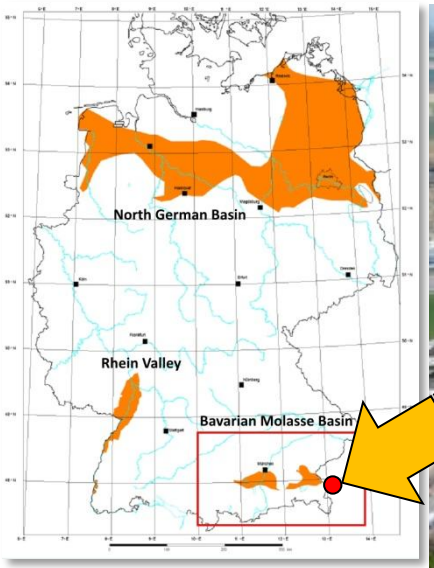
Altheim in Upper Austria – an example of cascaded geothermal energy use

Geothermal Workshop Veli Lošinj – August 2014

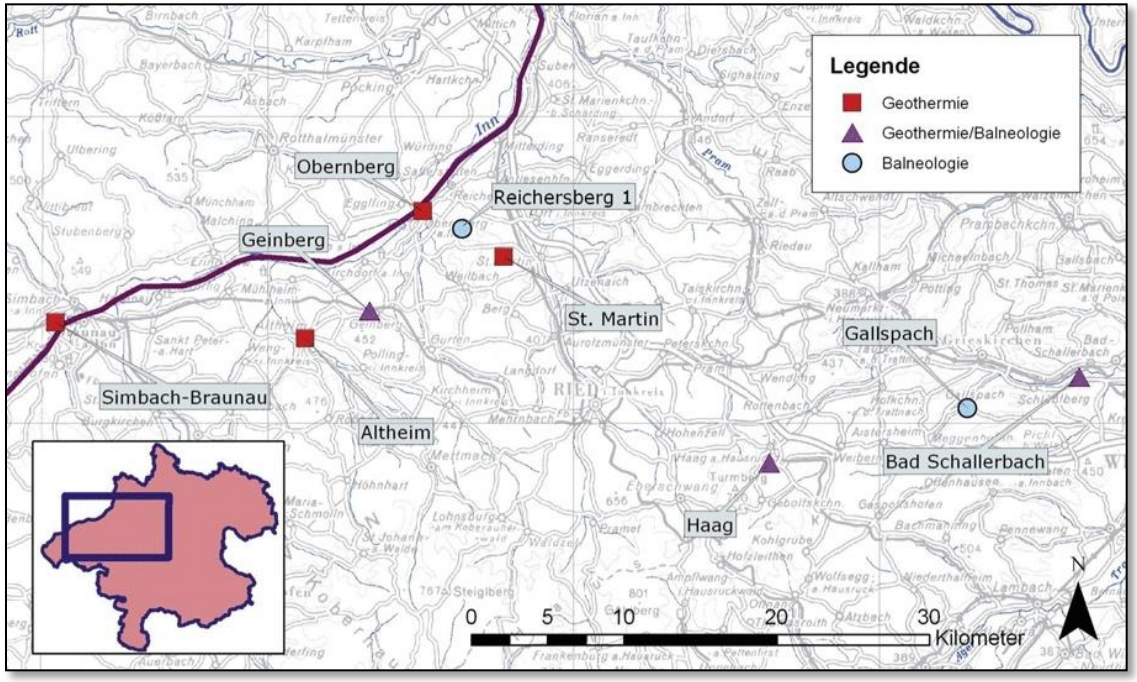
Altheim
A Geothermal Project in the Upper Austrian Molasse



- Altheim is located in the ‘Upper Austria’ District, close to the German/Bavarian Border, has ~5,000 inhabitants with several mid-sized industrial enterprises

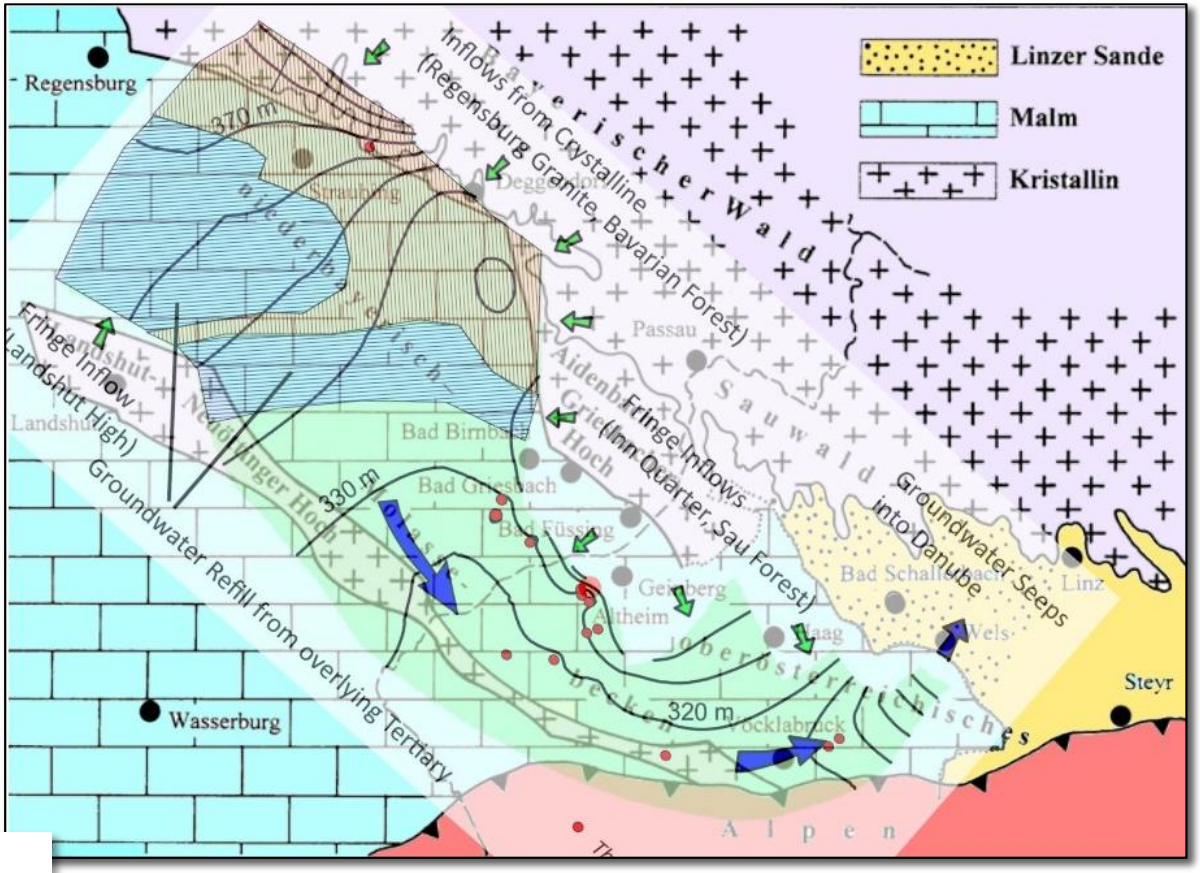
Altheim
A Geothermal Project in the Upper Austrian Molasse

- Usage of low-enthalpy geothermal water in the Austrian part of the Molasse Basin has been established since historic times
- More recently, the geothermal water flows have been studied more carefully with respect to origin, flow directions and coordinated offtake



Geothermal Water in the Upper Austrian Molasse

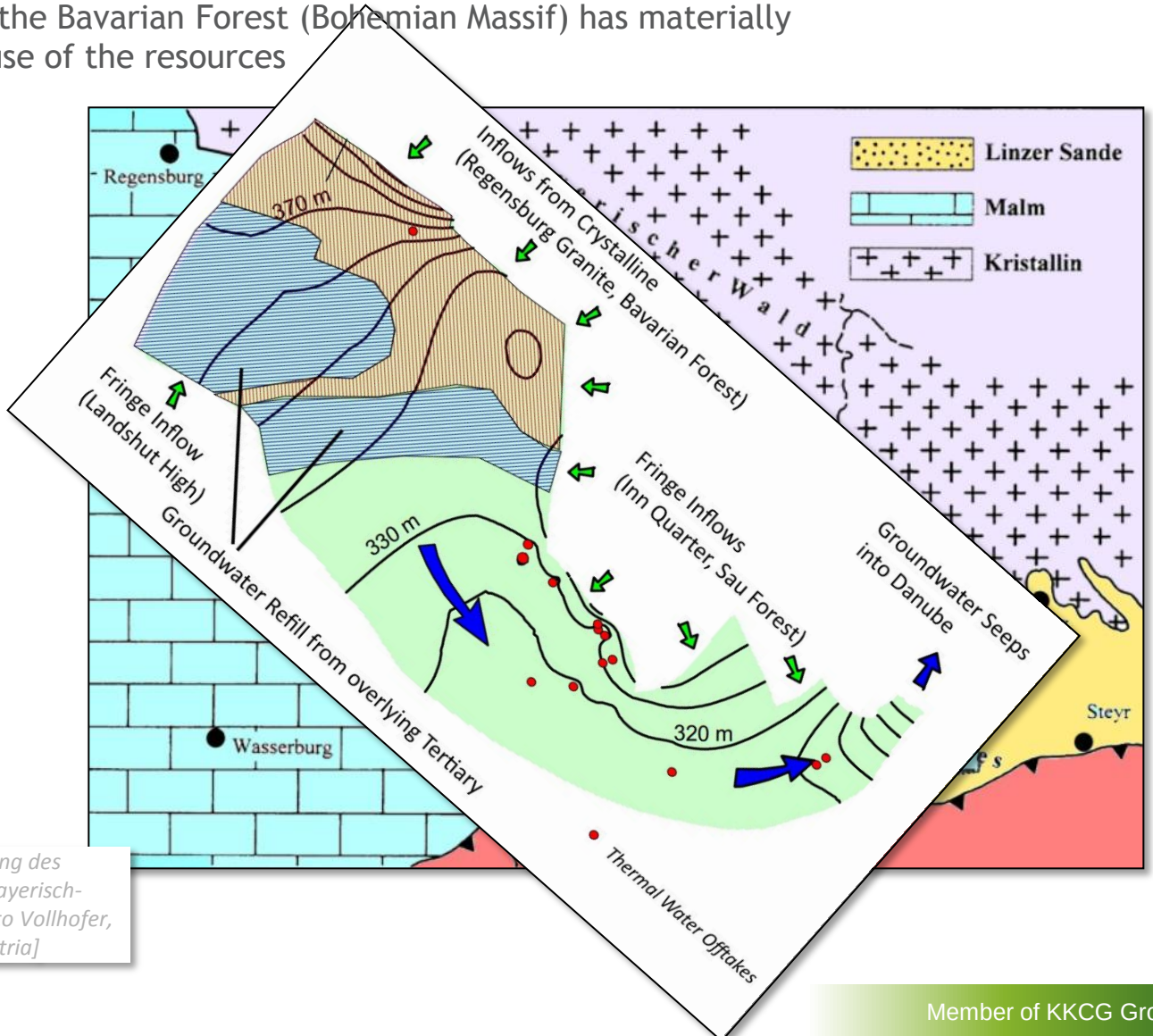
- Seismic data, well information and flow tests have been utilized to assess the Upper Jurassic geothermal ground water in the East Bavarian and Upper Austrian Molasse



Source: Bilanzierung und Bewirtschaftung des Thermalwasservorkommens im niederbayerisch-oberösterrichischen Molassebecken [Otto Vollhofer, Michael Samek – BfLFUW, Vienna – Austria]

Geothermal Water in the Upper Austrian Molasse

- The knowledge about water inflow from the crystalline formations at the Landshut High and the Bavarian Forest (Bohemian Massif) has materially improved the fair use of the resources



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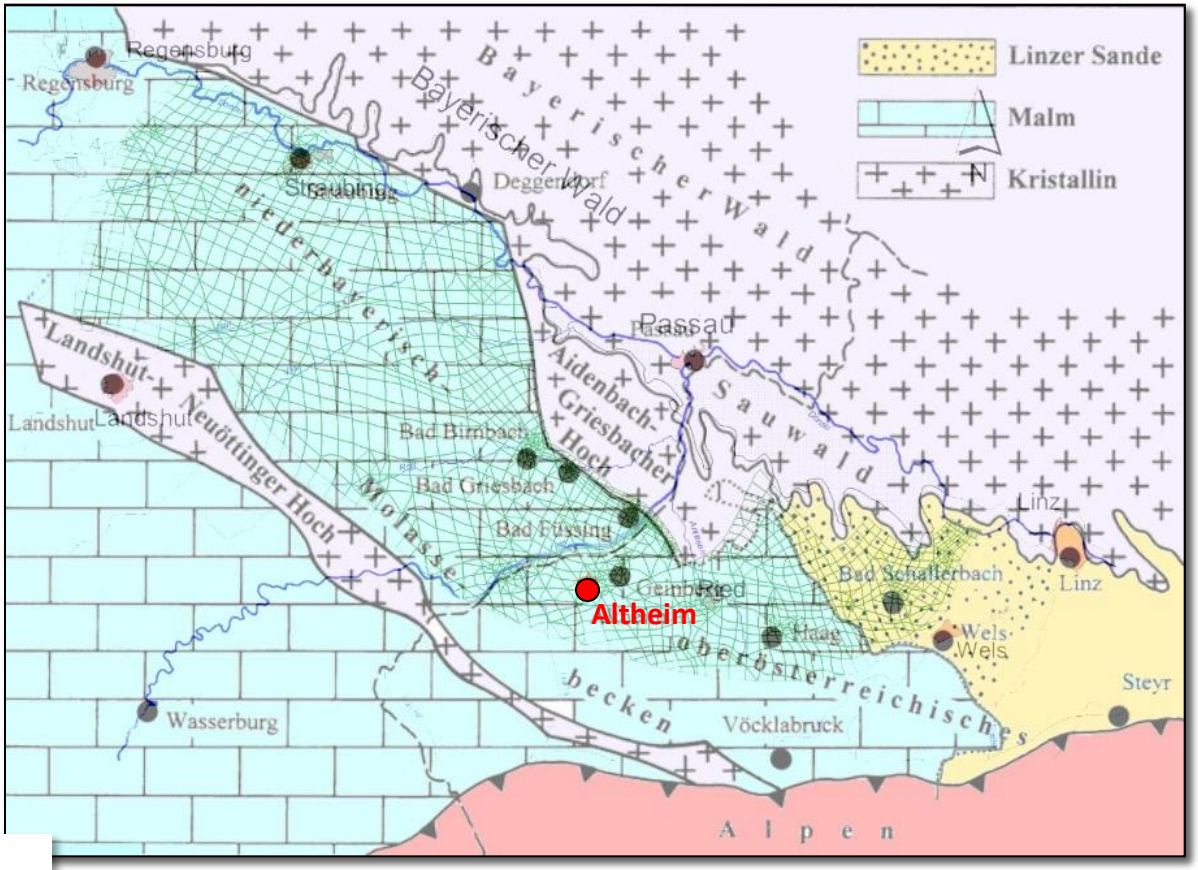
Geothermal Water in the Upper Austrian Molasse

- This has eventually led to the Austrian-German bilateral '1987 Regensburg Agreements' on the monitoring of existing and planning of new geothermal projects in the area of influence and interference for a sustainable exploitation

- The Altheim project is part of this cross-border surveillance program which has influenced the layout and design of the cascaded geothermal project commenced in 1989
- The inflow-offtake simulation program, now in use since three decades, is reviewed periodically for potentially necessary revisions and improvement



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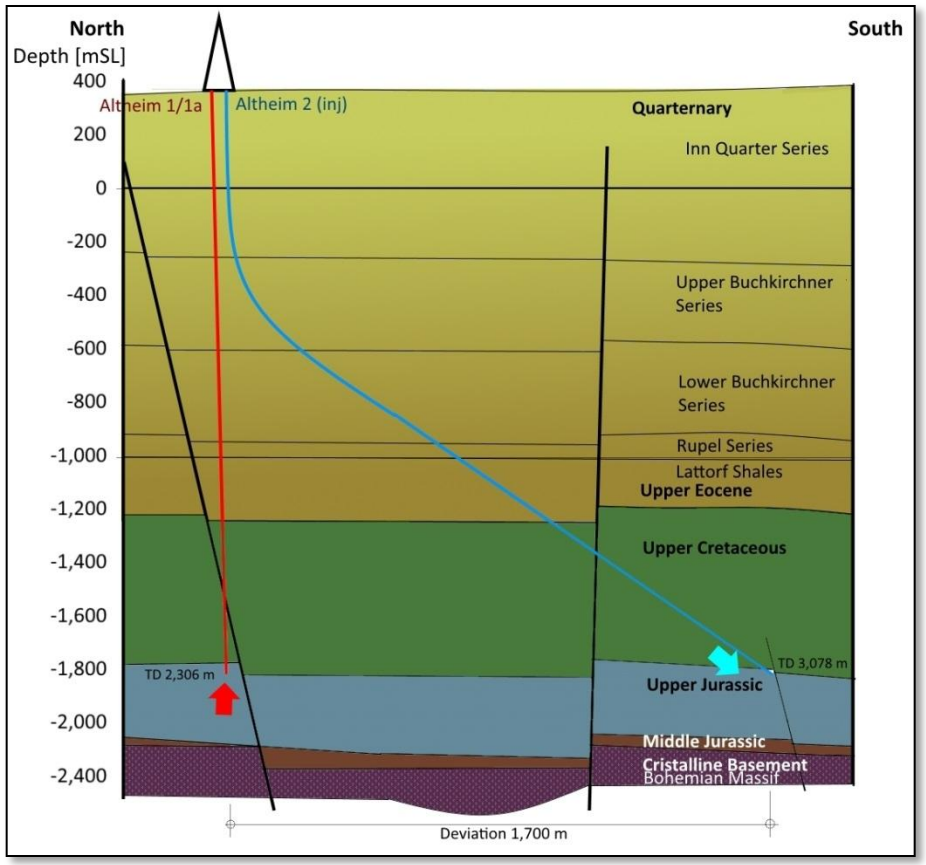
The Altheim Geothermal Project - Geology

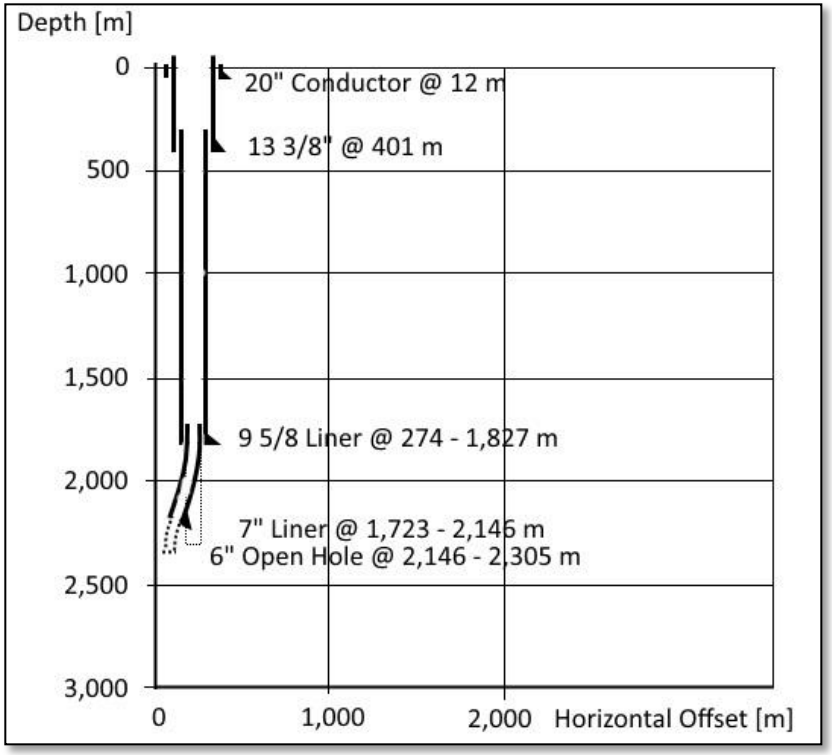
- The Phase I of the Altheim geothermal project aimed at the supply of hot water to the community for district heating of approx 1,500 households, requiring energy of some 10 $MW_{[th]}$
- A vertical production well was drilled to a TD of ~2,300 m into the Upper Jurrasic formation, resulting in a flow of 104° C hot water at a rate of 46 litre/sec in free (artesian) flow



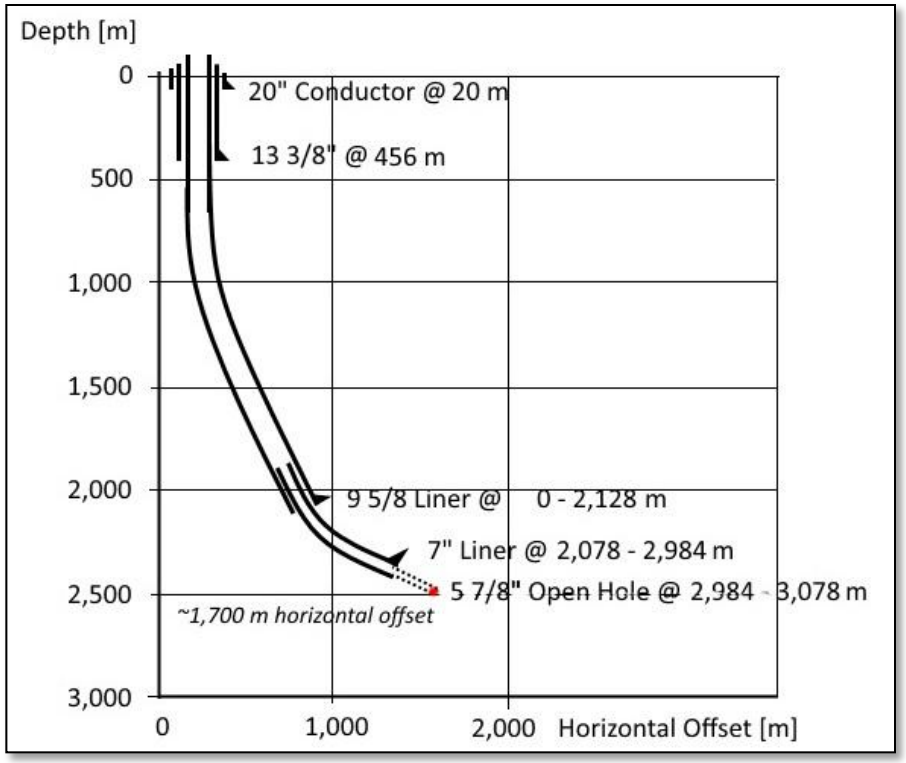
- As a consequence of the 'Regensburg Agreements', the produced water had to be re-injected into the aquifer:
- A directional disposal well was drilled, an electrical submersible pump (ESP) was installed in the production well to increase flow to 100 l/sec and the project was extended in 1994 by adding a 1 MW, ORC turbine (manufacturer: Turboden) for power generation

The Altheim Geothermal Project - Well Design

- Production well Altenheim 1/1a
  (the well was deviated in the lower section to access a better developed part of the reservoir)

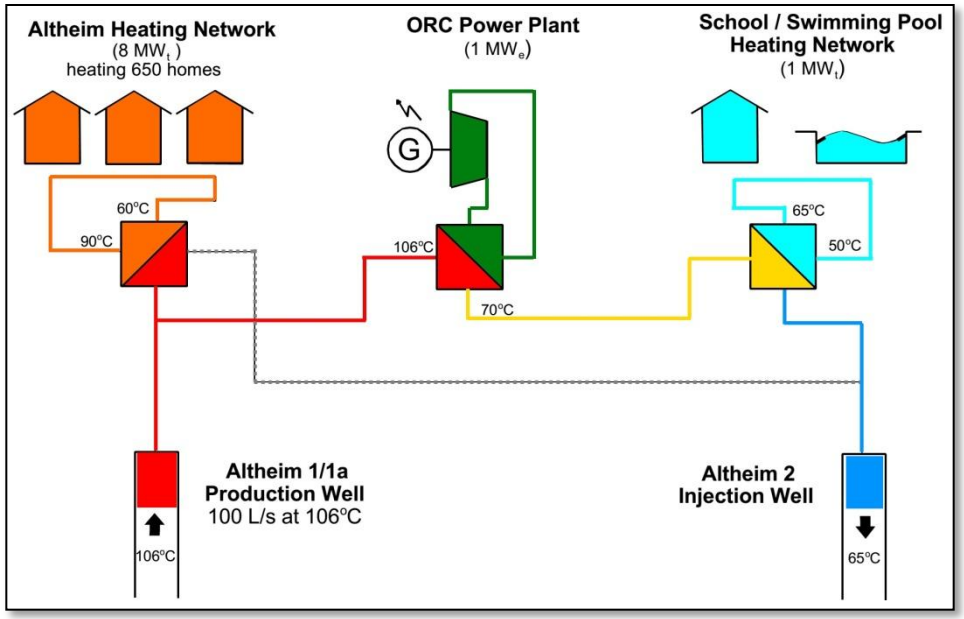


- Injection well Altenheim 2
  (the well was deviated to about 60 deg to achieve a sufficient offset from the producer)



The Altheim Geothermal Project – Flow Diagram

- The 104° C hot water flow from the production well is diverted into two streams
- After passing through a plate type heat exchanger and depending on ambient temperature, approx 8 to 9 $MW_{[th]}$ at 90° C secondary closed loop flow are used for residential heating of public buildings and private residential premises
- The remainder of the hot water flow is directed to an Organic Rankine Cycle (ORC) turbine and power generator with a capacity of approx 1 $MW_{[el]}$
- The ~70° C outflow from the ORC power plant is cascaded to the local school and indoor swimming pool heating system with a capacity of approx 1 $MW_{[th]}$



- *Adding a further low-temp cascade (25 - 30° C for greenhouses, wood or grain drying) would be technically viable and could improve overall efficiency and economics, but so far no customers could be secured*

The Altheim Geothermal Project - Design Parameter

- Produced geothermal water is low on TDS (Total Dissolved Solids) and aggressive minerals which avoids complications in the facilities

Sampling Date		21-Oct-03	25-Jan-06
Temperature	*[deg C]*	59.10	66.30
pH		7.31	7.23
Conductivity	*[µS/cm]*	1,245.00	1,303.00
Ammonium	*[mg/l]*	2.10	2.23
Sodium	*[mg/l]*	251.00	239.00
Potassium	*[mg/l]*	21.50	15.30
Magnesium	*[mg/l]*	2.20	1.70
Calcium	*[mg/l]*	11.60	8.90
Chloride	*[mg/l]*	120.00	206.00
Sulfate	*[mg/l]*	4.10	9.20
Hydrogencarbonate	*[mg/l]*	527.00	528.00
Total Electrolytes	*[mg/l]*	**939.50**	**1,010.33**

Flow Rate Offtake Well	*[litre/sec]*	82.0
Temperature Offtake Well - Inlet	*[deg C]*	106.0
Temperature Offtake Well - Outlet	*[deg C]*	70.0
Flow Rate Cooling Water	*[litre/sec]*	340.0
Temperature Cooling Water - Inlet	*[deg C]*	10.0
Temperature Cooling Water - Outlet	*[deg C]*	18.0
Capacity Thermal	*[MW-th]*	12.4
Capacity Electrical (ORC Power Gen)	*[MW-el]*	1.0

The Altheim Geothermal Project - - Facilities I

- Geothermal Production Well Wellhead

- The disposal well is located some 100 m away from the production well, housed in the wooden shag

The Altheim Geothermal Project - - Facilities II

- Hot Water Transfer Pumps

- Plate Type Heat Exchangers

The Altheim Geothermal Project - - Facilities III

- District Heating – Pressure balancing system

- District Heating – Water Treatment

The Altheim Geothermal Project - - Facilities IV

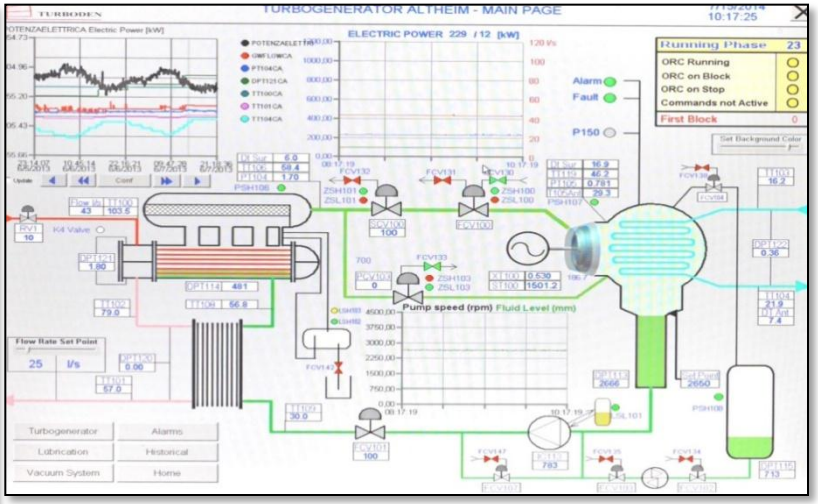
- ORC Turbine – Hot Side Heat Exchanger

- ORC Turbine – Power Pack

The Altheim Geothermal Project - - Facilities V

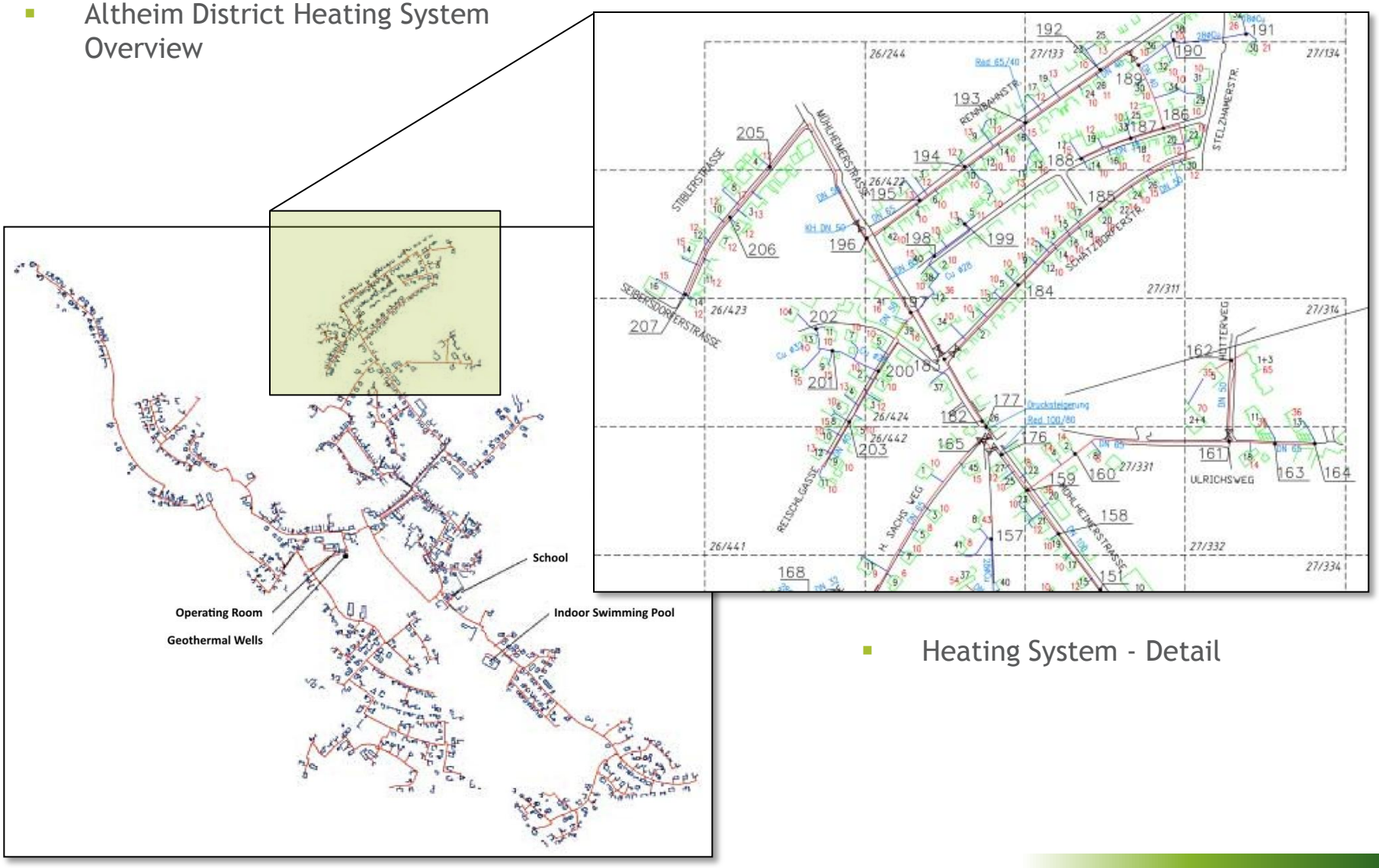
- ORC Turbine – Turbine and Cooling Water Inlet

- ORC Turbine – Control Screen



The Altheim Geothermal Project - Heating Network

- Altheim District Heating System Overview

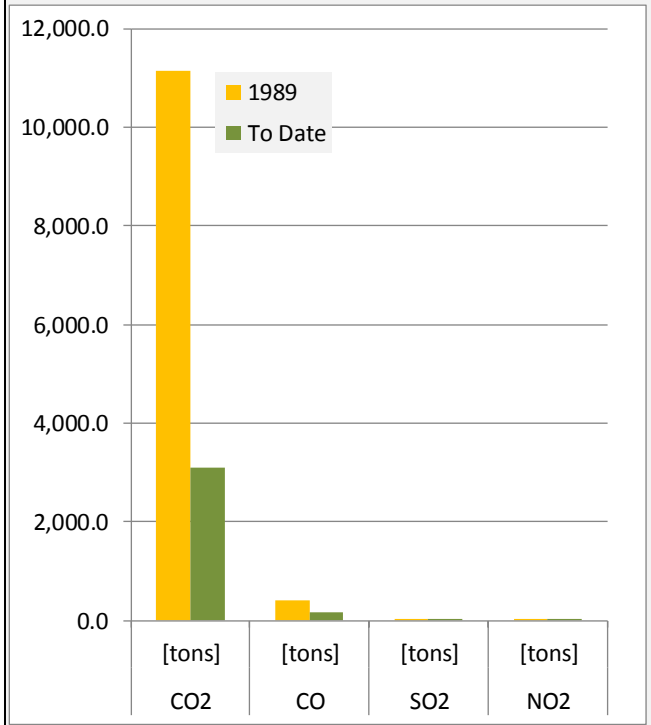


- Heating System - Detail

The Altheim Geothermal Project - Ecological Impact

- Ecological Footprint was materially reduced by reducing emissions from fossil fuels use

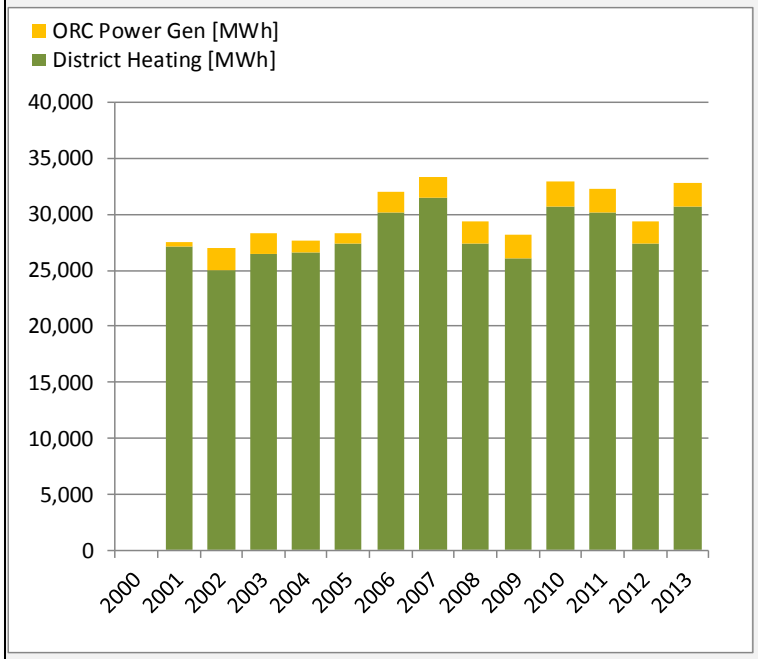
		1989	To Date	Savings
CO2	*[tons]*	11,150.0	3,094.0	72.3%
CO	*[tons]*	411.0	173.0	57.9%
SO2	*[tons]*	32.2	11.2	65.2%
NO2	*[tons]*	8.0	2.6	67.5%



The Altheim Geothermal Project - Production

- The project produced a remarkable total of almost 400 GWh of energy over the last 13 years, the majority of the low enthalpy geothermal water being used for district heating

		2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2000-13
District Heating	*[MWh]*		27,079	25,009	26,444	26,587	27,369	30,106	31,474	27,369	26,001	30,653	30,106	27,369	30,653	**366,219**
ORC Power Gen	*[MWh]*		388	2,020	1,819	1,006	916	1,916	1,865	2,012	2,134	2,243	2,190	1,987	2,210	**22,706**
Offtake	*['000 m3]*	682	977	2,070	2,057	1,668	1,539	1,693	1,770	1,539	1,462	1,724	1,693	1,539	1,724	**21,455**
Re-Injection	*['000 m3]*	682	977	2,070	2,057	1,668	1,539	1,693	1,770	1,539	1,462	1,724	1,693	1,539	1,724	**21,455**
Allowable	*['000 m3]*	3,154	3,154	3,154	3,154	2,523	2,523	2,523	2,523	2,523	2,523	2,523	2,523	2,523	2,523	**34,690**



The Altheim Geothermal Project - Economics

- Project shows reasonably good economics (1999 Basis) even at depressed energy prices

Base Assumptions		Fill in value
Parameter		Calculated
Depth of the well	2,800	*[m]*
Geothermal gradient	0.038	*[K/m]*
Reservoir temperature	106.4	*[°C]*
Flow of the well	100.0	*[l/s]*
Well head temperature	102.5	*[°C]*
Reinjection temperature	58.4	*[°C]*
Conversion efficiency thermal power	96.0	*[%]*
Full load hours per year	8,000	*[h]*
Thermal Power	17.7	*[MW]*
Thermal Energy	141.6	*[GWh]*
Heating hours per year	3,200	*[h]*
Heating energy per year	56.6	*[GWh]*
Annual growth heat sales	1.0	*[%p.a.]*
District heating wholesale price per MWh	30.0	*[EUR]*
Electricity per year	10.2	*[GWh]*
Received price per MWh electricity sold	50.0	*[EUR]*
Size of electric power station	1.8	*[MW]*
Total Investment	17.0	*[MM EUR]*
Conversion efficiency electric power	12.0	*[%]*
Price increase for electricity bought	4.0	*[%p.a.]*
Price increase general costs	3.0	*[%p.a.]*
Price of CO_2 Emission	5.0	*[EUR]*
Capacity of 1 W =	1.16222	*[kcal/h]*

CAPEX				
Parameter			***Depreciation***	
Well Drilling	6.0	*[MM EUR]*	30	*[yrs]*
Drilling Contingency	0.0	*[MM EUR]*	30	*[yrs]*
Building and Land	0.5	*[MM EUR]*	15	*[yrs]*
Submersible Pump	1.0	*[MM EUR]*	5	*[yrs]*
Heating Losses	2.0	*[MM EUR]*	5	*[yrs]*
District Heating Pipeline	5.0	*[MM EUR]*	30	*[yrs]*
Plant and Facilities	2.5	*[MM EUR]*	20	*[yrs]*
Other/Miscellaneous	0.0	*[MM EUR]*	5	*[yrs]*
Total CAPEX € million	**17.0**	*[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	100.0	*[M EUR p.a.]*
Other operating expenses	200.0	*[M EUR p.a.]*
Other operating	0.0	*[M EUR p.a.]*
Start up costs	0.0	*[M EUR p.a.]*
Maintenance	2.0	*[M EUR p.a.]*
Total OPEX	**350.0**	*[M EUR p.a.]*

Results	**BT**	**AT**	
Internal rate of return (ROR)	10.3%	9.2%	*[%]*
Net present value (NPV)	6.8	4.8	*[MM EUR]*
Pay back period	12.6	14.4	*[years]*

Thank You