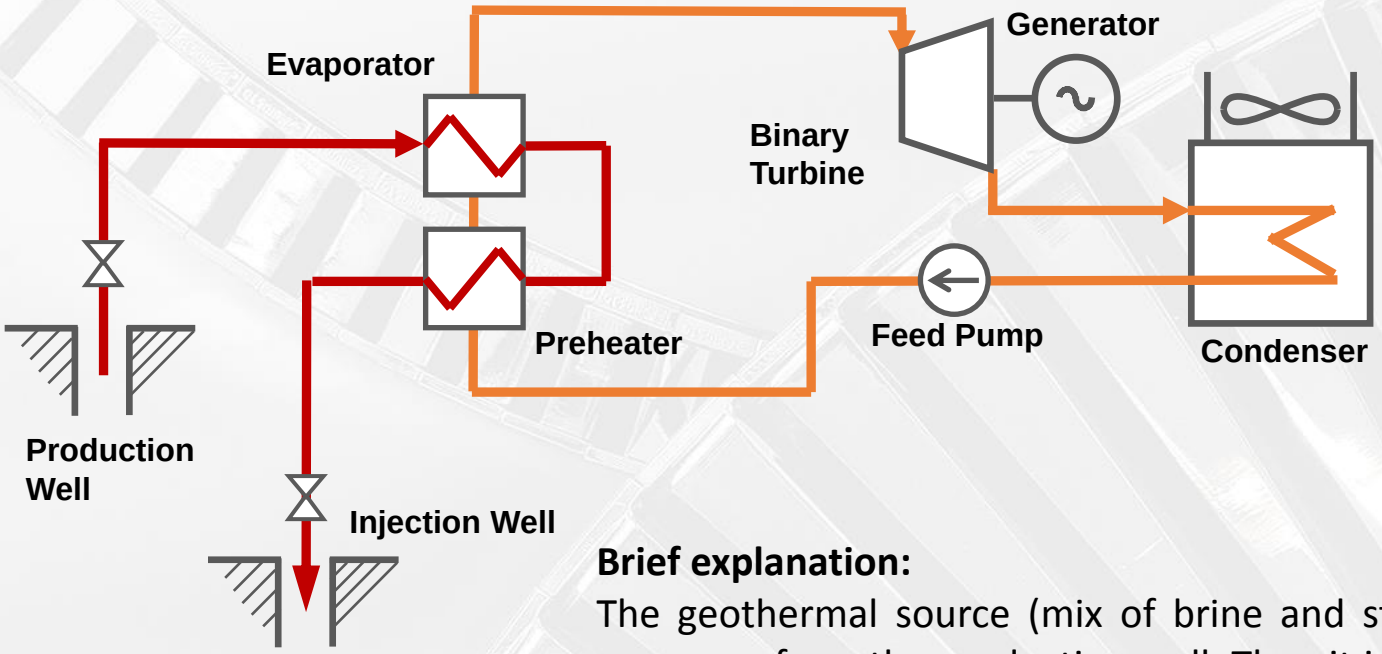






Geothermal technology: binary plant

BINARY PLANT

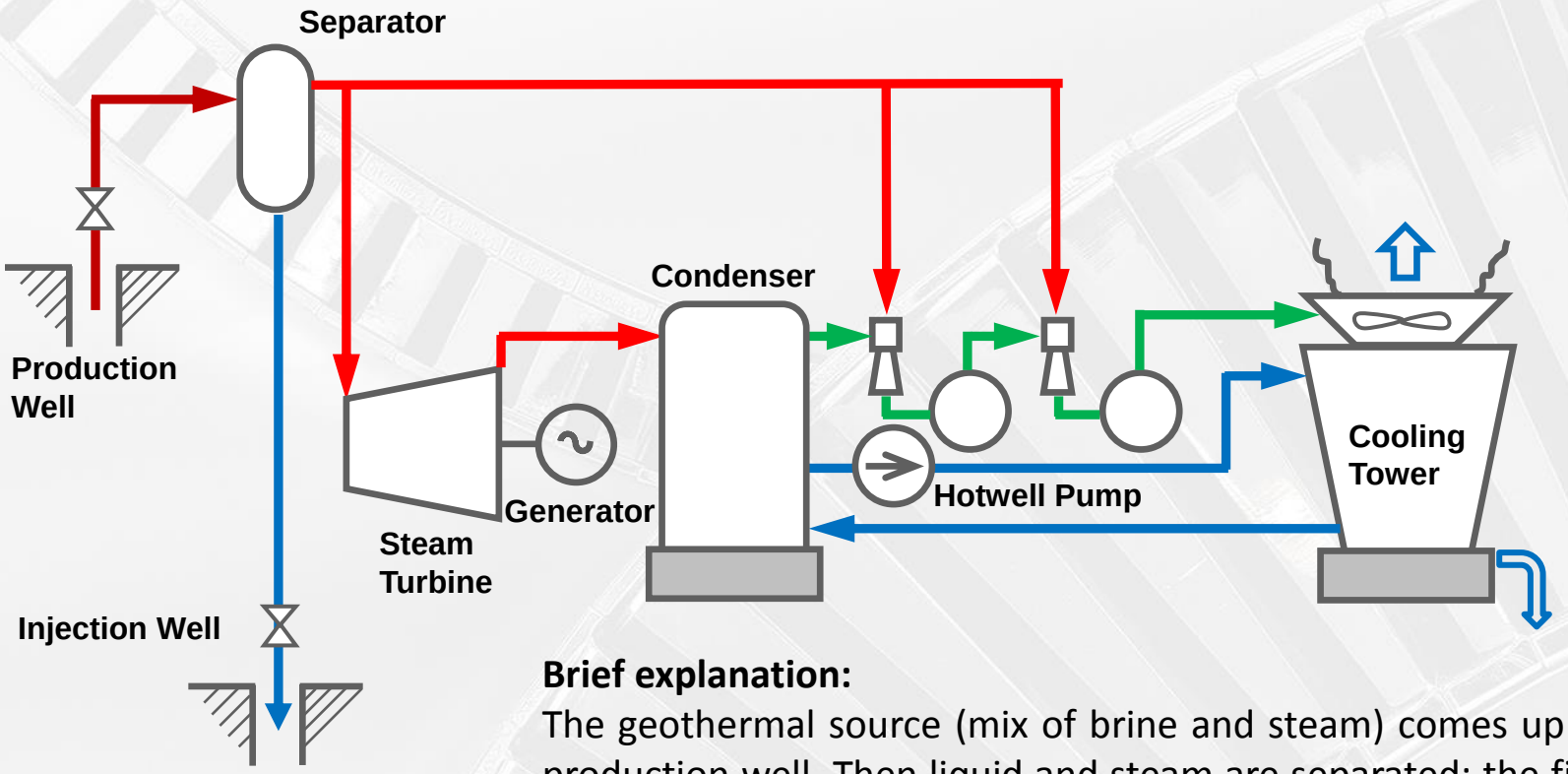


Brief explanation:

The geothermal source (mix of brine and steam or only brine) comes up from the production well. Then it is cooled through the heat exchangers giving heat to the binary fluid, which flows inside an independent loop. The cooled geothermal source is then entirely reinjected. The hot binary fluid passes through the turbine generating power, then it is condensed by means of a condenser (with water or air) and pumped again into the heat exchangers, so the cycle can restart.

Geothermal technology: flash plant

FLASH PLANT



Brief explanation:

The geothermal source (mix of brine and steam) comes up from the production well. Then liquid and steam are separated: the first one is reinjected, while the steam passes through the turbine to generate power. After the turbine, the exhaust steam is condensed by means of a semi-open circuit made by the condensate itself. The condensate is usually cooled in a cooling tower.

Geothermal technology: comparison between flash and binary plants

FLASH	BINARY
Mainly suitable for geothermal source when the **steam share is significant** and/or when the **temperature is higher than 150 ÷ 200 °C**	Mainly suitable for geothermal source where the **liquid share dominates** and the temperature is not so high (furthermore, binary plants are very favorable when the **source temperature is lower than about 150 °C or when there is only liquid**)
The plant uses the geothermal separated steam directly through the turbine, with related problems regarding the liquid formation and corrosion at the turbine blades	The plant has an independent closed fluid loop that exchanges heat with the geothermal fluids, so the geothermal fluid is in contact only with corrosion-resistant components
The cooling is usually made with water system, as the condensate becomes available as cooling medium	**The cooling system can be made with either water or air or both of them**
The cooled geothermal source is not entirely reinjected underground because part of it is lost in the cooling tower	**The cooled geothermal source can be completely reinjected underground**
Flash plants, together with dry steam plants, **represent most of the installed capacity worldwide (around 85 %)**	Binary plants represent **approximately half of the number of total power plant all over the world**

Global leadership in geothermal

over $40 billion (in fiscal 2014)

The largest segment of MHI
over $16 billion (in fiscal 2014)

MITSUBISHI HEAVY INDUSTRIES, LTD.

HITACHI

Other Business Domains

Energy & Environment, Domains

Power Systems Company

Other Companies

Integrate the thermal and geothermal power generation systems businesses in Feb, 2014, now known as

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MITSUBISHI HITACHI POWER SYSTEMS

> 320 ORC plants globally
0.5 GW ORC power

23 % market share

>100 units globally
> 3 GW power

Turboden is the worldwide reference ORC company for MHI

Geothermal Power Plant (Binary Cycle)

Geothermal Power Plant (Flash Cycle)

EU Turboden GEOTHERMAL Funded Demonstration Projects … since 2001

Marktgemeinde, Altheim, Austria

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

Started up: March 2001

Heat source: hot water at 106°C

Design electric power: 1 MW (normally operated by the owner at ~ 500 kW)

FP4-NNE-THERMIE C

Soultz-sous-Forêts, Alsace, France

Plant type: geothermal, 1st EU operating plant on EGS (Enhanced Geothermal System)

Started up: June 2008

Heat source: hot water at 180°C

Total electric power: 1.5 MW

FP6 - SUSTDEV

INTERREG IVC
INNOVATION & ENVIRONMENT
REGIONS OF EUROPE SHARING SOLUTIONS

Simbach-Braunau,Germany/Austria

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

Started up: August 2009

Heat source: air/water at 80°C

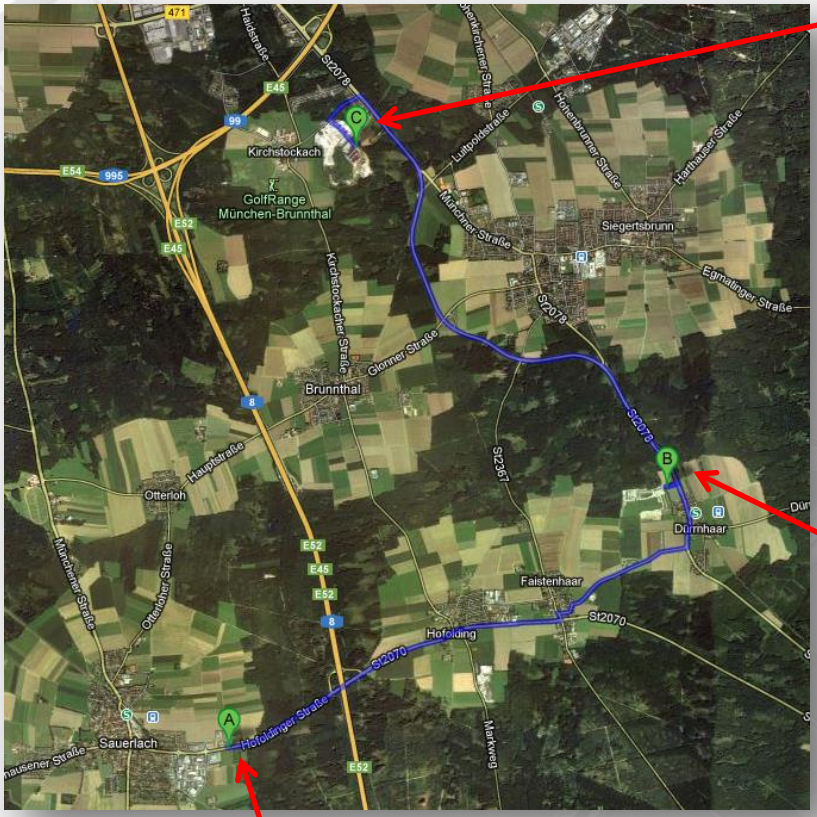
Design electric power: 200 kW

FP6 - SUSTDEV

LOW-BIN
GEOTHERMAL POWER

From pilots … to commercial projects

Turboden Geothermal Plants in operation in Bavaria since 2011 with 98% availability



Kirchstockach:
5,6 MWel

Dürrnhaar:
5,6 MWel

Sauerlach:
5 MWel + 4 MWth

→ Traunreut:
4 MWel + 12 MWth

5 MWel typical Layout, a picture from Bavaria

Foto www.ottaviotornasini.it

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

NER 300 project: CLEAG

CLEAG

Plant type: clozed loop technology

Customer: AAT Geothermae/CLEAG

Site: Croatia

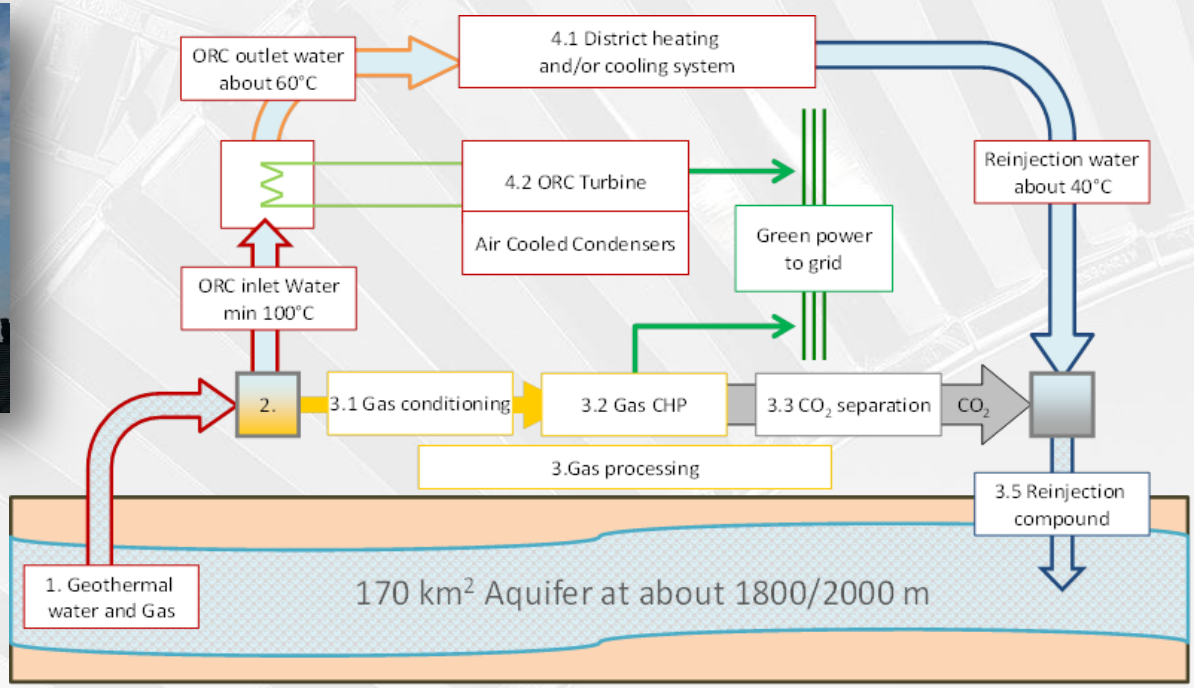
Start up: Q2 2017

Heat source: geothermal brine @103°C

Cooling device: Air Cooled Condenser

Total power: 4.2 MW on a single turbine

Working fluid: Isobutane



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Plant under construction: 16.5 MW Velika Ciglena (Croatia)

Plant type: ORC geothermal unit

Customer: MB Holding

Site: Croatia

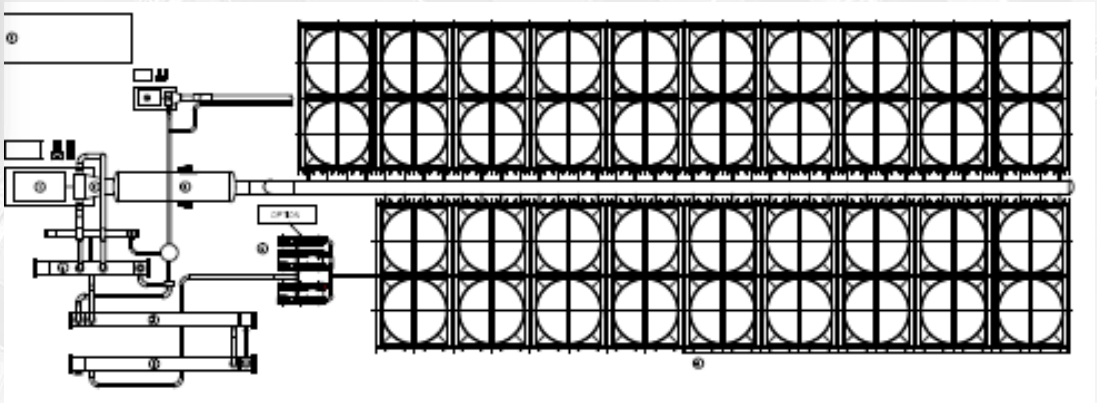
Start up: Q4 2016

Heat source: geothermal brine and steam @170°C

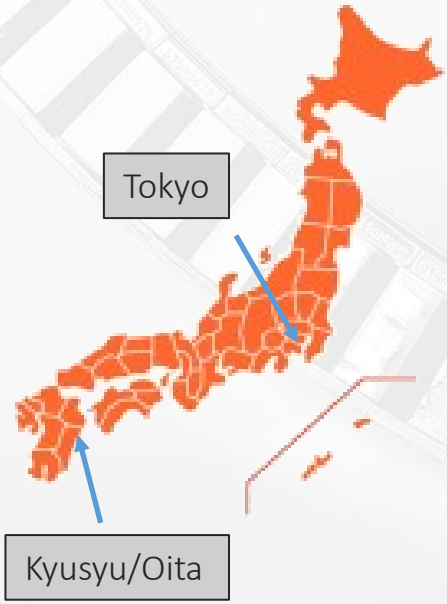
Cooling device: Air Cooled Condenser

Total power: 16.5 MW on a single turbine (including a 1.5 MW NCG expansion turbine)

Working fluid: Isobutane



Recent project: Sugawara plant in Japan



Plant type: brine + steam ORC geothermal unit
Location: Japan
Status: in operation since June 2015
Heat source: geothermal brine/steam 140°C
Cooling device: air condensers
Total electric power: 5+ MW
Working fluid: n-pentane

Plant under construction: Montelago geothermal (Philippines)

Plant type: 4 X Turboden 10 MW ORC units

Customer: Emerging Power Inc

Site: Mindoro Island, The Philippines

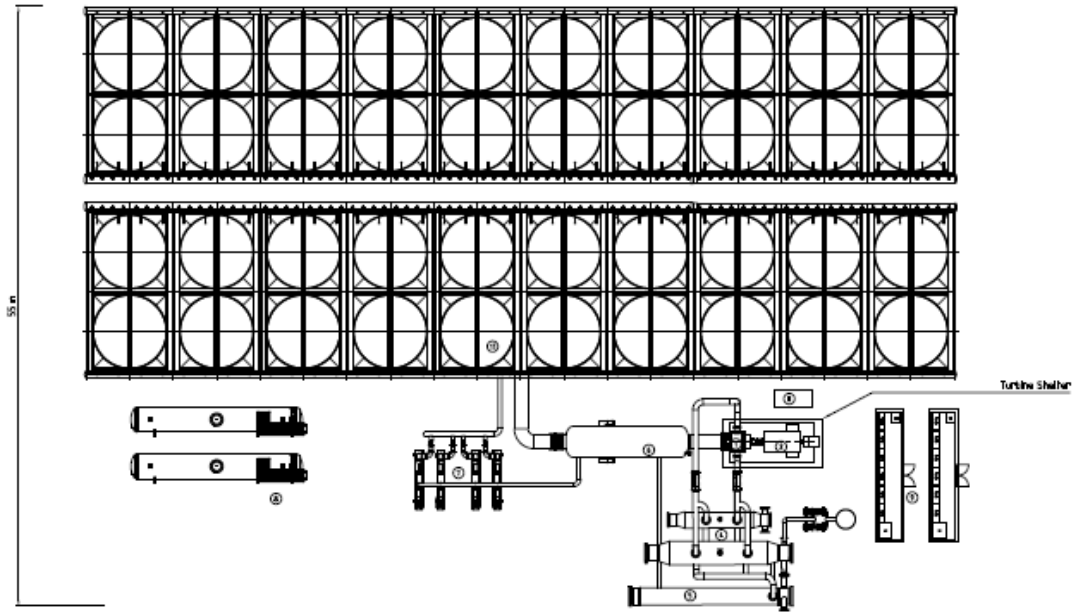
Start-up: under construction (first 10 MW foreseen for Q3/Q4 2017)

Heat source: geothermal fluid at 159°C

Cooling device: air condensers

Total power: 40 MWel net

Working fluid: Isopentane



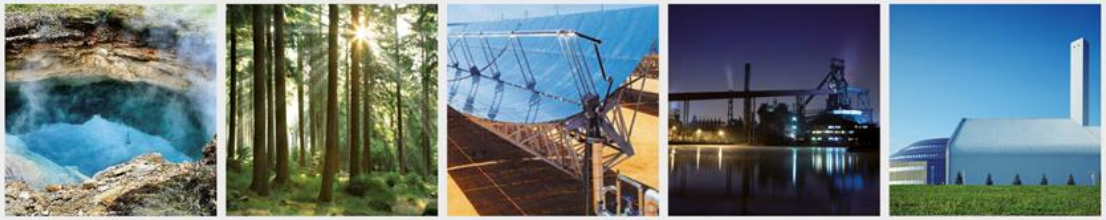
Turboden's vision of ETIP

Turboden is member of EGEC since 2007
Rete Geotermica

R&D was important and is still crucial for Turboden developments … with more than 320 ORC plants in 33 countries it represents an EU technology excellence

R&D further efforts are strongly recommended for ORC
✓ focus on specific components
✓ district heating application
✓ increase cooling system efficiency
✓ bottoming existing flash plants
✓ testing the next generation of working fluids
✓ storage and grid balance

Thank you for your attention



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