IEA Heat Pump Symposium
at Chillventa 2012

CHILLVENTA 2012

8 October 2012, Nürnberg

Ground Source Heat Pump systems for large commercial buildings in Central and Southern Europe

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European Geothermal Energy Council, Brüssel

EGEC

Large GSHP

Ground Source Heat Pumps (GSHP) for high capacity require:

- holistic design approach for building HVAC system and ground system
- balanced ground-side energy turnover
- adequate ground-side installations
- sophisticated control system for the whole installation

Large GSHP

A specific challenge for large plants with borehole heat exchangers (BHE) is drilling in given timeframe.

Drilling with 3 rigs simultaneously near Frankfurt/Main

(Project designed and supervised by UBeG, www.ubeg.de)

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Large GSHP in Germany

City, Name	Year	Inst. capacity [kW_{th}]	Type
Duisburg, ZBBW	2011	1480 (H) / 1030 (C)	180 BHE each 130 m deep, 3 HP
Bonn, Bonner Bogen	2009	920 (H) / 620 (C)	3 + 3 groundwater wells 28 m deep, HP
Munich, Dywidag	2001	840 (H) / 500 (C)	Several groundwater wells for 500 m^3/h, HP
Schwabach, MF Niehoff	2009	600 (H) / 900 (C)	103 BHE each 85 m deep, 2 HP
Frankfurt/M, Ordnungsamt	2009	600 (H/C)	112 BHE each 85 m deep, HP
Bonn, „Bonnvisio“	2004	600 (H) / 550 (C)	2 + 2 groundwater wells 11 m deep, HP
Golm near Potsdam, MPI	1999	560 (H) / 360 (C)	160 BHE each 100 m deep, HP
Nuremberg, Panalpina	2008	560 (H) / 270 (C)	81 BHE each 75 m deep, 2 HP
Münster, LVM 7	2008	550 (H/C)	91 BHE each 100 m deep, HP
Freiburg i.Br., Unterlinden	2011	ca. 500 (H/C)	108 BHE each 125 m deep, HP
Frankfurt/M, Maintower	1999	ca. 500 (C)	ca. 210 energy piles ca. 30 m deep, cold storage
Gelnhausen, MK-Forum	2005	400 (H) / 440 (C)	96 BHE each 99 m deep, HP
Frankfurt/M, CargoCity S 577	2010	380 (H) / 480 (C)	38 BHE each 130 m tief, HP
Leinfelden-Echertdingen, HC	2010	340 (H) / 355 (C)	80 BHE each 140 m tief, HP
Langen, DFS	2001	330 (H) / 340 (C)	154 BHE each 70 m deep, HP
Frankfurt/M, Baseler Platz	2003	300 (H) / 180 (C)	2 groundwater wells 80 m deep, HP

Large GSHP in Germany

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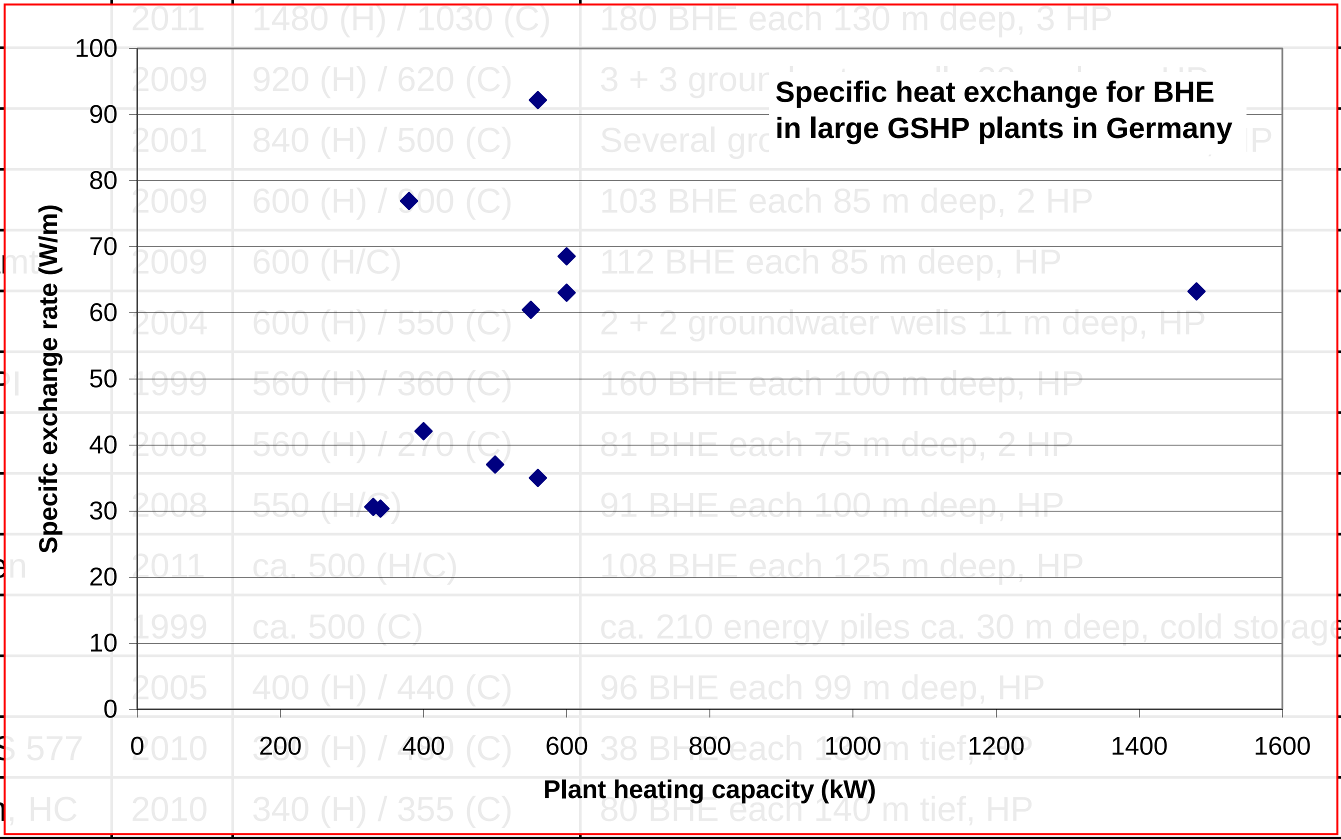

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Large GSHP in Germany

County administration in Gelnhausen,
“Main-Kinzig-Forum”

- Cooling from BHE 440 kW
- Heating from HP 400 kW
- 96 BHE each 99 m deep

Operational since 2005

Heat pump and BHE manifold

Large GSHP in Germany

Office Building “PLDS”, Wetzlar

- Cooling from BHE 140 kW
- Heating from HP 200 kW
- 30 BHE each 110 m deep

Operational since 2005

Drilling in 2004

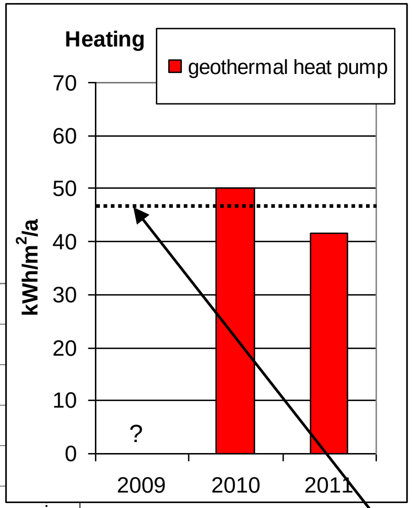
Large GSHP in Germany

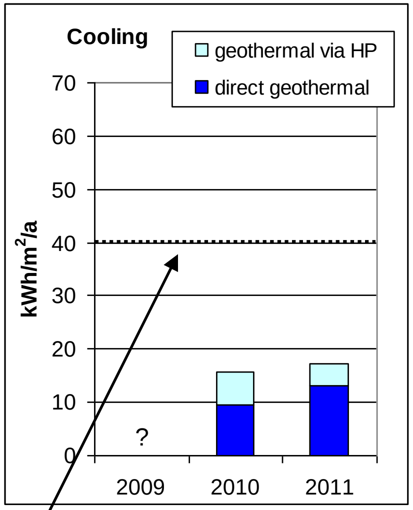
Office Building “PLDS”, Wetzlar

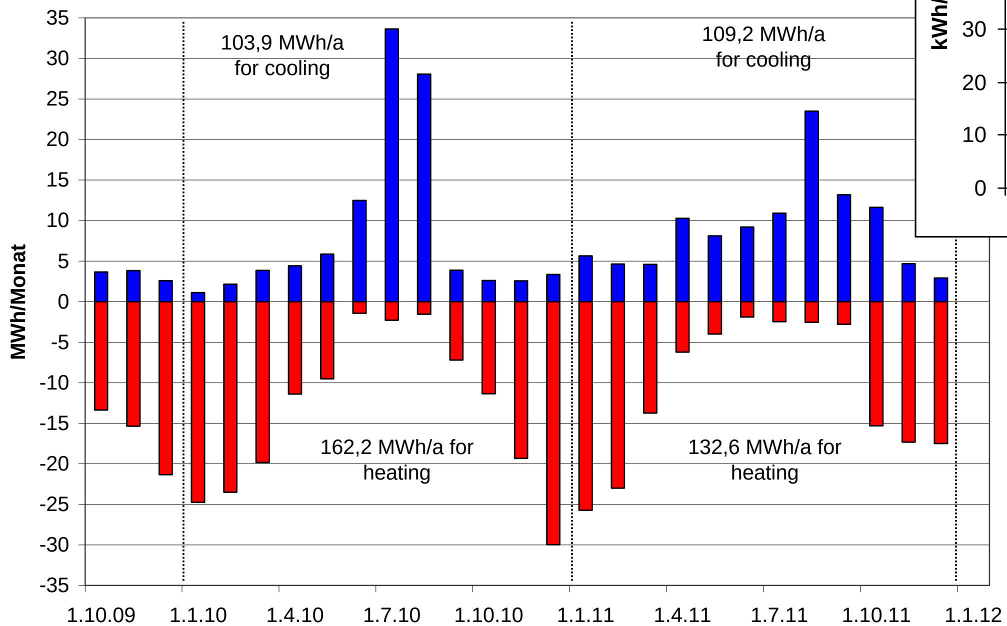
Monitoring funded by German BMWi for 2008-2011:

- Univ. Hannover (LUH)
- UBeG GbR, Wetzlar

  www.ubeg.de







dotted lines: design values

monthly heat extraction and injection (left) and specifc heat and cold supply (above)

Large GSHP – example DFS Langen

"Low-Energy Office" building near Frankfurt/Main:

- Usable area 57.800 m^2
- Cooling from BHE 340 kW
- Heating from HP 330 kW
- 154 BHE each 70 m deep

Operational since 2001

Monitoring funded by German BMWi for 2008-2011:

- Univ. Hannover (LUH)
- UBeG GbR, Wetzlar

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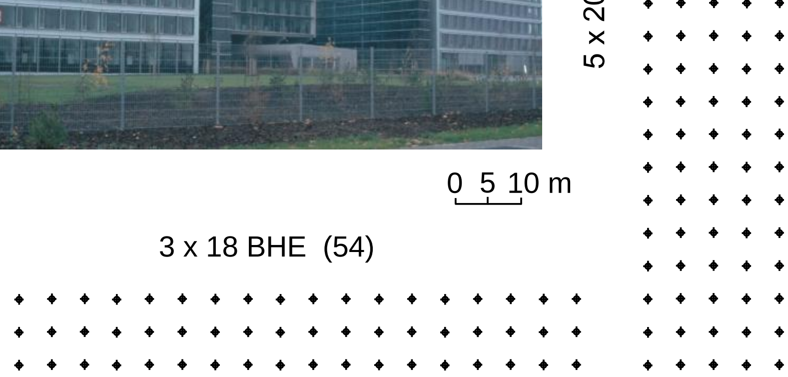
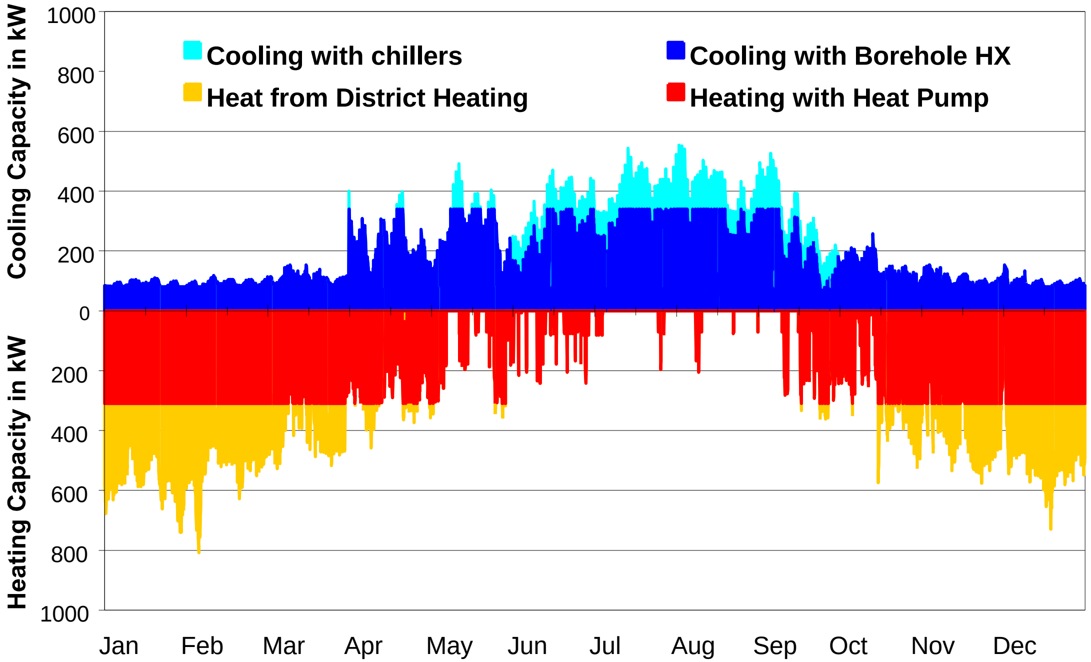


Schematic of BHE fields

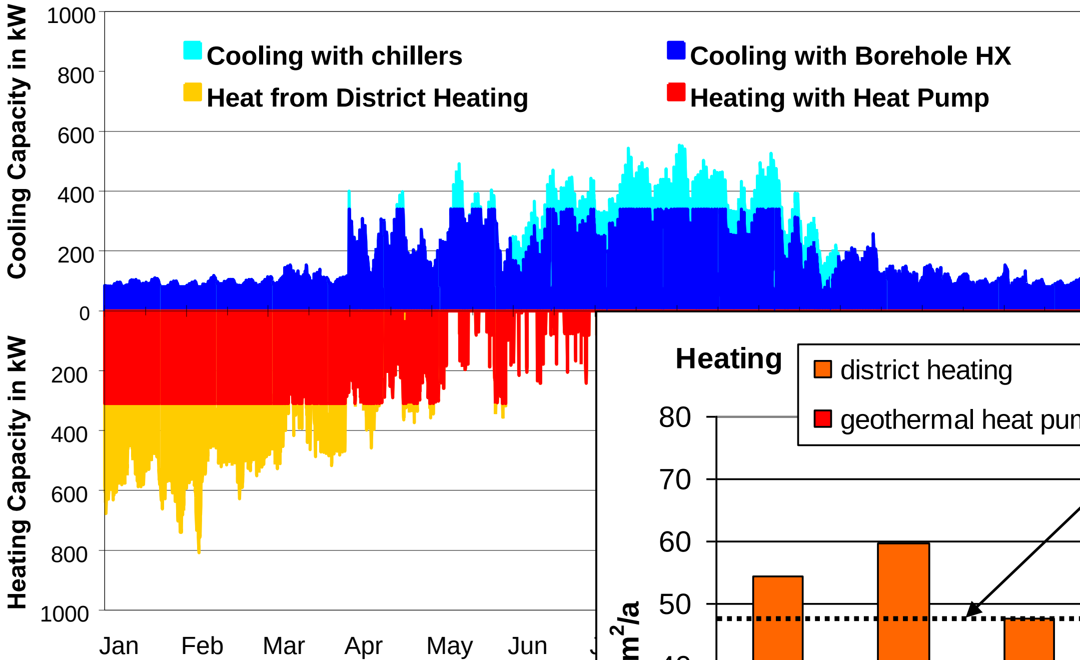
Large GSHP – example DFS Langen



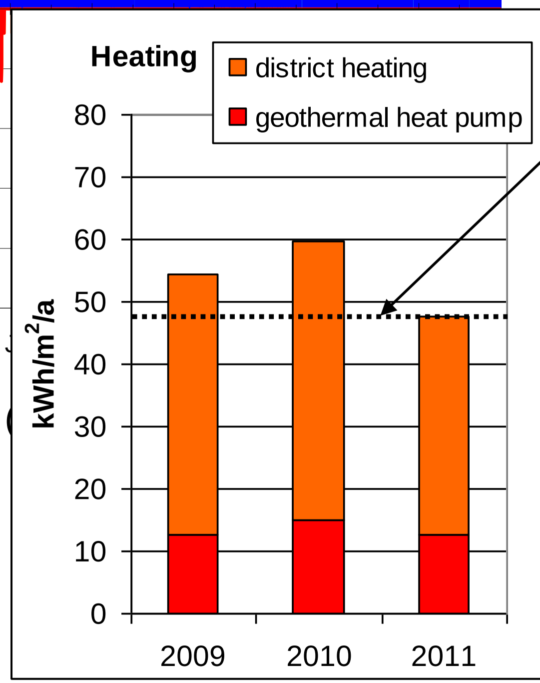
Design demand data (*Seidinger et al., 2000*)

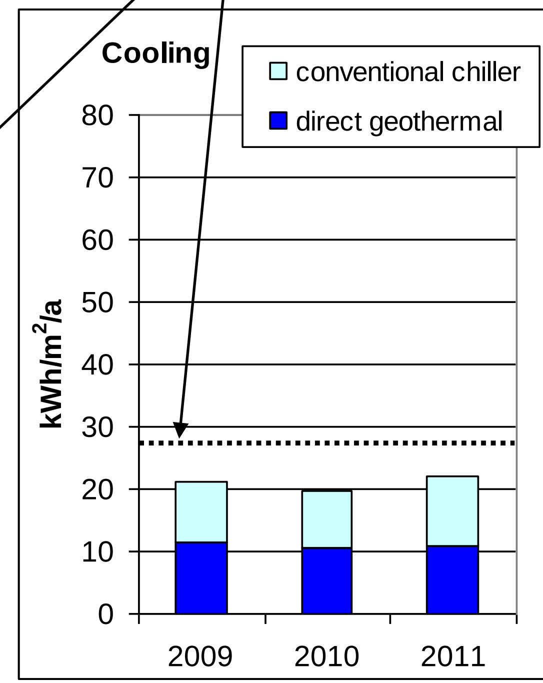
Large GSHP – example DFS Langen

dotted lines: design values



Design demand data (

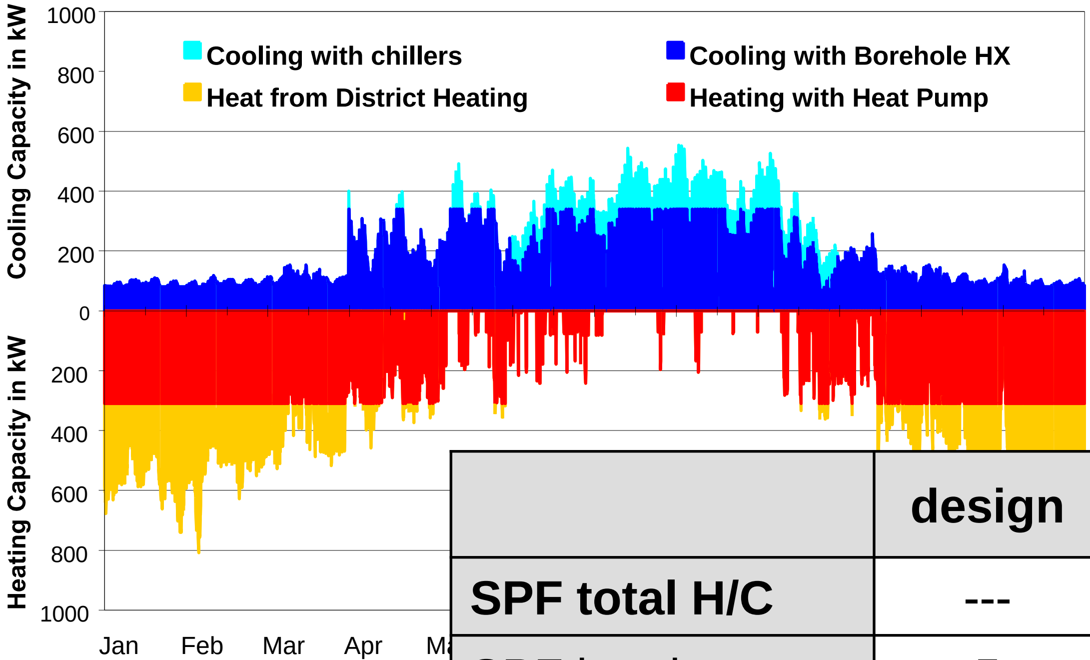




Monitoring results for 2009-2011

(*Bohne et al., 2012*)

Large GSHP – example DFS Langen



Design demand

	design	2009	2010	2011
SPF total H/C	---	**8.2**	**7.1**	**7.9**
SPF heating	5	6.5	5.6	6.1
SPF cooling	> 8	9.9	9.9	12.0
geoth. share heat	75 %	23.1 %	25.3 %	26.3 %
geoth. share cold	82 %	53.6 %	54.0 %	49.5 %

Monitoring results for 2009-2011

(*Bohne et al., 2012*)

Large GSHP – example DFS Langen

Use of monitoring for the validation of design tool EED:

- Using EED for calculating annually differing heat loads is only possible in plants with quasi-balanced energy flows at the ground side. In such cases, the surrounding ground temperature will be relatively stable over the years.
- For the ground thermal parameters of DFS Langen, values from first Thermal Response Tests (TRT) in Germany in 1999 and 2000 could be used
- For undisturbed ground temperature, the measured temperature from observation wells of 12.7 °C was assigned as the mean value over BHE depth

TRT in Langen in 2000

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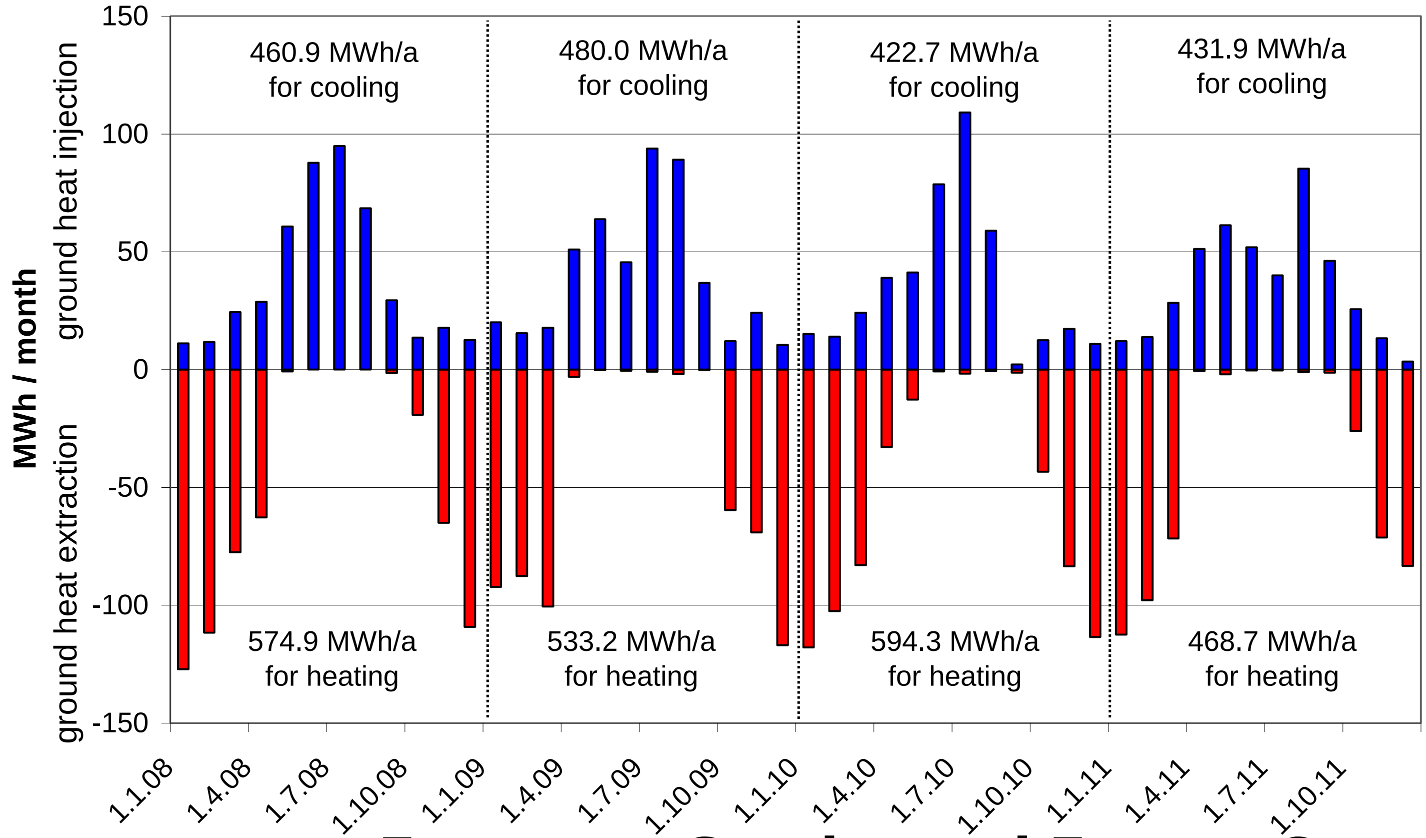
Large GSHP – example DFS Langen

Validation of design tool EED:

- monthly heat extraction from the ground (for heating) and injection into the ground (for cooling)



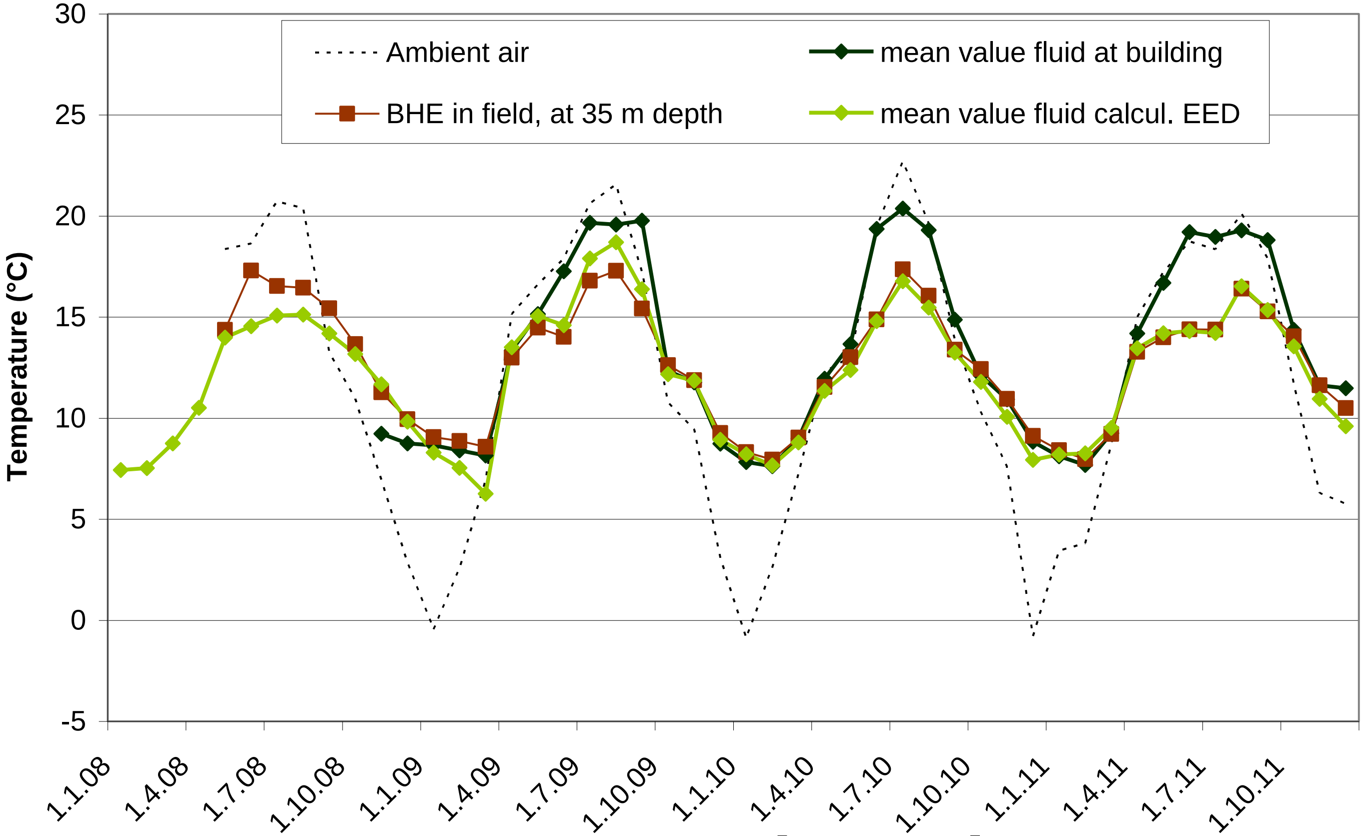
Monitoring data from LUH/UBeG

www.ubeg.de

Large GSHP – example DFS Langen

Validation of design tool EED:

• measured temperatures in ambient air and in the BHE (monthly averages), compared with EED-calculation of BHE



Calculation by UBeG

www.ubeg.de

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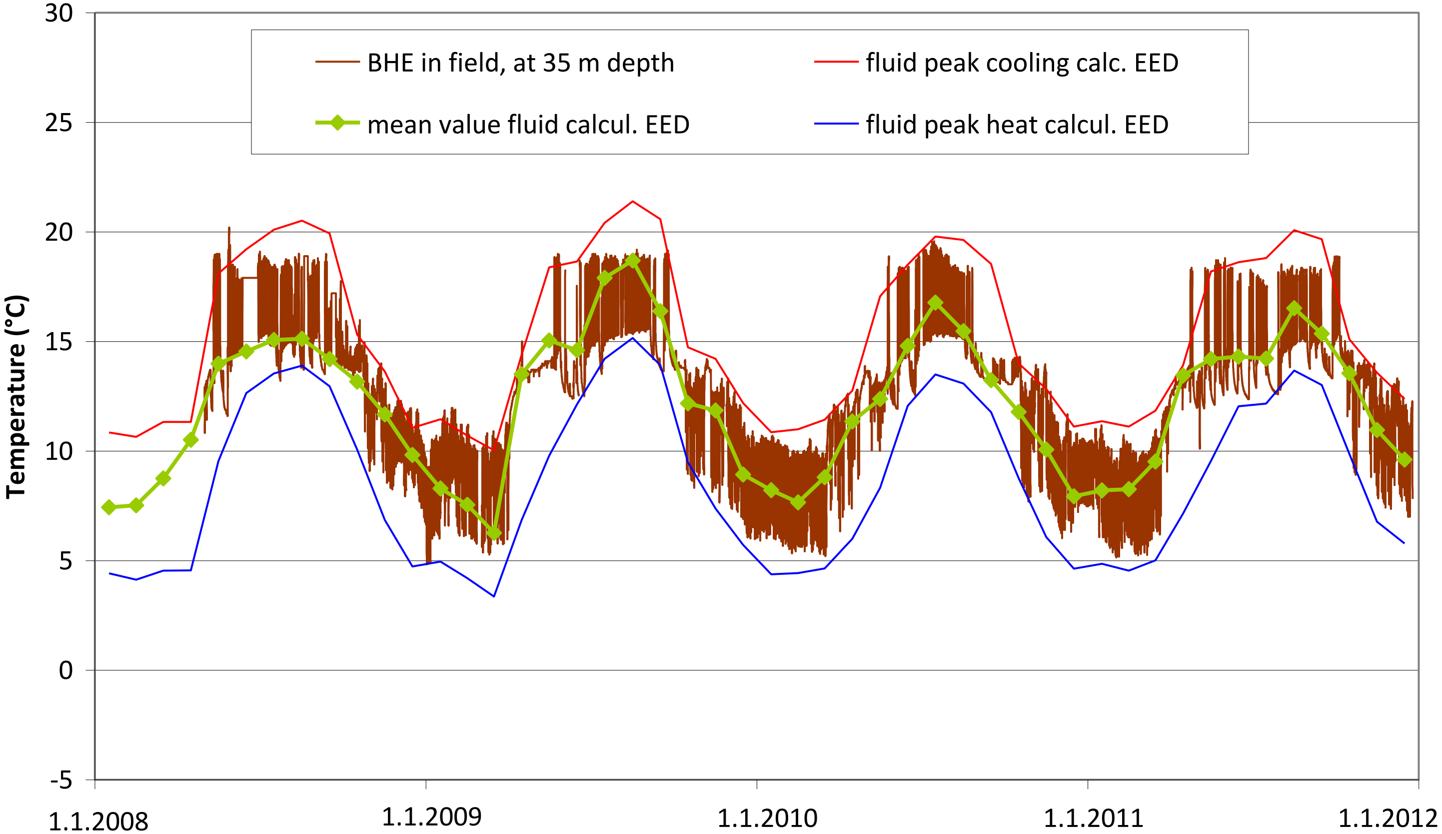
Large GSHP – example DFS Langen

Validation of design tool EED:

• measured temperatures in the BHE (hourly values), compared with EED-calculation of BHE



Calculation by UBeG

www.ubeg.de

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Large GSHP – example DFS Langen

Validation of design tool EED:

- EED could be validated as an easy design tool also for larger BHE fields
- For projects with groundwater influence, numerical simulation of both conductive and advective heat transport is required

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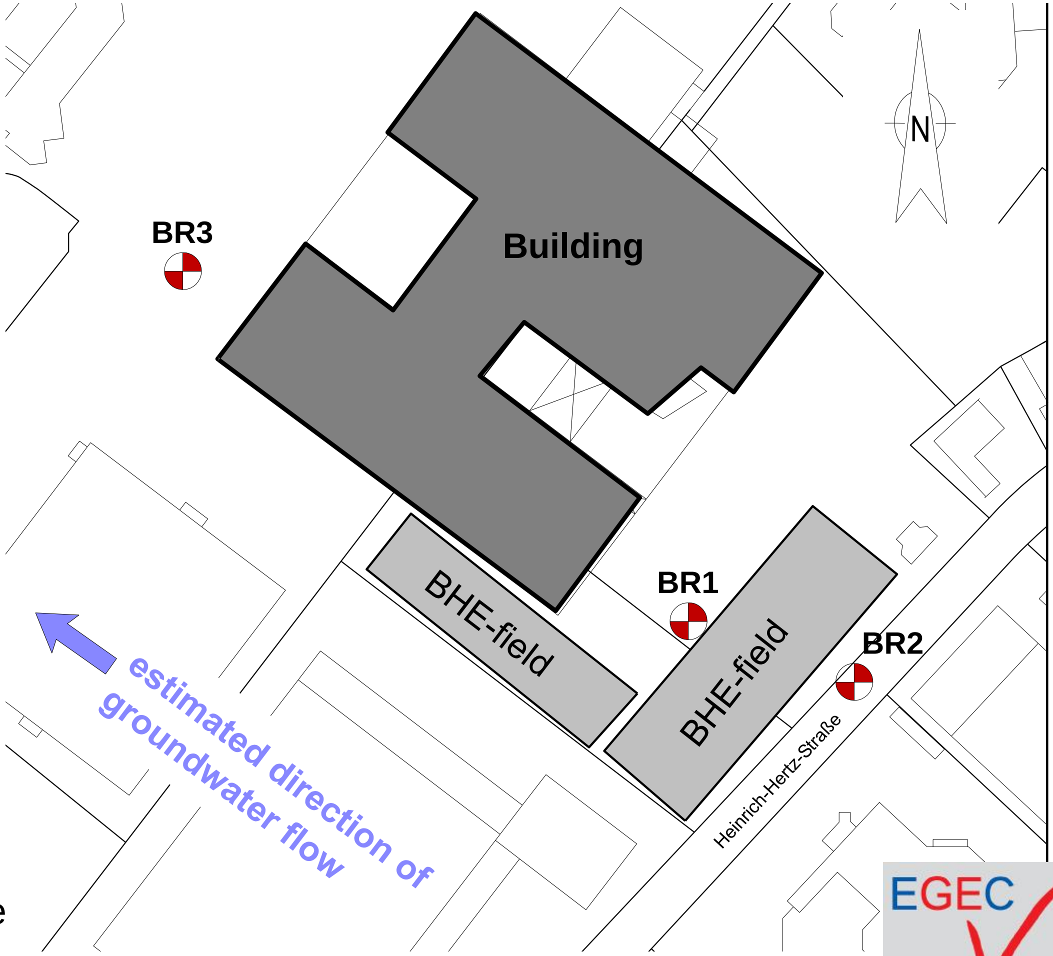
Large GSHP – example DFS Langen

Groundwater influence:

- A number of drinking water wells are located in the direction of assumed groundwater flow from the BHE fields.
- Three monitoring wells were drilled to a depth of 26 m into the active groundwater layer in order to monitor the groundwater temperatures.



Graph UBeG
www.ubeg.de

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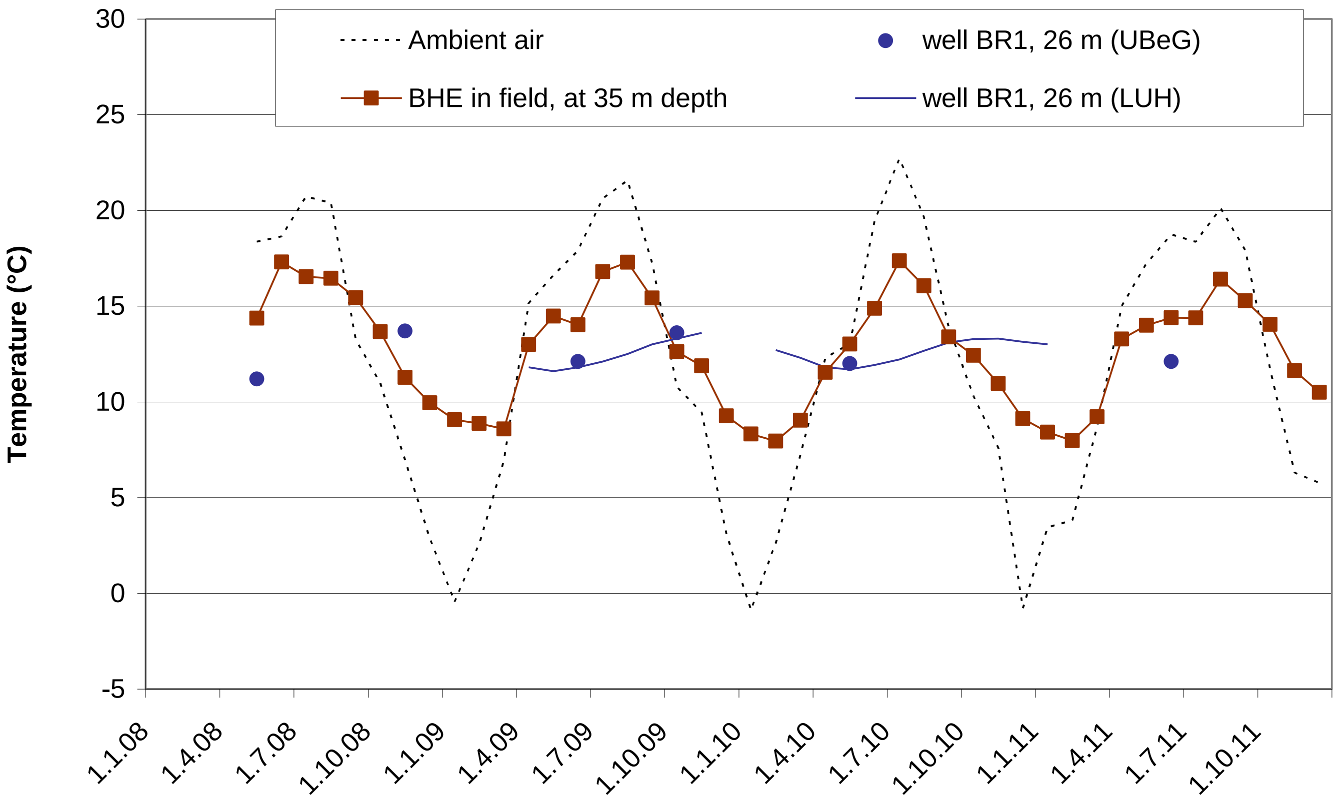
Large GSHP – example DFS Langen

Groundwater influence:

- Temperatures in well BR1 at 26 m depth in relation to temperature at BHE and temperature in ambient air (monthly average)

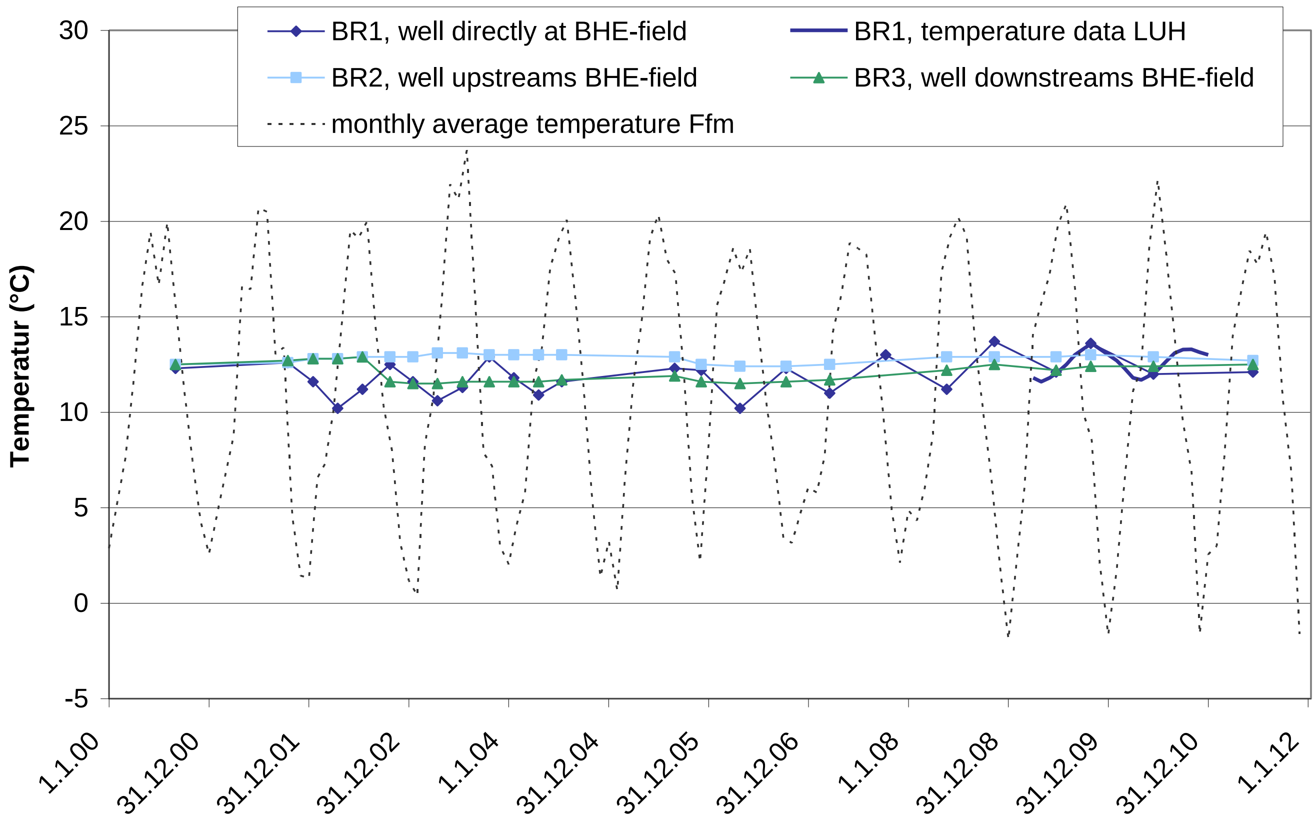


Graph UBeG
www.ubeg.de

Large GSHP – example DFS Langen

Groundwater influence:

- Temperature development in wells BR1-BR3 since start of operation



Graph UBeG

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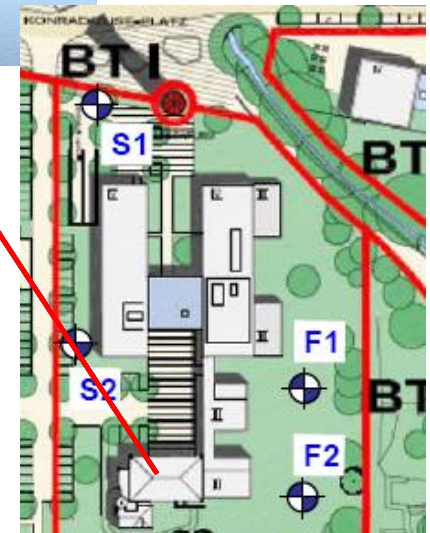
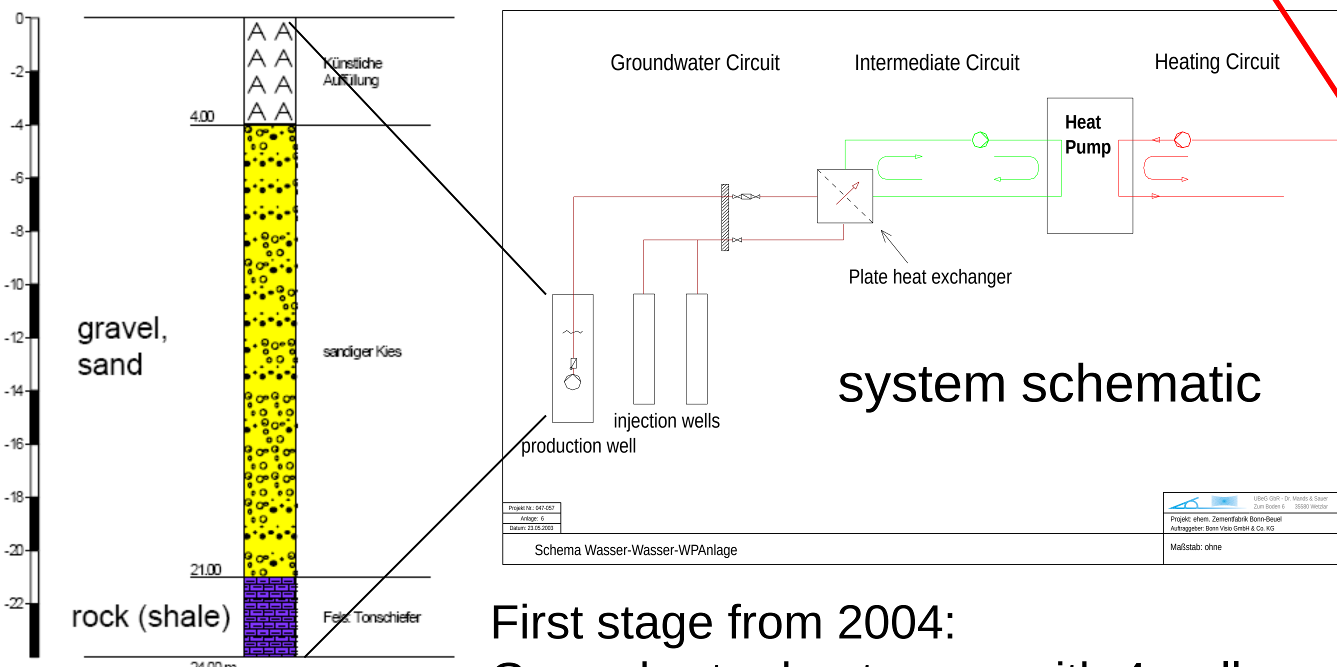
Large GSHP – example Bonn





First stage from 2004:
Groundwater heat pump with 4 wells

Photos und Graphs:
UBeG / BonnVisio
- Bonner Bogen

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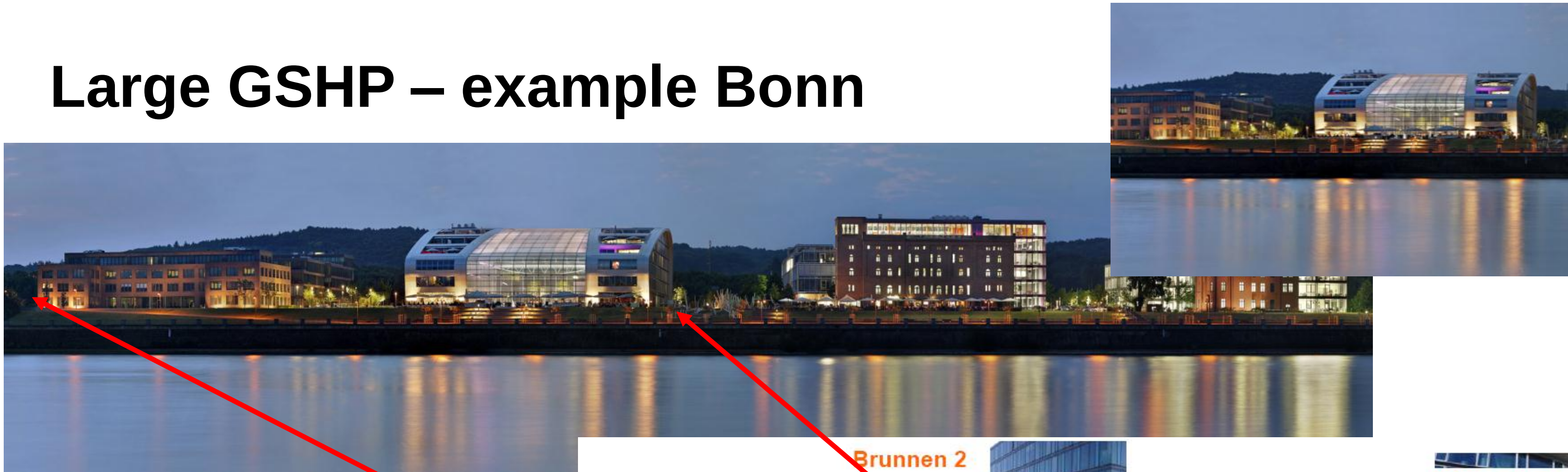
Large GSHP – example Bonn

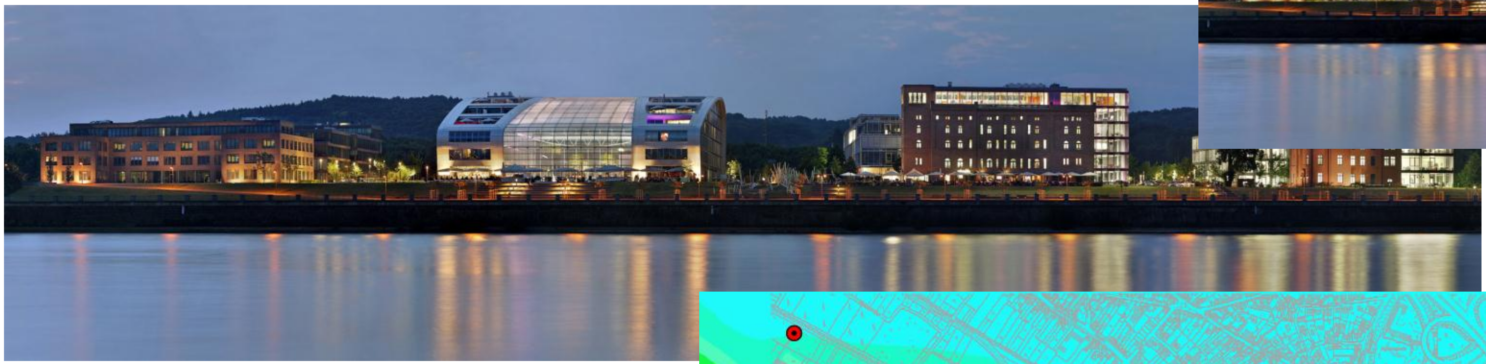


Added 2009: Groundwater heat pump with 6 wells

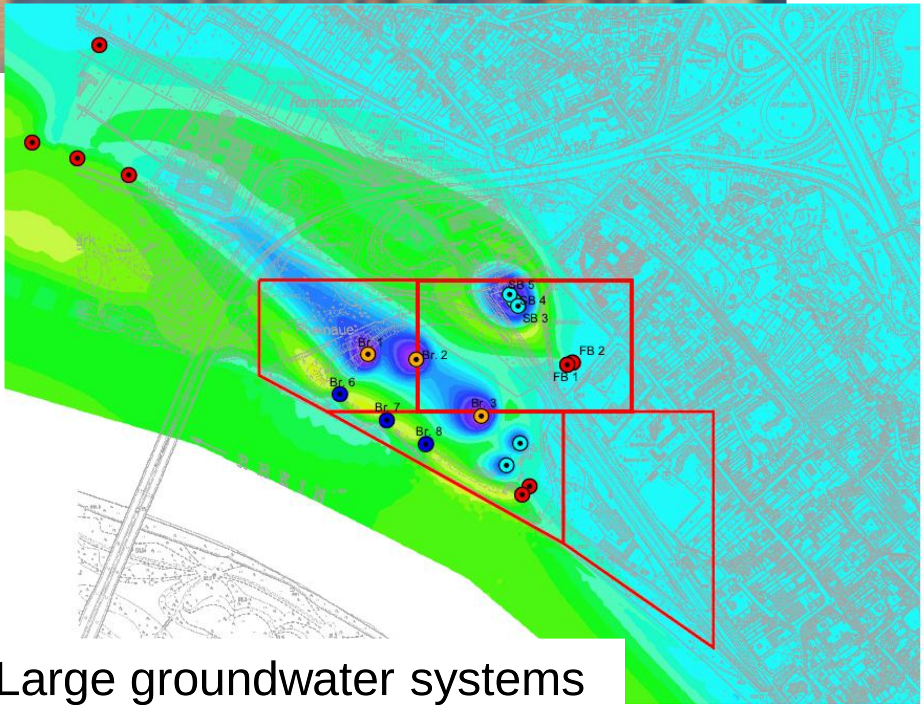
Photos und Graphs:
UBeG / BonnVisio
- Bonner Bogen

European Geothermal Energy Council

Large GSHP – example Bonn



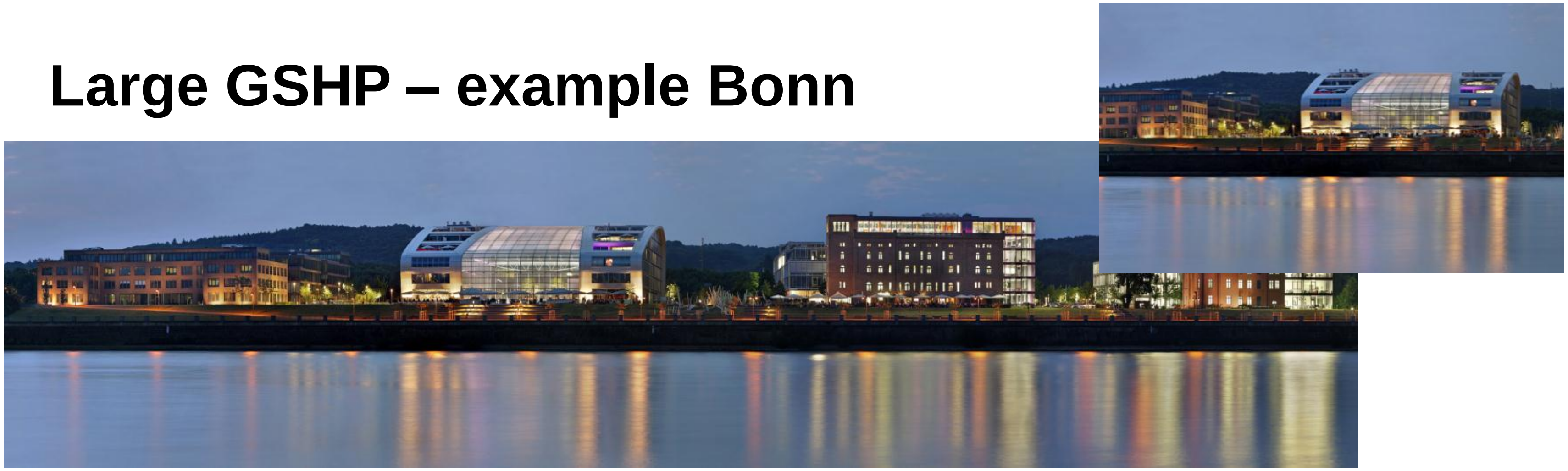
Added 2009: Groundwater heat pump with 6 wells



Large groundwater systems require numerical simulation for planning

Photos und Graphs:
UBeG / BonnVisio
- Bonner Bogen

Large GSHP – example Bonn



Providing about 1 MW baseload for heating and cooling

Added 2009: Groundwater heat pump with 6 wells

Well No. 8

Photos und Graphs:
UBeG / BonnVisio
- Bonner Bogen

Large GSHP in Europe

Country	City, Name	No. BHE	Depth BHE	Total BHE
NO	Lørenskog, Nye Ahus hospital	350	200 m	70’000 m
NO	Oslo, office/flats Nydalen	180	200 m	36’000 m
SE	Lund, IKDC / Chemical Inst.	153	230 m	35'190 m
SE	Stockholm, Vällingby Centrum	133	200 m	26’600m
SE	Stockholm, Kista Galleria	125	200 m	25’000 m
SP	Mollet de Valles, hospital	138	145 m	20'000 m
TR	Istanbul, Ümraniye mall	208	41-150 m	18’327 m
HU	Törökbálint, Pannon GSM	180	100 m	18'000 m
SE	Stockholm, flats Blackeberg	90	150 m	13’500 m
NO	Oslo, offices Alnafossen	64	200 m	12’800 m
SE	Örebro, music school	60	200 m	12’000 m
HU	Páty, Verdung logistics center	120	100 m	12’000 m
BE	Melle, office EANDIS	90	125 m	11’250 m
CH	Zurich, Grand Hotel Dolder	70	150 m	10’500 m
PL	Rudy, Zisterzian monastry	100	100 m	10’000 m

Large BHE project in Romania

Porsche-showroom Bucharest West 2

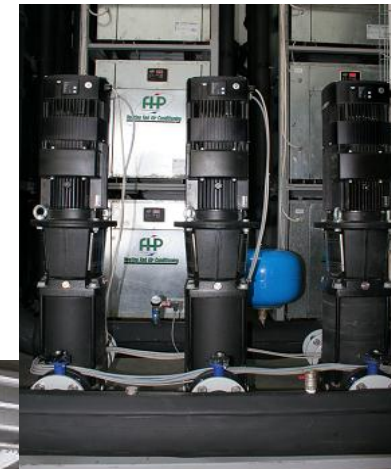
Metallic construction - total area 3’507 m²

Heating load:	308 kW_{th}
Cooling load:	313 kW_{th}
DHW:	200 kWh_{th}/day
Fresh air flow:	3000 m^3/h

Data and photos: ASA

Large BHE project in Romania

Porsche-showroom Bucharest West 2



Building equipment:

- 17 water-to-water and 12 water-to-air heat pumps (Florida Heat Pump), using R410A
- 750 m^2 of special surfaces of under-floor piping system for heating and cooling
- Ventilation channels connected to several water-to-air heat pumps, located mainly in the false ceilings of the building

Ground side equipment:

- 128 BHE each 70–75 m deep under a field of 3’500 m^2

Data and photos: ASA

Large BHE project in Turkey

Umraniye Meydan Shopping Center (Metro), Istanbul

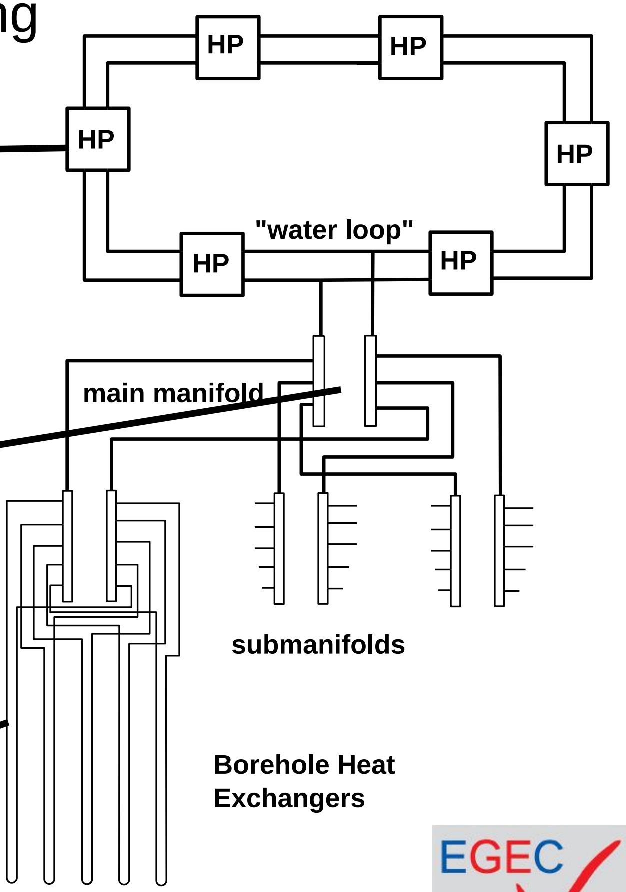
208 BHE, 40-150 m deep (average 88 m)
1 MW heating and cooling, hybrid

Data and part of photos: Form Group

Large BHE project in Turkey

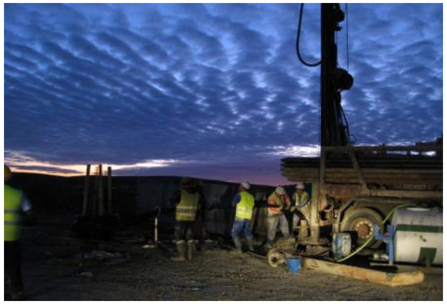
Umraniye Meydan Shopping Center (Metro), Istanbul

Water loop system following American practice



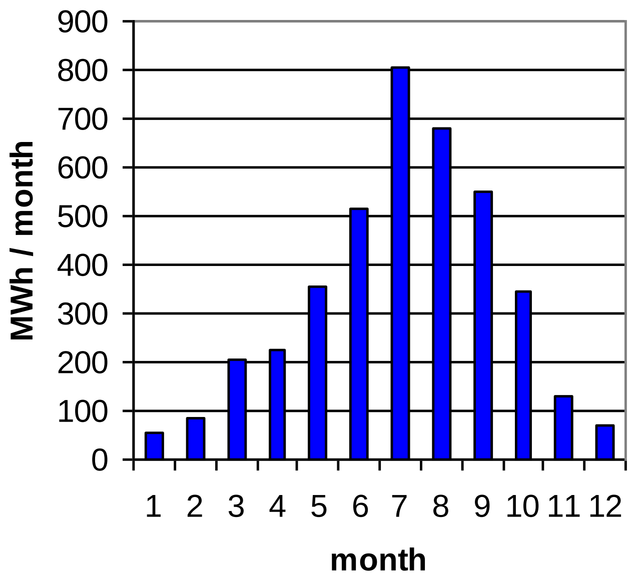
Data and part of photos: Form Group

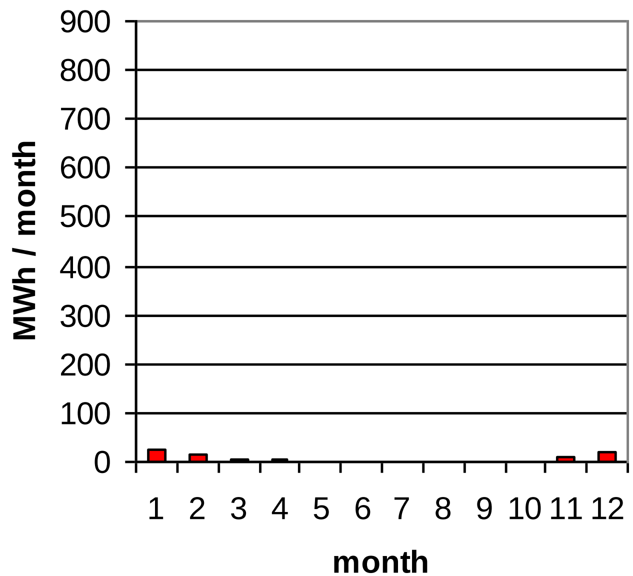
Large BHE project in warm climate



New retail outlet in Jerez de la Frontera, Spain

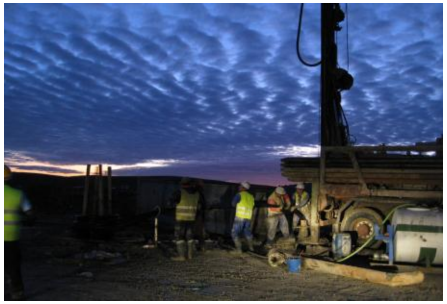
- Climate: mild winters and very hot and dry summers
- 17.7 °C annual average air temperature
- Cooling demand by far exceeds heating demand
- Seasonal storage is hardly feasible, with mean temperatures in winter not lower than 10 °C





(Fernandez et al., 2012)

Large BHE project in warm climate

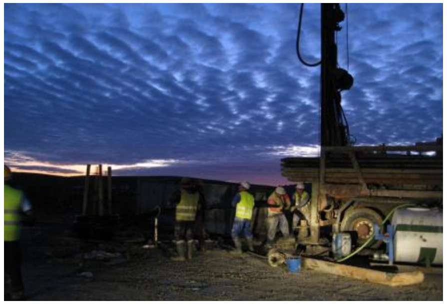


New retail outlet in Jerez de la Frontera, Spain

• Design constraints:

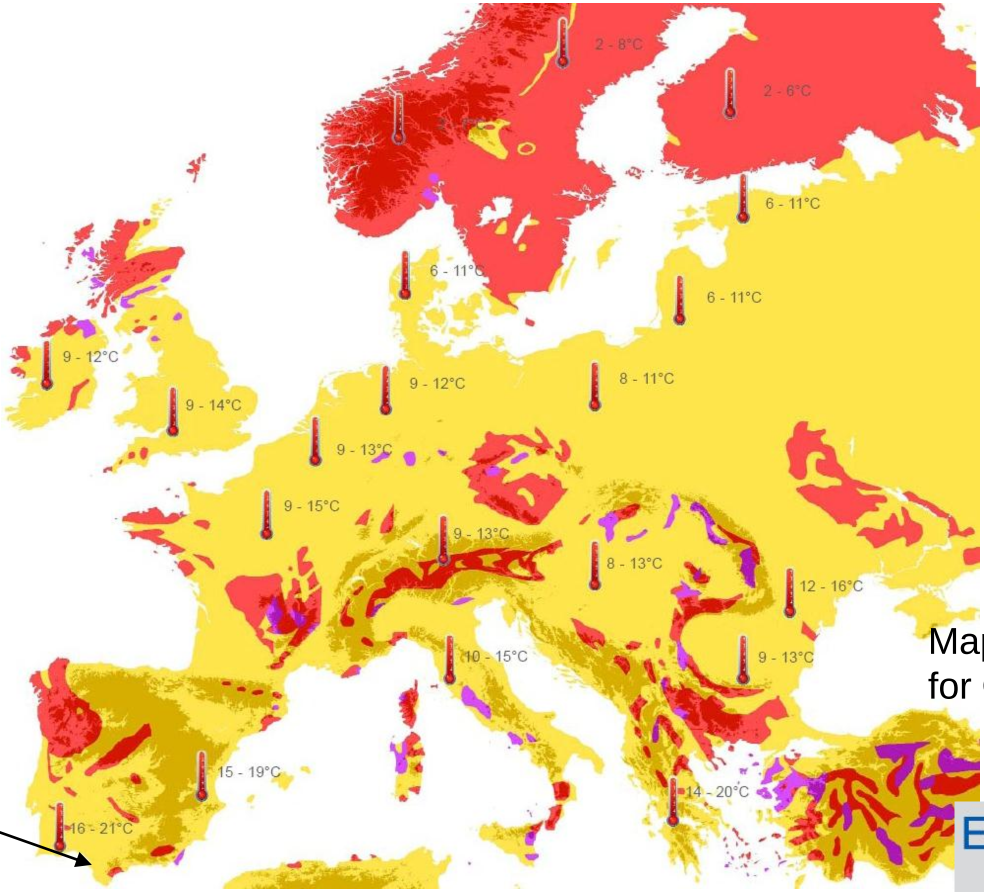
- From economic considerations, there were some constraints:
  maximum number of BHE limited to 50
  maximum BHE surface occuppied around 4’500 m^2
  maximum total length of BHE 6’500 m
- The main design task was to achieve 56 tons of reduction in CO_2 emissions as compared to other renewable energy sources
- Another important design task was to check what would be the maximum cooling that could be provided by a BHE-field of the given size.

Large BHE project in warm climate



New retail outlet in Jerez de la Frontera, Spain

- Undisturbed underground temperature 19.8 °C
- Thermal conductivity from TRT 1,5 W/m/K (rather low)



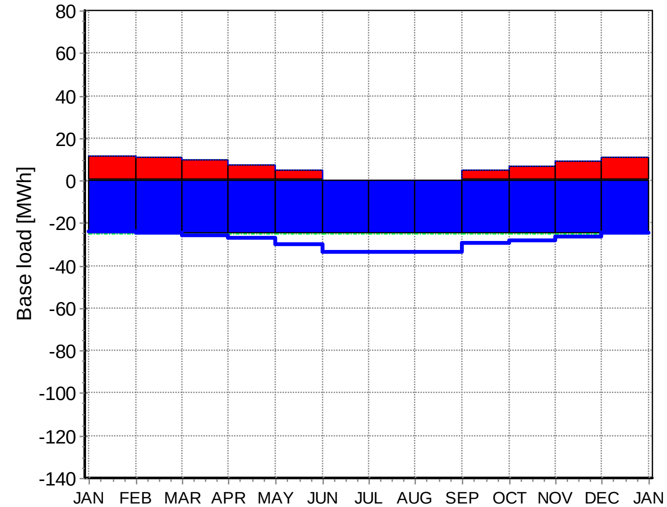
Map BRGM for Geotrainet

European Geothermal Energy Council

Large BHE project in warm climate

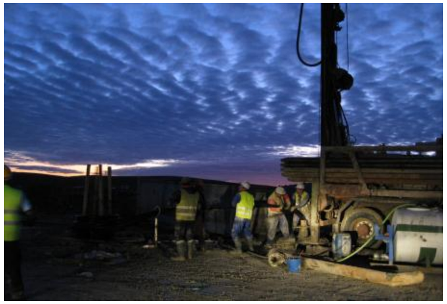
New retail outlet in Jerez de la Frontera, Spain

- Standard approach (all heating in winter, baseload cooling all year)
- Only about 7 % of the annual cooling demand of >4 GWh could be covered by the geothermal system that way



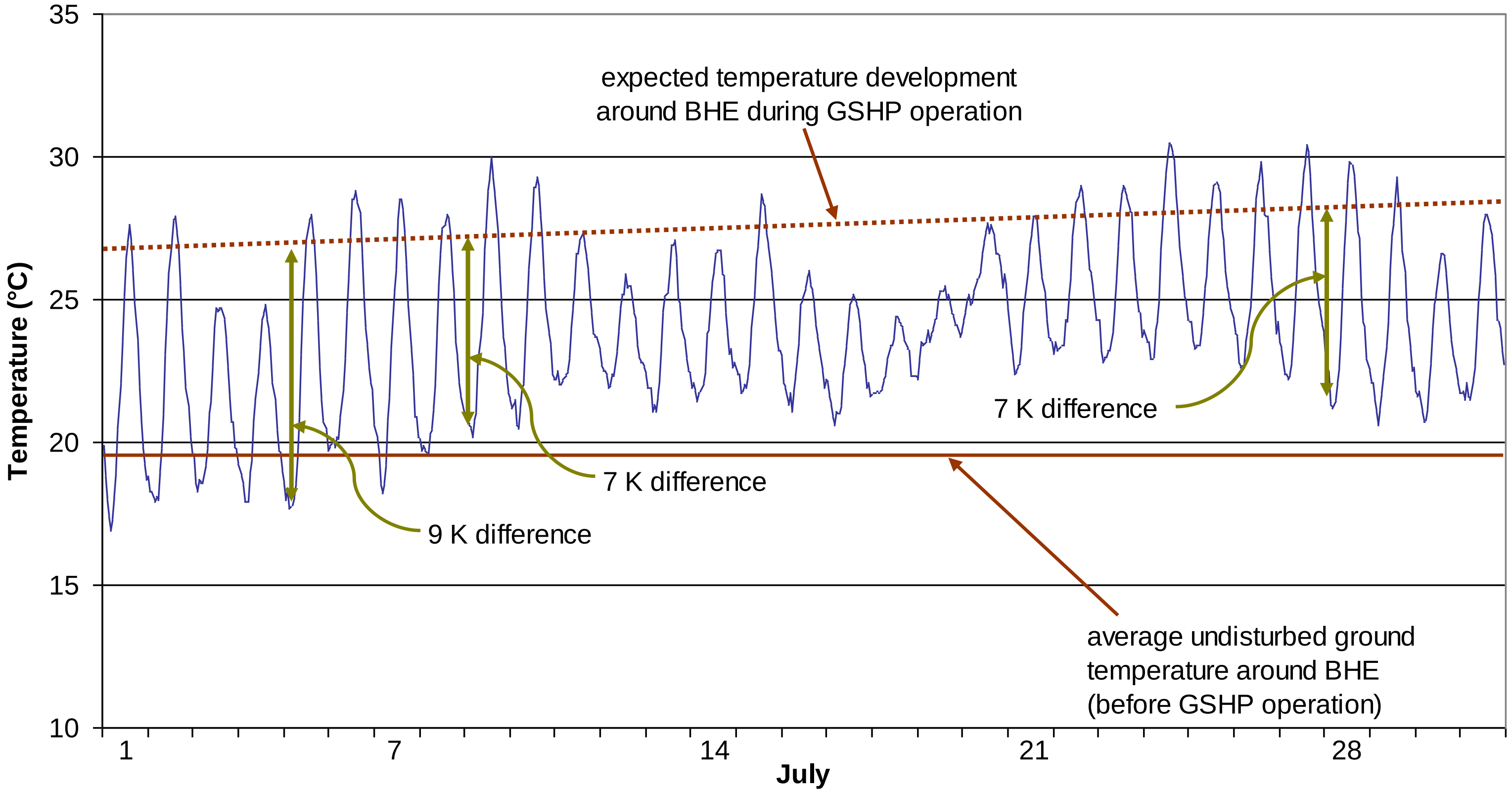
	Building supply	BTES coverage	expected SPF	BTES inj./extr.
Heating	75 MWh/a	100 %	5	60 MWh/a
Cooling	300 MWh/a	7 %	3	450 MWh/a

Large BHE project in warm climate



New retail outlet in Jerez de la Frontera, Spain

- Possible recooling at night in July
  => use all available cold below BHE temperature!



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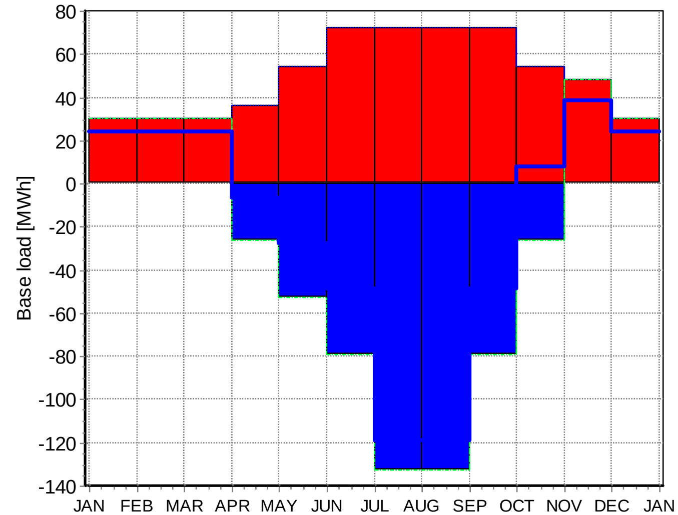
Large BHE project in warm climate

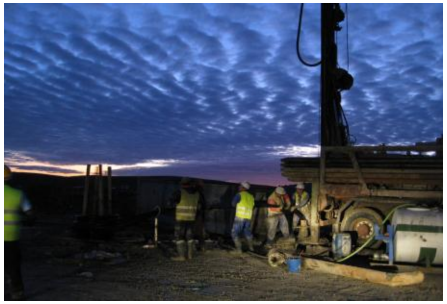
New retail outlet in Jerez de la Frontera, Spain

- Innovative approach (all heating in winter, recooling in winter, peak cooling in summer, night recooling in summer)
- Now about 13 % of the annual cooling demand of >4 GWh could be covered by the geothermal system



	Building supply	BTES coverage	expected SPF	BTES inj./extr.
Heating	75 MWh/a	100 %	5	60 MWh/a
Cooling	530 MWh/a	7 %	3	795 MWh/a

Large BHE project in warm climate



New retail outlet in Jerez de la Frontera, Spain

- Innovative design concept, adapted to Mediterranean climate and combining both diurnal and seasonal cold storage
- In summer, the underground works as a store of cold during the night and as a sink of heat during the day (diurnal storage)
- In wintertime, the regular operation of the heat pump delivers cold, and additional cooling (or re-cooling) is done by dry cooler (seasonal cold storage)
- The cooling output from BHE can be increased sustainably
- First operational experiences are encouraging and show that the systems runs correctly

Very large BHE project in Romania

Extreme Light Infrastructure Nuclear Physics Facility (ELI-NP) at the Horia Hulubei National Institute of Physics and Nuclear Engineering in Măgurele, Romania

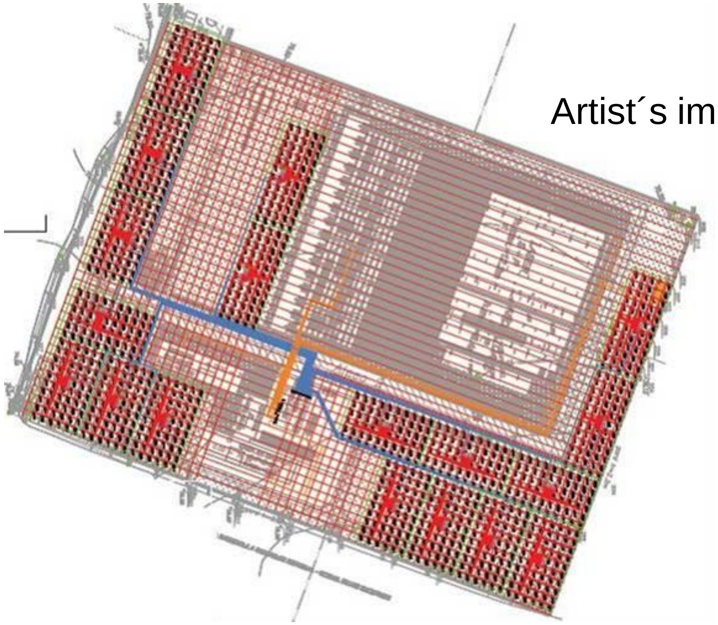
- European research center with the goal to generate laser pulses with 10 petawatts (10 billion MW) of power (for very short time)
- 180 million € confirmed by EU on 18.9.2012; the entire cost will be about 356 million €, paid mainly from Romania's allocation of EU structural funds

Artist´s impression: Hachiko

Very large BHE project in Romania

Extreme Light Infrastructure Nuclear Physics Facility (ELI-NP) at the Horia Hulubei National Institute of Physics and Nuclear Engineering in Măgurele, Romania

- Heating and Cooling in the 4-MW-range by a BHE-field with a number of BHE in the order of 1000 boreholes!
- Drilling planned to start end of 2012



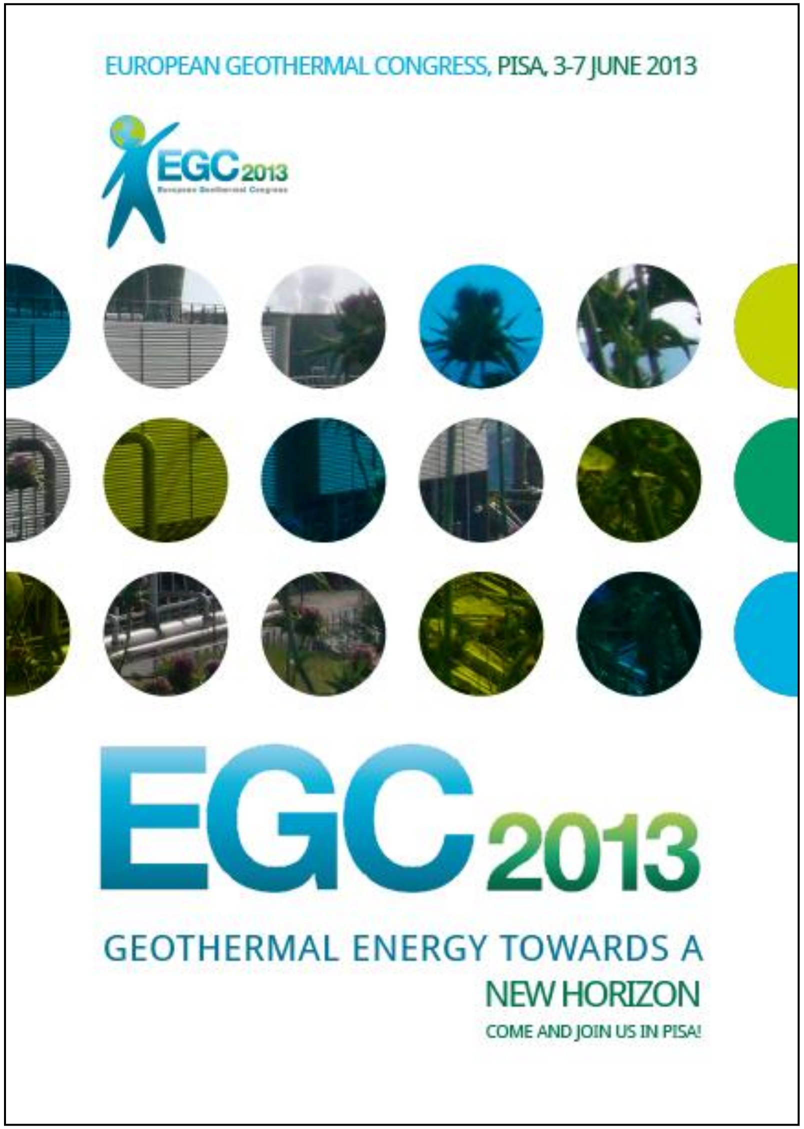
Artist´s impression: Hachiko

Graph: ASA

Thank you for your attention…

…and be invited to EGC 2013 in Pisa!

more information:
www.egec.org



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