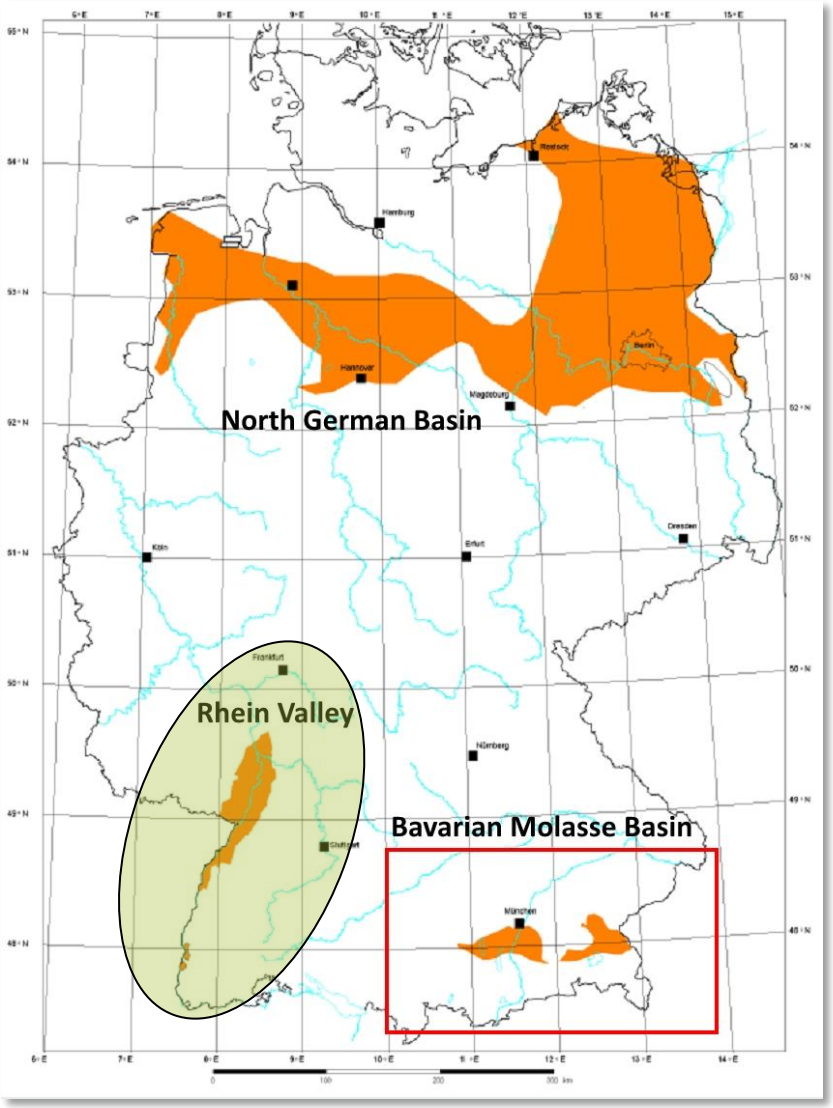
Deep Geothermal Project from the Perspective of a (Drilling) Contractor

Geothermal Workshop Veli Lošinj - August 2014

Geothermal Project in Germany

- In the early years of the new millennium, several investment companies used the enthusiasm to pursue geothermal energy to secure and acquire exploration licenses in Germany
- The majority of the companies (with few notable exceptions) were **unfamiliar with the process** to explore and drill for subsurface resources
- Regrettably, this resulted not only in insufficient geological planning, but cost cutting also lead to the **use of unsuitable and inexperienced** drilling contractors particular in the Rhein Valley area where several major incidents have been reported
- As the majority of the drilling activities were conducted within city limits to minimize infrastructure costs, the impact of these incidents has often lead to **irreparable damages**
- As a further consequence, geothermal projects in the Rhein Valley are **essentially aborted** and impossible to implement for the time being



Incidents in the Rhine Valley - Speyer

- In 2003, drilling activities for a geothermal project in **Speyer** discovered an oil field (Römerberg); the field is under development operated by Gas de France and presently produces some 5,000 boepd

Incidents in the Rhine Valley - Wiesbaden

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- Drilling for a geothermal project in **Wiesbaden** resulted in a water blowout right in front of the Finance Ministry

Incidents in the Rhine Valley - Staufen

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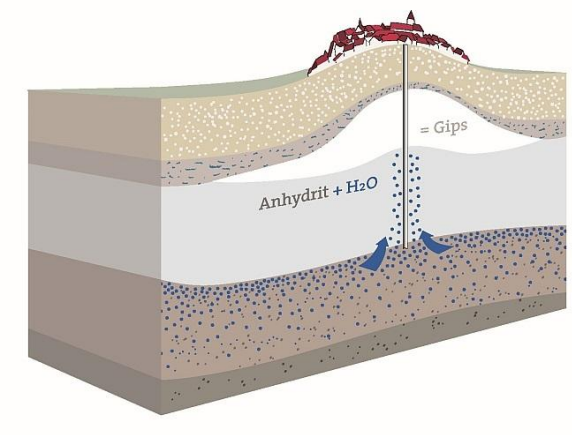
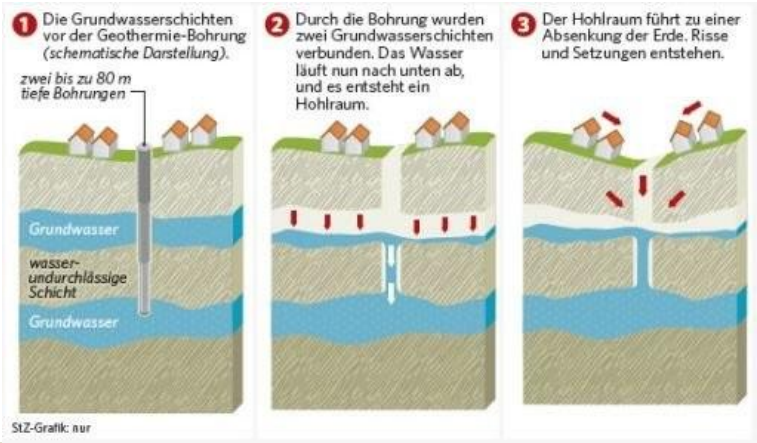
- Drilling for a geothermal project in Wiesbaden resulted in a water blowout right in front of the Finance Ministry
- Drilling for a geothermal project in **Staufen** resulted in punctuating an aquifer below an anhydrite layer – the anhydrite swells when in contact with water, causing the soil below the city to buckle and walls to crack



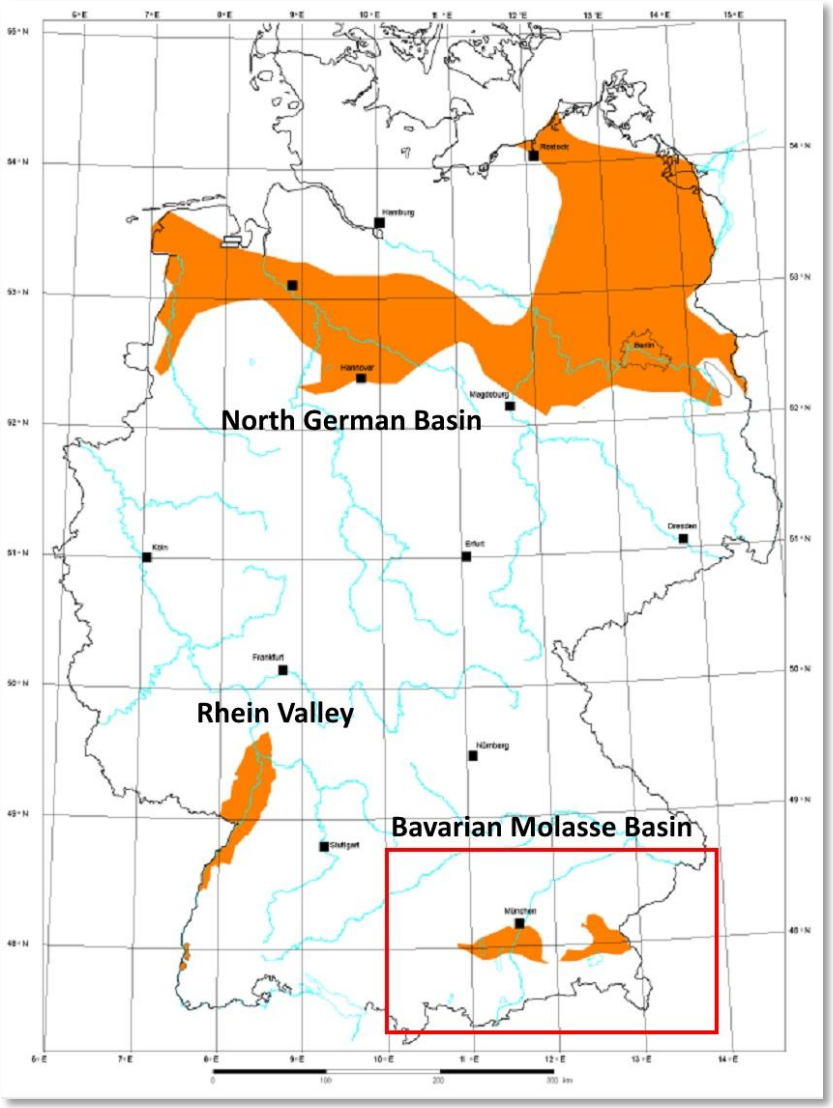
Incidents in the Rhine Valley - Rottenburg

- In 2003, drilling activities for a geothermal project in **Speyer** discovered an oil field (Römerberg); the field is under development operated by Gas de France and presently produces some 5,000 boepd
- Drilling for a geothermal project in **Wiesbaden** resulted in a water blowout - right in front of the provincial Finance Ministry
- Drilling for a geothermal project in **Staufen** resulted in punctuating an aquifer below an anhydrite layer – the anhydrite swells when in contact with water, causing the soil below the city to buckle and walls to crack
- Similar incidents were recorded in **Rottenburg, Schorndorf, Rudersberg** and **Leonberg**, where groundwater crossflows into a deeper aquifer



Geothermal Project in Germany

- Fortunately, the incidents in the Rhein Valley have not been experienced in the Bavarian Molasse Basin, where targets are **significantly deeper,** requiring extensive planning and permitting and the deployment of experienced drilling contractors
- The Bavarian Molasse Basin's hot aquifers in South Germany have historically been known for the usage of hydrothermal resources, main users of hydrothermal wells were spas for balneological applications
- Since spas use hot/warm water mainly in the 30 to 45˚C range, they are not overly concerned about resource temperatures or even need to cool produced waters down *(most times the produced geothermal water needs to be cooled to make it suitable for the spa)*



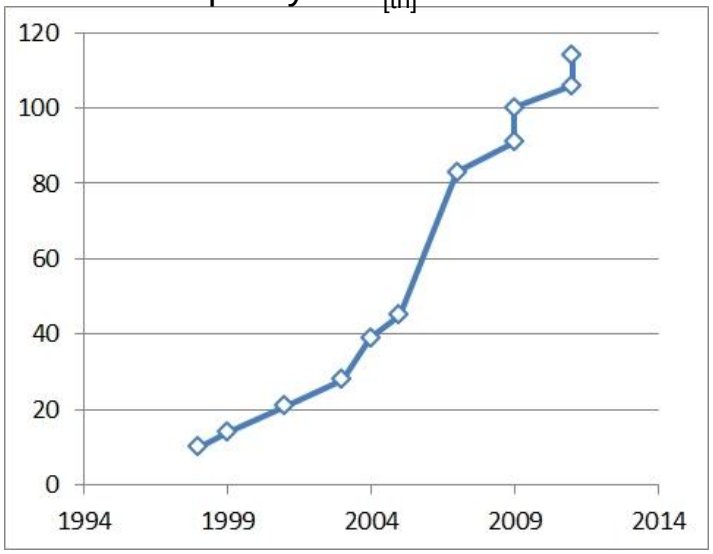
Geothermal Project in Germany

- However, over the past 15+ years, the development of geothermal project in the Bavarian Molasse Basin enjoyed a linear growth
- A dozen geothermal projects with a total of over **110 $MW_{[th]}$ installed capacity** (most of them including power generation), have been implemented mainly S-SE of Munich
- The **Geretsried Project** was planned to develop the deeper parts of the Jurassic aquifer

Project	Year	MW[th]
Erding	1998	10
Straubing	1999	4
Simbach	2001	7
Unterschleissheim	2003	7
Riem	2004	11
Pullach	2005	6
Unterhaching I	2007	38
Unterfoehring	2009	8
Aschheim	2009	9
Garching	2011	6
Poing	2011	8
		114

Source: EU Stats

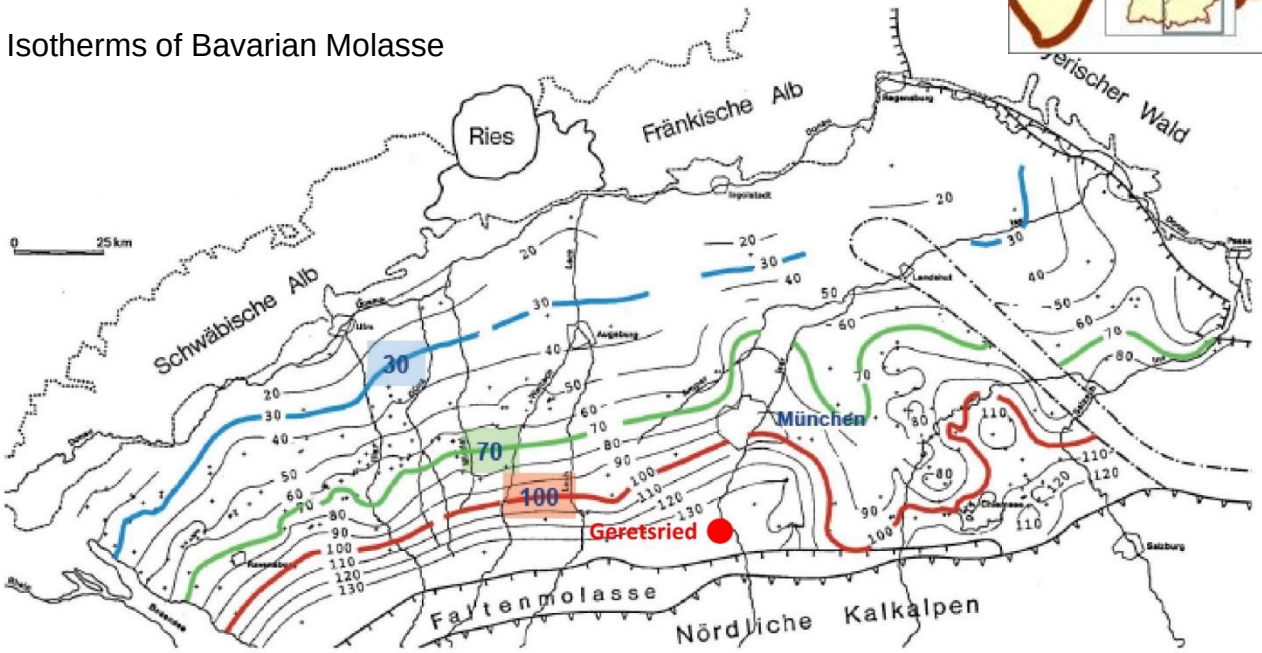
Installed Capacity $MW_{[th]}$



Geothermal Project in Germany

- The **Geretsried Project** was planned to develop the deeper parts of the Jurassic aquifer where the expected temperature was predicted to be around 140+ deg C.

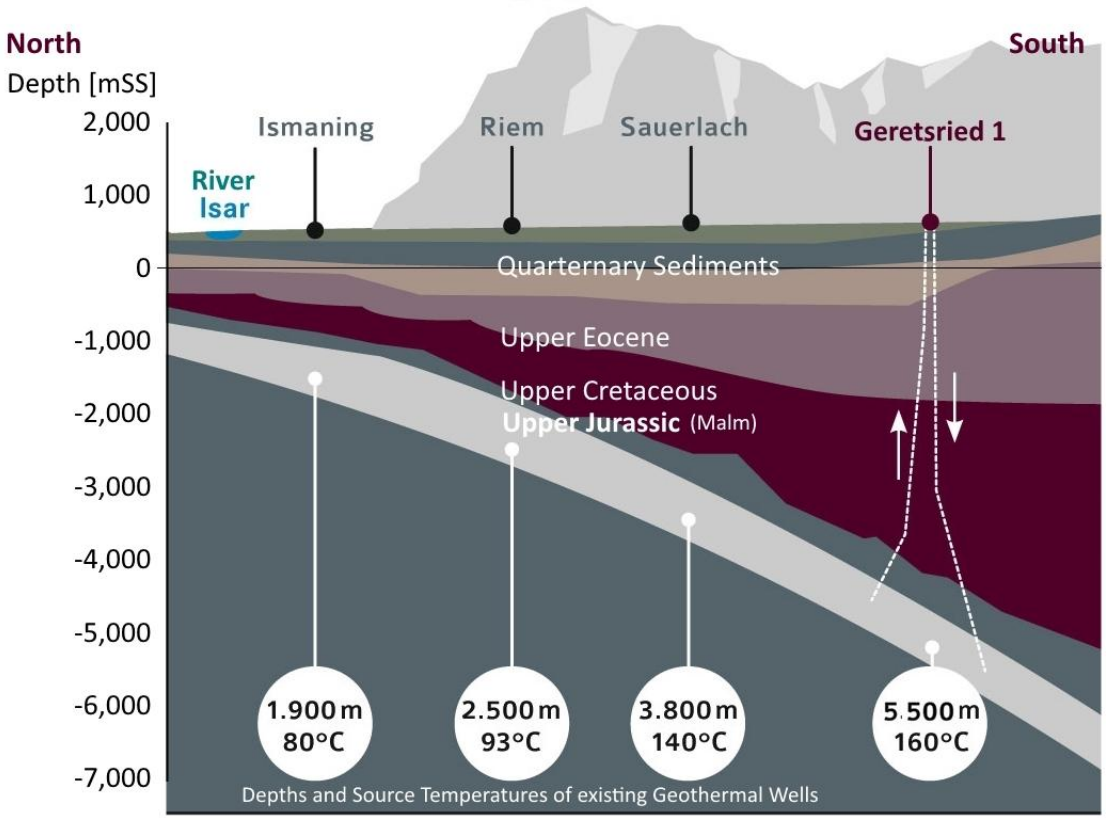
Isotherms of Bavarian Molasse



Jobmann & Schulz (1989)

Geothermal Project in Germany

- The **Geretsried-1 well** was laid out to reach the Upper Jurassic aquifer at around 5,500 mSS
- At the anticipated aquifer temperature of 140+ deg C, an **inflow of 100 litre/sec** was required for the geothermal power generation project

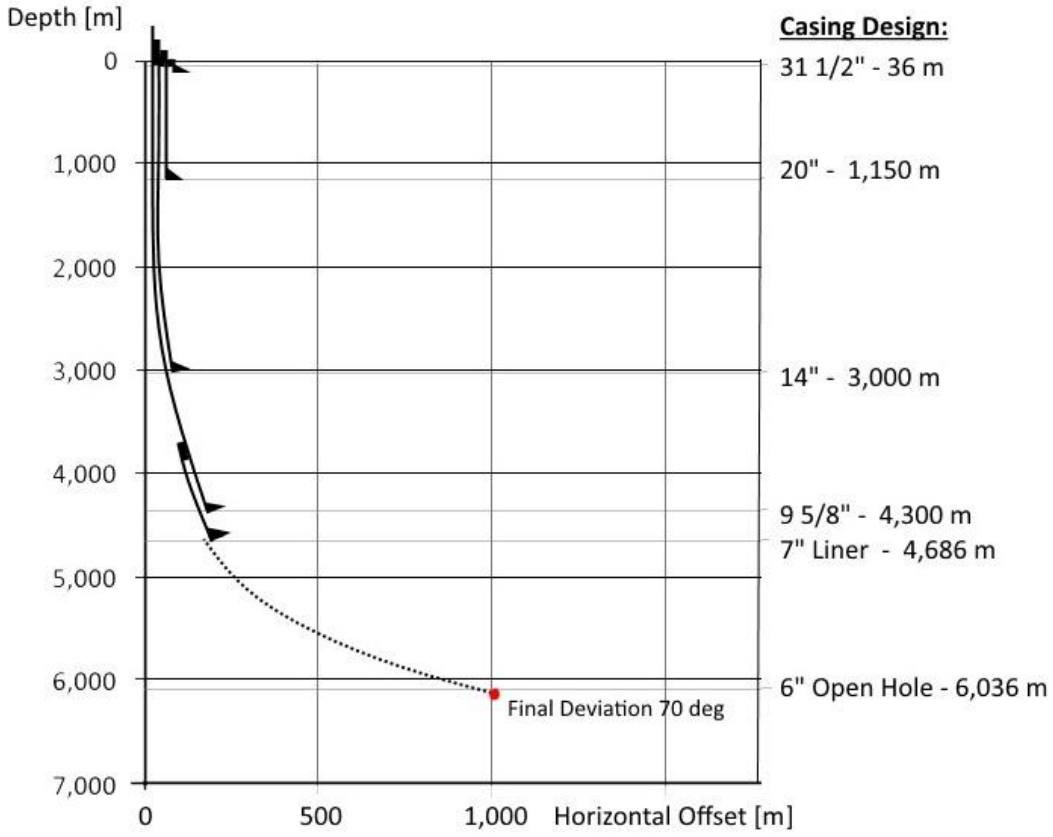


Deep Geothermal Project in Bavaria

- The project owner selected the joint venture between Daldrup and MND Drilling and Services as contractor
- The rig proposed and used was a brand-new EURO Benteq 450 with a hookload capacity of 450 tons at 2,000 Brake-Horsepower
- The rig was mobilized and rigged up in late December 2013 and commenced drilling shortly afterwards

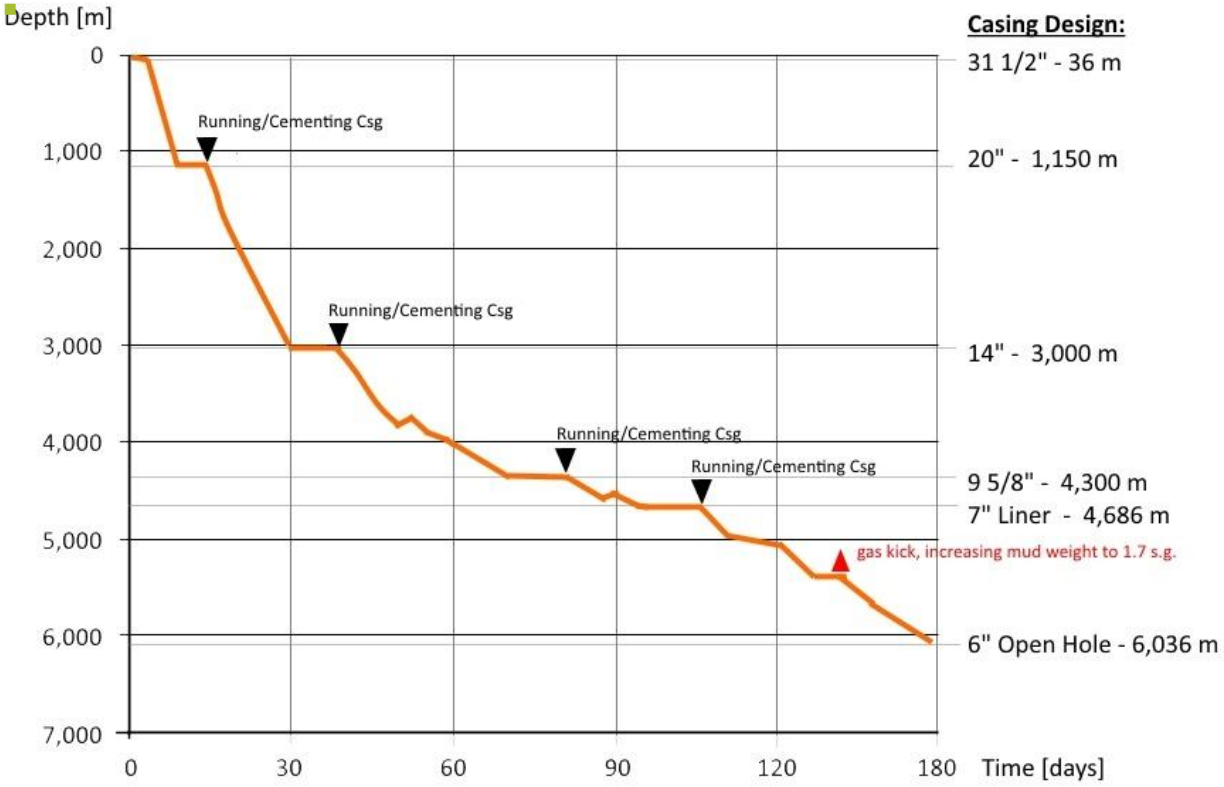
Deep Geothermal Project in Bavaria

- The well design called for conductor pipe, three subsequent casings and a liner
- The target of the Jurassic aquifer was planned to be drilled/completed as open hole
- The horizontal offset of the landing point was approx 1,000 m at a deviation of 70 deg



Deep Geothermal Project in Bavaria

- The well design called for conductor pipe, three subsequent casings and a liner
- The target of the Jurassic aquifer was planned to be drilled/completed as open hole
- The horizontal offset of the landing point was approx 1,000 m at a deviation of 70 deg
- The well reached the target depth after almost 180 days after several technical difficulties were overcome during drilling



Deep Geothermal Project in Bavaria

- Having reached TD (Total Depth as planned), the well was flow tested from the Upper Jurassic
- Unfortunately, the recorded inflow of **some 10 l/sec** was materially less than the prognosed 100 l/sec
- Although the inflow temperature was higher than expected (165 actual vs 140 Dec C prognosis), the total heat flow proved insufficient to make the well commercially viable
- The observed and unexpected gas inflow (as be seen at the flare on the photo) was an additional unplanned event
- Total well costs have accumulated to some **11.5 MM EUR (~ 16 MM USD)**
- Subsequent negotiations with the insurance company to fund a proposed sidetrack did not succeed and the well was abandoned

[EUR]

Planning and Engineering	400,000
Drilling Rig Mobilization	750,000
Site Preparation	1,750,000
Tangible Costs Drilling	2,200,000
Intangible Costs Drilling	4,680,000
Consumables	760,000
Drilling Rig De-Mobilization	1,000,000
Total Well Costs	**11,540,000**

Deep Geothermal Project in Bavaria - Economics

- **Pre-Drilling Economics assumptions** used to establish venture and fund project:

Base Assumptions		Fill in value
Parameter		Calculated
Depth of the well	6,040	*[m]*
Geothermal gradient	0.0255	*[K/m]*
Reservoir temperature	154.0	*[°C]*
Flow of the well	100.0	*[l/s]*
Well head temperature	145.6	*[°C]*
Reinjection temperature	83.0	*[°C]*
Conversion efficiency thermal power	96.0	*[%]*
Full load hours per year	8,000	*[h]*
Thermal Power	25.1	*[MW]*
Thermal Energy	201.1	*[GWh]*
Heating hours per year	3,200	*[h]*
Heating energy per year	80.5	*[GWh]*
Annual growth heat sales	3.0	*[%p.a.]*
District heating wholesale price per MWh	50.0	*[EUR]*
Electricity per year	14.5	*[GWh]*
Received price per MWh electricity sold	75.0	*[EUR]*
Size of electric power station	2.6	*[MW]*
Total Investment	49.7	*[MM EUR]*
Conversion efficiency electric power	12.0	*[%]*
Price increase for electricity bought	2.0	*[%p.a.]*
Price increase general costs	2.0	*[%p.a.]*
Price of CO_2 Emission	5.0	*[EUR]*
Capacity of 1 W =	1.16222	*[kcal/h]*

CAPEX			Depreciation	
Parameter				
Well Drilling	25.0	*[MM EUR]*	30	*[yrs]*
Drilling Contingency	2.5	*[MM EUR]*	30	*[yrs]*
Building and Land	1.2	*[MM EUR]*	15	*[yrs]*
Submersible Pump	2.0	*[MM EUR]*	5	*[yrs]*
Heating Losses	3.0	*[MM EUR]*	5	*[yrs]*
District Heating Pipeline	10.0	*[MM EUR]*	30	*[yrs]*
Plant and Facilities	5.0	*[MM EUR]*	20	*[yrs]*
Other/Miscellaneous	1.0	*[MM EUR]*	5	*[yrs]*
Total CAPEX € million	**49.7**	*[MM EUR]*		

OPEX		
Parameter		
Increase in provisions	48.0	*[M EUR p.a.]*
Material and third party costs	0.0	*[M EUR p.a.]*
thereof electric power	0.0	*[M EUR p.a.]*
thereof oil	0.0	*[M EUR p.a.]*
Personnel costs	200.0	*[M EUR p.a.]*
Other operating expenses	300.0	*[M EUR p.a.]*
Other operating	0.0	*[M EUR p.a.]*
Start up costs	0.0	*[M EUR p.a.]*
Maintenance	100.0	*[M EUR p.a.]*
Total OPEX	**648.0**	*[M EUR p.a.]*

Results	BT	AT	
Internal rate of return (ROR)	9.5%	8.6%	*[%]*
Net present value (NPV)	16.4	11.6	*[MM EUR]*
Pay back period	13.9	15.6	*[years]*

Deep Geothermal Project in Bavaria - Economics

- Although temperature was higher, a 72 l/sec flow was needed for break-even

Base Assumptions		Fill in value
		Calculated
Parameter		
Depth of the well	6,040	*[m]*
Geothermal gradient	0.028	*[K/m]*
Reservoir temperature	169.1	*[°C]*
Flow of the well	72.0	*[l/s]*
Well head temperature	160.7	*[°C]*
Reinjection temperature	91.6	*[°C]*
Conversion efficiency thermal power	96.0	*[%]*
Full load hours per year	8,000	*[h]*
Thermal Power	20.0	*[MW]*
Thermal Energy	159.8	*[GWh]*
Heating hours per year	3,200	*[h]*
Heating energy per year	63.9	*[GWh]*
Annual growth heat sales	3.0	*[%p.a.]*
District heating wholesale price per MWh	50.0	*[EUR]*
Electricity per year	11.5	*[GWh]*
Received price per MWh electricity sold	75.0	*[EUR]*
Size of electric power station	2.1	*[MW]*
Total Investment	49.7	*[MM EUR]*
Conversion efficiency electric power	12.0	*[%]*
Price increase for electricity bought	2.0	*[%p.a.]*
Price increase general costs	2.0	*[%p.a.]*
Price of CO_2 Emission	5.0	*[EUR]*
Capacity of 1 W =	1.16222	*[kcal/h]*

CAPEX

Parameter			***Depreciation***	
Well Drilling	25.0	*[MM EUR]*	30	*[yrs]*
Drilling Contingency	2.5	*[MM EUR]*	30	*[yrs]*
Building and Land	1.2	*[MM EUR]*	15	*[yrs]*
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Total CAPEX € million	**49.7**	*[MM EUR]*		

OPEX

Parameter		
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Maintenance	100.0	*[M EUR p.a.]*
Total OPEX	**648.0**	*[M EUR p.a.]*

Results

	BT	AT	
Internal rate of return (ROR)	6.3%	6.0%	*[%]*
Net present value (NPV)	1.5	0.0	*[MM EUR]*
Pay back period	19.2	20.0	*[years]*

- At assumed 72 l/sec the project NPV is zero; at the actually observed flow of **10 l/sec project was uneconomic**

Geothermal Projects – Lessons Learned

- Geothermal project require **at least as much technical preparation** as any other deep drilling project
- Confidence in geothermal projects **is seriously shattered in CEE**, trust needs to be rebuilt
- Present energy/electricity prices **discourage investors** to fund large(r) and risky geothermal projects

Thank You