

Quantification of Exploration Risks as Basis for Insurance Contracts

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Geothermal requirements

Exploration risk

Probability of success (POS)



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Geothermal Energy

Geothermal system

Type of use

Petrothermal systems
rock, magma

Hot Dry Rock techniques

Hydrothermal systems (>150 °C)
geopressured zones
steam systems
hot water systems

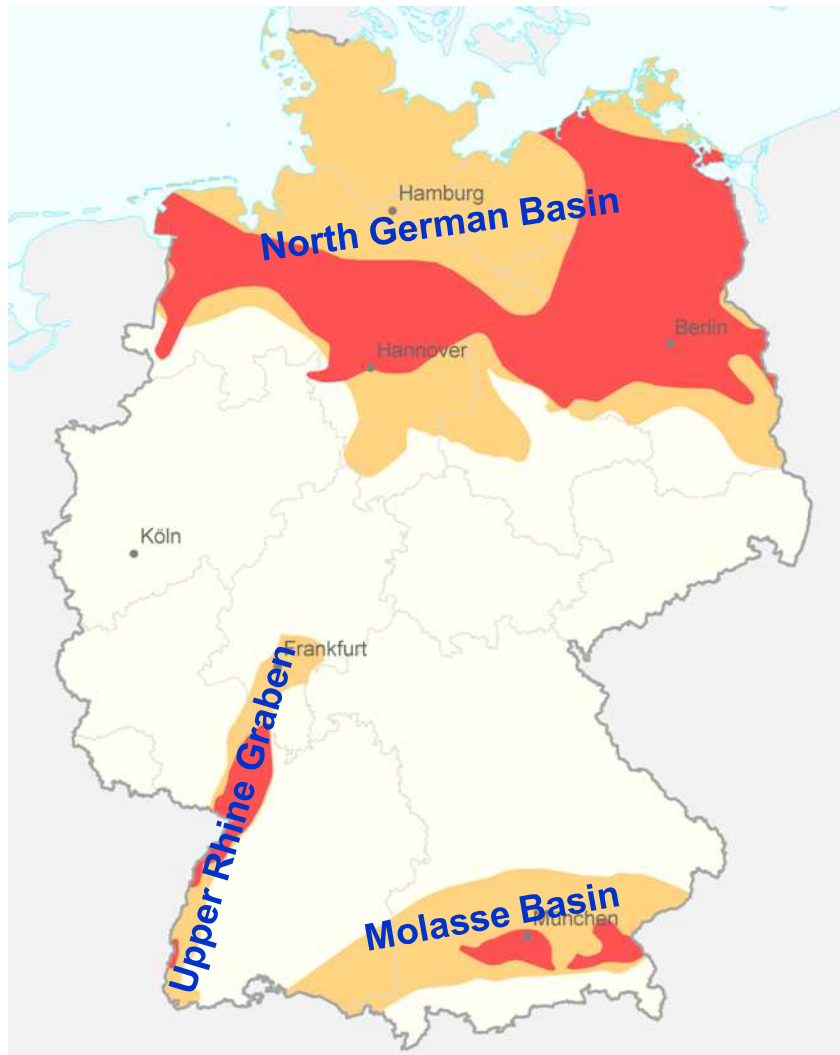
Power generation

Hydrogeothermal systems (<150 °C)
aquifers
thermal water

Power generation (>100 °C)
Direct use

Shallow systems
max. 25 °C, 400 m

Heat pumps



Aquifers

North German Basin

Lias-Rhaetian aquifer complex
Middle Bunter Sandstone
Rotliegend Sandstone
Lower Cretaceous Sandstone
Dogger Sandstone
Keuper Sandstone

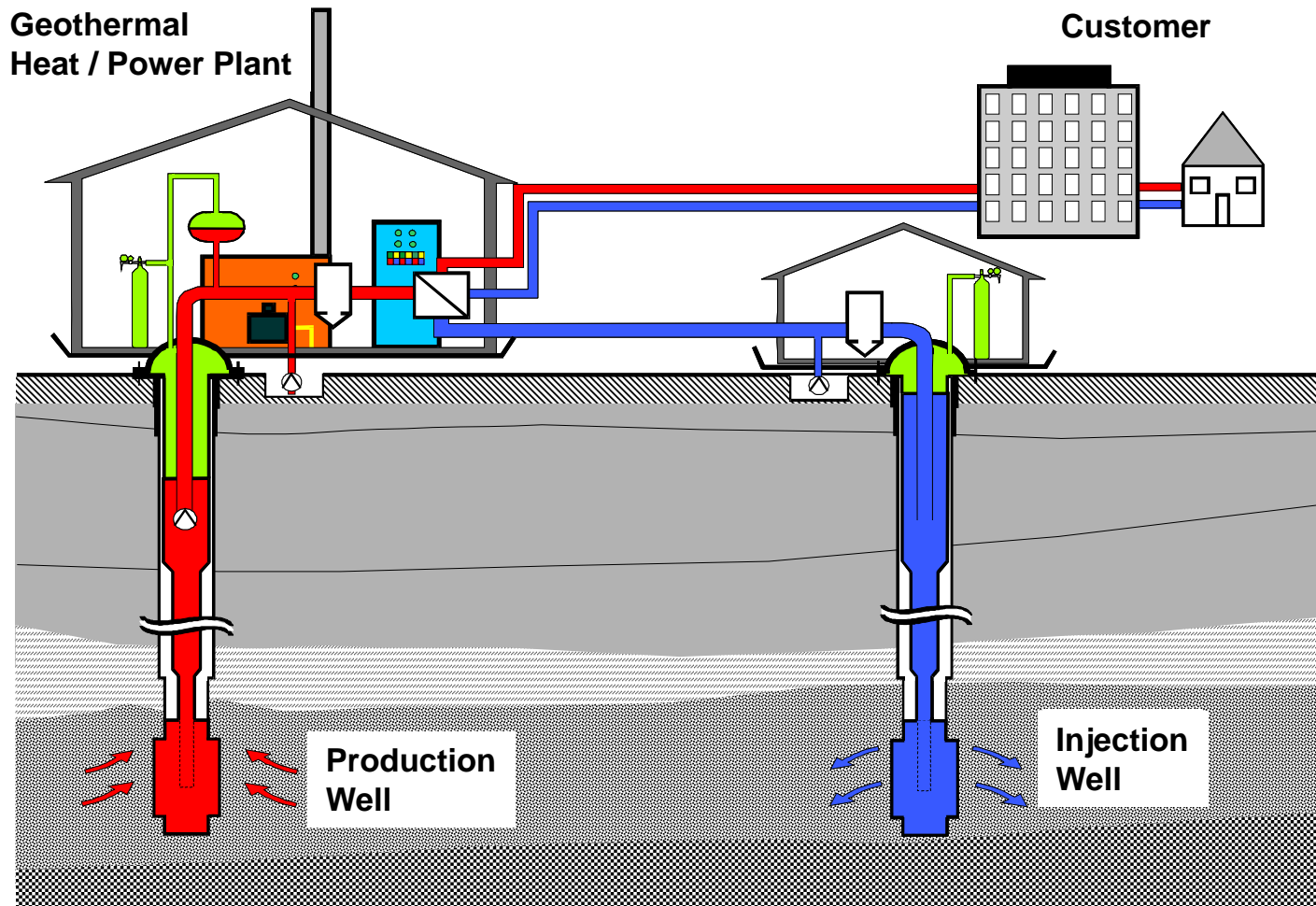
Upper Rhine Graben

Upper Muschelkalk
Middle Bunter Sandstone

Molasse Basin

Upper Jurassic (Malm)

Direkt Use / Power Generation



Doublet

1 - 50 MW_t
1 - 5 MW_e

Depth:
1 500 - 5 000 m

Direkt Use / Power Generation

Requirements on geothermal situation

	Temperature	Production rate
Spa (singlet)	30 °C	3 l/s
District heating	60 °C	30 l/s
better	80 °C	60 l/s
Power Generation	100 °C	80 l/s
better	> 120 °C	> 120 l/s

Exploration Risk

*Exploration risk concerning hydrogeothermal wells is the risk of not achieving a geothermal reservoir by one (or more) well(s) in sufficient **quantity** or **quality**.*

The term **quantity** is defined by the (thermal) power.

Power: $P = \rho_F c_F Q (T_i - T_o)$

Quality depends on the content of the fluid (total dissolved solids, gas, etc.).

Operation Risk

*Operation risk covers the change in input of geothermal energy during the geothermal utilization (**durability**),*

i. e. changes of quantity (production rate, temperature) and quality (content) of the fluid.

Energy: $E = \rho_F c_F Q (T_i - T_o) \Delta t$

This can be caused by e. g.

- corrosion or scaling in the technical part,
- clogging or thermal breakthrough in the aquifer.

Exploration Risk: Parameter

Type of aquifer: porous, fractured, karst
regional

Depth / Structure: reflection seismics
local

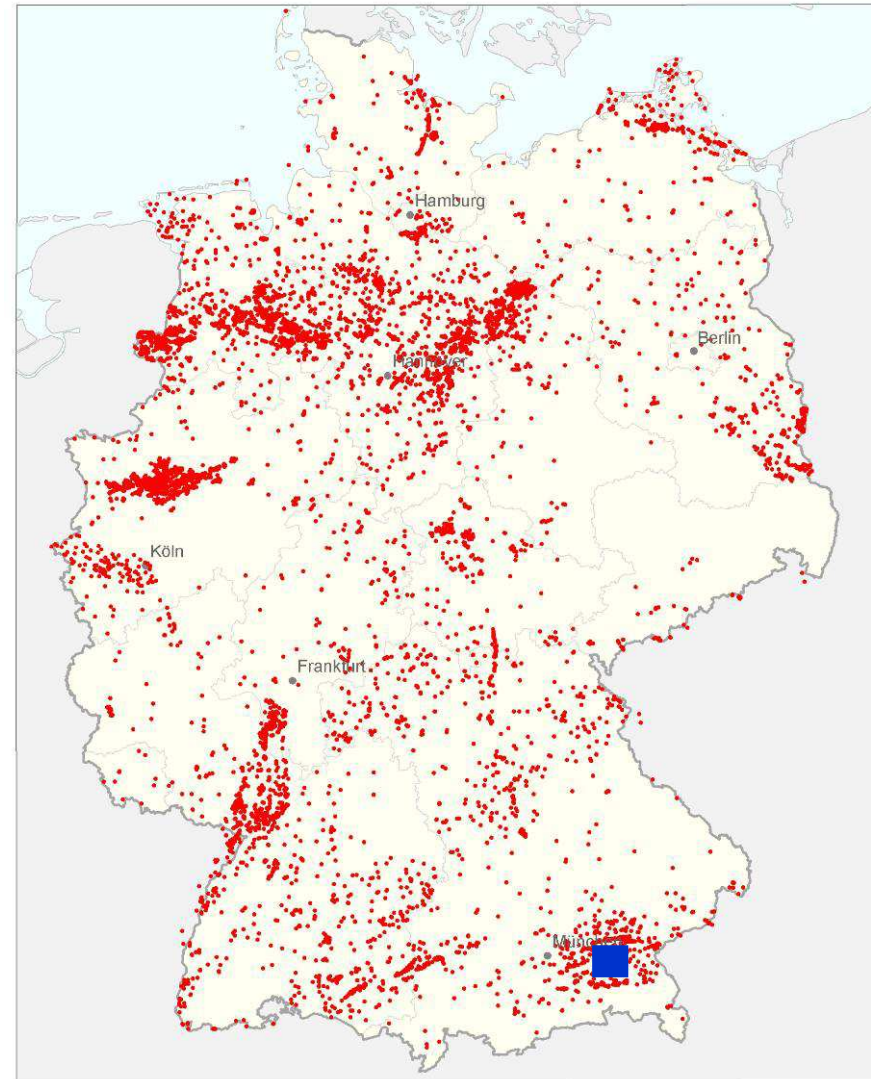
Temperature T: depending on depths
local

Production rate Q : depending on transmissivity
regional

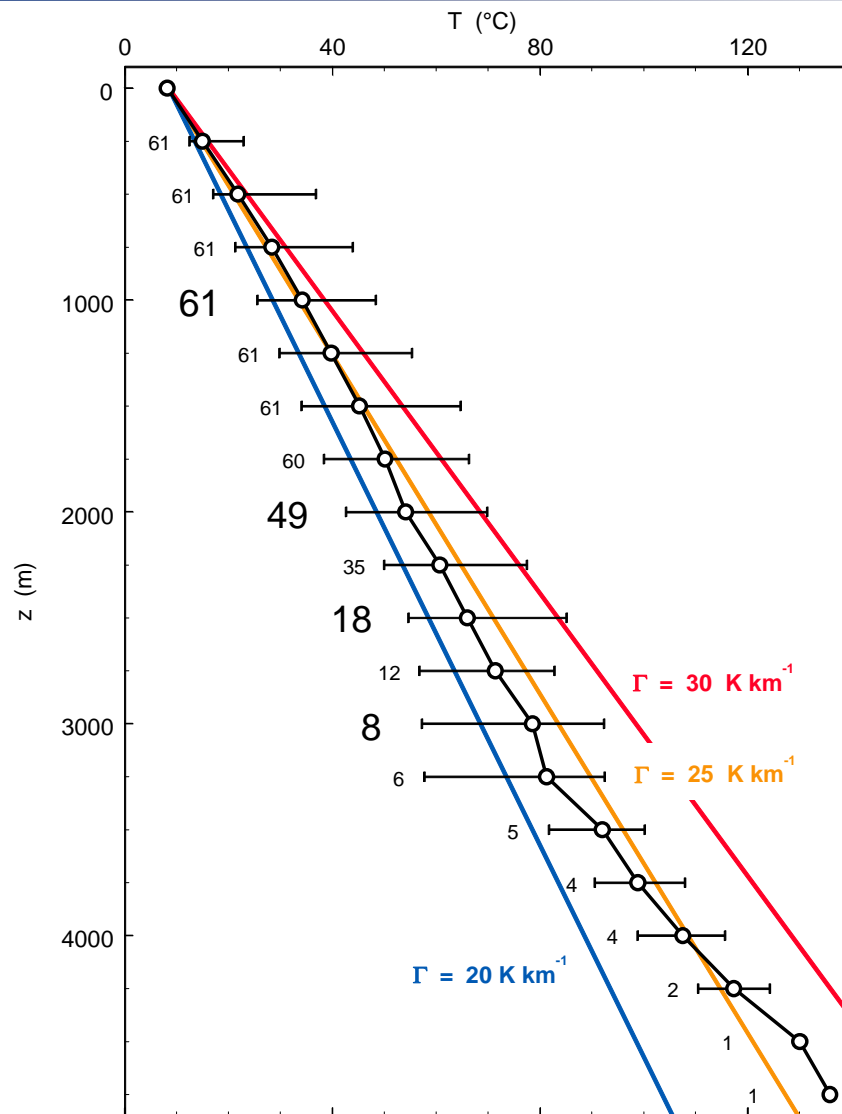
Temperature Data



- boreholes with temperature data
- investigation area



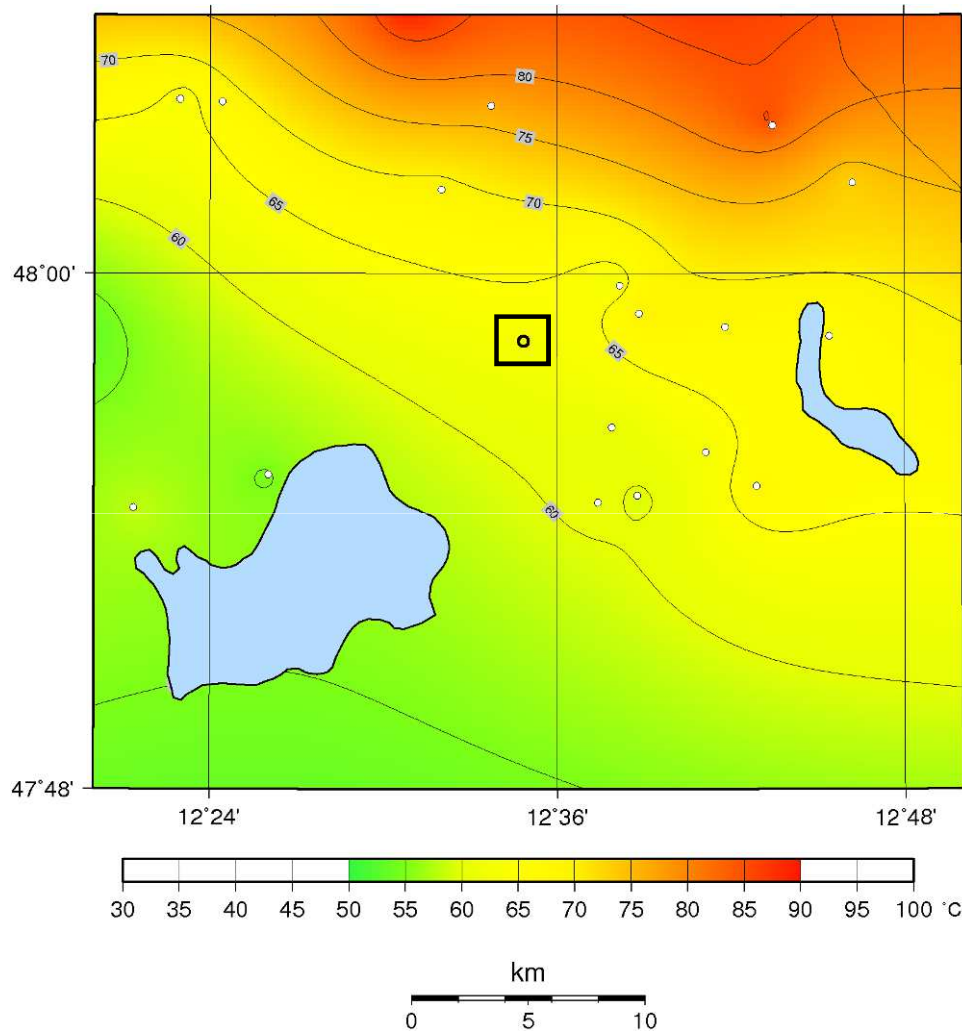
Temperature



temperature
depth
profile

local
investigation area
1 200 km²
(South East Bavaria)

Temperature

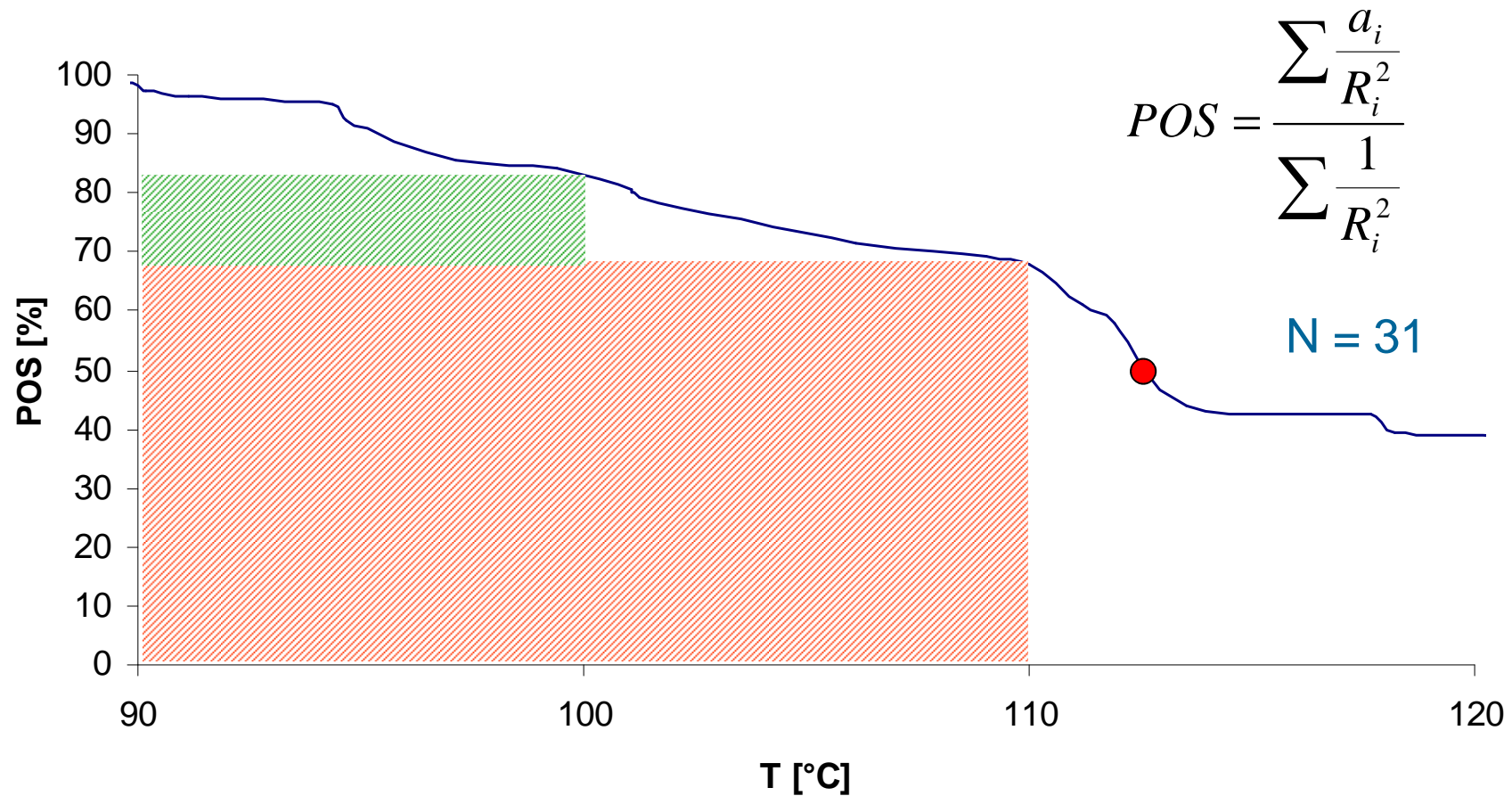


depth
2 500 m

local
investigation area
1 200 km²

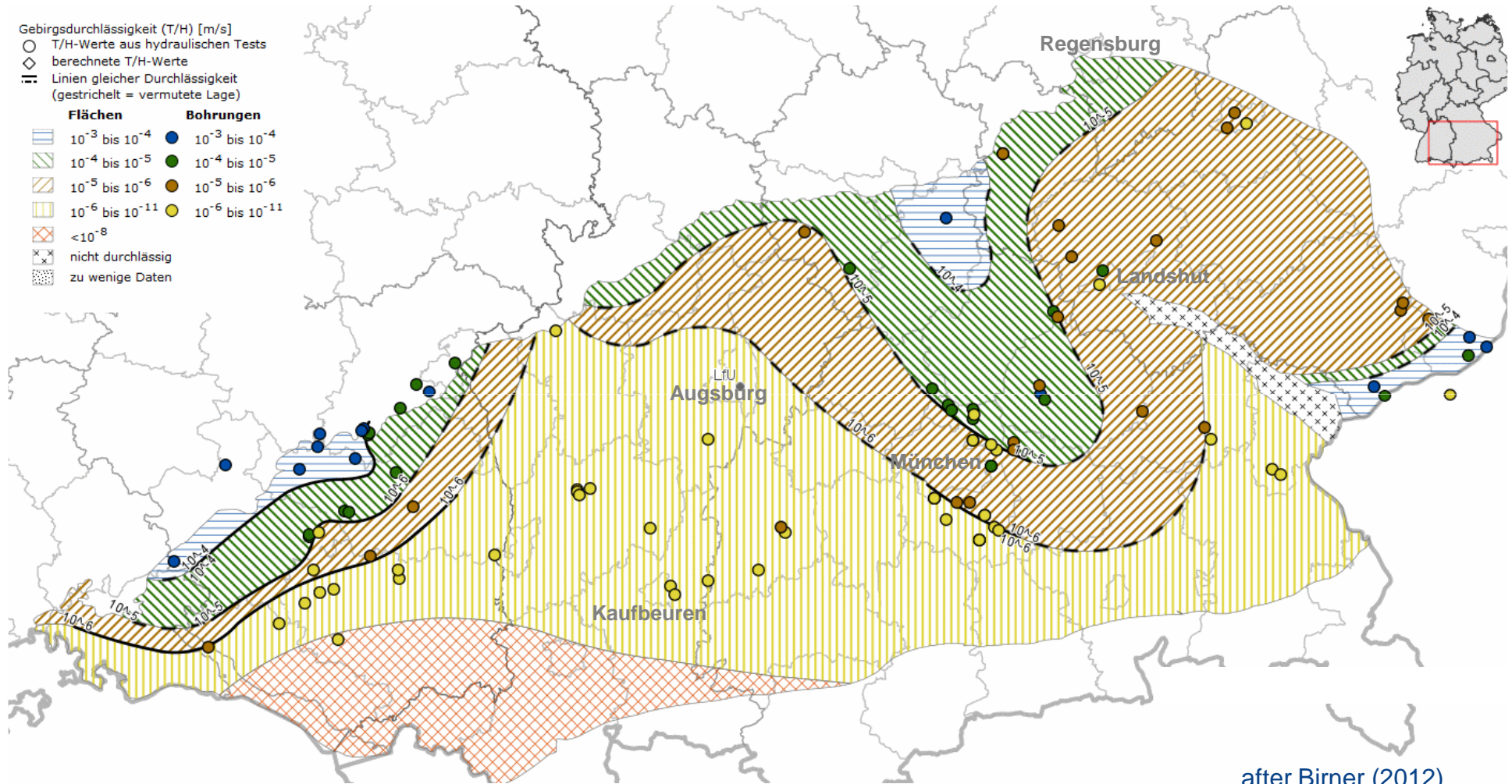
- boreholes with T - data
- ◻ target of the geothermal project

Temperature: POS



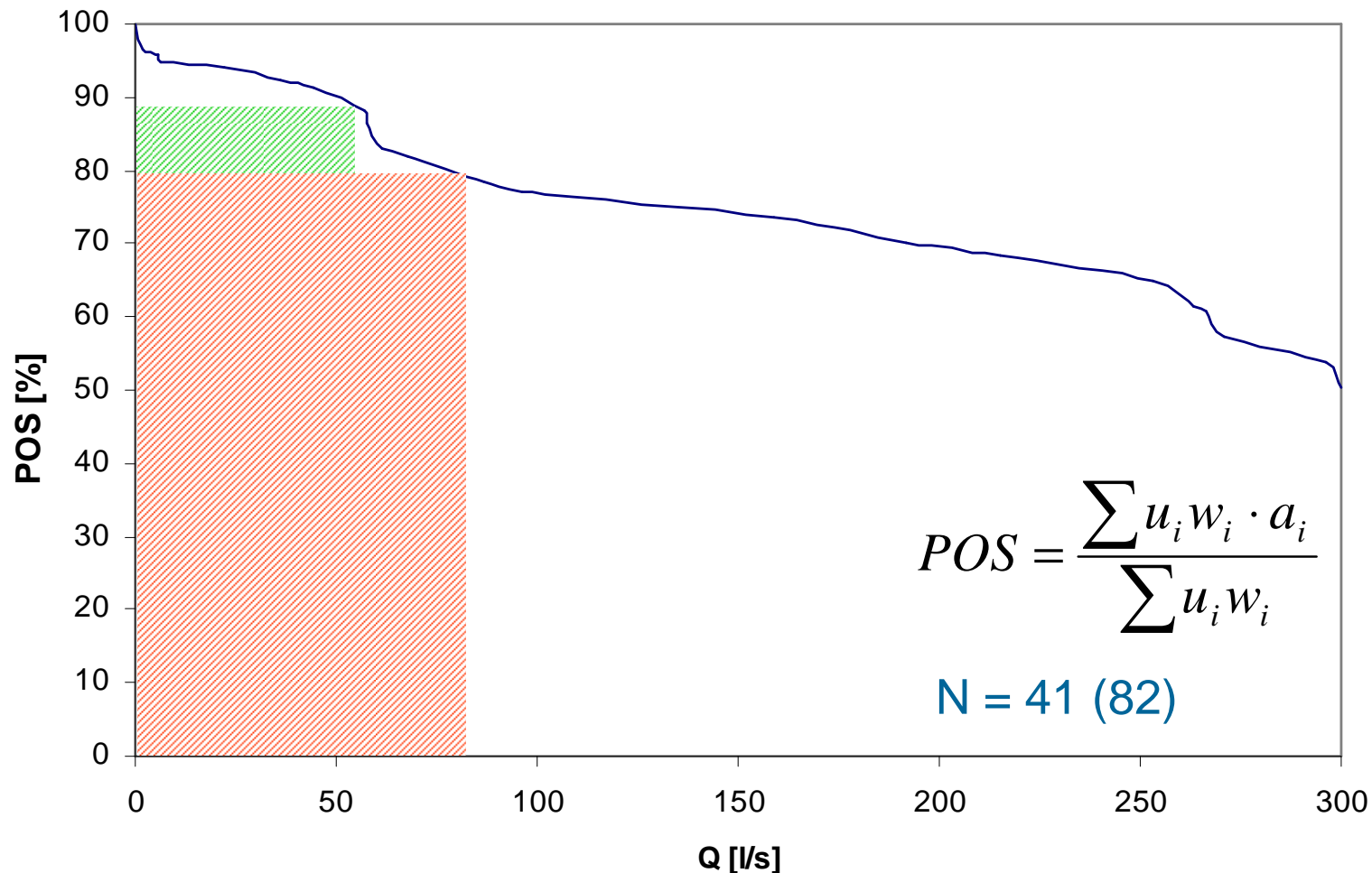
Probability distribution for temperature at the depth of 4 300 m

Rock Permeability T/H



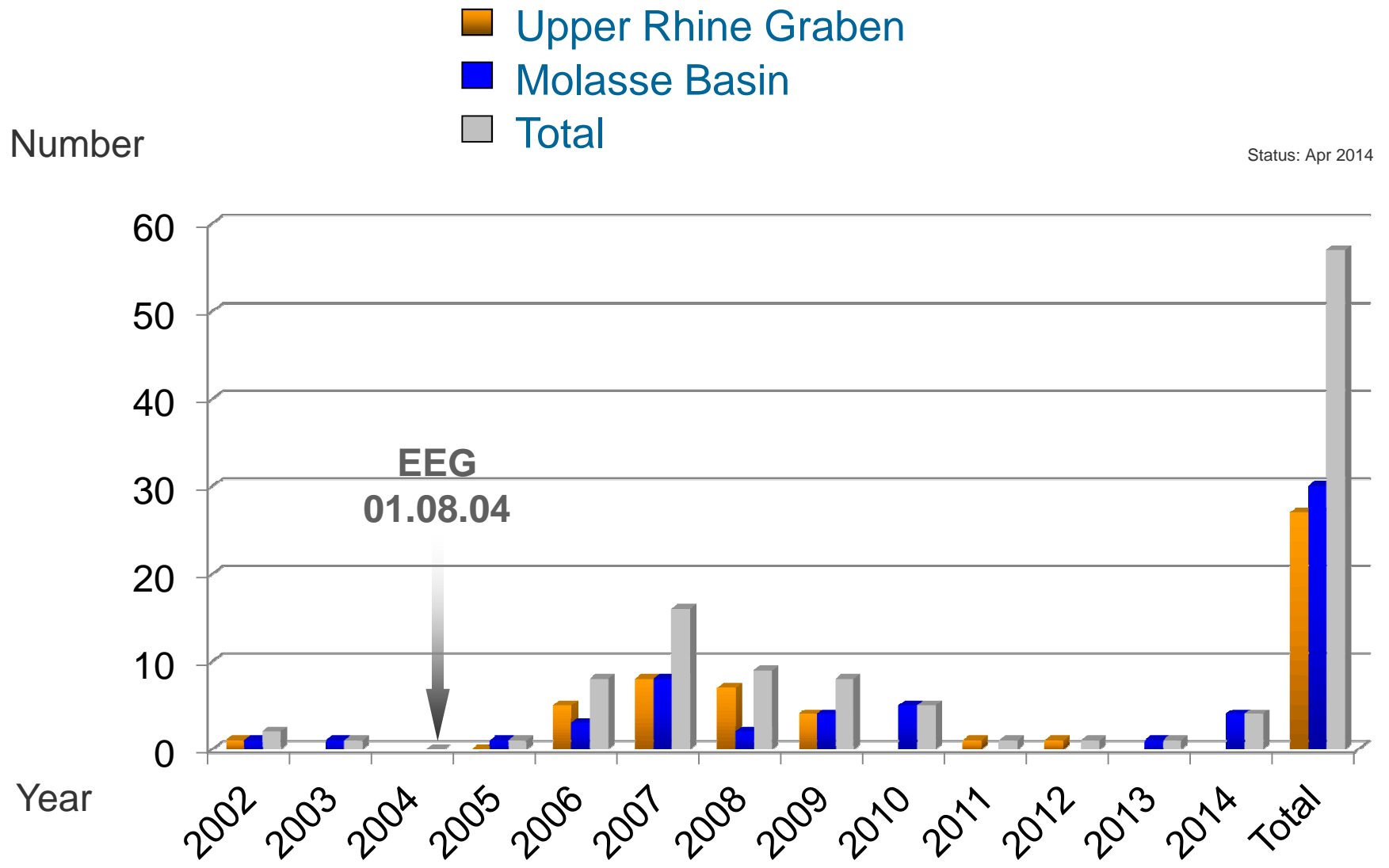
after Birner (2012)
www.geotis.de

Production Rate: POS



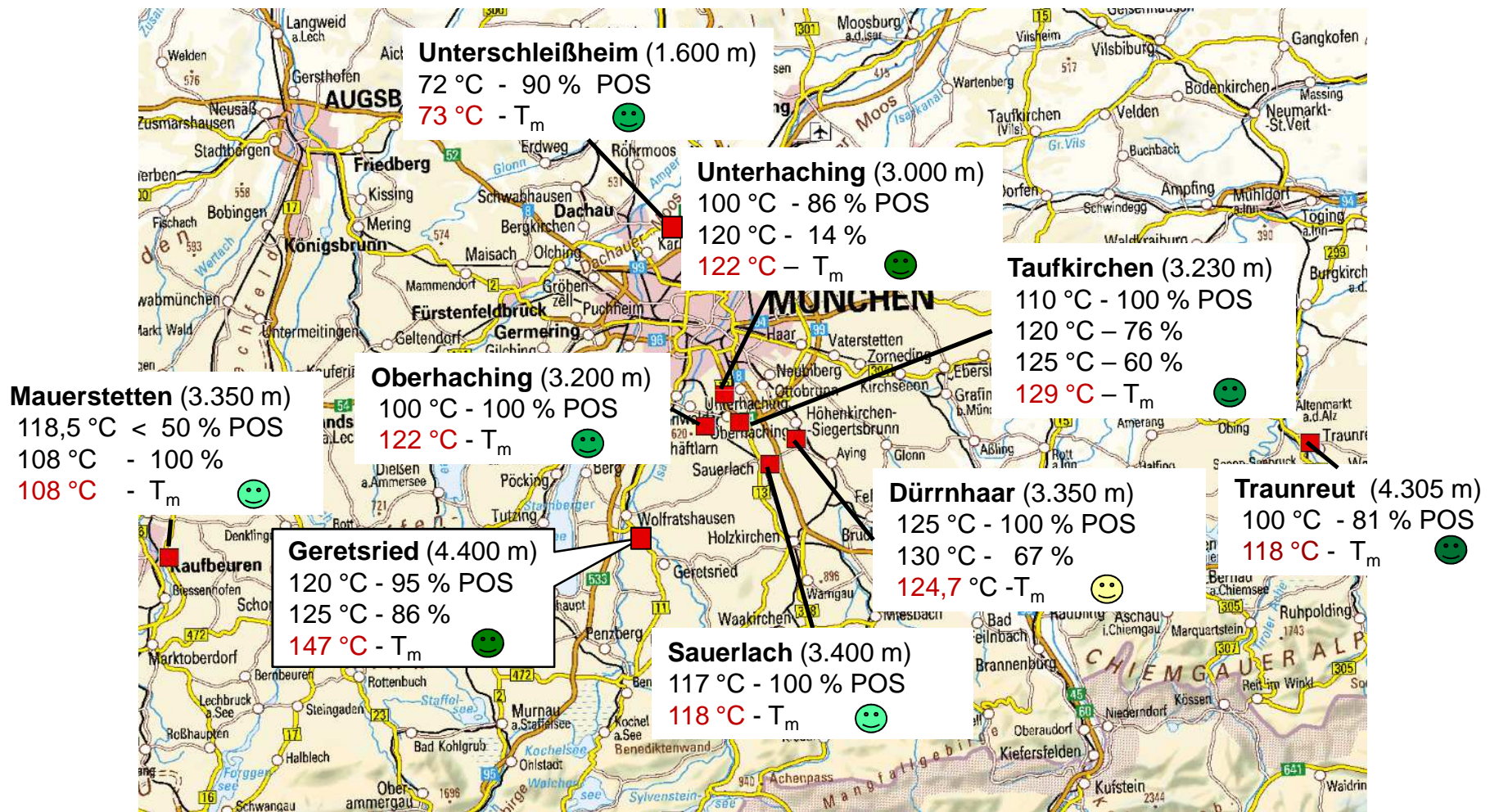
Probability distribution for reaching different production rates (max. draw down of 300 m)

Expert Reports



Insurability / Evaluation

POS for temperatures versus measured values



Conclusion

- Essential parameters: power $P \sim Q \cdot \Delta T$
production rate Q with drawdown s
temperature T at depth z
- Probability of success (POS): $p \cdot q$
 p for T : local
 q for Q : regional
- Low number of data for statistics
- But: POS seems to be realistic
- Quantitativ assessment of seismics ?