MARKET STUDY

FOR GEOTHERMAL BINARY PLANTS

PREPARED FOR THE LOW-BIN PROJECT

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LOW-BIN technology

- Low temperature power only ORC prototype
- Geothermal ORC heat and power cogeneration technology

External factors

Opportunities

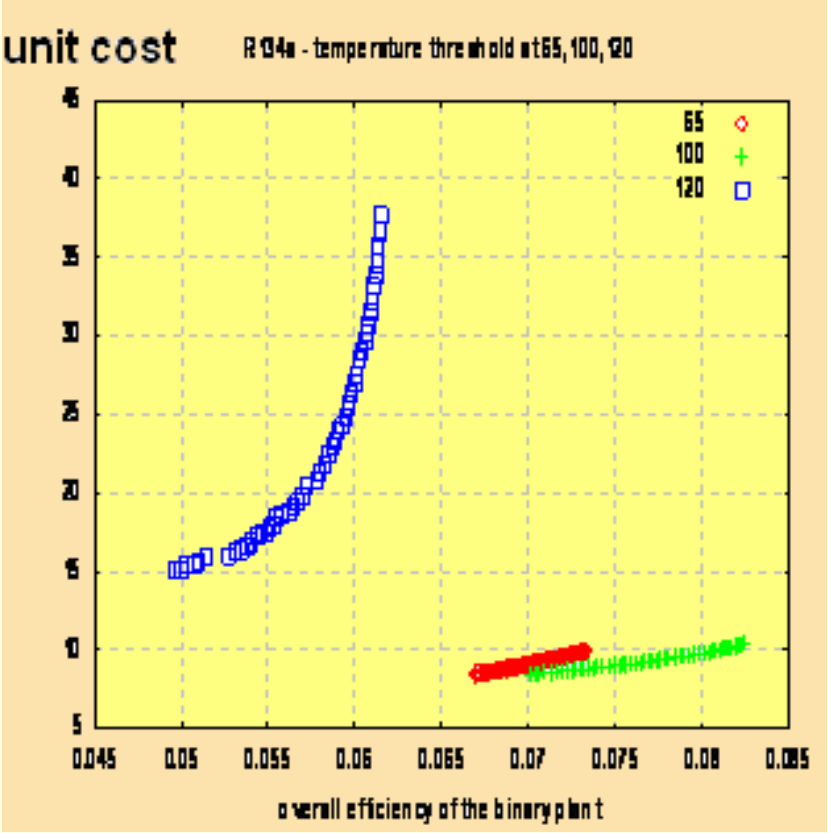
- A growing global shift to renewable energy
- The great number of announced geothermal projects worldwide
- Favorable policy (e.g. feed-in tariffs) in some countries

Threats

- Geothermal policy in Europe not so ambitious as elsewhere
- Limited availability of district heating systems
- Low priced fossil fuels

Manufacturing costs

- Green line: standard ORC machine designed for 100°C source
  - baseline
- Red line: Low-Bin prototype operating at low source temperature
  - 20% higher costs
- Blue line: Low-Bin cogeneration prototype
  - 100% higher costs



Low temperature Low-Bin prototype

Strengths:

- The prototype has the ability to generate power from low temperature resources, widening market opportunities and improving the feasibility of low temperature geothermal heat supply.
- The prototype can be coupled to an existing geothermal district heating system for summer operation improving the plant utilisation factor.
- It is a very reliable machine.
- The prototype can be remote controlled minimising the need for additional qualified personnel.
- It has limited needs for maintenance.
- It allows zero emissions geothermal exploitation.

Weaknesses:

- The prototype has 20% higher manufacturing cost than standard ORC plants.
- It yields 30% less power output than other ORC machines due to low resource temperature.

Cogeneration Low-Bin technology

Strengths:

- The unit has the ability to co-generate heat and electricity from medium temperature resources, in a very efficient manner, widening market opportunities and improving the feasibility of medium temperature geothermal heat supply.
- The unit can be coupled to an existing geothermal district heating system delivering free electricity during winter, and a lot additional electricity during summer improving considerably the plant utilisation factor and financial performance.
- It should be a very reliable machine, as other binary plants.
- The unit should be remote controlled minimising the need for additional qualified personnel.
- It should have limited needs for maintenance.
- It will allow zero emissions geothermal exploitation, as other binary plants.

Weaknesses:

- The unit has 100% higher manufacturing cost than standard ORC plants.
- In cogeneration mode it delivers 50% less power than in electricity only mode.

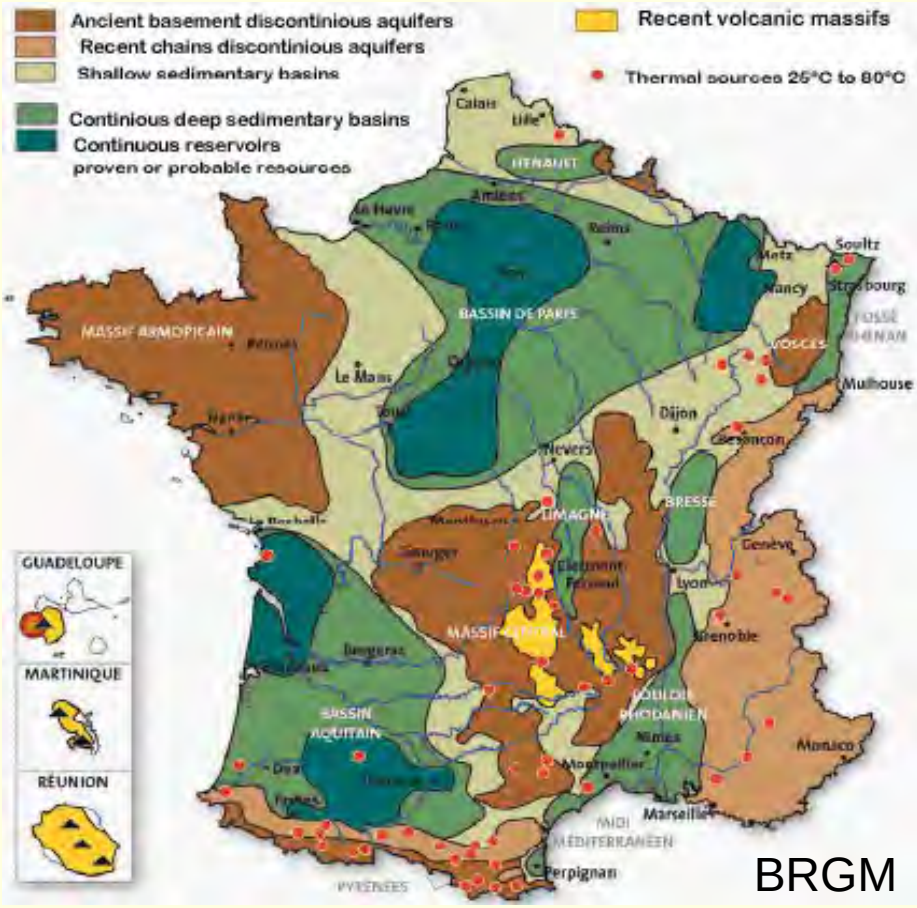
Markets for the Low-Bin binary plants

- EGS plants
- New geothermal power projects in resources 80-180°C (coupled or not to district heating)
- Power generation from existing geothermal district heating installations
- Power generation from oil exploration or production wells
- Attached to the separated brine line in existing or new flash plants (resources >180°C)
- Energy recovery from industrial processes
- Solar power

Geothermal resources of France

- Paris Basin: 65-120°C
- Aquitaine Basin: 75-115°C
- Limagne Graben: 70-100°C
- Rhine Graben: 80-200°C
- Rhône Graben: 65-150°C
- Bresse Basin: 75-130°C

- Guadeloupe: 250°C
- Martinique: 90°C
- Reunion: 100°C



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Geothermal utilization in Paris Basin

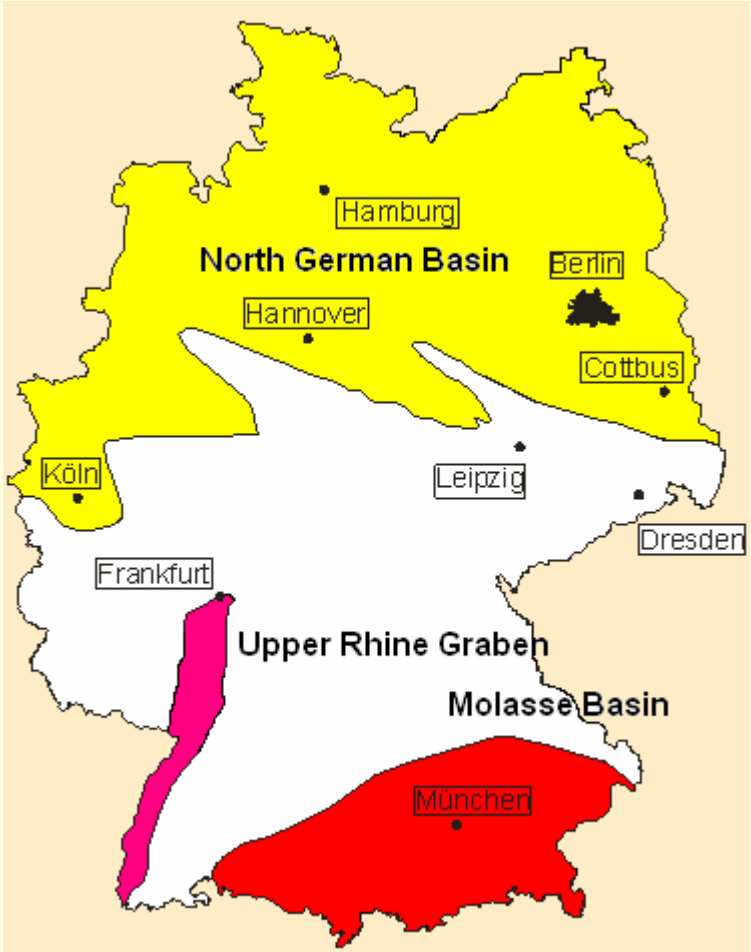
- ~30 district heating operations
- 65 - 85°C
- Total flow >2000 kg/s
- 26 Low-Bin prototypes can be installed for summer operation

Geothermal utilization for district heating in Iceland

- ~20 district heating operators
- 154 geothermal wells
- 70 - 205°C
- Total flow >5800 kg/s
- 73 Low-Bin prototypes can be installed for summer operation

Geothermal resources of Germany

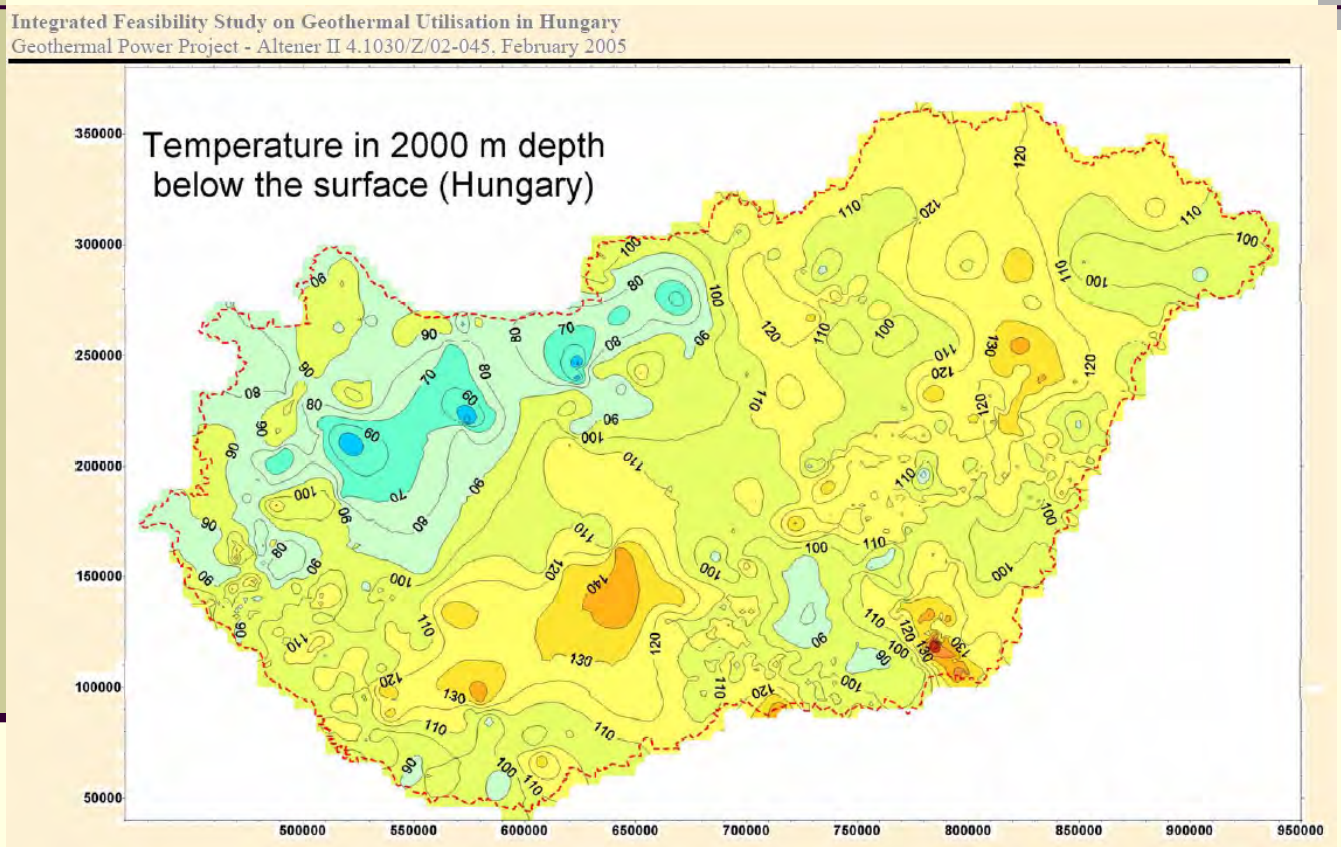
- North German Basin: 130-160°C
  - Low flow, high salinity
  - Depth: 4 – 5 km
- Molasse Basin: 100-170°C
  - High flow, low salinity
  - Depth: 2.5 – 4 km
- Upper Rhine Graben: 130-170°C
  - Medium flow, high salinity
  - Depth: 2.5 – 4 km



Geothermal utilization in Germany

- 5 power plants combined with district heating (8 MWe, 28 MWth) in operation
- 6 new district heating projects (50 MWth) announced
- 3 new power & district heating plants (20 MWe, 94 MWth) announced
- 9 new power plants (50 MWe) announced
- 150 additional combined power & district heating plants in the plans

Geothermal resources of Hungary



- More than 5000 wells drilled for oil exploration
- 80 – 130 °C at 2 km all over the country

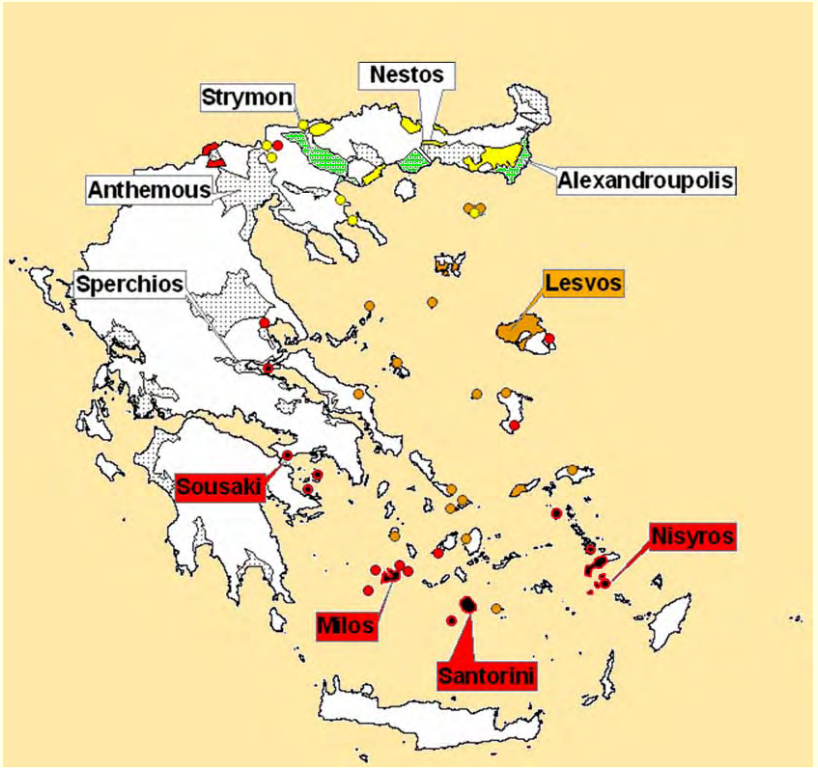
Geothermal resources of Romania

- Oradea-Bors: 70-115°C
  - Low-medium salinity,
  - Depth: 2 – 3 km
- Beius: 85°C
  - low salinity, 2.5 – 3 km
- Panonian Basin: 50-85°C
  - medium salinity, 1 – 2 km
- Olt Valley, 92-96°C
  - medium salinity, 2 – 2.5 km
- N. Bucharest, 60-75°C
  - Low salinity, 2- 2.5 km

- Total 124 wells, 1600 kg/s, 20 Low-Bin prototypes

Geothermal wells in Greece

- Milos island: 85-100°C
- Nisyros island: 180°C
- Lesvos island: 80-95°C
- Nestos Delta Basin: 65-80°C
- Alexandroupolis: 90°C
- Strymon Basin: 65-90°C
- Aedipsos: 80°C
- Sousaki: 80°C
- 1100 kg/s total flow
- Depth: 0.1 – 0.8 km
- 14 Low-Bin prototypes

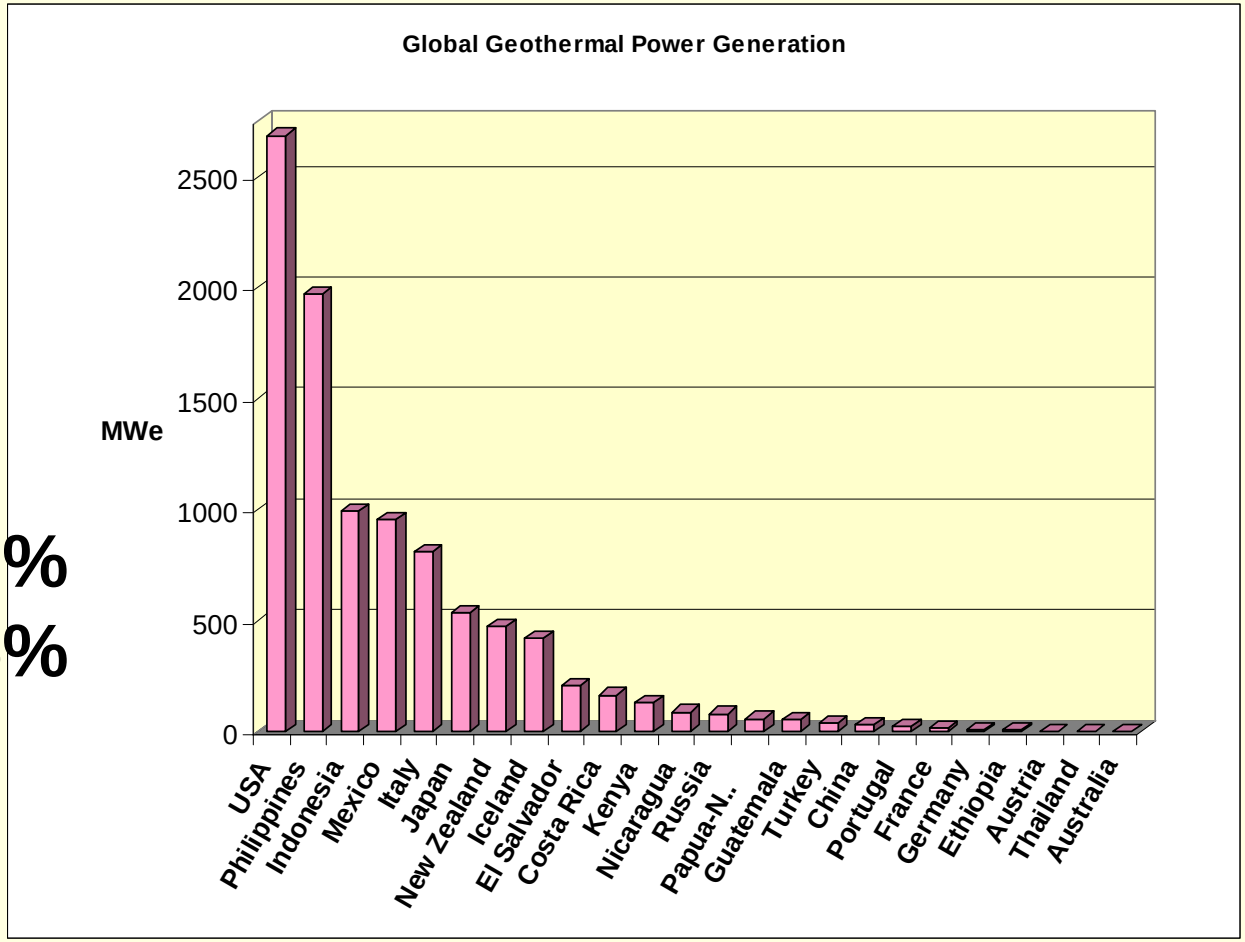


Geothermal Power Market

Capacity
~ 10 GWe
globally

Growth:
2000-2008: **3%**
2009-2016: **15%**

double growth
for the
binary market

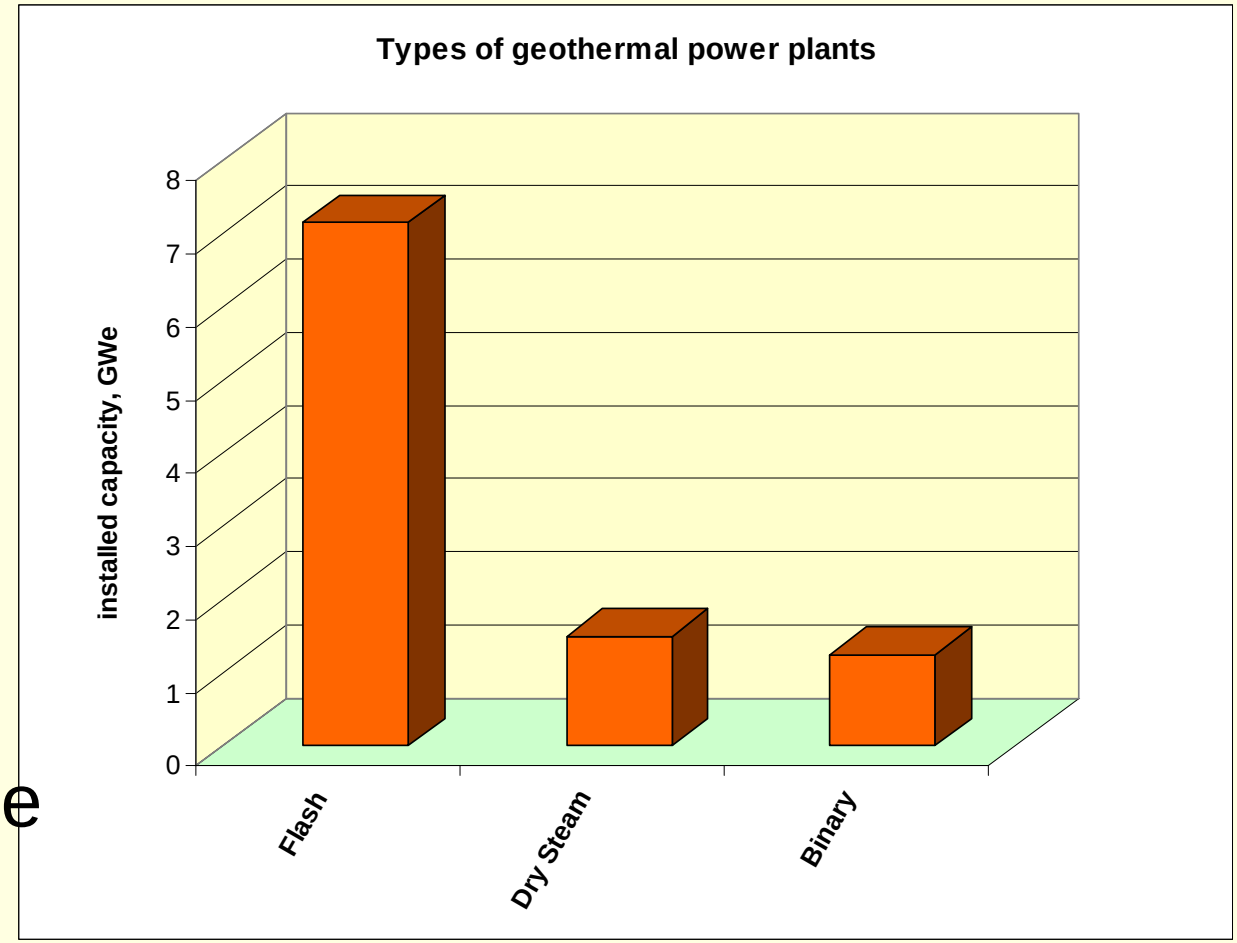


Geothermal Power Plants Types

Flash plants:
7.15 GWe

Binary plants:
1 GWe
at 50 sites

250 MWe
at the brine line
of flash plants



Geothermal Power Generation in Europe

Country	No of units	Installed power MWe	Technology
Italy, Larderello	21	562	Dry steam
Italy, Travale	**6**	**160**	**Flash**
Italy, Piancastagnaio - Bagnore	**5**	**88**	**Flash**
France, Soultz	1	1.5	Binary
France, Guadalupe	**1**	**15**	**Flash**
Portugal, Azores	3	35	Binary
Germany	5	8	Binary
Austria	2	1.2	Binary
Iceland	**12**	**412**	**Flash**
Iceland, Husavik, Svarstengi	2	10	Binary
Turkey, Kizildere	**1**	**14**	**Flash**
Turkey, Kizildere separated brine	**3**	**24**	**Binary**

Geothermal binary plants of Europe

Country	Site	Installed Power MWe
France	Soultz (EGS)	1.5
Portugal	Azores, Ribeira Grande	13
	Azores, Pico Vermelho	10
	Azores, Terceira	12
Germany	Neusdadt Glewe	0.2
	Landau	3.2
	Unterhaching	3.7
	Bruchsal	0.55
	Simbach	0.2
Austria	Bad Blumau	0.25
	Altheim	1
Iceland	Husavik	2
	Svarstengi	8
Turkey	Kizildere	24

Low-Bin manufacturer

Turboden

- the first European geothermal ORC manufacturer
- developed its geothermal unit through European support
- 30 years in the binary business
- provides machines tailor made for the geothermal site, optimising energy extraction
- strong presence in the high temperature biomass heat and power cogeneration market with 118 MWe installed capacity in 11 countries, mainly of central Europe
- in geothermal 2.7 MWe
- leadership in the new but promising EGS market by supplying the first EGS plant in Soulz
- leadership in low temperature power generation and cogeneration through its Low-Bin prototypes
- also active in the energy recovery sector

Mother company

Pratt & Witney

- recently acquired UTC Power, which developed the first modular low capacity ORC (225 kW) units both water cooled and air cooled, tested in the geothermal field of Chena in Alaska
- already sold its 250 first units to Raser Technologies in USA (Oregon, Nevada, Utah, New Mexico)
- installed capacity at 50 MWe
- plans to develop a new unit of 1 MWe capacity in order to expand its market share
- in June 2009, Pratt & Whitney agreed to purchase the majority shares of Turboden.
- with the products and experience of both Turboden and UTC power, Pratt & Whitney is in a good position to challenge the leadership of Ormat in the geothermal binary power market.

Conclusions

- Low-Bin project effectively enlarged the available product line of geothermal binary plants
- Geothermal binary market is well established and growing faster that other segments of geothermal power market
- The rapid growth of global geothermal power market foreseen during the forthcoming years, provides an excellent opportunity for commercial deployment of the Low-Bin technology

Thank you for your attention