Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Austria – Country Update

Johann Goldbrunner

Geoteam Ges.m.b.H., Bahnhofgürtel 77, AT-8020 Graz, Austria

Goldbrunner@geoteam.at

Keywords: Austria, Geothermal Energy, Molasse Basin, Styrian Basin, Vienna Basin, Alpine region, deep geothermal, wells, district heating balneology, shallow geothermal.

ABSTRACT

The use of deep geothermal resources in Austria is dominated by district heating. Examples of economically successful projects are those of Simbach-Braunau and Ried im Innkreis, both in the Upper Austrian Molasse Basin. They have seen significant extension since 2015. Another successful example of direct use is the greenhouse project Frutura in the Styrian Basin. The installed capacity of direct use of deep geothermal in Austria amounted to 95.8 MW in 2019 (compared to 63.4 MW in 2015; Goldbrunner 2015).

Electricity production from geothermal persists at a level 1.2 MW_{el} of installed capacity due to the lack of market incentives by the public sector.

The installed capacity of shallow geothermal energy is estimated to be 1,000 MW. Higher growth rates for earth-coupled heat pumps continue to be constrained by the market dominance of air-based systems.

The period 2015 to 2019 saw only limited drilling activity for deep geothermal. Greater impetus is to be expected when geothermal energy projects for the district heating of larger cities are implemented. Approaches along these lines can already be found in Vienna and Salzburg.

1. INTRODUCTION

The prerequisites for the use of geothermal energy vary considerably across the geological units of Austria (area 83,871 km², 8.9 million inhabitants in 2019) The area of the Bohemian Massif and large parts of the Central Alps are only partially suitable for exploiting deep geothermal energy due to the low permeability of the rocks and, with the exception of some local anomalies, low heat flow values. In some parts of the Northern Calcareous Alps the geothermal gradient is lowered significantly as a result of the distinctive convective overprinting of the temperature field by descending cold meteoric waters. For example, in the well Berndorf 1 (Wachtel & Wessely, 1981), situated at the border of the Vienna Basin some 40 km SW of Vienna, the cooling effect of descending fresh water was recognizable down to a depth of 6,000 m. Compared to the value expected on the basis of the regional heat flow in the Vienna Basin, this lowers the formation temperature by about 100 K.

The bordering basins of the Alps, namely the Upper Austrian Molasse Basin and the Styrian Basin (yellow color in Figure 1) can be regarded as the most promising geothermal provinces in Austria. The exploitation of the huge geothermal potential existing in the Vienna Basin is also still in its infancy.

Between 2015 and 2019 only one deep geothermal bore (extension well Mehrnbach Th 3.1/1a, Upper Austrian Molasse Basin; Ried Geothermal Project) was successfully drilled, A second well, drilled in the same period in the Province of Carinthia, with a total depth of 2,865 m, turned out to be dry and had to be abandoned (Table 1).

2. DEEP GEOTHERMAL USE

2.1 Overview

The operation of geothermal district heating (GDH) networks is the most important type of use in Austria. Seven such projects are currently operating in the Upper Austrian Molasse Basin, plus two further projects in the Styrian Basin. Plans to establish geothermal grids or to integrate geothermal energy into existing schemes have also been drawn up for the cities of Vienna and Salzburg. Under the right circumstances, district heating from geothermal energy can successfully compete with more conventional energy sources such as oil, natural gas, and biomass. In 2012, the share of geothermal energy in district heating in Austria was only 0.4%. This is expected to rise to a share of 8.7% by 2050 (Könighofer et al, 2014).

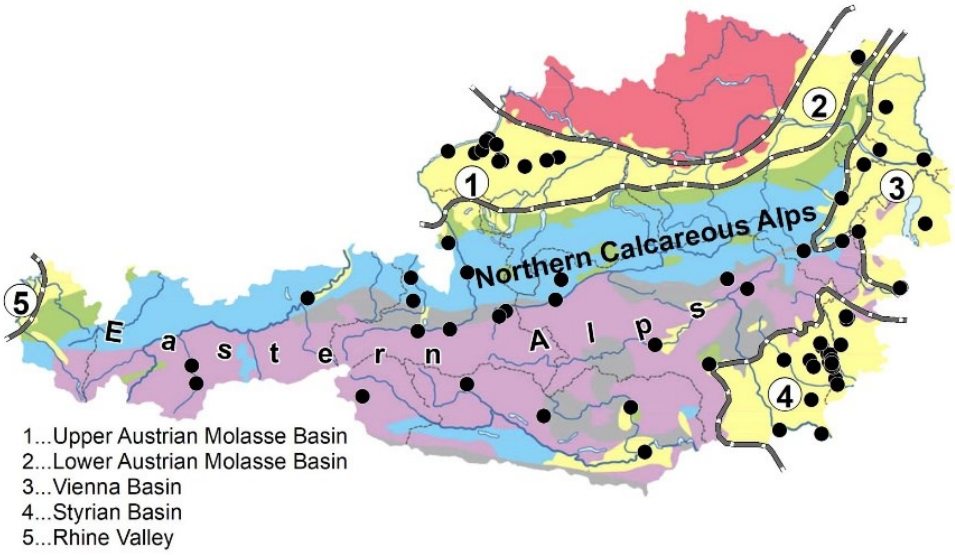


Figure 1: Geothermal wells in Austria.

Table 1: Deep Geothermal Drillings in Austria and number of new wells 2015 - 2019

Tectonical unit	total number of wells	No. of new wells 2015 – 2019	Length [m]	Cumulative length [m]
Styrian Basin	28			48,100
Upper Aust rian Molasse Basin	14	1	2,592	30,828
Vienna Basin and Lower Austrian Molasse Basin	8			12,605
Northern Calcareous Alps and Upper Austroalpine Units (mainly carbonate rocks)	7			14,802
Lower and Upper Austroalpine Units (mainly crystalline rocks)	19	1	2,865	27,483
Pannonian Basin	1			860
Total:	77	2	5,457	134,678

In the reporting period under review here (2015-2019), no drilling activities were recorded for balneological projects (classic cure and wellness treatments). Currently, 27 spas are in operation in Austria. However, the number of spa visitors, while relatively high (9.4 million in 2018), has not changed for years; The majority of spas are based on deep drillings sunk after 1975. The energy turnover due to the cooling in the baths corresponds to a roughly estimated thermal capacity of 10 MW. In some spas, water-water heat pumps were installed to utilize the energy content of the splash water. One such example is the facility in Bad Waltersdorf, Styrian Basin (Figure 2).

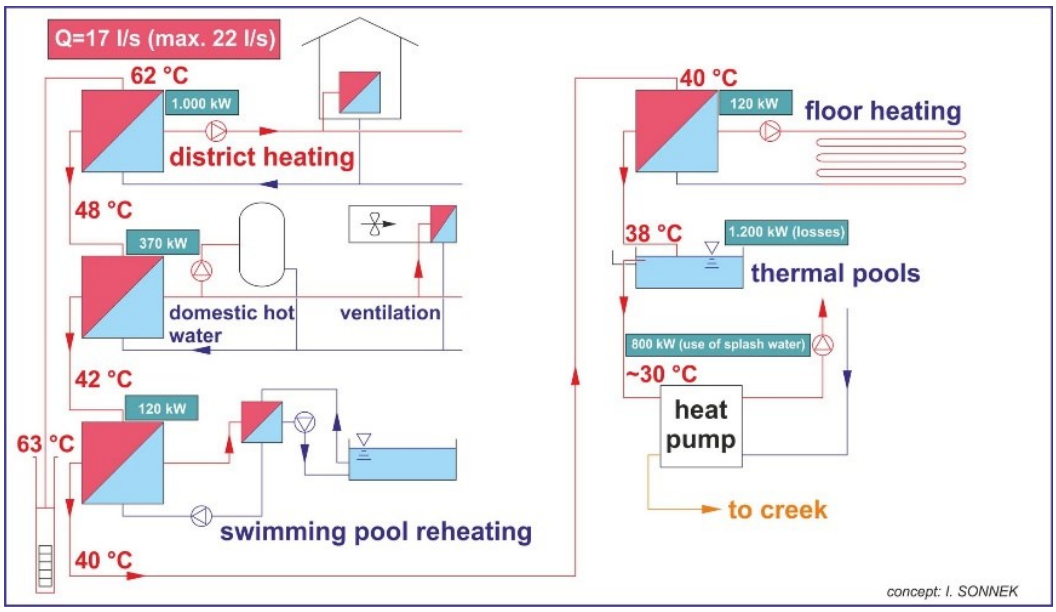


Figure 2: Geothermal cascading at Bad Waltersdorf (Styrian Basin) including heat pump use of splash water.

2.2 Upper Austrian Molasse Basin

The Upper Austrian Molasse Basin has the highest density of district heating projects. As in the South German Molasse Basin, dolomites and limestones of Upper Jurassic age form the main geothermal aquifer. Currently, seven district heating projects are in operation. Two of these also have additional uses (Geinberg: balneology and greenhouse; Altheim: ORC; see Table 2). The majority of the projects is located in the North of the Upper Austrian Molasse basin close to the German border. The density of the projects here is similar to that found for the projects located to the south of Munich (see Figure 3).

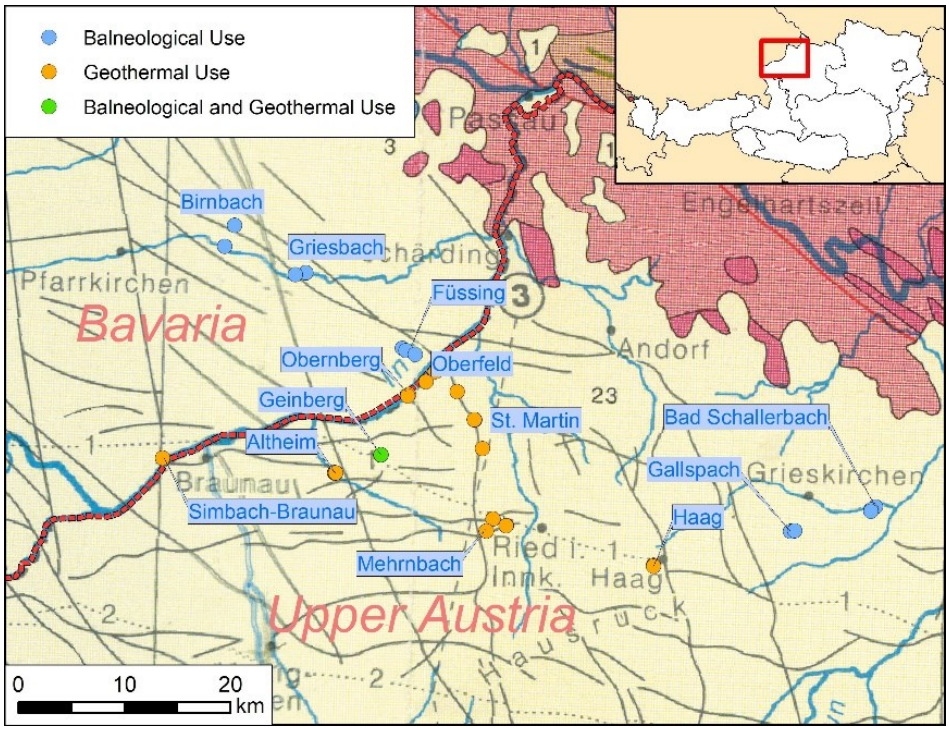


Figure 3: Geothermal wells and wells for balneological use in the Upper Austrian / Bavarian border region.

The upper temperature limit of the achievable temperature in the Malm Aquifer of Upper Austria is likely to be in the order of 120 °C.

Table 2: Geothermal projects of the Upper Austrian Molasse Basin.

Plant	Use	Mass Flow [kg/s]	Tin [°C]	Tout [°C]	Capacity [MWth]
Simbach/ Braunau	D	87.5	80	50	11.0
Altheim	D, E	71.6	105	70	10.5
Geinberg	D, B, G	48.5	103	30	14.8
Obernberg	D	19.4	80	55	2.0
Sankt-Martin	D	36.8	85	55	4.6
Ried-Mehrnbach	D	86.3	100	50	18.0
Haag am Hausruck	D	17.4	85	50	2.6
Schallerbach	B	15.9	38	20	1.2

B = balneology, D = district heating, G = greenhouse, E = power production.

Trial operation of the joint German-Austrian geothermal project of Simbach-Braunau, with a circulation rate of 90 l/s (87.5 kg/s), was completed in 2018. The procedure for acquiring permanent official approval for such a flow volume is still ongoing. At such a flow rate, installed thermal capacity will rise to 11.0 MW. In addition to the increased flow, a lowering of the return temperature from 50 °C to 40 °C is also envisaged in order to allow for the use of heat pumps. This will increase the share of geothermal energy in annual heat production from currently 70% to 75%, to 90%.

As of 2018, the geothermal district and local heating scheme in the communities Ried im Innkreis and Mehrnbach (Figure 4) supplied 2,258 apartments, 169 houses and 97 commercial facilities. The network length was 35.3 km.

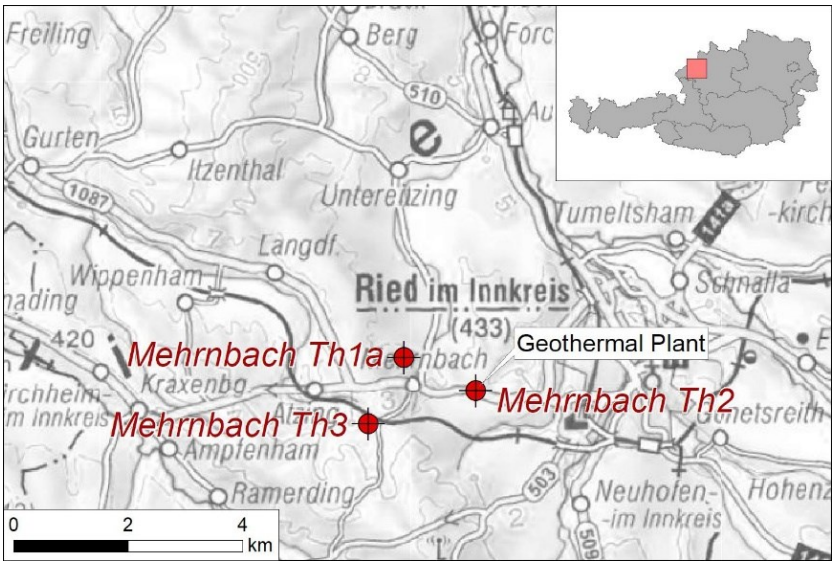


Figure 4: Wells of the GDH project Ried/Mehrnbach.

To meet the growing thermal demand a third well (Mehrnbach Th 3) was sunk at the turn of the year 2018/2019. Figure 5 shows the tectonic position of the geothermal wells. Mehrnbach 1/1a and Mehrnbach 3.1/3.1a (the "a" denotes, that the wells were side-tracked; 1a for geological, 3.1a for technical reasons). These tapped the Malm carbonates at the down-thrown block, while Th 2 tapped the up-thrown block of the Ried Fault. The Malm aquifer of the two blocks is hydraulically separated due to the fault throw of more than 800 m.

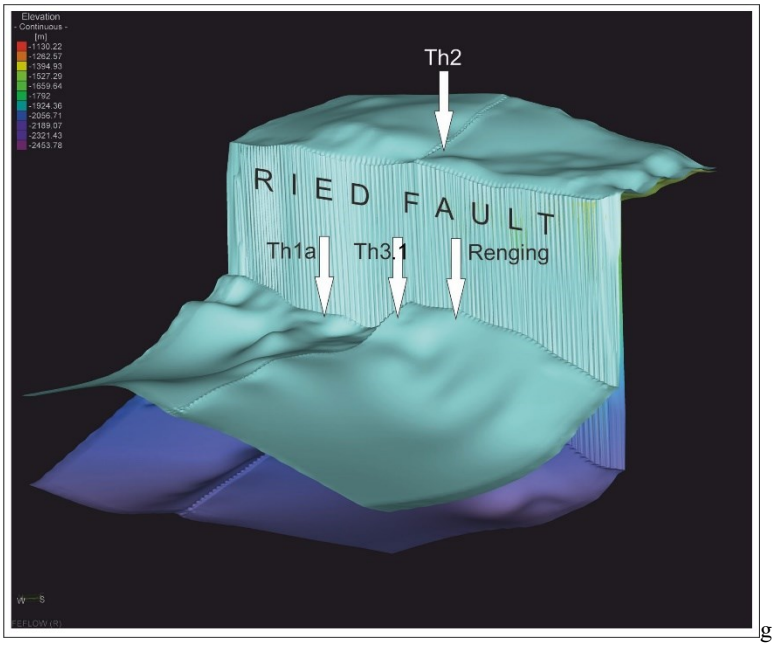


Figure 5: Block diagram showing the position of the wells Mehrnbach Th 1a, Mehrnbach Th 3.1 and Renging 1 at Top of the Malm carbonates (at the down thrown block the surface of the crystalline basement is also shown).

Th 3.1a tapped the Malm aquifer at a depth of 2,362 m and reached a total depth of 2,592 m. It opened the Malm carbonates in the vicinity of an antithetic fault which has a throw of some 90 m (Figure 6). The predominant occurrence of dolomite can be ascribed to it being fault-related and of hydrothermal origin (e.g. Sha et al., 2016).

A six-week pumping and reinjection test revealed that a withdrawal rate of 100 l/s at a temperature of 105 °C at well head can be achieved. The transmissivity of the aquifer tapped by the well was assessed as 1.2 x 10^{-3} m²/s.

In 2018, 50.6 GWh of heat were produced in the Mehrnbach Geothermal Plant, of which 10 % had to be represented by natural gas. The commissioning of the Mehrnbach Th 3.1.a and Mehrnbach 1a geothermal doublet with higher flow rates and the significantly higher well head temperatures of 105 °C (compared to Mehrnbach Th 2 which was used as production well from 2014 to mid-2019) can thus significantly reduce the share of additional gas needed as well as cover the expected additional future heating requirements of 16.5 GWh. Mehrnbach 2 will serve as a back-up well and can be used either as a production or reinjection well in a second doublet envisaged at the up-thrown block on the Ried Fault.

2.3 Vienna Basin

At the down-throw block of the Leopoldorf Fault located east of Vienna, carbonate rocks of the Alpine basin floor which occur in the different nappes of the Northern Calcareous Alps (mainly Middle and Upper Triassic dolomites) are generally found 3,000 to 6,000 m below surface, with their bottom expected at a depth range of more than 8,000 m. This thus allows for temperatures of up to 215 °C (Wessely, 2006). A water test from the borehole Aspern 1 in 1974 (Ronner, 1980) showed that the aquifers are dominated by NaCl type connate waters with a salinity of 150 g/l.

The first deep geothermal drilling "Aspern Eßling Th 1", sunk in 2012, revealed that the Alpine basin floor is dominated by folding structures which limit the extension of possible aquifers. The bore opened up 3,355 m of Neogene strata before entering the Pre-Neogene basin floor, consisting of an imbricate structure formed by tight limestones, calcareous marlstones of Middle Triassic to Permian age above a sequence of Upper Cretaceous marlstones and calcareous marlstones with steep dip associated with an overturned syncline (Figure 7). Hole problems caused by sloughing led to the termination of the drilling at a depth of 4,424 m MD (4,180 m TVD)

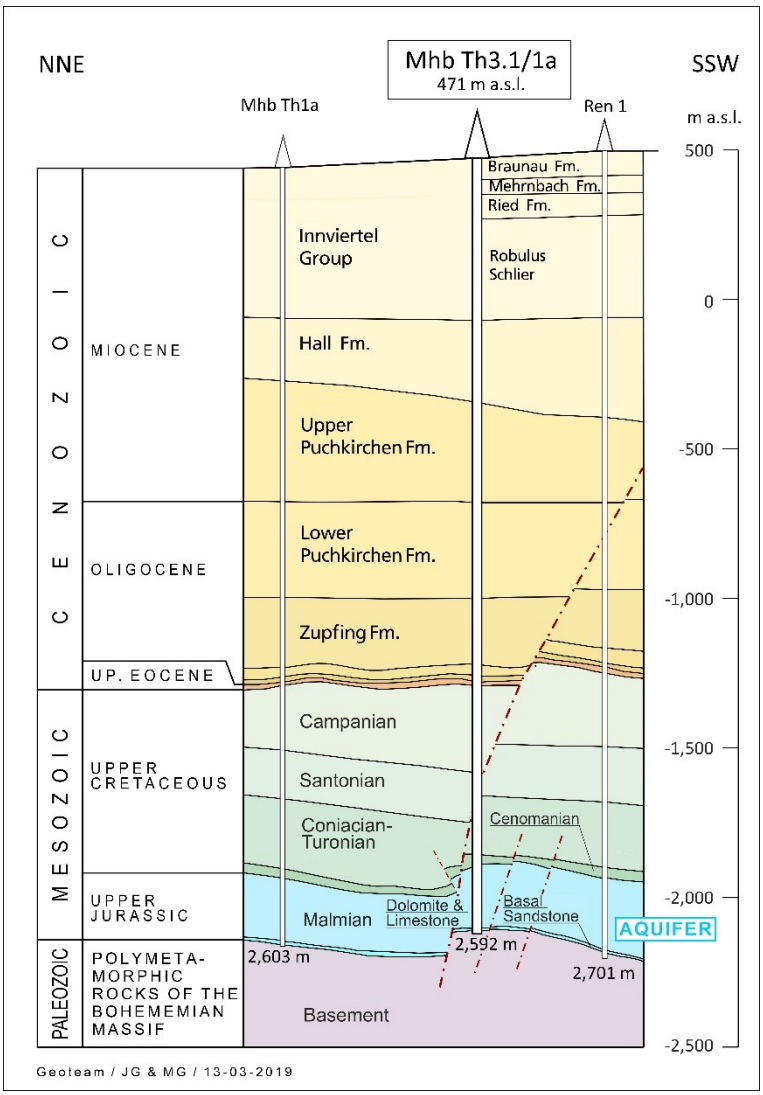


Figure 6: Geological Profile based on the wells Mehrnbach 1/1a (Mhb Th1a), Mehrnbach 3.1/3.1a (Mhb Th3.1/1a) and the abandoned hydrocarbon well Renging 1 (Ren 1).

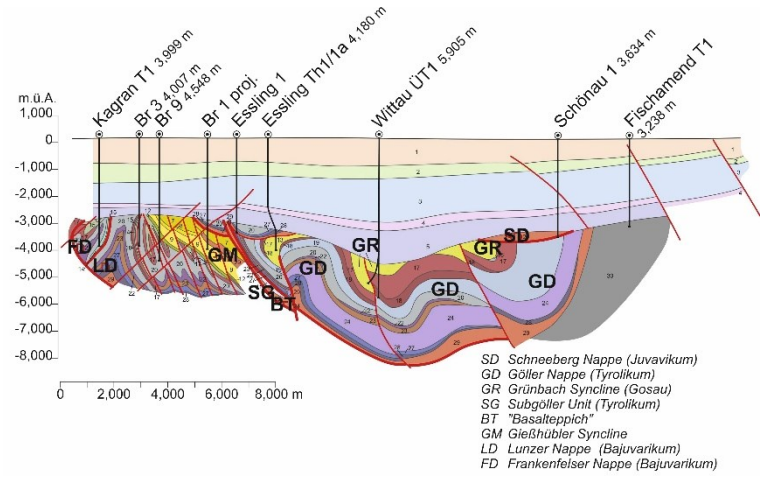


Figure 7: Geological profile displaying the position of well Aspern-Eßling Th 1 (Elster et al., 2016).

It became obvious that satisfactory resolution of the partially small-scale structures is only possible with 3D seismic surveys. A 3D seismic campaign has already been carried out, and the evaluation and creation of geological models is currently underway.

2.4 Styrian Basin

The approximately 4 km deep Neogene Styrian Basin, the westernmost margin basin of the Pannonian Basin System, is located at the southeastern border of the Alpine orogen. It has an elongated shape of about 100 km in length and 60 km in width and represents an extensional structure on top of a crustal wedge (Sachsenhofer, Sperl & Wagini, 1996). Geothermal gradients in the basin range from 3 K to 5 K/100 m, with the lower values being found in wells close to the recharge areas since it is here that convection masks the high heat flow caused by the high position of the mantle in the Pannonian realm.

By far the highest level of geothermal drilling has been witnessed in the Styrian basin (28 wells), with the majority of the wells focussing on balneology. These partially tap aquifers in the Neogene basin filling, whereas the geothermal projects target the Paleozoic carbonate rocks of the basin floor. Besides the eight spas and thermal resorts there are also three noteworthy geothermal projects in the area (see Figure 8 and Table 3). Bad Waltersdorf was the first geothermal project in Austria at the end of the 1980s and nowadays makes use of a multi-stage cascade involving heat pumps (see Figure 2). It is the only district heating project in Austria without reinjection. The geothermal project Bad Blumau comprises district heating, an ORC plant, balneology and liquification of CO_2 (Goldbrunner, 2005).

Table 3: Geothermal projects of the Styrian Basin.

Project	Use	Mass Flow [kg/s]	Tin [°C]	Tout [°C]	Capacity [MWth]
Sebersdorf/ Waltersdorf	B	2,5	33	20	0.1
Bad Waltersdorf	D, B, G	21.6	63	28	3.2
Bad Blumau	E, D, B	28.5	110	50	7.2
Frutura Project	G	56.3	124	45	18.6
Loipersdorf	B	3.9	61	30	0.5
Bad Radkersburg	B	4.9	70	30	0.8

B = balneology, D = district heating, G = greenhouse, E = power production.

The two deep wells for the Frutura greenhouse geothermal project were drilled in 2014 and targeted Paleozoic limestone rocks of the basin floor. Well Frutura GT 1 tapped the Paleozoic sequence in 2,800 m and opened 460 m of limestones and dolomites. As the results of pumping tests were not satisfactory, a side track (Fru GT 1a) was drilled based on the evaluation of borehole seismic measurements. Frutura GT 2 encountered the top of the Paleozoic sequence only marginally higher than in GT 1. As the deviation of GT 2 is higher than that of GT 1/1a, the drilled length or carbonate rocks, which are entirely dolomites, is 557 m. After testing it was decided to use GT 2 as production well and GT 1/1a for reinjection. As the gas/water ratio in GT 2 is as high as 12 : 1 the downhole centrifugal pump was installed at 900 m depth to prevent degassing during production, as draw down in the well is only 150 m. This makes it possible to produce 60 l/s of fluid at a well head temperature of 124.5 °C, currently making Frutura GT2 the hottest well in Austria. The portion of CO_2 in the gas is as high as 90 %.

The geothermal heating of the greenhouses started in 2016. The currently installed geothermal power is 18.6 MW, the glasshouse area was 17.5 ha in 2018, and the delivered heat amounted to 63 GWh. Upon project completion a total glasshouse area of some 24 ha. is foreseen. The vegetables cultivated are tomatoes, paprika and cucumber. They are sold exclusively on the Austrian market thus decreasing the need for imported vegetables, especially during winter. The use of carbon dioxide has not yet been installed but has been planned for the next phase of the project.

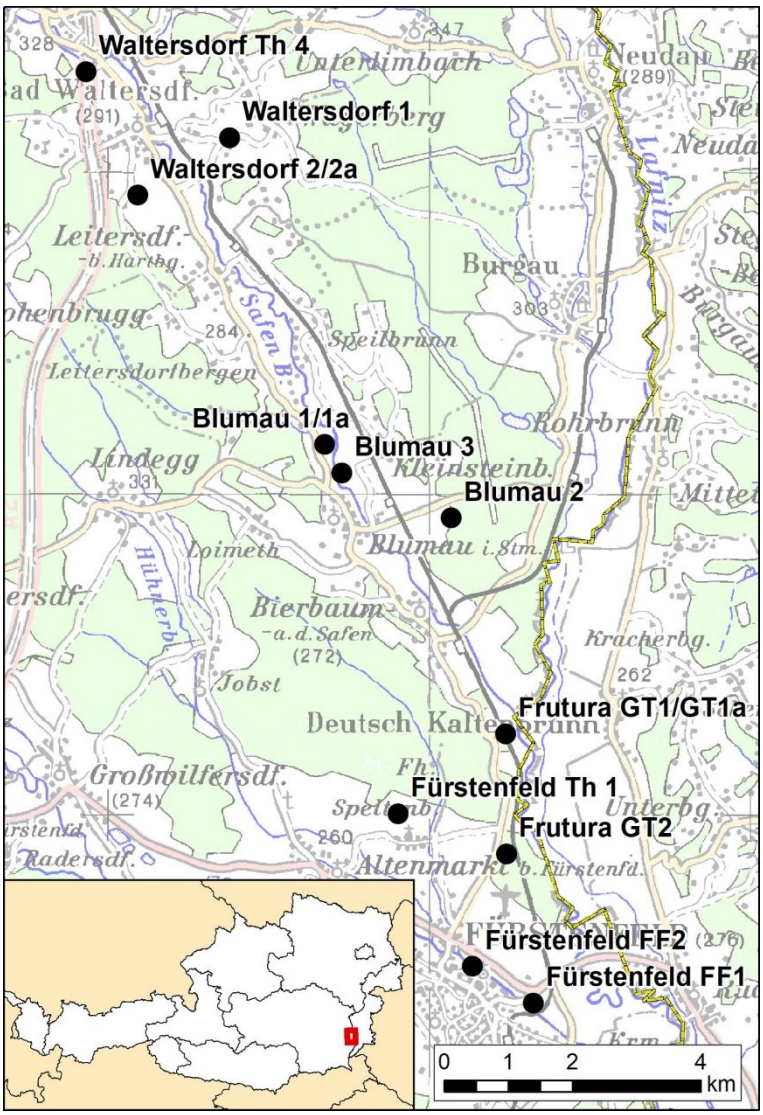


Figure. 8: Location of the geothermal boreholes of the projects Bad Waltersdorf, Bad Blumau, Frutura and Fürstenfeld (the latter currently not in operation).

2.5 Eastern Alps

There has been no drilling activity in the region of the eastern Alps since 2006. In general, it appears that market saturation has been reached in the existing balneological projects and that only small annual growth rates among spa visitors are now to be found.

In 2018 a well was sunk in Carinthia some 35 km NNE of the capital Klagenfurt. The private investor behind the drilling remained somewhat vague concerning the specific purpose of the hole, describing it generically as "energy production". This included potential exploitation of thermal water as well as that of hydrocarbons. The drilling was terminated at 2,865 m without success. The geological results remain unknown, but according to regional geological profiles, the major part of the drill hole is likely to lie in crystalline rocks.

3. SHALLOW GEOTHERMAL

The heat pump (HP) market in Austria is nowadays dominated by air-based systems. The data available for 2017 show that the share of air-based HPs in newly installed facilities was 72.5 % (Biermayr et al., 2018). The reasons for the steady increase in the number of air heat pumps since 2004 are manifold. Their relative ease of installation seems to be one major reason behind this accelerating trend. Further factors are the poor quality of drilling activities in various projects and the numerous bureaucratic barriers that have to be overcome. The total length of boreholes, at the end of 2014, for down hole heat exchangers was estimated to be 6.240 km (Goldbrunner, 2018).

Down hole heat exchangers can also operate in Alpine regions at high altitudes. One impressive example for this is the heating of a hotel complex at Obergurgl, Tyrol, at an altitude of 1,900 m. The average underground temperature is 4 –

5 °C, the average annual outside temperature 3 – 4 °C. For heating and DHW a heating capacity of 462 kW is required which is covered by 66 DHEs with an individual length of 120 m. Summer regeneration by solar panels was installed in order to cope with the relatively low underground temperatures (https://www.alpine-space.eu/projects/greta/deliverables/d3.3.1-annex-i-best-practices-examples. pdf).

The total installed thermal power of earth-coupled systems by the end of 2018 is estimated to be 1,000 MW. This figure is based on the 2016 estimate of 840 MW (Goldbrunner & Götzl, 2016) and on the assumption of an annual increase of 53 MW.

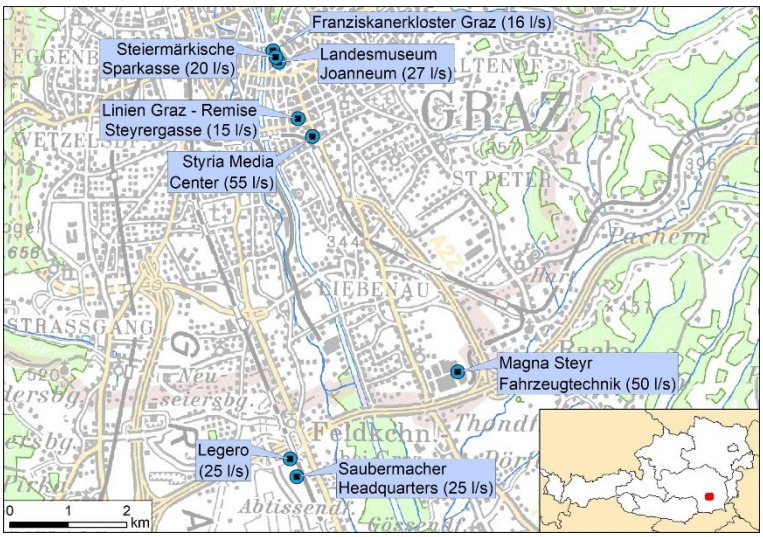


Figure 9: Location of large-scale water-water heat pump projects in the area of Graz.

Water-Water heat pumps play an important role in the energy supply of larger buildings, especially for cooling, which is becoming increasingly important. This is due to the effects of climate change as well as the excessive use of glass facades by architectural planners. Cooling with heat pumps leads to a noticeable warming of shallow groundwater. This effect is especially noticeable in areas with a high concentration of projects. One example is the city of Graz (Figure 9), the second largest city in Austria with nearly 290,000 inhabitants. With one exception, the installed heat pumps use the shallow groundwater of the Quaternary gravel-sand, characterized by high permeabilities and groundwater velocities. The total licensed circulation volume of all installations in Graz City is in the order of 230 l/s. the installed capacity for heating and cooling is 5.4 MW and 4 MW respectively. A general warming of groundwater of about 2 °C has been observed in recent years.

4. THE ROLE OF GEOTHERMAL ENERGY IN NATIONAL AUSTRIAN STRATEGIES

Despite wide-spread use of shallow geothermal energy and the exemplary effect of successful geothermal district heating projects, the role played by geothermal energy in Austrian climate and energy strategies remains insignificant.

The Austrian National Renewable Energy Action Plan (AT-NREAP 2010) proposed the following measures for supporting the market diffusion of geothermal energy: (1) Feed-in tariffs of at least 7.5 €cent/kWh, (2) investment incentives of up to 30% for CAPEX greater than € 35,000 as well as (3) the re-use of abandoned hydrocarbon wells. However, despite these proposals, the tariff of 7.5 €cent/kWh, which was seen as being far from comprehensive, was still reduced to 7.22 €cent/kWh in 2019 (BGBl. II Nr. 408/2017).

In 2018, the Austrian government defined a new strategy for climate mitigation and energy supply (#mission2030). Although no specific goal or role was defined for geothermal, the following aims of the strategy might be of relevance: (1) Expansion of heating grids linked to RES, (2) inclusion of storage into heating grids and use of waste heat, (3) re-use of abandoned hydrocarbon infrastructure.

Relating to this strategy, a national Energy- and Climate Action Plan for the period 2021 to 2030 is in preparation (BMNT, 2018). While it is believed that geothermal technologies may help contribute in areas such as subsurface heat storage and decarbonized heating and cooling, present policy statements remain far too vague such as to represent a real boost for geothermal energy.

5. CONCLUSIONS

Geothermal district heating remains the most important use for deep geothermal energy in Austria. Given compact utilization structures, projects such as those of Simbach-Braunau and Ried Mehrnbach can be economically successful. In areas where there is

a good match between prevailing deep geothermal resources and local energy needs, large-scale project implementation is quite realistic. This was found to be the case in the cities of Salzburg and Vienna.

It appears that regarding balneological usage, deep geothermal has more or less reached a saturation point and no new projects are to be expected. New wells will probably only be drilled at known sites, either for replacement purposes or for possible extensions.

Owing to the dominance of air-based systems in the market, future growth rates in earth-coupled heat pumps are likely to be quite moderate.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (Wind, Biomass, Photovoltaic)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2019	1.25	2.2	7,327	16,610	10,741	38,489.5	0	0	4,632	12,541.5	22,700.63	67,640.49
Under construction in December 2019												
Funds committed, but not yet under construction in December 2019												
Estimated total projected use by 2020												

TABLE 2. **UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2019**

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash
2F = Double Flash
3F = Triple Flash
D = Dry Steam
B = Binary (Rankine Cycle)
H = Hybrid (explain)
O = Other (please specify)

3) Electrical installed capacity in 2019

4) Electrical capacity actually up and running in 2019

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1)]	Type of Unit[2)]	Total Installed Capacity MWe[3)]	Total Running Capacity MWe[4)]	Annual Energy Produced 2019 GWh/yr	Total under Constr. or Planned MWe
Altheim	Altheim	2002	1		B-ORC	1.0	0.5	1.0	0
Bad Blumau	Blumau	2001	1		B-ORC	0.25	0.2	1.2	0
Total			2			1.25	0.7	2.2	0

TABLE 3.

1) H = Individual space heating (other than heat pumps)
D = District heating (other than heat pumps)
B = Bathing and swimming (including balneology)
G = Greenhouse and soil heating
O = Other (please specify by footnote)

2)

3) (MW = 10^6 W)

4) (TJ = 10^{12} J)

5)

Note: please report all numbers to three significant figures.

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (°C)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Simbach-Braunau	D	87.5	80	50			11.0	70	277.0	0.80
Altheim	D	71.6	105	70			10.5	60	277.0	0.84
Geinberg	D, B, G	48.5	103	30			14.8	40	385.1	0.82
Obernberg	D	19.4	80	55			2.0	12	39.6	0.62
St. Martin i. Innkreis	D	36.8	85	55			4.6	25	98.9	0.68
Ried/Mehrnbach	D	86.3	100	50			18.0	70	461.7	0.81
Haag am Hausruck	D	17.4	85	50			2.6	12	55.4	0.69
Schallerbach	B	15.9	38	20			1.2	12	28.5	0.76
Sebersdorf/Waltersdorf	B	2.5	33	20			0.1	2.5	4.3	1.0
Bad Waltersdorf	D, B, G	21.6	63	28			3.2	17	78.5	0.79
Bad Blumau	D, B	28.5	110	50			7.2	17	134.5	0.60
Frutura Project	G	56.3	124	45			18.6	40	416.8	0.71
Loipersdorf	B	3.9	61	30			0.5	3.9	15.9	1.0
Bad Radkersburg	B	4.9	70	30			0.8	4.9	25.9	1.0
TOTAL		501.1					95.1	386.3	2299.1	

TABLE 4. GEOTHERMAL (GROUND-SOURCE) HEAT PUMPS AS OF 31 DECEMBER 2019

This table should report thermal energy used (i.e. energy removed from the ground or water) and report separately heat rejected to the ground or water in the cooling mode. Cooling energy numbers will be used to calculate carbon offsets.

rejected to the ground in the cooling mode as this reduces the effect of global warming.

1) Report the average ground temperature for ground-coupled units or average well water or lake water temperature for water-source heat pumps

2) Report type of installation as follows: V = vertical ground coupled (TJ = 10^{12} J)
H = horizontal ground coupled
W = water source (well or lake water)
O = others (please describe)

3) Report the COP = (output thermal energy/input energy of compressor) for your climate - typically 3 to 4

4) Report the equivalent full load operating hours per year, or = capacity factor x 8760

5) Thermal energy (TJ/yr) = flow rate in loop (kg/s) x [(inlet temp. (°C) - outlet temp. (°C)] x 0.1319
or = rated output energy (kJ/hr) x [(COP - 1)/COP] x equivalent full load hours/yr

6) Cooling energy = rated output energy (kJ/hr) x [(EER - 1)/EER] x equivalent full load hours/yr

Note: please report all numbers to three significant figures
Due to room limitation, locality can be by regions within the country.

Locality	Ground or Water Temp. (°C)[1)]	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type[2)]	COP[3)]	Heating Equivalent Full Load Hr/Year[4)]	Thermal Energy Used[5)] (TJ/yr)	Cooling Energy[6)] (TJ/yr)
	no detailed information is available; the estimated installed capacity of shallow geothermal energy by the end of 2019 is 1,000 MW							
TOTAL								

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2019

[1] Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

[2] Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

[3] Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^{6} W)
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% capacity all year

[4] Other than heat pumps

[5] Includes drying or dehydration of grains, fruits and vegetables

[6] Excludes agricultural drying and dehydration

[7] Includes balneology

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]			
District Heating [4]	61.79	1517.18	0.78
Air Conditioning (Cooling)			
Greenhouse Heating	21.90	501.68	0.73
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	12.09	316.35	0.83
Other Uses (specify)			
Subtotal	95.78	2,335.21	
Geothermal Heat Pumps	1,000	6,309	0.2
TOTAL	1,095.78	8,644.21	

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2015 TO DECEMBER 31, 2019 (excluding heat pump wells)

1) Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)					
Production	>150° C					
	150-100° C		2			5.5
	<100° C					
Injection	(all)					
Total			2			5.5

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Programs
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	8	2	3	4		7
2016	8	2	3	4		7
2017	8	2	3	4		7
2018	8	2	3	4		7
2019	8	2	3	4		7
Total	40	10	15	20	0	35

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2019) US$

Period	Research & Development Incl. Surface Explor. & Exploration Drilling	Field Development Including Production Drilling & Surface Equipment	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	44.3	6	19	3	59	41
2000-2004	24.2	1.8	1.5		60	40
2005-2009	14.3	0.9	1.5	0.5	60	40
2010-2014	30.0	1.2	1.5		60	40
2015-2019	5.0	6.0	2.0		60	40