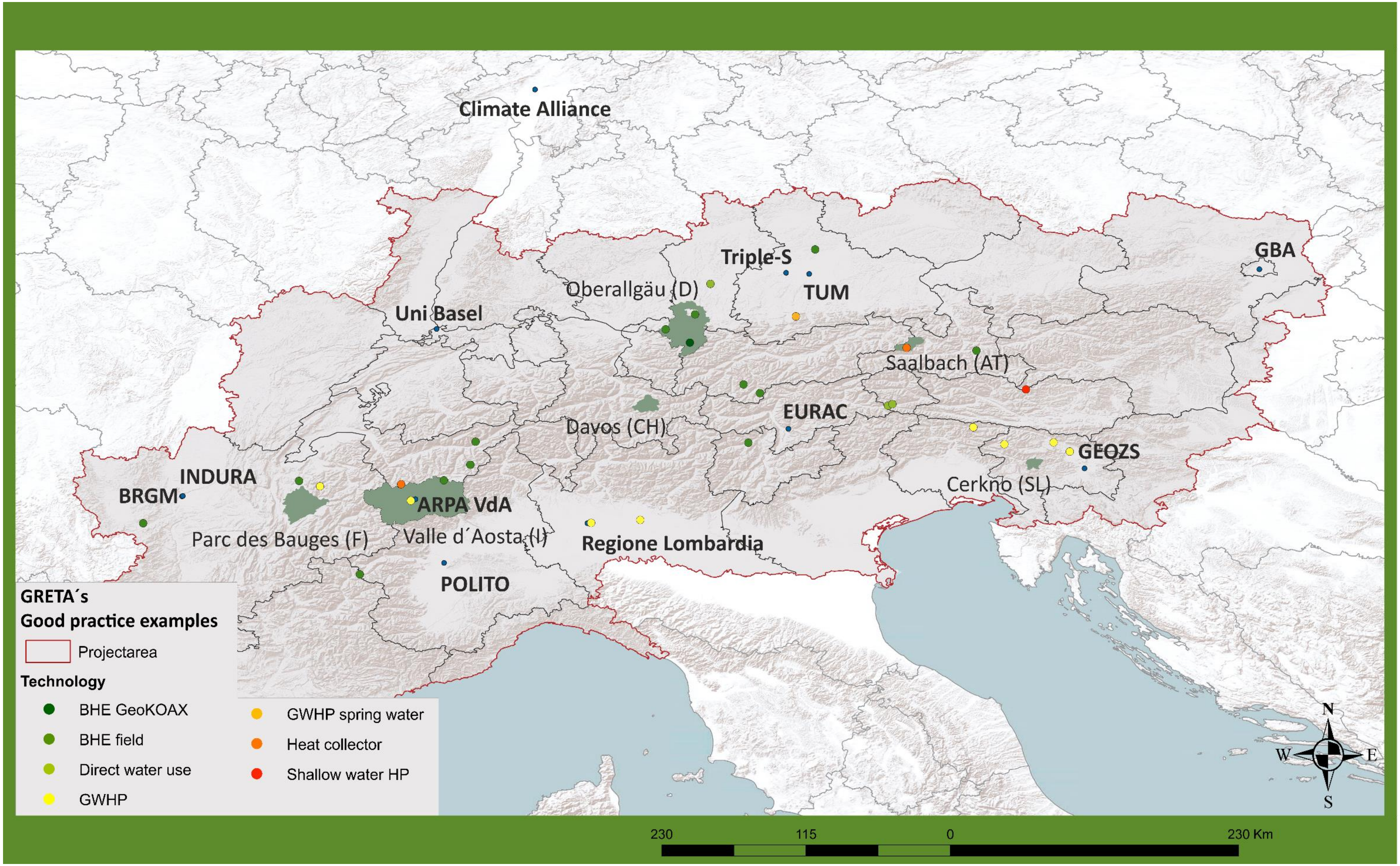
GRETA´s

GOOD PRACTICE EXAMPLES

Every partner country has provided a list of examples of existing shallow geothermal energy installations, which proved to be effective and sustainable. Non-conventional applications were highlighted, to give insight on the variable fields of application of shallow geothermal energy. The most interesting examples from different techniques and topics were chosen to serve as “good practice examples”.

The figure on the next page shows the location of the “good practice examples” within the projectarea.

This project is co-financed by the European Union through the Interreg Alpine Space programme	Project duration 16/12/2015 - 15/12/2018	Funding Total eligible costs: 2.962.952,30 € ERDF grant: 2.308.232,96 €



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OVERVIEW OF GOOD PRACTICE EXAMPLES

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Company EGO-Austria Elektrogeräte GesmbH

Heinfels, Tyrol (Austria)

Direct groundwater use for free cooling

Altitude: **1088 m**

Average annual outside temperature: **7 °C**

Average heating degree days: **4.500 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **1994**

Since 1994 water is used directly (without a GWHP) to cool machinery at the production site. 3 machines are being cooled – those are: a Vermiculite-expansion kiln, a dryer for Vermiculite products and an oven for hardening of steel parts. The water is taken from one well, filtered, used for cooling and afterwards drained in a small stream at the site. They hold an 8 m³ buffer storage and are able to connect the system to the tap in case of system failure. The performance of the water well is constant since the implementation. Heat recovery is not being performed because the whole heating/ventilation system would have to be adapted.

Water is taken from a 15 m deep well with about 6 - 10 °C for cooling of three machines in the production cycle. Afterwards the water is drained into a small stream.

System usage	*Cooling only, permanent use* Additional non-NSGE installations: *oil heating* Possible integration with other energy sources: *usage of tap water from regional water supplier if well is not productive*		
Energy output	Volume or area to be acclimatised: *3 production machines are being cooled*		
Economic & ecologic key facts	Running costs/year: about *100.000 kWh*0.06 € = 6.000 € (electrical energy), about 500 € maintenance*		
Geothermal heat exchanger details	Production well(s) depth: *15 m* Infiltration well(s): *After cooling water is drained into a small stream*	Distance between wells: *15 m from the well to the stream (Villgratterbach)* Well tube diameter: *15 cm*	Minimal flow- and return: *4 m³/h* Flow temp. before / after HP: *6 - 10 °C / max. 30 °C*
System performance	Heat pump (HP) rated power (W10/W35): no heat pump installed	Flow rate per well: *4 m³/h (consent: 10,8 m³/h)*	
Geological & hydrological specifics	Geological region: *Periadriatic seam (S-alpine)* Rough description of bedrock: *Quaternary sediments (Würm and post-glacial)*	Groundwater temp.: Avg. *8 °C* Min. *6 °C* Max. *10 °C* Description of aquifer: *gravel* Water level in borehole: 10 m	

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GOOD PRACTICE

Company Euroclima

Sillian, Tyrol (Austria)

Groundwater use for heating and domestic hot water

Altitude: **1083 m**

Average annual outside temperature: **7 °C**

Average heating degree days: **4.500 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **1983**

The air-condition machinery production site of the company Euroclima in Sillian, eastern Tyrol, was one of the first in Austria to implement a GWHP for heating purposes. They use a 35 m deep aquifer with relatively high temperatures of > 10 °C all year round at an altitude of > 1.000 m. The water is used to heat offices (about 20 °C) and a production hall to about 15 - 18 °C via floor heating and is drained to a small stream at the site.

Water from two wells (max. 28 l/s) is used for heating offices and one production hall via two GWHPs. Return water is drained into a small stream.

System usage	*Groundwater heat pump for heating and domestic hot water production, permanent use incl. seasonal peaks* Additional non-NSGE installations: *Air HP + pellets burning to heat a new production hall. PV system for electrical energy production and DHW.* Possible integration with other energy sources: *pellets stove*		
Energy output	Volume or area to be acclimatised: *about 38.000 m³, 4.500 m²*		
Economic & ecologic key facts	Installation costs: *about 75.000 €* Running costs/year: *(part of the electricity is produced via PV system) + about 600 € maintenance for HP* Avoided CO_2 emissions/CO_2 reduction: *100 %*		
Geothermal heat exchanger details	Count/depth of wells: *two wells each 58 m deep* Infiltration well(s): *After heating the water is drained into a small stream*	Distance between wells: *20 m from the well to the stream*	Minimal flow- and return: *28 l/s* Flow temp. before / after HP: *8 - 11 °C / 5 – 6 °C*
System performance	Heat pump (HP) rated power (W10/W35): *2 HPs, each 109 kW (installed 2013)* Annual HP working hours: *4320 h* Annual electricity consumption of the HP: *20,4 kW * 4.320 h/a → about 90.000 kWh/a*	Flow rate per well: *max. 47 m³/h (demand ~186.000 m³/a)* HP outlet temperature on building side: *max. 45°C (temp of inlet fluid in heating/cooling emitters)*	Coefficient of performance (W10/W35): *>3*
Materials used	Completion/backfilling material in wells: *filtersand*	Heat pump working fluids (refrigerant): *R407C*	
Geological & hydrological specifics	Geological region: *Periadriatic seam (S-alpine)* Rough description of bedrock: *Quaternary sediments (Würm and post-glacial)*	Groundwater temp.: Avg. *8 °C* Min. *6 °C* Max. *11 °C* Description of aquifer: *gravel* Thickness of aquifer: *34 – 57 m* Water level in borehole: *~30 m*	

Gipfelstadl Wagrain

Wagrain, Salzburg (Austria)

Borehole heat exchangers for heating and domestic hot water

Altitude: **1850 m**

Average annual outside temperature: **3 °C**

Average heating degree days: **5.800 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2015**

Located at an altitude of almost 1800 m, the mountain restaurant has implemented a BHE field after renovation of the alpine hut. 15 deep drillings were constructed to heat the chalet and the outside terrace area.

The installation of a geothermal heat pump system with 1760 meters of drillings in total replaces the pre-existing gas heating system. A low-temperature kitchen- and restaurant ventilation system was implemented as well as the installation of an outdoor heating for the terrace area.

System usage	*Heating and domestic hot water production, seasonal use* Additional non-NSGE installations: *wood stove, buffer storage 3.000 l*
Energy output	Volume or area to be acclimatised: *about 400 m²*
Economic & ecologic key facts	Amortization: *7 – 8 [a]* Reduction of heating energy costs: *15.000 [€/a]*
Geothermal heat exchanger details	Count and length of BHEs: *15 wells with a total length of 1760 m* BHE type: *double-U*
System performance	Heat pump (HP) rated power (W10/W35): *90 kW (KNV Energietechnik)*
Geological & hydrological specifics	Geological region: *Wölzer Nappe system* Rough description of bedrock: *Quartzphyllite, Phyllonite, Micashists - Devonian*

Hotel Hochschober

Turrach, Carinthia (Austria)

Lake water use via heat pump to heat swimming pool

Altitude: **1763 m**

Average annual outside temperature: **3,5 °C**

Time of geothermal heat exchanger implementation: **1994 - 1995**

Lake-water is used to heat a swimming pool within this lake from mid of May to mid of September at an altitude of 1763 m via a groundwater heat pump.

Water with temperatures of about 15 – 17 °C is taken from the lake to heat a swimming pool within this lake. The groundwater heat pump rises the temperature to about 30 °C, the return flow is being drained into the lake with about 10 °C.

System usage	*Heating, seasonal use* Additional non-NSGE installations: *Pellets from October until May* Possible integration with other energy sources: *pellets stove*		
Energy output	Volume or area to be acclimatised: *lake pool with 25 x 10 m*		
Economic & ecologic key facts	Installation costs: *20.000 € for the system, not including the pool itself* Running costs/year: *about 8.000 € electricity + about 500 € maintenance, so 8.500 €/a* Avoided CO2 emissions/CO2 reduction: *100 %*		
Geothermal heat exchanger details	Count/depth of wells: *one HP in the lake*	Flow temperature before HP: *15 – 20 °C* Flow temperature after HP: *10 °C*	
System performance	Heat pump (HP) rated power (W10/W35): *42 kW* Annual HP working hours: *1600 h* Annual electricity consumption of the HP: *about 70.000 kWh/a (550 kWh/day; 13h/day; 4 months)*	Flow rate per well: *about 20 m³/h* HP outlet temperature on building side: *> 30 °C*	Coefficient of performance (W10/W35): *< 3*
Materials used	Completion/backfilling material in wells: *filtersand*	Heat pump working fluids (refrigerant): *R407C*	
Geological & hydrological specifics	Geological region: *Upper Carboniferous – Permian* Rough description of bedrock: *Phyllite – Phyllonite, shists*	Lake water temp.: Min. *15 °C* Max. *20 °C*	

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Biohotel Crystal

Obergurgl, Tyrol (Austria)

Borehole heat exchanger field for heating

	Altitude: **1905 m** Average annual outside temperature: **about 3-4 °C** Average heating degree days: **about 5.800 Kday** (base temperture 20 °C) Time of geothermal heat exchanger implementation: **2008**

This winter sports hotel fosters the implementation of renewable energy sources to cover heating demand. The hotel is split into two parts, an old and a new building connected by a bridge across the main street. The old building is still being heated with oil but the new part (constructed in 2008), including indoor and outdoor swimming pools, as well as an adjacent sports market are being heated via the BHE field. The underground is certainly cold in this altitude, this is why the BHE field needs to be regenerated in summer by the solar panels installed at the roof-top of the hotel.

The BHE field is located underneath the new part of the hotel and is made up of 66 probes (grouped to 4, connected in parallel), each about 120 m deep – in total about 8.000 m pipe length. 4 heat pumps (thereof 3 low temperature, 1 high temperature) are running to produce the heat. A buffer storage of 20 m³ is available.

System usage	*Heating and domestic hot water production, seasonal use* Additional non-NSGE installations: *265 m² solar collector for regenerating the underground in summer; oil burner (old building)*		
Energy output	Volume or area to be acclimatised: *40.000 m³ (hotel, wellness-area, swimming pools)*		
Economic & ecologic key facts	Installation costs: *> 1 m €* Amortization: *10-12 a* Running costs/year: *30.000 €/a (electrical energy), 2.000 € (maintenance + solar costs)* Avoided CO2 emissions/CO2 reduction: *about 80 %* Reduction of primary energy consumption: *about 70 %*		
Geothermal heat exchanger details	Count and length of BHEs: *66 wells with an overall length of 7920 m and a max. depth of 120 m* Spacing of boreholes (BHEs): *5 - 6 m, underneath the building*	BHE type: *double-U pipe* Area of activation for storage: *about 4.000 m²* Volume of activation for storage: *about 400.000 m³*	Flow temp. before / after HP: *5 °C / -1 °C* Cooling capacity for BHE: *20 – 30 W/m*
System performance	Heat pump (HP) rated power (W10/W35): *3 low temp. HPs for heating (each 127.7 kWh) + 1 high-temp. HP (78.3 kWh) (booster for DHW to 60 °C)*	Annual HP working hours: *~2.000h*	Coefficient of performance (W10/W35): *> 2,5*
Materials used	Completion/backfilling material: *Concrete – bentonite suspension*	Heat transfer media/heat carrier fluid: *Ethanol Watercote*	Heat pump working fluids (refrigerant): *R407C*
Geological & hydrological specifics	Geological region: *Eastern Alpine Crystalline rocks (Ötztal-Bundschuh-System)* Rough description of bedrock: *About 18 m of gravel (Quaternary sediments), underneath gneiss*	Thermal conductivity of the underground: *about 2.9 W/mK* Ground temperature (Av./Min/max) *4 – 5 °C (geopot study)*	

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Stiegeralm

Saalbach-Hinterglemm, Salzburg (Austria)

Horizontal heat collector for heating

Altitude: **1487 m**

Average annual outside temperature: **6 °C**

Average heating degree days: **about 5.100 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2013**

Chalet with ground heat collectors installed in approximately 1.8 m depth with horizontal design in the same altitude (problem of air in the line).

System usage	*Heating and domestic hot water production, seasonal use* Additional non-NSGE installations: *wood stove*	
Energy output	Volume or area to be acclimatised: *about 180 m²*	
Economic & ecologic key facts	Installation costs: *about 50.000 €* Running costs/year: *about 1.200 € electrical energy*	
Geothermal heat exchanger details	Area of collector: *about 500 m²*	Installation depth of collector pipes: *1.8 m*
Geological & hydrological specifics	Geological region: *Eastern Alpine Units / Greywacke zone (Upper Ordovician + Devonian)* Rough description of bedrock: *sand-, silt- and claystones*	

„Sunna Alm“ mountain restaurant

Pitztal, Tyrol (Austria)

Borehole heat exchanger field for heating

Altitude: **2291 m**

Average annual outside temperature: **about 1 °C**

Average heating degree days: **about 7.000 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2008**

This reconstruction currently represents the highest passive-energy restaurant in the Alpine region and is associated to the mountain station of the Rifflsee cable car. Solar and geothermal technology allow the complete abandonment of fossil fuels - with 135 open days in winter and 100 in summer, this results in an annual saving of 35.000 litres of fuel oil.

Seven deep drilling were conducted up to 120 m depth adjacent to the building. The underground temperatures are negative in this very high altitude location – thus the efficiency of the system is fairly low. To enhance the system, the BHE field is regenerated in summer via solar panels which are installed on top of the roof. This makes it a combined heating & storage application. The building is heated by a panel heating system. It is attached to the cable car mountain station, also in terms of property and electrical installations – thus electrical energy demand is not counted separately.

System usage	*Heating, storage and domestic hot water production, seasonal use* Additional non-NSGE installations: *34 m² solar collectors (steep angle due to architecture) for regeneration of the underground in low- and off-season*		
Energy output	Volume or area to be acclimatised: *about 560 m²*		
Economic & ecologic key facts	Amortization: *unknown (motivation for the installation was not amortization time, rather innovation / ecologic motivation)* Final energy efficiency rating of the building: *12 kWh/(m²*a)*	Running costs/year: *about 500 € (maintenance) + ? € (see “descr. of the installation”) electrical energy* Reduction of heating energy costs: *new building*	Avoided CO2 emissions: *100 %* Reduction of primary energy consumption: *100 %*
Geothermal heat exchanger details	Count and length of BHEs: *7 wells with an overall length of 840 m and a max. depth of 120 m* Specific abstraction capacity / cooling capacity of BHE: *about 50 W/m*	Spacing of boreholes (BHEs): *5 m* BHE type: *simplex probe DN 40, Ø 32 mm* Outer diameter of PE pipes: *4 cm*	Flow temp. before / after HP: *-3 °C / -9 °C*
System performance	Heat pump (HP) rated power (W10/W35): *47 kW (AHWP 5000 S Geosol HP)* Annual electricity consumption of the HP: *el. nominal consumption 10.9 kW*	Flow rate prim. circuit at HP: *~ 10 m³/h* Area of activation for storage: *~ 200m²* Vol. of activation for storage: *~ 20.000 m³*	Coefficient of performance (W10/W35): *low efficiency < 2*
Materials used	Completion/backfilling material: *Concrete – bentonite suspension*	Heat transfer media/heat carrier fluid: *Glycol based (“Powercool” by Thermo Chema)*	Heat pump working fluids (refrigerant): *R407C*
Geological & hydrological specifics	Geological region: *Eastern Alpine Crystalline rocks (Ötztal – Bundschuh nappe system)* Rough description of bedrock: *About 1 m of soil, underneath gneiss- and micashists*	Thermal conductivity of the underground: *about 2.5 W/mK* Ground temperature (Av./Min/max): *-3 °C*	

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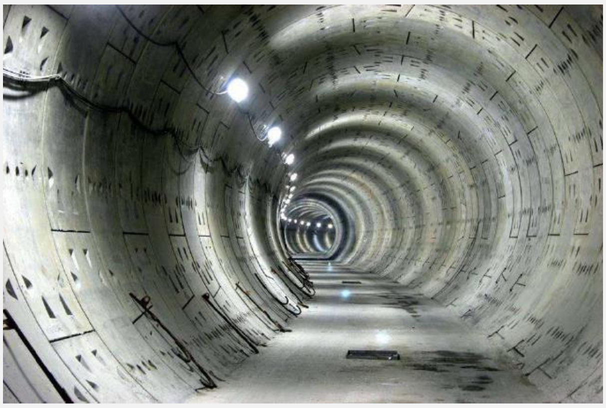
Thermal tunnel activation

Jenbach, Tyrol (Austria)

Heat collector in tunnel wall

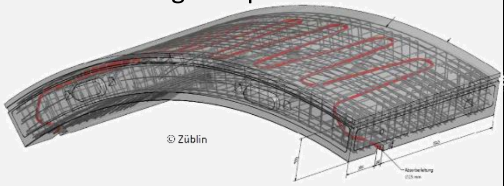


Altitude: **563 m**

Average annual outside temperature: **10,2 °C**

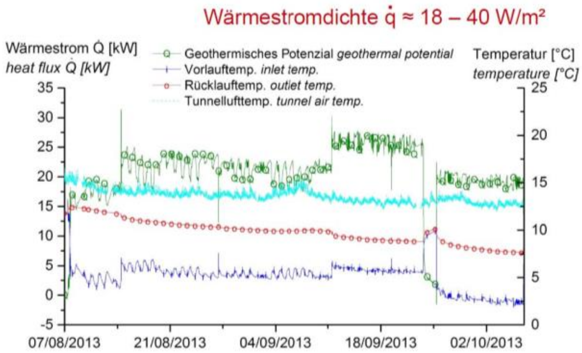
Average heating degree days: **3480 Kday** (base temperture 20 °C, threshold temp. 15 °C)

Time of geothermal heat exchanger implementation: **2011**



A section of 54 m of the railway tunnel underneath Jenbach have been thermally activated and hydraulically connected to a 40 kW heat pump in a commercial building of the “Zillertalbahn”. The tunnel has been built with pre-fabricated segments, where the absorber pipes have been attached to the steel reinforcement, see pictures. The installation is a pilot / demonstrator project of Züblin (tunnel elements) and REHAU (pipe technology) The operation results showed that max 50 % of the geothermal installation would have been sufficient. Therefore, the economic figures of this demonstrator project are poor, but would be much better with projects designed on the basis of the results obtained – and if a reversible heat pump allowing heating and cooling would be applied.

System usage	*Heating within the pre-fabricated wall segments of a railway tunnel*		
Energy output	Annual energy output Heating: *75.000 kWh*	Practically demanded peak load: Heating: *40 kW*	Volume or area to be acclimatised: *350 m³*
Economic & ecologic key facts	Installation costs: *69.000 €* Amortization: *23 years* Electricity source: DE mix, PV %	Running costs/year: *3.600 €* Reduction of heating energy costs: 50 % or 3.000€/a	
Economic & ecologic key facts	Avoided CO_2 emissions / CO_2 reduction: *48 % or 11 t/a* Reduction of primary energy consumption: *70 %*		
Geothermal heat exchanger details	Length of installed pipes: *4700 m* Area of collector: *2200 m* Specific abstraction capacity of HP: *25 W/m²²*	Spacing of collector pipes: *0,4 m* Min. flow- and return flow temp. for heating: *5 - 0 °C;* (For cooling max: *20 – 15 °C)*	
System performance	Heat pump (HP) rated power (B0/W35): *40 kW* Annual HP working hours: *2500 h* Annual electricity consumption of the HP: *18.750 kWh/a*	Flow rate primary circuit at HP: *11 m³/h* HP operation mode: *monovalent* Coefficient of performance (B0/W35): *4*	
Materials used	Heat transfer media/heat carrier fluid: *water and ethylene glycol*		
Geological & hydrological specifics	Geological region: *Central Alps* Rough description of bedrock: *Palaeozoic, Quartzphyllite*	Thermal conductivity of the soil: *3,4 W/(m·K)*	Ground temperature *Avg.: 15 °C*, Min: *12 °C*, Max: *17 °C*



Left: figure showing monitoring data

Right: figure illustrating The tunnel section

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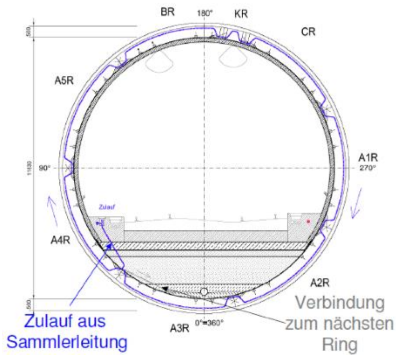

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Collective housing Metz-Tessy

Metz-Tessy, Rhône-Alpes, 74 (France)

Borehole heat exchanger field for heating and cooling

Altitude: **461 m**

Average annual outside temperature: **10 °C**

Time of geothermal heat exchanger implementation: **2012 - 2016**

A HP and 15 BHE to heat 2000 m² of collective housing.

The SNC CPGEDIM SAVOIE LEMAN company uses a HP connected to 15 100 m deep BHE to heat and cool (free-cooling) 2000 m² of collective housing. Due to geological conditions (clay and silt) the amount of available underground water is limited. A close-loop solution has therefore been chosen. On the 1st year of exploitation, Monitored installation SPF is 5.33.

Data collected with the courtesy of ADEME (French Environment and Energy Management Agency), Regional Direction of Rhône-Alpes-Auvergne.

<table>
<tr><td>System usage</td><td colspan="3">Heating and cooling, permanent use
Additional non-NSGE installations: Electrical heater. Power = 36 kW (rarely used)</td></tr>
<tr><td>Energy output</td><td colspan="2">Annual energy output - Design values :
Heating: 138.5 MWh Cooling: 13.5 MWh (geocooling)</td><td>Volume or area to be acclimatised: 2000 m²</td></tr>
<tr><td>Economic & ecologic key facts</td><td>Installation costs: see below
Amortization: see below</td><td>Running costs/year: see below</td><td>Avoided CO_2 emissions/CO_2 reduction: 5 t CO_2/y</td></tr>
<tr><td>Geothermal heat exchanger details</td><td>Count and length of BHEs: 15 wells with a depth of 100 m and an overall length of 6.000 m</td><td colspan="2">Specific abstraction capacity / cooling capacity of BHE: 48 W/m
BHE type: double-U, GeoCOAX</td></tr>
<tr><td>System performance</td><td>Heat pump (HP) rated power (W10/W35): Calorific power = 84.5 kW with COP =4.07 at condenser temperature 35.0 / 45.0 °C. Model DYNACIAT ILG 300V R410A with 2 scroll compressors.</td><td colspan="2">Coefficient of performance (W10/W35): HP performance has been monitored from Mai 2013 to April 2014 (1st year of operation). 141.06 MWh of heating was delivered to the building. Cooling is negligible (0.35 MWh). The installation SPF was monitored to 5.33</td></tr>
<tr><td>Materials used</td><td>Completion/backfilling material: Küchler K-Injekt-Therm</td><td>Heat transfer media/heat carrier fluid: water + glycol</td><td>Heat pump working fluids (refrigerant): R410A</td></tr>
<tr><td>Geological & hydrological specifics</td><td>Rough description of bedrock: 0-20m: silt+gravel, 20-24 m: silt+clay, 24-50 m: gravel+sand, 50-100 m: silt+clay+some gravels</td><td colspan="2">Thermal conductivity of the underground: 1,7 W/mK
Ground temperature (Av./Min/max): Avg.: 13.2 °C</td></tr>
</table>

Details for Installation costs: The geothermal installation was compared to a reference solution, made of a gas boiler for heating and an air/water HP for cooling. Below are the investment costs (tax excluded) for both solutions:

	Geothermal Solution	Reference Solution
Heating production	55 436.00 €	15 790.00 €
Cooling production	0.00 €	17 977.00 €
BHE, etc.	90 000.00 €	
Monitoring system	7 000.00 €	7 000.00 €
Design	4 800.00 €	4 500.00 €
Distribution	204 903.00 €	204 903.00 €
TOTAL	362 139.00 €	250 170.00 €

The annual running costs was estimated to be 3.3 k€ for the geothermal solution against 7.9 k€ for the reference solution. Without any subsidy the payback time would have been 31 years. The ADEME granted 144 k€ reducing the payback time to 1 year.

Monastry of Ganagobie

PACA, Ganagobie, 04 (France)

Borehole heat exchanger field for heating

Altitude: **650 m**

Average annual outside temperature: **12,4 °C**

Time of geothermal heat exchanger implementation: **2012**

A ground-sourced heat pump to heat an historical monastery. Data collected with the courtesy of AFPG and CIAT.

In order to save fossil fuels, the Monastery of Ganagobie, located between Sisteron and Manosque, was equipped with a ground-source heat pump associated with a heating floor in 2012. 1.000 m² including the dining room, kitchen, hall and church, are heated thanks to borehole heat exchangers that ensure 50 kW of heating. The former propane boiler is solicited as a backup.

System usage	*Heating, seasonal use* Additional non-NSGE installations: *propane boiler*
Energy output	Practically demanded peak load: Heating: *50 [kW]* Volume or area to be acclimatised: *1.000 m²*
Economic & ecologic key facts	Installation costs: *estimated at 100.000 € (drilling and installation of probes: 50.000 € HT; heat pumps: 50.000 €)* Amortization: *8 years* Reduction of heating energy costs: *Estimated annual savings 13.000 €*
Geothermal heat exchanger details	Count and length of BHEs: *9 wells with a depth of 100 m each* Spacing of boreholes (BHEs): *10 m*
System performance	Flow rate primary circuit at HP: *1,55 m^3/h*
Materials used	Heat transfer media/heat carrier fluid: *Water*

Industrial building Les Periades

Thones, Rhône-Alpes, 74 (France)

Groundwater heat pump

Altitude: **574 m**

Average annual outside temperature: **10,2 °C**

Time of geothermal heat exchanger implementation: **2015**

A heat pump on an open-loop system to heat an industrial building. Data collected with the courtesy of ADEME (French Environment and Energy Management Agency), Regional Direction of Rhône-Alpes-Auvergne. The ADEME supported the project with a founding of 22.600 €.

A 3.660 m² industrial building is heated by a geothermal HP. The geothermal HP was installed in 2015 to replace a gas boiler, so that to decrease energy costs. Further improvement of the insulation of the building northern façade decreased the estimated energy consumption from 183 to 171 MWh/y. The building is heated with fan-coils. The HP condenser outlet temperature was initially in the range 50 - 55 °C. It was lowered by a few °C; the COP appeared to increase without affecting the comfort of building users.

System usage	*Heating, seasonal use* Additional non-NSGE installations: *gas boiler (power: 280 kW, efficiency = 80 %) installed in 2008. Only for backup in case HP failure*	
Energy output	Annual energy output for heating: *171 MWh (design value); Monitored from 01/01/2016 to 31/12/2016 : 94.6 MWh* Practically demanded peak load for heating: *116 kW (design value, to cover the whole heat demand by -13 °C outside temperature* Volume or area to be acclimatised: *3660 m²*	
Economic & ecologic key facts	Installation costs: *The cost of HP + well was 72.900 €*	
Geothermal heat exchanger details	Distance between wells: *40 [m]*	
System performance	Annual HP working hours: *2000 h* Flow rate per well: *Max. 20 m³/h* Flow rate on the operation period: *7,5 m³/h*	Coefficient of performance (W10/W35): *Monitoring from 01/01/2015 to 31/12/2015 :* *- Electrical consumption = MWh (without pumping energy).* *- SPF = 3.02*
Materials used	Completion/backfilling material in wells: *Well cemented on the upper 6 m.*	Heat pump working fluids (refrigerant): *R410A*
Geological & hydrological specifics	Rough description of bedrock/aquifer: *0 to 1 m depth : vegetal soil* *1 to 30 m depth : sand and gravels, alluvium*]	Aquifer specifics: Thickness of aquifer: *30 m* Water level in borehole: *-8 m*

Parador Resort

PACA, Vence (France)

Borehole heat exchanger for heating and cooling

Altitude: **280 m**

Average annual outside temperature: **13.3 °C**

Time of geothermal heat exchanger implementation: **2014**

A ground-sourced heat pump to heat and cool a resort. Data collected with the courtesy of AFPG and CIAT.

The Parador Resort encompasses 2 villas, a common building and one chapel. The thermal energy demand of these buildings is totally covered by the GSHP, both in heating and cooling. No backup is needed. The HP heating and cooling powers are respectively 112 kW and 103 kW. The geothermal solution has been chosen since there it is invisible, silent, and produces both heating and cooling with one system.

System usage	*Heating and cooling*	
Energy output	Practically demanded peak load: *50 kW*	Volume or area to be acclimatised: *1.000 m²*
Economic & ecologic key facts	Installation costs: *estimated at 100.000 € (drilling and installation of probes: 50.000 € HT; heat pumps: 50.000 €)* Amortization: *8 a*	Reduction of energy costs (incl. cooling, DHW etc.): Estimated annual savings: 13.000 €.
Geothermal heat exchanger details	Count and length of BHEs: *9 wells with a depth of 100 [m] each* Spacing of boreholes (BHEs): *10 m*	
System performance	Flow rate primary circuit at HP: *1.55 m³/h*	
Materials used	Heat transfer media/heat carrier fluid: *water*	

Industrial building “La Talaudière”

Rhône-Alps, 42 (France)

Borehole heat exchanger field for heating

Altitude: **507 m**

Average annual outside temperature: **10.1 °C**

Time of geothermal heat exchanger implementation: **2011**

Heating of an industrial building through HP on 10 BHE 100 m deep

Data collected with the courtesy of ADEME (French Environment and Energy Management Agency), Regional Direction of Rhône-Alps-Auvergne.

The SAIB Connectique company designs and makes electronics devices. In 2010 they built their new 2039 m² factory. Geothermal energy was chosen. A 58 kW HP is connected to 10 100 m deep BHE. Offices are heated by a heating floor, while fan-coils are used for workshops. From June 2013 to June 2014, 55.6 MWh of heating have been produced by the HP, with a performance factor of 3.56. The project has been financially supported by the ADEME, with the objective of reducing the system amortization from 16 y to 6.5 y. Compared to a gas boiler, the yearly economy by the geothermal installation is estimated to be 3.9 k€.

System usage	*Heating only, permanent use*		
Energy output	Annual energy output Design values Heating: *25 MWh* Monitored values from 18/06/2013 to 18/06/2014 Heating: *55.55 MWh*	Practically demanded peak load: *25 kW (design value, not monitored). The HP peak load is 58.3 kW.*	Volume or area to be acclimatised: *2.039 m²*
Economic & ecologic key facts	Installation costs: *242 k€* Amortization: *planned: 6.5 y with subsidy, would have been 16 y without subsidy.*	Reduction of energy costs (incl. cooling, DHW etc.): *estimation compared to a boiler: 3.928 €/a [% or €/a]*	Avoided CO_2 emissions / CO_2 reduction: *5 t CO_2/y [% or t/a]*
Geothermal heat exchanger details	Count and length of BHEs: *12 BHE, 100 m deep [m]*	BHE type: *BHE equipped with double-U, so 4800 m of pipes*	Flow temperature before HP: *0 °C* Flow temperature after HP: *-3 °C* Specific abstraction capacity / cooling capacity for BHE: *57 W/m W/m*
System performance	Heat pump (HP) rated power (B0/W35): *58.3 kW. Model Dynaciat 240V serie LG (2 compressors)*	Seasonal performance factor: *Monitored SPF from 18/06/2013 to 18/06/2014:* *- SPF in heating = 3.56*	
Materials used	Completion/backfilling material: *Füllbinder EWM*	Heat transfer media/heat carrier fluid: *water+glycol*	Heat pump working fluids (refrigerant): *R410A*

Details for Installation costs:

The total installation cost of a boiler was estimated to be 176.432 €. The overcost of the geothermal installation was 56.381 €. The ADEME founded 72 % of this (40.255 €).

	Cost (duty free)
Trenches	*90.000.00 €*
Boiler room	*22.346.00 €*
Heating production	*22.000.00 €*
Network	*36.366.00 €*
BHE field	*50.500.00 €*
Design	*21.000.00 €*
TOTAL	*242.212.00 €*

Lido Benediktbeuern

Bad Tölz-Wolfratshausen, Bavaria (Germany)

Use of spring water with a heat pump

Altitude: **617 m**

Outside temperature: **8.2 °C**

Average heating degree days: **3910 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2011**

The old drinking water springs of the municipality Benediktbeuern are used to heat the open-air pool.

Since 2011 a heat pump (HP) replaced the oil heating, which consumed 44.000L fuel oil per season. The HP has a total heating capacity of 160kW and uses the water from a spring at the mountain side. Previously the spring provided drinking water for the municipality, but because of contamination problems they had to be abandoned, leaving the pipeline and the water unused.

System usage	*Heating only, seasonal use*		
Energy output	Annual energy output Heating: *330.000 kWh*	Practically demanded peak load: Heating: *149 kW*	Volume or area to be acclimatised: *Pool with 1100 m³ water*
Economic & ecologic key facts	Running costs/year: *60.000 kWh (HP) = 11.000 € [€/a]* Reduction of heating energy costs: *5.500 €/a at 50 €/100l*		Avoided CO2 emissions / CO2 reduction: *56 t/a, 60 %* Increase of RES share: *100 %* Reduction of primary energy consumption: *75 %*
Geothermal heat exchanger details	Catchment of spring: *Three springs at 950 m a.s.l. are located at a aquitard layer (till)*		
System performance	Heat pump (HP) rated power (W10/W35): *149 kW* *Combitherm HWW 2/400 R134e* Annual HP working hours: *1.600 h* Annual electricity consumption of the HP: *60.000 kWh/a*	Flow rate spring: *5 - 8 l/s*	Coefficient of performance (W10/W35): *5,5*
Materials used	Completion/backfilling material in wells: *1-10m gravel; 0-1m clay*		
Geological & hydrological specifics	Geological region: *Northern Limestone Alps and Flysch* Rough description of bedrock/aquifer: *Würm-glacial sediments (sandy-silty gravel), above clay-silt layers (till)*	Groundwater temperature: Minimum: *5 °C* Maximum: *8 °C*	Thickness of aquifer: *10 – 50 m*

GROB-WERKE Mindelheim

Unterallgäu (Germany)

Groundwater heat pump for heating and cooling

Altitude: **608 m**

Average annual outside temperature: **8.2 °C**

Average heating degree days: **3900 Kday**

Time of geothermal heat exchanger implementation: **1983/2012**

Older apartment building with 35 flats.

The machinery at this site produces heat during operation, which has to be dissipated. This is done by thermal groundwater use from 9 wells distributed all over the site of the company. Groundwater is available in sufficient quality and quantity and near to surface to achieve high efficiency. The use of groundwater for heating office buildings and further cooling system are also foreseen.

System usage	*Heating and cooling, permanent use*		
Energy output	Volume or area to be acclimatised: *200.000 m²*		
Economic & ecologic key facts	Avoided CO_2 emissions / CO_2 reduction: *2.000 t/a*		
Geothermal heat exchanger details	Count / depth of wells: *8 wells*	Distance between wells: *10 – 40 m*	Flow- and return flow temp.: *between 3 and 10 °C*
System performance	Heat pump (HP) rated power (W10/W35): *140 kW*		Flow rate per well: *15-158 m³/h*
Materials used	Completion/backfilling material in wells: *gravel*		Heat pump working fluids (refrigerant): *water*
Geological & hydrological specifics	Geological region:*Prealps* Rough description of bedrock/aquifer: *coarse grained Quaternary sediments*	Groundwater temperature: Average: *10 °C*	Thickness of aquifer: *6 - 8 m* Water level in borehole: *3 - 9 m* Hydraulic conductivity: *1,5 $*10^{-2}$ m/s m/s*

GOOD PRACTICE

Kranzberg

Kranzberg, Bavaria (Germany)

Borehole heat exchanger

Altitude: **490 m**

Average annual outside temperature: **10 °C**

Time of geothermal heat exchanger implementation: **2015**

Five GeoKOAX borehole heat exchangers are used for heating and cooling of a house in Kranzberg.

Sine 2016 a heat pump (HP) replaced the oil heating, which had a heat output of 28 kW. The HP has a total heating capacity of 60 kW. It is connected to five borehole heat exchangers with a depth of 47 m each.

System usage	*Heating and cooling, permanent use* Additional non-NSGE installations: *solar energy via photovoltaic*		
Energy output	Annual energy output Heating: *25.492 kWh*	Practically demanded peak load: Heating: *149 kW*	Volume or area to be acclimatised: *369,2 m²*
Economic & ecologic key facts	Final energy efficiency rating of the building: *29 kWh/(m²*a)*	Running costs/year: *60.000 kWh (HP) = 11.000 €* Reduction of heating energy costs: *5.500 €/a at 50 €/100 l*	Avoided CO_2 emissions / CO_2 reduction: *56 t/a 60 %* Increase of RES share: *100 %* Reduction of primary energy consumption: *75%*
Geothermal heat exchanger details	Count and length of BHEs: *5 wells with a depth of 47[m] and an overall length of installed pipes of 470 m*	Spacing of boreholes (BHEs): *ca. 5 m* BHE type: *GeoCOAX*	Flow temperature before HP: *1 - 27 °C* Flow temperature after HP: *-2,5 – 22,7 °C* *(Minimum and maximum values between 15.02.2016 and 27.03.2016 and between 07.07.2016 and 12.07.2016)*
System performance	Heat pump (HP) rated power (B0/W35): *7,2 – 20,1 kW* *Heliotherm HP20S-M-WEB*	Flow rate primary circuit at HP: *1,5 – 2,5 m³/h* Annual HP working hours: *1600 h*	Coefficient of performance (B0/W35): *5.5* Annual electricity consumption of the HP: *60.000 kWh/a*
Materials used	Completion/backfilling material: *GeoSOLID 240 HS used for BHE1-3* *WE 1.4 HS used for BHE4-5*	Heat transfer media/heat carrier fluid: *Coracon GEKO AF-8*	Heat pump working fluids (refrigerant): *R410A*
Geological & hydrological specifics	Geological region: *Upper Freshwater Molasses (Tertiary)* Rough description of bedrock: *sandy gravel with layers of silt and sand in between*	Thermal conductivity of the soil: *1 - 1,4 W/mK* Avg. ground temp.: in 0,5 m depth: *11,2 °C* In 45 m depth: *ca. 10 °C*	Thickness of aquifer: *8 – 20 m* Water level in borehole: *40 m* Hydraulic conductivity: *0,001 -0,005 m/s*

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Settlement Ludwigshöhe

Kempten (Germany)

Borehole heat exchangers for heating

Altitude: **607 m**

Average annual outside temperature: **7.6 °C**

Average heating degree days: **4108 Kday** (base temperture 20 °C)

Borehole Heat Exchanger Array for 22 accommodation units.

At Kempten, Bavaria 72 double-U BHE with 150 m depth each are installed for the heating of 22 accommodation units. A detailed FE-model was validated with depth-related temperature measurements at two locations: first, at the groundwater monitoring well, to record the impact of BHEs operation and second, at the groundwater monitoring well, to record the impact of BHEs operation.

System usage	*Heating only, permanent use including seasonal peaks*	
Energy output	Volume or area to be acclimatised: *1100 m²*	
Economic & ecologic key facts	Running costs/year: *4300 €/a*	
Geothermal heat exchanger details	Count and length of BHEs: *72 wells with a depth of 150 m each. Overall length of installed pipes (150 x 4) x 72 = 43.200 m*	BHE type: *double-U*
System performance	Heat pump (HP) rated power (B0/W35): *140 kW*	
Materials used	Completion/backfilling material: *grouting from Schenk AG with thermal conductivity of ca. 2 W(m·K)*	Heat transfer media/heat carrier fluid: *Ethylene glycol*
Geological & hydrological specifics	Rough description of bedrock: *Lower Triassic sedimentary basin consist of alternating sandstones, mudstones and marlstones with calcareous cement.*	Thermal conductivity of the soil: *2.5 W/(m·K) – 3.1 W/(m·K)* Avg. Ground temperature: *9,3 °C*

Heated railway switches Oberstaufen

Oberallgäu (Germany)

Borehole heat exchanger

Altitude: **790 m**

Average annual outside temperature: **6.8 °C**

Average heating degree days: **4.100 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2016**

Two equivalent systems of one railway switch pair each with geothermal heating from a GSHP at the railroad crossing Kalzhofer Street, Oberstaufen and at the tunnel entrance, Rainwaldstreet 10, Oberstaufen.

Caution: Some of the following numbers refer to both systems.

Four snow and ice free railroad switches with GSHP heating. Normally electric heating panels are attached to a switch to keep it ice free during winter, but Triple-S invented a system for passive or active heating via HP with a specially designed heat exchanger. Enhanced to the two systems is a weather station at each location, which monitors the relevant atmospheric parameter to anticipate the correct heat demand.

System usage	*Heating only, seasonal use*		
Energy output	Annual energy output heating: *26.720 kWh for both systems*	Practically demanded peak load heating: *33,4 kW for both systems*	Volume or area to be acclimatised: *two railroad switches*
Economic & ecologic key facts	Installation costs: *238.000 € for both systems* Running costs/year: *15.000 €/a with 0,56 €/kWh for both systems* Reduction of heating energy costs: *70 - 75 % (Theoretical value, because systems don't replace an old electrical heating)*		Increase of RES share: *100 %* Reduction of primary energy consumption: *70 – 75 %*
Geothermal heat exchanger details	Count and length of BHEs: *System 1: 4 boreholes with a depth of 50 m each and a total length of all installed pipes of 800 m* *System 2: 3 boreholes at a tunnel one with a depth of 99 m two with 60 m, length of installed pipes 879 m*	Spacing of boreholes (BHEs): *7 m at crossing, 6 m at tunnel* BHE type: *double-U BHE both systems*	Specific abstraction capacity / cooling capacity of BHE: *56,7 W/m*
System performance	Heat pump (HP) rated power (B0/W35): *22,5 kW at S0/W35 at ΔT 10K* Annual HP working hours: *60 – 800 h depending on winter*	Flow rate primary circuit at HP: *2.6 m³/h 0,65 m³/h per BHE* Annual electricity consumption of the HP: *8,3 kW 500 - 6.640 kWh/a*	Coefficient of performance (B0/W35): *4,3 S0/W35 at ΔT 10K* **SPF f** after EnEV: *Highly weather dependent, see working hours of HP*
Materials used	Completion/backfilling material: *ThermoCem Plus*	Heat transfer media/heat carrier fluid: *70% Water und 30% Glykol*	Heat pump working fluids (refrigerant): *R407C (4,78 kg with 30 bar)*
Geological & hydrological specifics	Geological region: *Allgäuer Molasse Vorberge* Rough description of bedrock: *sandy gravel, few silt layers <2m*	Thermal conductivity of the soil: *TRT with pure water: 2,2 W/mK* Ground temperature: *10,7 °C (avg.)*	Water level in borehole: *12,6 m*

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Heated railway switches Oberstdorf

Oberallgäu (Germany)

Borehole heat exchanger GeoKOAX

Altitude: **813 m**

Outside temperature: **1,7-12,4 °C**

Designed for 1800 operating hours per year. The rail temperature to be reached is 7.0°C

Time of geothermal heat exchanger implementation: **2016**

In Oberstdorf 20 railroad switches will be heated with near surface geothermal energy. All switches will be heated from a Borehole heat exchanger field with 20 heat exchangers, each 43 m long. The control and regulation technology is stored in a single station together with two heat pumps (see photo above) at Bahnhofsstraße 14 in Oberstdorf.

GeoKOAX heat exchanger: Normally electric heating panels are attached to a switch to keep it ice free during winter, but Triple-S invented a system for passive or active heating via HP with a specially designed heat exchanger. Enhanced to the system is a weather, which monitors the relevant atmospheric parameter to anticipate the correct heat demand.

System usage	*Heating only, seasonal use*		
Energy output	Practically demanded peak load: Heating: *21 kW*		Volume or area to be acclimatised: *20 railroad switches*
Economic & ecologic key facts	Installation costs: *560.000 €* Running costs/year: *8366,4 €/a with 0,56 €/kWh for both systems* Reduction of heating energy costs: *70 - 75 %* *Theoretical value, because systems don't replace the old butane gas heating*		Avoided CO_2 emissions / CO_2 reduction: *70 - 75%* Increase of RES share: *100%* Reduction of primary energy consumption: *70 - 75%*
Geothermal heat exchanger details	Count and length of BHEs: *20 boreholes with a length of 43 m each (total: 1147 m)*	Spacing of boreholes (BHEs): *6 m* BHE type: *GeoCOAX*	Specific abstraction capacity / cooling capacity of BHE: *1,4 – 1,6 W/(m*K)*
System performance	Heat pump (HP) rated power (B0/W35): *2 x 45 kW (2x 2SW300)* Annual HP working hours: *60 – 900 h* Annual electricity consumption of the HP: *2 x 10,5 kW 1.260 – 18.900 kWh/a*	Flow rate primary circuit at HP: *11 m³/h per heat pump* *22 m³/h both* *1,1 m³/h per BHE*	Coefficient of performance (B0/W35): *4,3 S0/W35 at ΔT 10K* **SPF f** after EnEV: *Highly weather dependent, see working hours of HP!*
Materials used	Completion/backfilling material: *Schwenk Füllbinder EWM*	Heat transfer media/heat carrier fluid: *70 % Water und 30 % Glykol*	Heat pump working fluids (refrigerant): *R407C (4,78 kg with 30 bar)*
Geological & hydrological specifics	Geological region: *Allgäuer Alpen, Holocene to quaternary fluviatile* Rough description of bedrock: *gravel, few sandy gravel layers <2m*		Water level in borehole: *26.20 m*

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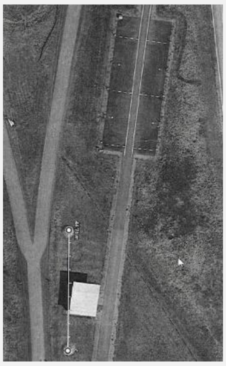
Lorry test site heating

Munich, Bavaria (Germany)

Groundwater heat pump for road surface heating



Altitude: **491 m**

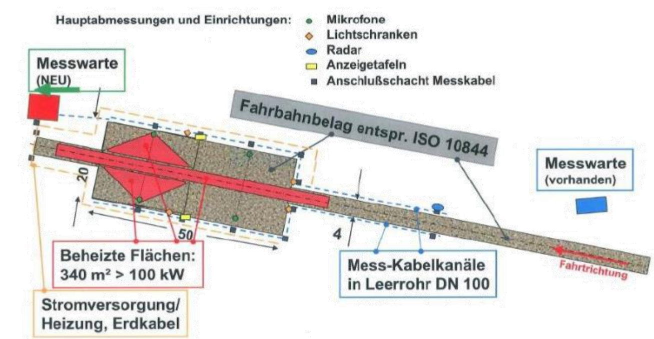
Average annual outside temperature: **7,5 °C**

Average heating degree days: **3830 Kday** (base temperture 20 °C and threshold temp of 15 °C)

Time of geothermal heat exchanger implementation: **2010**

In order to make the noise test site of a lorry manufacturer independent from weather conditions, a heated area has been incorporated, driven by a 75 kW ground water heat pump. The heating pipes are covered in melted asphalt, i.e. have to withstand temperatures of up to 240 °C Purpose of the installation: For testing and approval purposes, dry road conditions are required for noise measurements. In order to ensure a sufficient availability of the test site, surface heating is required to eliminate moisture and snow from the test area, which consists of the driving path and triangular extension, at the tip of which the microphones are positioned.

System usage	*Heating, drying and snow melting*		
Energy output	Annual energy output heating: *140.000 kWh* Practically demanded peak load: Heating: *75 kW*	Volume or area to be acclimatised: *440 m²*	
Economic & ecologic key facts	Installation costs: *135.000 €* Electricity source: DE mix	Running costs/year: *5.500 €* Reduction of heating energy costs: *56 % or 4650 €*	Avoided CO2 emissions: *67 % or 29 t/a* Reduction of primary energy consumption: *50 %*
Geothermal heat exchanger details	Count and depth of wells: *2 wells / 60 m* Production well: *12 m* Infiltration well: *12 m*	Distance between wells: *45 m* Borehole diameter: *470 mm* Well tube diameter: *419 mm*	Minimal flow- and return flow temp heating: *70 °C*
System performance	Heat pump (HP) rated power (W10/W35): *75 kW* Annual HP working hours: *2500 h* Annual electricity consumption of the HP: *140.000 kWh/a*	Flow rate per well: *25 m³/h* HP operation mode: *monovalent*	Heat pump name: *Alpha Innotec SWP 820-B6/W53*
Materials used	Submersible pump type: *WILO KD 25*	Heat pump working fluids (refrigerant): *R407C*	
Geological & hydrological specifics	Geological region: *Molasse zone* Rough description of bedrock: *Quaternary gravel, peat*	Ground temperature Avg.: *10 °C, Min.: 9 °C*	



Left: site and installation scheme

Right: fixing of pipes (© REHAU)

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Road surface heating

Munich, Bavaria (Germany)

Direct groundwater use and groundwater heat pump

Altitude: **520 m**

Average annual outside temperature: **7,5 °C**

Average heating degree days: **3830 Kday** (base temperture 20 °C and threshold temp of 15 °C)

Time of geothermal heat exchanger implementation: **2014**

Underneath a railway bridge over the Bergsonstraße in Munich there is a ground water reservoir which in some sections penetrates and covers the road. Additionally, some rainwater trickles through joints of the bridge. In winter time, this water froze to massive ice shields which only could have been removed mechanically. As a counter measure, the road has been equipped with heating pipes. Up to a temperature of -8°C, the ground water with temperature of 12°C all year can be used directly. Only at lower temperatures, water from a buffer tank with a temperature of 35°C is being used. This water is being heated by a 45 kW heat pump. Due to the warm ground water and the shielding effect of the bridge above, the heat pump however has to be operated very few hours per year (typically 15) only. As the road surface is made from asphalt, special pipes had to be used.

System usage	*Heating, seasonal use (at temperatures below 0 °C only* Additional non-NSGE installations: *900 l buffer tank for water at 35 °C to cover peak demands*		
Energy output	Annual energy output heating: *280.000 kWh* Practically demanded peak load: Heating: *150 kW*	Volume or area to be acclimatised: *450 m²*	
Economic & ecologic key facts	Installation costs without road pipe system: *50.000 €* Amortization: *2,4 a* Electricity source: DE mix	Running costs/year: *1.450 €* Reduction of heating energy costs: *94 % or 20.700 €*	Avoided CO2 emissions: *93 % or 63 t/a* Reduction of primary energy consumption: *93 %*
Geothermal heat exchanger details	Count and depth of wells: *2 well á 10 m*	Distance between wells: *30 m* Borehole diameter: *275 mm* Well tube diameter: *175 mm*	Flow temp @ passive operation: *12°C* Flow temp @ active (heat pump) operation: *35°C*
System performance	Heat pump (HP) rated power (W10/W35): *100 kW* Annual HP working hours: *135 h* Annual electricity consumption of HP: *1.500 kWh/a*	Flow rate per well: *22 m³/h* HP operation mode: *monovalent*	Coefficient of performance (W10/W35): *5* Heat pump name: *Weidner*
Geological & hydrological specifics	Geological region: *Molasse zone* Rough description of bedrock: *Quaternary gravel*	Ground temp.: *Avg. 13 °C, Min. 12 °C, Max. 14 °C*	

Left: installation pattern

Right: PE-Xa based pipe system being converted by melted asphalt at 240 °C

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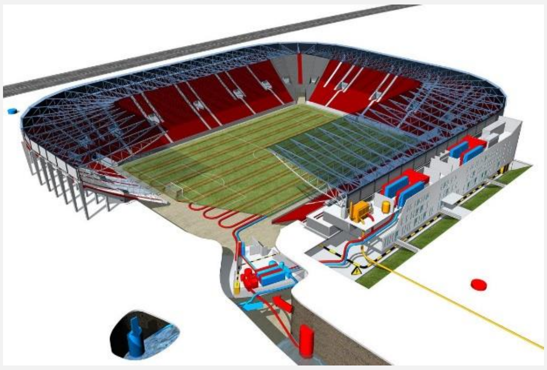
GOOD PRACTICE

Football stadium heating

Augsburg, Bavaria (Germany)

Groundwater heat pump



Altitude: **500 m**

Avg. annual outside temperature**: 8,3° C**

Time of geothermal heat exchanger implementation: **2009**

Description of installation:

- ***Short general description:***
    - *Location: Bürgermeister-Ulrich-Str. 90 in 86199 Augsburg, a city 50 km northwest of Munich*
    - *30660 visitors + staff*
    - *in 2009 a groundwater heat pump heating system was integrated in the construction of a new stadium*
    - *heating of the playing field, players' cabins, business lounges/club and offices*
- ***Key features of the hole system:***

From two deep wells on the west of the stadium the water is transported through circulating pumps towards two plate heat exchangers. Within a second water cycle the detracted heat is processed in the heat pumps and forwarded to the hot water buffer tank which transmits the water to the heaters. In case of high heat requirement, a natural gas peak load boiler can be connected. An emergency generator is available. Electricity for compressors and control devices is derived by a substation next to and right at the stadium. Return of the water into the ground is seeped through discharge wells.

System usage	*Heating, and free cooling* Additional non-NSGE installations: *natural gas peak load boiler, emergence generator*	
Energy output	Annual energy output heating: *280.000 kWh* Practically demanded peak load: Heating: *150 kW*	Volume or area to be acclimatised: *450 m²*
Economic & ecologic key facts	Electricity source: DE mix	Avoided CO2 emissions: *97 t/a*
Geothermal heat exchanger details	Count and depth of wells: *2 wells á 45 m*	Well tube diameter: *83 cm*
System performance	Flow rate per well: *100 m³/h*	
Geological & hydrological specifics	Ground temp.: *Avg. 9.5 °C, Min. 8 °C, Max. 11 °C*	

Further examples

Bavaria and Baden-Württemberg (Germany)

Mammut Logistik- und Verwaltungszentrum

Wolfertschwenden, Bavaria (Germany)

Groundwater heat pump

Altitude: **678 m**
Avg. annual outside temperature: **7,2 °C**

System usage	*Heating and free cooling*	
Energy output	Heating: *423 kW*	Cooling: *160 kW*
Geothermal heat exchanger details	Two production wells with depths of *52 and 31,5 m* Depth of Infiltration well: *42,3 m*	
System performance	Flow rate: *61,2 m³/h*	

Swabian media publishing house

Ravensburg, Baden-Württemberg (Germany)

Borehole heat exchanger field

Altitude: **437 m**
Avg. annual outside temperature: **8,8 °C**

The Heating and Cooling of this building complex is solely provided by geothermal energy.

System usage	*Heating and free cooling for 8803 m²*	
Energy output	Heating: *292 kW*	Cooling: *292 kW*
Geothermal heat exchanger details	*54 boreholes with a depth of 140 m each.*	
Geological & hydrological specifics	Thermal conductivity of the underground: *2,2 W/(m K)* Average ground temperature: *12,6 °C*	

Winterhalter Gastronom GmbH

Meckenbeuren, Baden-Württemberg (Germany)

Borehole heat exchanger field

Altitude: **437 m**
Avg. annual outside temperature: **8,8 °C**

System usage	*Heating and free cooling for 7300 m²*	
Energy output	Heating: *115 kW*	Cooling: *140 kW*
Geothermal heat exchanger details	*40 boreholes with a depth of 60 m each.*	

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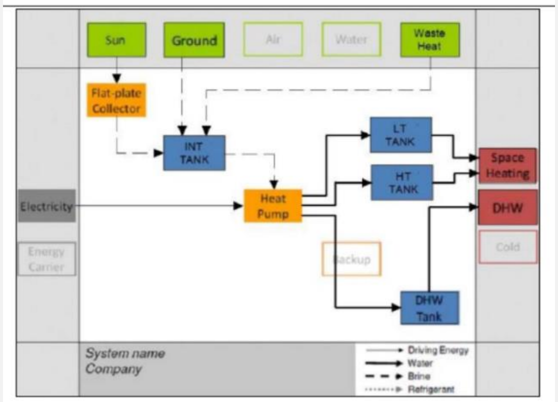
Bar-Restaurant 'Pit-Stop'

Valle d'Aosta (Italy)

Borehole heat exchanger and vertical heat collectors



Altitude: **2400 m** Average annual outside temperature: **2 °C**	Average heating degree days: **4524 Kday** (base temperture 20 °C) Time of geothermal heat exchanger implementation: **2014**

The GSHP plant at highest altitude in Europe is used to meet the energy demand of a bar-restaurant in winter days.

The bar & restaurant "Pit Stop" on the Pancheron ski track in Cervinia (Aosta) is heated by a shallow geothermal system designed and built by GEONOVIS. A 60 kW heat pump is connected to 6 Borehole Heat Exchangers (BHEs). Large heat storage tanks are installed for the peak shaving of thermal loads. Heat extraction from the ground is reduced through the recovery of heat from the kitchen wastewater and through the recharge with solar thermal collectors during summer.

System usage	*Heating and domestic hot water production, seasonal use* Additional non-NSGE installations: *solar thermal system, waste water heat recovery system*		
Energy output	Annual energy output Heating: *80 MWh* DHW: *20 MWh*	Practically demanded peak load: Heating: *56 kW*	Volume or area to be acclimatised: *1.600 m³*
Economic & ecologic key facts	Installation costs: *120.000 €* Amortization: *7-10 a*		
Geothermal heat exchanger details	Count and length of BHEs: *6 boreholes with a depth of 200 m, length of overall installed pipes 1.200 m*	Spacing of boreholes (BHEs): *12 m*	
System performance	Heat pump (HP) rated power (B0/W35): *60 kW* Annual HP working hours: *1200 h* Annual electricity consumption of the HP: *21 MWh/a*	Coefficient of performance (B0/W35): *4.3*	
Materials used	Heat transfer media/heat carrier fluid: *water/glycol mixture (35% glycol)*		
Geological & hydrological specifics	Geological region: *Pennine Alps, Cervino/Matterhorn* Rough description of bedrock: *gravel-sand matrix with polygenic rocks. Metamorphic cracks at 50 -60 m depth. Water infiltrations during perforations at 40 - 50 m depth.*		

Chaberton residence

Claviere (Italy)

Borehole heat exchanger

Altitude: **1760 m**

Average annual outside temperature: **4.5 °C**

Average heating degree days: **5000 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2014**

The Chaberton residence is heated by a ground source heat pump which produces also DHW for users.

A GSHP provides heating and DHW for a block of apartments used as a second home for the holidays. A fractured dolomite aquifer was intercepted by Borehole Heat Exchangers, with very high groundwater flow velocities. The ground is therefore characterized by an outstanding thermal exchange capacity, which allowed for a significant saving in drilling expenses and a very high COP of the heat pump.

Domestic hot water boilers and storage volume is 2 x 1000 l. If the setpoint for DHW (50-55 °C) is not achieved by HPs, oil burners start. Error between energy actually provided by the HP and design value < 1%.

System usage	*Heating and domestic hot water, permanent use including seasonal peaks* Additional non-NSGE installations: *2 x 27 Kw oil burners*		
Energy output	Annual energy output Heating: *90.7 MWh/a* DHW: *22.7 MWh/a*	Practically demanded peak load: Heating: *68 kW at –17 °C*	Volume or area to be acclimatised: *3 floors, 27 apartments, 2.300 m2 heated with radiating floor panels at low temperature*
Economic & ecologic key facts	Installation costs: *99.000 € + 65.000 € for BHE drilling and installing* Final energy efficiency rating of the building: *A Class (<30 kWh/m²/a)*	Running costs/year: *9.600 €/a*	Energy demand covered by the HP: 78.0% heating, 50.3% DHW
Geothermal heat exchanger details	Count and length of BHEs: *5 boreholes with a length of 170 m each, overall length of installed pipes 850 m*	Spacing of boreholes (BHEs): *15 m*	
System performance	Heat pump (HP) rated power (B0/W35): *2 x 21 kW HPs in cascade, integrated by oil burners.* Annual HP working hours: *1.949 h*	Coefficient of performance (B0/W35): *4.6 for heating, 3.2 for DHW* Seasonal performance factor: *14.8*	
Materials used	Completion/backfilling material: *Grout thermoplast Laviosa*	Heat transfer media/heat carrier fluid: *water/glycol mixture (25% propylene glycol)*	Heat pump working fluids (refrigerant): *R407*
Geological & hydrological specifics	Geological region: *Western Alpes - Monviso/Monginevro* Rough description of bedrock: *pale white-yellow dolostones with fine granulometry and saccharoids present in large banks with shallow clayish interpositions, laying on a level of compact crystalline limestone located at 150 m*	Thermal conductivity of the soil: *2.77 W/m/K* Ground temperature: *10 °C (avg.)* Hydraulic conductivity: *High-velocity gw flow: 7.6E-5 m/s* *BHE thermal resistance : 0.104 mK/W*	

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Bus and train garage Croviana

Trentino Alto Adige (Italy)

Borehole heat exchanger field

Altitude: **1400 m**

Average annual outside temperature: **9,3 °C**

Average heating degree days: **3516 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2014**

A geothermal plant to power the new bus and train garage in Croviana, a small municipality of Valle di Sole.

Trentino Trasporti S.p.a built a plant that combine the shallow geothermal plant with a photovoltaic system to cover the heating and cooling demand of a bus and train garage in Croviana (Trentino). The geothermal plant peak powers are: about 200 kW thermal for heating in winter, about 100 KW refrigerators for summer cooling as free-cooling and about 200 KW of photovoltaic array. The geothermal field consists of 39 PE-Xa probes, each of a depth of 130m, for a total length of 5.070 m. The carrier heat fluid is a mix of water and glycol, with no major impact on the soil in case of leaking. The geothermal system consists of two geothermal heat pumps, which produce hot water for the floor based heating system and for domestic uses (with a dedicated isolated thermal storage). The geothermal field allows also to cool the building thanks to the employment of a heat exchanger. The first meters of connection pipes of the geothermal probe field have been properly insulated in order to avoid the thermal impact on the biotic layer of the soil. The exchange of geothermal energy takes place in depth, in a closed circuit and is accomplished without extraction or reintroduction of fluids in the soil nor on the surface.

System usage	*Heating, cooling and domestic hot water, seasonal use* Additional non-NSGE installations: *Photovoltaic system*		
Energy output	Annual energy output Heating: *760 MWh/a*	Practically demanded peak load: Heating: *200 kW*	Volume or area to be acclimatised: *5.700m³*
Economic & ecologic key facts	Installation costs: *~1.1 M€* *(geothermal probes: ~300 k€, underfloor heating system: ~290 k€, photovoltaic system: ~480 k€)* Amortization: *<12 a* Final energy efficiency rating of the building: *133 kWh/m²/a*		
Geothermal heat exchanger details	Count and length of BHEs: *39 boreholes with a length of 130 m each, overall length of installed pipes 5.070 m*		
System performance	Heat pump (HP) rated power (B0/W35): *200 kW* Annual electricity consumption of the HP: *200 MWh/a*	Coefficient of performance (B0/W35): *3.8* Seasonal performance factor: *13*	
Materials used	Heat transfer media/heat carrier fluid: *water/glycol mixture*		

Maison Lostan

Aosta town, Aosta valley (Italy)

Groundwater heat pump for heating and cooling

Altitude: **550 m**

Average annual outside temperature: **10 °C**

Average heating degree days: **2850 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2017**

Located in the historical center of Aosta, the building has been restored by the regional administration with the purpose of allocating the new headquarters of the Superintendence of Cultural Heritage.

A first proposal was to construct a plant with a geothermal source of the type "closed" by adopting geothermal probes that reached a depth of 150 - 200 m – the procedure being simultaneously controlled through a continuous archaeologic monitoring. An "open loop" solution has been finally preferred, because of the several issues arisen related to the construction procedure and the specific historical context. At last, the decision has been to drill two withdrawal wells - one alternative to the other – 55 m deep. Reinjection occurs in a close drain since groundwater reinjection is currently forbidden in the Aosta Valley region.

System usage	*Heating and cooling, permanent use*		
Energy output	Annual energy output Heating: *300.000 kWh* Cooling: *50.000 kWh*	Practically demanded peak load: Heating: *300 kW (thermal load)*	Volume or area to be acclimatised: *3.650 m²*
Economic & ecologic key facts	Installation costs: *3.166.000 € (total cost of electrical and mechanical systems); of which 1.300.000 €, just HVAC system* Amortization: *N.a. (there was no HVAC system in the building before this installation)* Running costs/year: *13.300 €/a (energy for heating)*	Final energy efficiency rating of the building: *41.7 kWh/(m²*a) (primary energy for heating)*	
Geothermal heat exchanger details	Count / depth of wells: *70 m (just suction, reinjection in a close drain)*	Flow temperature before HP: *11 °C* Flow temperature after HP: *7 °C*	
System performance	Heat pump (HP) rated power (W10/W35): *448 kW (heating)* Annual HP working hours: *4.392 h (conventional heating season)*	Flow rate per well: *70 m³/h* Annual electricity consumption of the HP: *78.125 kWh/a (electricity for heating)*	Coefficient of performance (W10/W35): *3.84* Seasonal performance factor: *13*
Materials used	Heat transfer media/heat carrier fluid: *water*	Heat pump working fluids (refrigerant): *R410A*	
Geological & hydrological specifics	Geological region: *metamorphic rocks* Rough description of bedrock/aquifer: *Quaternary sediments*	Thermal conductivity of the soils and rocks: *1-2.5 W/mK* Average ground temperature: *12°C*	Thickness of aquifer: *100 m* Water level in borehole: *25 m* Hydraulic conductivity: *10^{-4} m/s*

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Palazzo Lombardia

Milano (Italy)

Groundwater heat pump for heating and cooling

Altitude: **120 m**

Average annual outside temperature: **12 °C**

Average heating degree days: **2404 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2010**

The complex named “Palazzo Lombardia” in Milan is the new headquarters of Region Lombardia, which was completed in July 2010. The complex includes the offices of the regional administration, an auditorium, restaurants and supermarkets. Since the area of the town is characterized by a very productive aquifer at a depth comprised between 20 and 50 m, with a temperature of about 15°C, a Ground Water Heat Pump (GWHP) system with 3 Heat Pumps was installed for heating and cooling purposes. Heat pump are able to fully meet the winter heating load and therefore the conventional boilers installed will act only as reserve units in case of exceptional heating demand. Water is discharged in a surface ditch after the heat exchange. Heat distribution systems consist of chilled beams and air handling unit heat exchangers circuits, the delivery and return temperatures are respectively 48/40 ° C. The chilled water production for summer air conditioning, in addition to heat pumps, is obtained by other water cooled chillers.

The largest building in the world fully heated and cooled by means only of geothermal sources, represented by ground water with the utilization of heat pumps.

System usage	*Heating and cooling, permanent use* Additional non-NSGE installations: *photovoltaic array (2000 m²)*	
Energy output	Practically demanded peak load: Heating: *6.3 MW* Cooling: *13 MW*	Volume or area to be acclimatised: *140.000 m²*
Geothermal heat exchanger details	Count / depth of wells: *8 boreholes with a length of 50 m, overall length of installed pipes 400 m*	Flow temperature before HP: *14 °C (Winter), 16°C (Summer)* Flow temperature after HP: *12 °C (Winter), 22° C (Summer)*
System performance	Flow rate per well: *144 m³/h*	Coefficient of performance (W10/W35): *4.5 heating* *6.0 cooling*
Geological & hydrological specifics	Geological region: *Po Valley – alluvial floodplain* Rough description of bedrock/aquifer: *gravel-sand Quaternary sediments*	Groundwater temperature: Average: *15 °C* Thickness of aquifer: *30 m*

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Ice Rink 'Pala Vuerich'

Pontebba (Italy)

Groundwater use for heating and cooling

Altitude: **570 m**

Average annual outside temperature: **9 °C**

Average heating degree days: **3630 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2013**

An open-loop Ground Water Heat Pump (GWHP) plant is used to produce cooling to maintain the ice rink and heating for locker rooms of the building.

The obsolescent refrigeration system of the ice rink has been replaced with two ammonia GWHPs after the ban of R22 refrigerant within the EU countries. High-efficiency ground water heat pumps were installed. The main aim of the project was to reduce the energy consumption to produce and maintain the ice for the rink, reducing at the same time the CO_2 emissions and increasing the overall reliability of the plant. The system exchanges heat with ground water flow abstracted from 2 wells at 32 m depth; the water is then reinjected in the same unconfined aquifer through a single well located 180 m downstream near the building. The system provides cooling for the ice rink and hot water (30-40 °C) for space heating.

System usage	*Heating and cooling, seasonal use*		
Energy output	Annual energy output Cooling: *750 MWh/a*	Practically demanded peak load: Heating: *720 kW,* Cooling: *640 kW*	Volume or area to be acclimatised: *180 m² Ice rink, 120 m² Lockers room*
Economic & ecologic key facts	Installation costs: *780.000 €* Amortization: *<10 a (incentives excluded)* Running costs/year: *60.000 €/a* Reduction of heating energy costs: *40 %* Reduction of energy costs (incl. cooling, DHW etc.): *40 %*	Avoided CO_2 emissions / CO_2 reduction: *244 t/a* Increase of RES share: *100 %* Reduction of primary energy consumption: *40% power consumption and 40% methane*	
Geothermal heat exchanger	Count / depth of wells: *2 Production wells, 1 Infiltration well* *Production well(s): 32 m each, Infiltration well(s): 30 m* Distance between wells: 180 m	Flow temperature before HP: *8 °C* Flow temperature after HP: *11 °C*	
System performance	Heat pump (HP) rated power (W10/W35): *720 kW* Annual electricity consumption of the HP: *150.000 kWh/a*	Flow rate per well: *max. 130 m³/h*	Coefficient of performance (W10/W35): *5* Seasonal performance factor **SPF a'+a''**: *6*
Materials used	Completion/backfilling material in wells: *Wells casing is steel zinc-coated, indoor distribution pipes are insulated stainless steel and the ice rink piping is HDPE. Upper 6 m of the wells casing is cemented, piezometers and wellheads are completed with manholes and inspection chambers.*	Heat pump working fluids (refrigerant): *R717* Heat transfer media/heat carrier fluid: *water/glycol mixture*	
Geological & hydrological specifics	Geological region: *NE Alpine Range, Fella river valley.* Rough description of bedrock/aquifer: *Mesozoic limestones and sand-stones outcropping on the valley flanks. The valley is filled by fluvioglacial sediments with a thickness of up to about 100 m. The production wells are very close to the eastern flank of the valley and reach almost the bedrock.*	Thickness of aquifer: *100 m* Water level in borehole: *3 – 6 m* Hydraulic conductivity: *~5x10⁻³ m/s*	

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GOOD PRACTICE

Municipal and registry office

Milano, Lombardia (Italy)

Groundwater heat pump for heating, cooling and domestic hot water

Altitude: **120 m**

Average annual outside temperature: **13 °C**

Average heating degree days: **2250 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2010**

The installation is based on a centralized system that is constituted by 2 heat pumps that are located within a technical room sited next to one of the two buildings. Each building has its own unit for the heating and cooling distribution. The geothermal system is constituted by two groundwater wells located at 30 m depth. Each well is equipped with two groundwater pumps. The heating and cooling is performed by means of both roof and floor radiant panels. The heating and cooling system works in combination of a "Forced Air Ventilation System". The heat pumps are powered by photovoltaic panels. The data was collected with the courtesy of Directorate of Energy Environment and Sustainable Development (Regione Lombardia).

System usage	*Heating, cooling and domestic hot water production, permanent use* Additional non-NSGE installations: *Forced air ventilation system, photovoltaic panels*		
Energy output	Annual energy output Heating: *237.069 kWh* Cooling: *73.190 kWh*	Practically demanded peak load: Heating: *180 kW* Cooling: *210 kW*	Volume or area to be acclimatised: *8.515 m³*
Economic & ecologic key facts	Installation costs: *534.000 €* Final energy efficiency rating of the building: *registry + municipal build. = 53.61 kWh(m2*a) and 3.51 kWh/(m²*a);* *library build. = 90.73 kWh/(m²*a)*		
Geothermal heat exchanger details	Count / depth of wells: 1 Production well(s): *30 m* 1 Infiltration well(s): *30 m*		
System performance	Heat pump (HP) rated power (W10/W35): *235 kW in heating and* *245 kW in cooling*	Average Flow rate per well: *30.6 m³/h* Maximum Flow rate per well: *46.8 m³/h*	Coefficient of performance (W10/W35): *4.8*
Geological & hydrological specifics	Geological region: *Alluvial valley of the Po Plain* Rough description of bedrock/aquifer: *alluvial deposits*		Thickness of aquifer: *>30 m*

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District heating Ostana

Piemonte (Italy)

Groundwater heat pump for heating and domestic hot water

Altitude: **1250 m**

Average annual outside temperature: **7,1 °C**

Average heating degree days: **3900 Kday ± 200 Kday** (base temperture 20 °C)

System usage	*Heating and domestic hot water production*	
Energy output	Annual energy output for heating: *20304 kWh, for* DHW: *8884 kWh* Volume or area to be acclimatised: *1776 m^3*	
Economic & ecologic key facts	Installation costs: *241.000 €+VAT* Final energy efficiency rating of the building: *49,9 [kWh/(m²*a)]* Running costs/year: *5837 €* Reduction of heating power costs: *2100 €*	Increase of RES share: *56 %* Reduction of primary energy consumption: *40 %*
System performance	Heat pump (HP) rated power (W10/W35): *116,89 kW* Annual HP working hours:*1250 h* Annual energy consumption of the HP: *22247 kWh/a*	Coefficient of performance (W10/W35): *4.8* Seasonal performance factor of heat pump (HSPF): *5,81*
Geological & hydrological specifics	Geological region: *Western Alps* Thermal conductivity of the soils and rocks: *2,9 W/m K* Avg. ground temp.: *13 °C*	

Museo Egizio

Piemonte (Italy)

Groundwater use for heating, cooling and domestic hot water

Altitude: **240 m**

Average annual outside temperature: **13,9 °C**

Average heating degree days: **3900 K·day ± 200 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2015**

System usage	*Heating, cooling and domestic hot water, permanent use with seasonal peaks* Additional non-NSGE installations: *2 condensing boilers (850 kW)*	
Energy output	Peak load: *857 kW (cooling); 860 kW (heating)*	
Economic & ecologic key facts	Amortization: *7-8 years* Reduction of heating power costs: *80k €/y*	Avoided CO_2 emissions / CO_2 reduction: *2k t/y*
System performance	Flow rate per well: *6.9 x 2 m³/h*	Coefficient of performance (W10/W35): *4.6*
Geological & hydrological specifics	Geological region: *Po Plain* Rough description of bedrock: *Quaternary and actual sands & gravels with local fine-grained and cemented strata*	Rough description of aquifer: *Alluvial sands & gravels* Thickness of aquifer: *40 m* Water level in borehole: *17 m* Groundwater temp.: *15.5°C* Hydraulic conductivity: *10^{-3} m/s*

GOOD PRACTICE

District heating Canavese

Milano, Lombardia (Italy)

Groundwater use for heating

Altitude: **120 m**

Average annual outside temperature: **13.1° C**

Average heating degree days: **3900 K·day ± 200 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2010**

System usage	*Heating, seasonal use* Additional non-NSGE installations: *GWHP integrated in a cogeneration power station for district heating*	
Energy output	Peak load: *15 MW (heating)* Volume or area to be conditioned: *4mln m3*	
Economic & ecologic key facts	Amortization: *7-8 years*	Avoided CO_2 emissions / CO_2 reduction: *20k t/y (whole cogeneration power plant)*
System performance	Flow rate per well: *1000 m³/h (divided into 6 pumping wells)*	Coefficient of performance (W10/W35): *3*
Geological & hydrological specifics	Geological region: *Po Plain* Rough description of bedrock: *Quaternary and actual sands & gravels with local fine-grained and cemented strata*	Rough description of aquifer: *Alluvial sands & gravels* Thickness of aquifer: *40-45 m* Groundwater temp.: *15°C* Hydraulic conductivity: *10^{-3} m/s*

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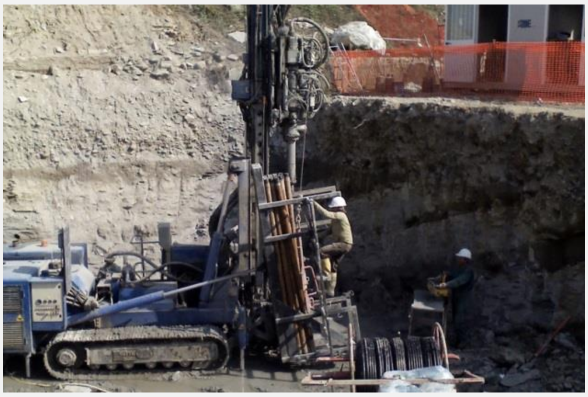
GOOD PRACTICE

Terme Acqui

Piemonte (Italy)

Borehole heat exchangers for heating and domestic hot water



Altitude: **156 m**

Average annual outside temperature: **13,3 °C**

Average heating degree days: **3900 K·day ± 200 Kday** (base temperture 20 C)

Time of geothermal heat exchanger implementation: **2013**

System usage	*Heating and domestic hot water, permanent use*	
Energy output	Practically demanded peak load: Heating: *145 kW*	Volume or area to be acclimatised: *2800 m²*
Economic & ecologic key facts	Installation costs: *230k€+VAT*	
Geothermal heat exchanger	Count and length of BHEs: 20 x 100 m BHE, in total 2000 m	
System performance	Heat pump (HP) rated power (W10/W35): *145 kW*	
Materials used	Heat pump working fluids (refrigerant): *R134a* Heat transfer media/heat carrier fluid: *Propylene glycol 25% vol.*	
Geological & hydrological specifics	Geological region: *Langhe Hills (Tertiary Piedmont Basin)* Rough description of bedrock: *marls* Thermal conductivity of the soils and rocks: *2.1 W/(mK)*	

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Data center of the provider "Aruba"

Lombardia (Italy)

Groundwater use for free cooling

Altitude: **224 m**

Average annual outside temperature: **12,5 °C**

Average heating degree days: **2500 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2017**

The largest data centre of Italy is cooled with groundwater through a free cooling system, reducing cooling costs of about 80% compared to conventional air-water chiller.

The Global Cloud Data Center is a data center campus with a surface area of 200,000m² in Ponte San Pietro (BG), just a few minutes from Milan. All the systems have been designed and built to meet and exceed the highest levels of resilience set by ANSI/TIA 942-A Rating 4 (formerly Tier 4).A surface area of 90,000m² dedicated to the data center in a total area of 200,000m². Maximum logical and physical security, with armed guards 24/7 and 7 different security perimeters. Up to 90MW of power, with self-produced hydroelectric and photovoltaic energy. Double multi-modular power center with UPS boasting 2N + 1 redundancy. Made-to- measure power of up to 40kW per rack. Redundant emergency generators with 48-hour full-load autonomy without refuelling. Further information at: https://www.datacenter.it/en/aruba-data-center/italy-milan-dc-it3.aspx; https://www.datacenter.it/en/aruba-ecosustainability/green-energy.aspx.

System usage	*Groundwater free cooling, peranent use* Additional non-NSGE installations: *a hydropower plant (1150 kW) and a photovoltaic system (450 kW). Air-water chillers are installed for emergency only (i.e. in case of failure of the free-cooling system)* Possible integration with other energy sources: *the data centre is 100 % fed with renewable electrical energy*		
Energy output	Annual energy output Cooling: *35 GWh/a*	Practically demanded peak load: Cooling: *4 MW*	Volume or area to be acclimatised: *7.000 m²*
Economic & ecologic key facts	Amortization: *not relevant; backup air-water chillers installed* Energy efficiency rating of the building: *5000 kWh/(m²*a)* Reduction of energy costs (incl. cooling, DHW etc.): *reduction of cooling costs of of about 80% compared to conventional air-water chiller.*	Avoided CO_2 emissions / CO_2 reduction: *80% compared to air-water chiller* Increase of RES share: *100 %* Reduction of primary energy consumption: *80 % compared to air-water chiller*	
Geothermal heat exchanger	Length/Depth of wells: *4 water wells, 16 m deep each, total flow rate of 80 l/s*		
System performance	Heat pump (HP) rated power (W10/W35): *no heat pump, it is a free cooling system with a power of 4 MW* Annual HP working hours: *8760 h* Annual electricity consumption of the HP: *no heat pump; the energy consumption of the wells is not known*	Flow rate per well: *144 m³/h*	
Geological & hydrological specifics	Geological region: *Po plain* Rough description of bedrock/aquifer: *alluvial sand and gravel deposits*	Rough description of aquifer: *alluvial shallow aquifer* Groundwater temp.: *14 °C*	

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GRETA AWARD Winner:

Planica Nordic Center

Kranyska Gora (Slovenia)

Groundwater heat pump

Altitude: **950 m**

Avg. annual outside temperature: **6.1 °C**

Avg. annual heating degree days: **4700 K·day** with a base temp. (indoor temp). of **20 °C**

Time of implementation: **2016**

Innovative concept: GWHP system is used for heating and cooling the central building and the underground garage. The central building is heated in winter, and in summer the underground garage is cooled with reversible HPs to preserve snow conditions inside.

For heating and cooling the central building and the underground garage the shallow geothermal energy with GWHPs is used. The central building is heated in winter, and in summer the garage is cooled with reversible HPs. Water is drawn from 2 wells at a depth of 60 m. 30 l/s of water is allowed to be pumped. The groundwater temperature is only 7 °C, but it is enough to heat the building. Water that flows through water HPs loses ca 3-4 K and is cooled down to 3 or 4 °C. In winter this cooled water is used for more efficient production of artificial or so called man-made snow with snow making machines. The temperature in the main building and in the garage in winter is 20 - 22°C. During the competitions in ski jumping and cross country skiing the garage area is used as a dining room for VIP guests, PRESS centre for journalists and wardrobe for the athletes. In March the snow from the jumping hill is put into garage. In summer the air temp. in the garage is -1 to -2°C and the glycol in pipes in concrete is cooled down to -12°C. So snow is preserved all summer and autumn long and used for the underground track. For heating the central building 2 HP units are used with heating power 78,4 kW each, and for cooling the garage 3 HPs with cooling power 31,5 kW each (for cooling the cross country track) and heating power 51,3 kW each (use during competitions for PRESS, VIP and athletes). The second building, mainly used for athletes and employees, is heated by 2 HPs with heating power 58,9 kW each.. Because of rather cold underground water, COP of the whole system is ca 3.

Key words: *sport facility, ski trails, GWHP system, water wells, Southern Alps, Tamar valley, Quaternary terrestrial deposits (sand, gravel).*

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GRETA AWARD Winner:

Planica Nordic Center

Kranyska Gora (Slovenia)

Groundwater heat pump

System usage	*Heating and cooling* Additional non-NSGE installations: *Two air-sourced heat pumps for another two buildings*		
Energy output	Annual energy output Heating: *488 MWh* Cooling*: 295 MWh*	Peak load: *405 kW*	Volume or area to be acclimatised: *8500 m³ (buildings) and 10300 m² (garage)*
Economic & ecologic key facts	Installation costs: *40.000.000 €*		
Geothermal heat exchanger details			Flow- and return flow temp.: *7/3,5 °C*
System performance	Heat pump (HP) rated power (W10/W35): *2 x 78.4 + 3 x 51.3 + 2 x 58.9 = 428.5 kW (heating power); 3 x 31.5 = 94.5 kW (cooling power)* Annual HP working hours: *5478 [h], of these 70% in cooling mode* Annual electricity consumption of the HP: *49600+34585=94185 kWh/a for heating,* *80727 kWh/a for cooling*		Flow rate per well: *17 m³/h* Avg. coefficient of performance: *3,0* Seasonal performance factor **SPF**: *4,37 for heating* *5,41 for cooling*
Geological & hydrological specifics			
Geological region: *Southern Alps, Julian Alps* Rough description of bedrock*:* *karstified dolomites and limestones, coarse grained Quaternary sediments*	Thermal conductivity of the soils and rocks: *[from 1.0 to 4.0 W/mK]* Groundwater temp.: *7.0/5.8/9.0* Avg/Min/Max Ground temp.: *app. 6.0*	Rough description of aquifer: *Till morena* Thickness of aquifer: *several 10s of m or even >100 m* Water level in borehole: *46 [m]* Groundwater temp.: *7 [°C]* Hydraulic conductivity: *in order of 10-2 [m/s]*	

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Swimming Club Gorenjska Banka

Radovljica (Slovenia)

Horizontal heat collector for heating and domestic hot water

Altitude: **495 m**

Average annual outside temperature: **8 °C**

Average heating degree days: **3900 Kday ± 200 Kday** (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2005**

It is the installation with the longest horizontal collectors' system in Slovenia so far. It is used for heating of the pool's water and for DHW heating within the pool facility. The swimming pool is more or less in permanent use. From September to May, it is covered with a balloon. The whole year around the equivalent full load hours of the HP operation is approximately 2600 h. Spacing between the pipes of 6000 m length is 0.8 m, and the loops are 200 m long each. The amount of energy supplied per HP (140 kW rated power) is 0.2726 GWh.

System usage	*Heating & domestic hot water, permanent use* Additional non-NSGE installations: *gas boiler, solar collectors*		
Energy output	Annual energy output Heating: *363,440 kWh* DHW: *ca 30,000 kWh*	Practically demanded peak load: Heating: *40 kW*	Volume or area to be acclimatised: *1575 m³ or 1050 m²*
Economic & ecologic key facts	Installation costs: *102,119.55 €* Running costs/year: *18,000 €* Reduction of heating energy costs: 40% lower use of gas Reduction of energy costs (incl. cooling, DHW etc.): 70 %		
Economic & ecologic key facts	Avoided CO_2 emissions / CO_2 reduction: *100 % or 99.9 t/a* Increase of RES share: *100 %* Reduction of primary energy consumption: *80 %, at the condition that electricity is from hydropower plants*		
Geothermal heat exchanger details	Length of installed pipes: *6000 m* Area of collector: *5500m²*	Flow- and return flow temp.: *2/6 °C*	
System performance	Heat pump (HP) rated power (B0/W35): *140 kW* Annual HP working hours: *2596 h -- full load hours* Annual electricity consumption of the HP: *90,860 kWh/a*	Flow rate primary circuit at HP: *25 m³/h* Coefficient of performance (B0/W35): *4.78* Seasonal performance factor **SPF a'+a''**: *4.0*	
Materials used	Completion/backfilling material around collector pipes: *layer of sand and then soil*	Heat transfer media/heat carrier fluid: *70 % water, 30 % glycol*	Heat pump working fluids (refrigerant): *R407*
Geological & hydrological specifics	Geological region: *Southern Alps, Ljubljana basin* Rough description of bedrock: *layers of Oligocene marine clay*	Thermal conductivity of the soil: *clay: 1,43 W/(m·K);* *dolomite: 4,2 W/(m·K)*	Average ground temperature*: 9 °C*

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Campsite KLIN Lepena

Soča, Lepena (Slovenia)

Groundwater use for domestic hot water

Altitude: **1083 m** Average annual outside temperature: **7.8 °C** Average heating degree days: **4100 Kday** (base temperture 20 °C) Time of geothermal heat exchanger implementation: **2007**	

It is a GWHP installation with a doublet of 2 wells (24 m deep, reinjection one much shallower, and 15 m apart). The system is permanently used for DHW for the apartments and the main camp building. During the opening time form October to May the heating of apartments is carried out with stove on wood (30 kW of power). The restaurant is heated with a fireplace on wood. Space heating is with boiler on heating oil (100 kW power). The HP heats the DHW up to 55°C, and it is further heated to 75-80°C with oil boilers due to legionella problems. The equivalent full load hours of the HP operation is 700 h/yr only. The amount of energy supplied per HP technology (30 kW rated power) is ca 0.01423 GWh/yr.

System usage	*Domestic hot water production, permanent use* Additional non-NSGE installations: *The boiler on heating oil (100 kW), wood stove (30 kW) for apartments and a fireplace in the restaurant*	
Energy output	Annual energy output Heating: *3 x 800 l tank storage on oil boiler, 500 l for water from HP*	Volume or area to be acclimatised: *1250 m³ or 500 m²*
Economic & ecologic key facts	Running costs/year: *3000 €/a* Reduction of heating energy costs: *before they used 5500 l of oil /a* Reduction of energy costs: *60-70 %*	Avoided CO_2 emissions / CO_2 reduction: *100 %* Reduction of primary energy consumption: *100 %*
Geothermal heat exchanger details	Count / depth of wells: *2 wells* Production well(s): *24 m* Infiltration well(s): *much shallower* Distance between wells: *15 m*	Flow- and return flow temp.: *8/5 °C*
System performance	Heat pump (HP) rated power (W10/W35): *30 kW* Annual HP working hours: *700 h full load hours of operation* Annual electricity consumption of the HP: *20.000 – 25.000 kWh/a*	Flow rate per well: *15 m³/h* Coefficient of performance (W10/W35): *4.2* Seasonal performance factor **SPF a'+a''**: *3.1*
Materials used	Heat transfer media/heat carrier fluid: *water*	
Geological & hydrological specifics	Geological region: *Southern Alps* Thermal conductivity of the soils and rocks: *2,1 – 4,6 W/(m·K)* Avg. ground temp.: *7,5 °C*	Thickness of aquifer: *20 m* Water level in borehole: *7 m* Average Groundwater temperature: *8,5°C*

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Kindergarten Oton Župančič

Slovenska Bistrica – Unity Poljčane (Slovenia)

Groundwater use for heating and cooling

Altitude: **259 m**

Avg. annual outside temperature: **10 °C**

Avg. annual heating degree days: **3300 Kday** with a base temp. (indoor temp). **of 20°C**

Time of implementation: **2015**

Multifunctional hybrid heat pump REWATEMP installed for heating and cooling, in combination with passive cooling

A multifunctional hybrid heat pump REWATEMP is installed for heating and cooling. A groundwater is exploited through one well (10 m deep), with reinjection well too. The permanent yield is 3.2 l / s (11.5 m3/h). The pumped water temperature is 11.8 to 13 °C. - The hybrid HP is selected and dimensioned to cover all the energy needs of the heating and cooling in one appliance. The maximum required heating power for the object is 134 kW (winter) and the maximum cooling power is 95 kW. The rated heating power of the appliance is 130 kW and the rated cooling power is 120 kW. The SPF of water capture at the object level is 3.6 in heating mode and 9.1 in cooling mode with combination of passive cooling. Passive cooling means free cooling with the well water when only the electricity of the circulation pumps is consumed.- The monitoring shows that in 2016 the total amount of energy from this renewable energy source amounted to 122 MWh / year and resulted in savings of 13,500 litres of heating oil annually and a reduction of 33 tonnes of CO_2 emissions. - Hybrid HP "RewaTemp" has integrated an integrated digital hot water and coolant fluid management, all the way to distribution branches inside the heat substation. This ensures complete control and management of energy production, there are no duplicates of uncontrolled functionality.- The great advantage is that it is necessary to maintain only one appliance and not separately the heat pumps, a cooling unit and a heating boiler.

Key words: *public low-energy building, GWHP system, water well, Pannonian basin, Dravinja valley, Neogene coarse and fine-grained deposits (gravel, silt, sand, clay).*

System usage	*heating and cooling of the building* *Domestic hot water production, permanent use*		
Energy output	Annual energy output Heating: *122000 kWh* Cooling: *11540 kWh, partly passive cooling*		
System performance	Heat pump (HP) rated power (capacity of HP): *130 kW in H mode, 120 kW in C mode* Annual HP working hours: *1300 h in H mode, 108 h in C mode*	Flow rate per well/borehole: *11.5 [m³/h]*	Seasonal performance factor of heat pump (HSPF): *3.6, and in cooling mode: 9.1*
Materials used	Heat transfer media/heat carrier fluid: *water*		
Geological & hydrological specifics	Geological region: *Pannonian basin* Thermal conductivity of the soils and rocks*: 1.0 – 2.3 W/(m·K)* Avg/Min/Max. groundwater temp.: *12,4/11,8/13 °C*	Thickness of aquifer: *20 m* Water level in borehole: *7 m* Average Groundwater temperature: *8,5°C*	

Aquifer specifics: *The gravel aquifer with intergranular porosity and medium hydraulic conductivity. In the entire field, the direction of flowing groundwater is estimated from west to east. The estimated surface area of the water body is 310,000 m2 and its volume is around 1.24 million m3. The stationary water level: at 2.6 m depth (without pumping), and the dynamic water level: stabilized at 4.6 m depth (with pumping of 3.2 l/s).*

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Termoshop industrial and commercial building

Šempeter v Savinjski dolini (Slovenia)

Groundwater use

Altitude: **274 m**

Avg. annual outside temperature: **10 °C**

Avg. annual heating degree days**: 3300 Kday** with a base temp. (indoor temp). of **20 °C**

Time of implementation: **2006**

The combination of geothermal heat pump with variable power and solar power plant that covers all energy needs so that the object has been practically independent for more than 5 years.

System with 2 heat pump units installed for heating and cooling. A groundwater is exploited through one well (ca 20 m deep), with reinjection well. The yield is 1.33 l / s (4.8 m3/h). The pumped water temperature is 12-16 °C (aver. 14°C) . – One HP unit is for Heating and Cooling with 25 kW rated power, the other is only for Cooling with 19 kW rated power. It is dimensioned appliance with variable power in combination with solar power plant to cover all the energy needs of the heating and cooling. The SPF in heating mode is 4.3, and in cooling mode ca 4.6 on water capture . The object has been practically independent for more than 5 years.

Key words*: business-production building, GWHP system, water well, Pannonian basin, Savinja valley, Neogene coarse and fine-grained deposits (gravel, silt, sand, clay).*

System usage	*heating and cooling of the building* Additional non-NSGE installations: *Air-sourced HP for domestic hot water*		
System performance	Heat pump (HP) rated power (capacity of HP): *25 + 19 kW* Annual HP working hours: *2340 + 2170 [h]*	Flow rate per well/borehole: *4,8 [m³/h]*	Avg. coefficient of performance (COP): *4.1* Seasonal performance factor of heat pump (HSPF): *4,3*
Materials used	Heat pump working fluids (refrigerant): *R410a, R407c*		
Geological & hydrological specifics	Geological region: *Pannonian basin* Rough description of bedrock: *compact clay layers of Oligocene age beneath Q aquifer; J-T carbonatic rocks beneath the Oligocene layers (at ca 600-700 m depth)*		Thermal conductivity of the soils and rocks: *1 to 3 W/mK* Groundwater temp.: Avg/Min/Max *14/12/16 °C*
Aquifer specifics: *Quaternary coarse and fine-grained deposits (gravel, silt, sand).* Thickness of aquifer*: 32 [m];* of this: the upper aquifer: *10 m* Water level in borehole*: 4 [m]*			

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National Interprofessional Nordic Center

Kranj (Slovenia)

Groundwater heat pump for heating

Altitude: **378 m**

Average annual outside temperature: **8.7 °C**

Average heating degree days: **3700 Kday** ± 200 Kday (base temperture 20 °C)

Time of geothermal heat exchanger implementation: **2012**

It is a GWHP installation with a doublet of 2 wells (22 m and 18 m deep, ca 40 m apart). The system is used for DHW and space heating of the rooms and offices below the ski jump landing all year around. There is underfloor heating for the entire building with HP energy use of groundwater and in winter, there is supplying of used chilled water into reservoirs, from which this water is taken away for snowmaking. Taking into account the knowledge of the HP and its energy performance the special pipeline was constructed 'for chilled groundwater' from the heat pump to the water tanks during the operation of the snow cannons. For a time, when snowmaking does not take place, the reinjection well is in function. The basic idea of this system is that the temperature of groundwater (avg. is 9 ° C), after the withdrawal of temperature in the HP, is reduced by 4 °C, and with such a temperature the water tank is filled. With the favourable external temperature, water before snowmaking is further cooled to 2 °C. Due to the underfloor heating system, which requires a maximum temperature of 30 °C, the saving of energy for heating is done, so that chilled water from the heat pump reduces the need for electricity for the needs of water for artificial snow. The equivalent full load hours of the HP operation is ca 1800 h/yr. The amount of energy supplied per HP technology (50 kW rated power) is ca 0.064286 GWh/yr.

System usage	*Heating, permanent use*	
Energy output	Annual energy output DHW: *500 l storage tank*	Volume or area to be acclimatised: *4000 m³ or 1000 m²*
Economic & ecologic key facts	Avoided CO_2 emissions / CO_2 reduction: *100 %* Increase of RES share: *100 %*	
Geothermal heat exchanger details	Distance between wells: *40 m* Flow temperature before HP: *9 °C* Flow temperature after HP: *4 °C*	
System performance	Heat pump (HP) rated power (W10/W35): *50 kW* Annual HP working hours: *1800 h (full load hours)* Annual electricity consumption of the HP: *30.000 kWh/a*	Coefficient of performance (W10/W35): *3.8 (3 - 4)* Seasonal performance factor **SPF a'+a''**: *3.5* Flow rate per well: *<18 m³/h*
Materials used	Heat pump working fluids (refrigerant): *water*	
Geological & hydrological specifics	Geological region: *Southern Alps* Rough description of bedrock/aquifer: *black clayey schists, greywackes, tuffites, limestone (Ladinian, Carnian) or bedded cherty limestones (Ladinian, Carnian, Norianj?) / Quaternary alluvial gravel aquifer*	
	Thermal conductivity of the soils and rocks: *1,8 – 3,0 W/(m·K)* Average ground temp.: *9 °C*	Average groundwater temperature: *9 °C* Thickness of aquifer: *20 – 30 m* Water level in borehole: *2 m*

Holiday resort Reka Blatten-Belalp

Valais (Switzerland)

Borehole heat exchanger field for heating and thermal storage

Altitude: **1327 m**

Average annual outside temperature: **11 °C**

Average heating degree days: **4.175 Kday**

Time of geothermal heat exchanger implementation: **2014**

Zero Emission Project of 50 holiday flats including an indoor swimming pool.

Hybrid solar collectors (PTV) in combination with a BHE field acting as thermal storage (BTES) and additionally a heat recovery from the facility waste water are installed.

System usage	*Heating & domestic hot water, permanent use* Additional non-NSGE installations: *Hybrid solar collectors (PTV), heat recovery from waste water*	
Energy output	Annual energy output Heating: *250.000 kWh* DHW: *250.000 kWh* Electricity: *200’000 kWh* Swimming pool: *100’000 kWh* Deficiency: *80’000 kWh* Storage: *-300’000 kWh* heat restoration WW: *-200’000 kWh* Water electricity: *external -230’000 kWh* Photovoltaic: *-150’000 kWh*	Practically demanded peak load: Heating: *380 kW*
Ecologic key facts	Avoided CO_2 emissions / CO_2 reduction: *100 %*	
Geothermal heat exchanger details	Count and length of BHEs: *31 BHE´s with a length of 150 m double U pipe, overall length of installed pipes: 18.600 m*	

Saas-Fee district heating

Valais (Switzerland)

Borehole heat exchanger field for district heat supply

Altitude: **1792 m**
Avg. annual outside temperature: **8 °C**
Avg. heating degree-days (VDI 2067):**4770 K·day**
Time of geothermal heat exchanger implementation: **2015**

Supply of district heat by BHE field acting as thermal storage (BTES) in combination with photovoltaic driven air heat pump as a central unit. Decentral units (heat pumps) could be linked to the central supply system.

System usage	*Heating only, permanent use and seasonal peaks* Additional installations: *air heat pump, photovoltaic*		
Energy output	Annual energy output Heating: *2.100.000 kWh*	Practically demanded peak load: Heating: *2.100.000 kWh*	Volume or area to be acclimatised: *1.000 m²*
Economic & ecologic key facts	Installation costs: *4.000.000 CHF*		
Geothermal heat exchanger details	Count and length of BHEs: *90 BHE´s with a length of 150 m, double U pipe, overall length of installed pipes:54.000*	Spacing of boreholes (BHEs): *6 m* Area of activation for storage: *4.000 m²* Volume of activation for storage: *600.000 m³*	Flow- and return flow temp. difference: *ca 4.0 K*
System performance	Heat pump (HP) rated power (B0/W35): *560 kW*	Flow rate primary circuit at HP: *1.2 m³/h*	Coefficient of performance (B0/W35): 10
	Annual electricity consumption of the HP: *1.500.000 kWh/a*		
	Annual HP working hours: *2.400 h*		
Materials used	Heat transfer media/heat carrier fluid: *water-glycol mixture 35%*	Heat pump working fluids (refrigerant): *ammonia heat-pump* *primary: water-glycol mixture* *secondary: water*	
Geological & hydrological specifics	Geological region: *Monte Rosa, Bernhard nappe complex*	Thermal conductivity of the soil: *3.3 W/mK* Specific abstraction capacity: *35 W/m* Average ground temperature: *10 °C*	

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Tunnel Great St. Bernard

Valais (Switzerland/Italy)

Heat collector from tunnel air for heating

Altitude: **1850 m**

Avg. annual outside temperature: **8 °C**

Avg. heating degree-days (VDI 2067): **4770 K·day**

Time of geothermal heat exchanger implementation: **1999**

Heat extraction from the tunnel air placed 1500 m inside above the traffic lines. Heat collector inside the tunnel is used to heat new administrative building on the north portal.

System usage	*Heating only, permanent use and seasonal peaks*	
Energy output	Annual energy output Heating: *139.002 kWh*	Volume or area to be acclimatised: *748 m²*
Economic & ecologic key facts	Installation costs: *163.015 CHF*	Avoided CO_2 emissions / CO_2 reduction: *370 t/a*
Geothermal heat exchanger details	Flow- and return flow temp. difference: *ca 1.3 K*	
System performance	Heat pump (HP) rated power (B0/W35): *36 kW* Annual HP working hours: *4.440 h* Annual electricity consumption of the HP: *38.298 kWh/a*	Coefficient of performance (B0/W35): *3.72*
Materials used	Heat transfer media/heat carrier fluid: *glycol water/air*	Heat pump working fluids (refrigerant): *glycol water*