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Status and Development on Geothermal Energy Use in Belgium, a New Momentum for the Growth of Deep Geothermal Energy Production

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ABSTRACT

For decades, the use of geothermal energy in Belgium focussed mainly on shallow applications. In comparison with other Western European neighboring countries, shallow geothermal development started later and grew slower despite the introduction of multiple stimulation measures by local and federal government. However, the mandatory legislation on building energy performance and the obligation to use renewable energy sources stimulates sales numbers in the heat pump market. This gained momentum since the tightening of the obligated energy level in 2018. In that regard, air source heat pumps are still the most favorite type, but ground source heat pumps are gaining market share.

Concerning deep geothermal energy, for several decades there were only three geothermal projects in operation near Mons, Hainaut. Since 2010, new initiatives in Flanders and Wallonia were set up. In 2018, a first new deep geothermal project was brought into operation in Mol. It operates as a combined power and thermal energy installation with in first phase about 15 MW heat and 1,5 MW power. On long term this will be expanded to 5 MW power production. Almost simultaneously, the Walloon government launched an initiative with the aim for developing three pilot projects in the area of Charleroi and Mons.

This paper gives an overview of the status of shallow and deep geothermal energy applications in Belgium with figures on installed capacity and overall environmental benefits. A similar country update of 2019 is presented at the European Geothermal Congress 2019 (Lagrou et al., 2019).

1. INTRODUCTION

Beside coal, Belgium is a country with few or no underground natural resources such as oil, gas or valuable metals and minerals. On the other hand, the subsurface can play an important role in making our energy supply more sustainable. Geothermal energy can play a substantial role in the heating sector, which counts for 50% of the total use of energy. The federal government is negotiating a period within which heating of buildings can no longer be provided with fossil fuels. The use of heat pumps will therefore receive a huge boost, with geothermal energy playing an increasingly important role.

In Belgium, the largest potential for deep geothermal development is provided by sedimentary basins located in the Hainaut Basin in the South and Campine Basin in the North. The use of shallow geothermal systems is more developed in the northern part of the country (Flanders) than in the South (Wallonia), because of cheaper drilling costs and favourable legislation.

2. GEOLODY BACKGROUND, RESOURCES AND POTENTIAL

Belgium is a small country (in surface area) with a large variation in geology.

For the application of shallow geothermal energy, we look at the geological structure of the underground to a depth of about 200 m. There are sediments of quaternary/tertiary age in the north and mostly secondary/primary age in the south of the country. Here we see large variations with predominantly sand (northeast), clay (northwest), chalk and marl (east/center), shale/limestone/sandstone (south).

The sedimentary basins to the North (Campine basin) and South (Namur basin) of the Brabant Massif provide the largest potential for deep geothermal energy. The largest potential is localized in the thick sequences (up to 2000 m) of Devonian-Carboniferous platform carbonates in these basins. In Flanders, the Campine region is the most attractive area for deep geothermal extraction where Lower Carboniferous limestones are located at a depth of 1 to 6 km. In the Walloon region (in the Hainaut), Lower Carboniferous carbonates (at a depth of 1 to 3 km) and Middle Devonian limestones (at a min. depth of 4.5 km) are targeted.

In these basins the rocks have been partly faulted but slightly different processes have led to their high permeability and potential as geothermal reservoirs. In the western part of Campine basin sub-aerial exposure prior to Namurian sedimentary deposition led to widespread karstification along pre-existing fault zones and abundant collapse structures in the top tens of meters of the reservoir. In contrast to earlier geothermal wells in the Lower Carboniferous carbonates in the western part of the Campine Basin, the project in Mol did not aim for enhanced permeability in karst zones but was rather targeting fault and fracture zones (Broothaers et.al, 2020). In the Hainaut (western part of the Namur basin), rapid artesian fluid-flow pathways exist primarily along sedimentary breccia zones overlying the partially dissolved anhydrite interval of up to hundreds of meters between depths of 1350 and 2500 m.

Geothermal potential also exists in later clastic sedimentary formations. Westphalian (Upper Carboniferous) and Triassic sediments onlap the Brabant Massif in the Campine basin and Roer Valley Graben. These and a large proportion of the Brabant Massif are overlain by widespread and thick chalk deposits of the Cretaceous period.

The geothermal gradient is not well constrained in Belgium, however geothermal anomalies, except for a rapid increase in gradient in the Lower Carboniferous, are not apparent (apart from springs in the Chaudfontaine region). Nevertheless, the geothermal reservoirs described above have sufficient permeability at depth to allow for heat exploitation and possibly even electricity generation. However, more to the East in the Campine Basin (Mol area), it is important to drill to a permeable fault-zone to tap the geothermal water.

The presence of numerous coal mines in both Walloon and Campine basins could be an opportunity for future geothermal heating (and cooling) production, but also for deep geothermal reservoir exploration (Dupont et al. 2020).

3. GEOTHERMAL UTILIZATION

3.1 Deep geothermal project - Balmatt

In January 2016, VITO completed the geothermal exploration well MOL-GT-01 in Mol-Donk, northern Belgium (Bos et al. 2018). The well targeted a Lower Carboniferous fractured carbonate reservoir at a depth between 3000 and 3600 m. Reservoir temperatures encountered at the bottom of the well at 3600 m were 138 – 142°C and a well test proved the geothermal potential of the limestones. This led to the drilling of a second well to close the geothermal loop. Well MOL-GT-02 was completed and tested in summer 2016. Both wells will form a doublet that will deliver heat to an existing district heating network of VITO and surrounding companies. The geothermal plant also includes facilities for research on materials (corrosion testing and development of coatings) as well as test facilities for heat exchangers and binary systems. Next to the heat delivery, electricity production is foreseen using the Organic Rankine Cycle (ORC) technology. The initial thermal power output of the geothermal plant will only be about 8-9 MW since the return temperature is as high as 80°C, imposed by the existing high temperature heating grid already in place on the location. Connecting low temperature heating networks, that could go as low as 30°C, would double the thermal output. Regarding this addition of extra low temperature heating networks, VITO drilled a 3rd well in 2018, MOL-GT-03. MOL-GT-03 targeted the same faulted and fractured zone as MOL-GT-01, although now in a SE direction at 1.6 km distance to MOL-GT-01 and furthermore explored the potential of lower lying Devonian strata. Comparable reservoir characteristics were expected in MOL-GT-03, however, the results of the well test were lower than expected. To have a better understanding of the reservoir, a more detailed analysis was started, using data gathered from all three wells. The evaluation involves both structural, geological, petrographical and hydrogeological aspects (Broothaers et al. 2019; 2020). It should lead to a decision on which steps need to be taken to make MOL-GT-03 a successful well.

3.2 Deep geothermal project – Hainaut

In Wallonia, the use of deep geothermal energy is currently limited to the Mons-Borinage area, in the central part of Hainaut. Three heating networks operate using existing unique deep wells in Saint-Ghislain, Douvrain and Ghlin. These networks are managed and still developed by IDEA, the regional economic intermunicipality.

The geothermal potential of the deep Lower Carboniferous carbonate reservoir was discovered during the drilling of the Saint-Ghislain exploration well in 1976 (Delmer et al. 1982). The drilling of two additional geothermal wells was then conducted in 1980 and 1981 at Douvrain and Ghlin, respectively (Leclercq 1980 ; Delmer et al. 1982). These wells produce artesian geothermal water (~100 m³/h) from depths ranging between -1350 m (Douvrain) and -2500 m (Saint-Ghislain). Despite these different depths, encountered temperatures are quite similar : from 67°C in Douvrain to 73°C in Saint-Ghislain. Thermal-induced convection loops within the Lower Carboniferous reservoir would explain the behaviour of the geothermal gradient in this area (Licour 2014).

The Saint-Ghislain and Douvrain wells produce geothermal water for heating networks since 1985. This heating is provided to public building, such as hospitals, schools, swimming pool, etc. and to few hundreds of housings. Ultimately, the residual heat from the Saint-Ghislain network is send in the Wasmuël water treatment plant to stimulate fermentation process. More recently, a new economic activity area called “Geothermia” have been developed by IDEA nearby the Ghlin well, which provide its heating network since 2018. For now, the total geothermal capacity installed in the Hainaut is 17 MW_{th}, and 2018 production was 14.55 $GW_{th}h$/y.

3.3 Shallow geothermal projects

Belgium needs all possible shallow geothermal technologies as there is no one technology that can be applied in an economical feasible way for every location/application. Every type of geothermal system is applied, both open and closed, superficial and deeper, with water or air as energy transport medium. This is mainly caused by the very diverse geological structure with big local differences and rapid succession of different sediments. Price-wise, a shallow geothermal project will be more feasible in the North of the country. Partly because of this, the development of geothermal projects takes place at two speeds, with a clearly larger market and growth in Flanders and Brussels. Also, the regional governments have an impact on geothermal progress. Belgium has three administrative regions, each with its own and mutually very different licensing policy. There are also important regional differences in the stimulation of the building sector in the use of renewable energy systems.

After a hesitation in the elaboration of shallow geothermal energy systems in Belgium between 2014 and 2017, a clear revival can now be observed. In Flanders this is mainly due to the tightening of the E-level (max E40 from 2018) and the obligation to produce at least 15 kWh/m^2 renewable energy. This is also encouraged in Brussels where passive construction has been mandatory since 2015 with an obliged heat demand not exceeding 15 kWh/m^2. As a result, there is a boost in the use of heat pumps. Although air/water systems have the upper hand, more and more geothermal heat pumps are being installed.

In 2019, the price ratio of gas/electricity is unfavorable to realize large savings and short payback times, this still has an inhibitory effect. Nevertheless, shallow geothermal systems can attract more and more individuals/companies because they are invisible and completely silent. An even more important asset is the possibility of passive cooling, an important asset to guarantee good summer comfort.

4. DISCUSSION

A clear revival can be observed for shallow geothermal systems compared to the last country update (Loveless et al. 2015). In Flanders this is mainly due to the tightening of the E-level and the obligation to produce renewable energy. This is also encouraged in the Brussels area. As a result, there is a boost in the use of heat pumps. Although air/water systems have the upper hand, more and more geothermal heat pumps are being installed.

For several decades, Belgium had only one deep geothermal project in operation. Today, two deep geothermal projects are in production: (1) 3 heating networks using existing unique deep wells in the Hainaut basin and (2) a pilot project in the Campine Basin consisting of 3 deep wells (the Balmatt project) will deliver heat to company buildings in 2019.

Deep geothermal energy project permitting and insurance made several evolutions over the last decade. For northern Belgium (Flanders), the Flemish Decree of 8 May 2009 concerning the deep subsurface regulates the licensing for deep, i.e. deeper than 500 m, geothermal projects. It follows a two steps procedure with exploration and production licenses. Since the end of 2018 also an insurance system for geological risk is in place. Applicants for an exploration licence need to submit a complete application covering the necessary data and information, including a thorough geological study. The application is opened for fair competition for 90 days. The permit grants the exclusive right for a well-defined 3D-volume at depth to explore in detail how much heat might be produced and what are the boundary conditions. During the validity period of the exploration permit (default 5 years), a production plan is set up based on detailed reservoir data. This production plan needs to be validated before a production permit can be granted. Apart from the exploration / production permit, also an environmental permit is needed. To stimulate the investments in geothermal energy, which is characterized by high initial investment cost and high uncertainty risk, the Flemish government provides an insurance system for geological risk (VPO 2019). This covers the exploration risk, i.e. the short-term geological (uncertainty) risk. Long-term performance, technical fails and geohazards are not covered in the insurance. The maximum amount per project that can be covered is 18.7 MEUR. Only 85% of the eligible costs can be insured. A participation fee of 7% on this amount must be paid. The applicant must validate the expected thermal power (P90 value) by a set method and perform adequate testing to prove the outcome.

In southern Belgium (Wallonia), a regional guarantee system was adopted on 24 January 2019 by the Walloon government. The decree has two parts: 1) The regional geothermal guarantee scheme: the region covers the risk, based on the opinion of a technical committee and compensates if necessary; 2) The creation of a "geothermal guarantee" section in the Kyoto Fund, with a specific budget (to be provided during budget programming) used for compensation. To benefit from the compensation, investors contribute to the fund by paying a premium proportional to the cost of a project. The particularity of this regional guarantee is that the cost is linked to the first drilling of the doublet and covers almost all the investment before knowing if the resource reaches the expected level. The procedure to obtain a guarantee is as follows: a developer studies a project and evaluates the expected resource that could be exploited from the subsoil (thermal power). He applies for a guarantee with the Walloon government to benefit from the coverage. The technical committee (composed of the administration and scientific experts in geology and geothermal energy) validates the project based on the best scientific knowledge and recommends to the Walloon government to grant or not the guarantee (under conditions). The applicant who has obtained the guarantee pays a premium (a kind of insurance policy). Then, it carries out its first drilling and evaluates the real resource that will be exploited. If this is lower than the expected resource (in flow or temperature), he can submit a claim for compensation. The technical committee validates the actual resource and determines the actual amount of compensation to partially cover losses due to a less than expected resource. The legal framework of the deep geothermal energy should be evolving in 2019 with the adoption of a new decree for the underground resources management. This framework will consider deep geothermal energy as a strategic resource, such as fossil fuels and metallic substances. By this way, the achievement of this new policy should stimulate industrial investment in deep geothermal energy in Wallonia.

5. RESEARCH, FUTURE DEVELOPMENT AND INSTALLATIONS

5.1 Deep geothermal project – Porte de Nimy Mons

Thanks to European Regional Development Fund, a new geothermal plant will be implemented by IDEA in the city of Mons in the “Porte de Nimy” area, especially for the heating supply of the Ambroise Paré hospital. The drilling and completion of the geothermal doublet is planned in 2020, the geothermal plant building in 2021 and the heating network deployment in 2022. The expected thermal power is estimated to 7 MW and the thermal energy distributed should reach 10.5 to 14 GWh per year.

5.2 Research projects

Belgian scientists from different institutes and universities are involved in several ongoing geothermal research projects.

5.2.1 MORE-GEO project

The MORE-GEO project is supporting the “Porte de Nimy” deep geothermal doublet project and is also granted by the European Regional Development Fund.

This project, held by the University of Mons, wants to promote in a sustainable way the development of the deep geothermal resource of the Hainaut, especially of the Carboniferous carbonate reservoir (Licour 2014) already exploited by IDEA. It requires to limit the geological risk by improving the knowledge of the geothermal reservoir, but also to assess the economic risk by testing mid- and long-term realistic scenarios.

MORE-GEO is divided in three main parts: 1) the acquisition of new data from the deep geothermal reservoir; 2) the development of a hydrogeological model of the geothermal reservoir; 3) the test of exploitation scenarios within the hydrogeological model.

The new data shall provide from geophysical surveys (Martin et al. 2018) and from the drilling of the “Porte de Nimy” doublet. Five deep seismic reflection lines of about 100 km-length in total were acquired in this area in February and March 2019, from the French border to the East of Mons (Hainaut2019 survey). These lines spatially complete former seismic acquisitions in the area (2DMons2012 and Hainaut79) to explore the structure of the geothermal reservoir at a regional scale. During the summer of 2019, a gravimetric survey was carried out along the Hainaut2019 seismic lines, to support and complete the seismic data. In 2020, the drilling of the “Porte de Nimy” doublet will provide new deep geological data, which will allow to precise locally the structure and the properties of the geothermal reservoir.

The development of a hydrogeological model of the geothermal reservoir requires former geological data completed by the results of the new acquisitions. Before the set-up of a regional-scale model, a first model of the “Porte de Nimy” area has been built to model heat transfers and flows at the scale of the new geothermal doublet (Gonze et al. 2018).

After the completion of the regional-scale model, several realistic exploitation scenarios will be tested to evaluate the impact of varying geothermal energy production parameters, but also to assess the effects of the establishment of new geothermal doublets in the area. At the end, the use of this model will provide an efficient management tool of the deep geothermal resources of Hainaut.

5.2.2 MEET project

The main objective of MEET (2018-2021) is to capitalize on the exploitation of the widest range of fluid temperature in EGS (Enhanced geothermal systems) plants and abandoned oil wells. The aim is to demonstrate the lower cost of small-scale production of electricity and heat in wider areas with various geological environments, to support a large increase of geothermal based production sites in Europe in a near future. To boost the market penetration of geothermal power in Europe, MEET project main goal is to demonstrate the viability and sustainability of EGS with electric and thermal power generation in all kinds of geological settings with four main types of rocks: granitic (igneous intrusive), volcanic, sedimentary and metamorphic with various degrees of tectonic overprint by faulting and folding. MEET brings together 16 European partners: Industrials, small and medium enterprises, research institutes and universities, but also several geothermal demonstration sites in Europe located in the various geological environments described above. The assessment of the technical, economic and environmental feasibility of EGS is an integral part of the project, as well as the mapping of the main promising European sites where EGS can or should be implemented soon. Thus, MEET will provide a roadmap of next promising sites where demonstrated EGS solutions could be replicated in a near future for electricity and heat production with an evaluation of the technology and its economic feasibility and environmental positive impacts. For Belgium the possibility of re-opening the deepest well from Belgium, Havelange well (5648 m in depth), and its conversion in a geothermal well is studied.

5.2.3 DGE Rollout

The exploration of Deep Geothermal Energy (DGE) in most NWE regions requires specific expertise and technologies in the complex geological situations (strongly faulted high permeable carbonates and coarse clastic rocks) that could be found exemplary clear cross border in Germany, France, the Netherlands and Belgium. It is the objective of DGE-Rollout (2018-2022) to produce energy and reduce CO_2 emissions by replacing fossil fuels through increasing the usage of DGE in NWE for high-temperature heat supply of large-scale infrastructures to cover the energetic base load. This will be achieved by mapping and networking, by applying innovative decision and exploration strategies and testing for production optimization. Belgian exploration will be led by seismic surveys, 3 new profiles are scheduled in 2020-2021 totalizing about 100 km. In two pilots (Balmatt, BE; Bochum, DE) the production optimizing will be tested by implementing high temperature heat pumps and new cascading schemes from high (>100°C, big network) to low temperature (>50°C, single enterprise) and gain a CO_2 reduction of 25.000 tons/year. By realizing further plants in DE, FR, BE, NL this could reach up to 215.225 t/y until 2023. 10 years after project’s end at least 1.000.000 t/y will be achieved, but it is expected to reach up to 5.000.000 t/y in the long run. Further activities will apply innovative decision and exploration strategies that are cheaper, risks minimizing, more reliable and see a 3D Atlas of the complex geological situation as the spatial basis usable for DGE. To set the stage for DGE tools to increase social acceptance will be checked out, (planning) legal conditions as well as business models for enterprises will be evaluated and compiled, a network “NWE-DGE” will be set up to sustain the outputs and investments in the long-term roll-out after the end of the project.

5.2.4 Brugeo project: shallow geothermal resource assessment (Brussels)

In Brussels, the Brugeo project (2016-2020) receives ERDF funding from the Brussels-Capital region and the European Union. The project's goal is to promote geothermics in the Brussels area, especially shallow geothermal installations with a heat pump. The geothermal energy has significant development potential in this urban area despite a lack of accurate geological and hydrogeological data.. The geothermal potential of Tertiary sediments over the first 40 to 120 m is relatively well known. The exploration phase of the project focused his interest to the probable geothermal potential of the Paleozoic rocks encountered at greater depths (from about 40 m depth). An exploration drilling at Anderlecht was conducted in 2018 by the Geological Survey of Belgium (Brugeo member) and demonstrated the high potential (productive water flows, high thermal properties of the Cambrian sandstone and quartzites). This promising result has encouraged the private sector to realize the first open system in the Brussels Paleozoic basement. This pilot-project of 10 wells (150 m - 200 m depth) started end of summer 2018. The installation will provide 1396 kW to partly heat the 45,000 m^2 of the covered town of the Gare Maritime (Extensa project). The Brugeo consortium planned to provide the Brussels geothermal potential maps for beginning of 2020 and to strongly increase the communication towards the public to foster the use of shallow geothermal energy in the coming years.

5.2.5 Assessment of the geothermal potential of the old mines of Wallonia

A one-year project has been launched in February 2019 by the Directorate of the sustainable energy promotion of the Walloon administration (SPW-DGO4) to evaluate the geothermal potential of the Walloon old mines. The interest for this technique in Wallonia has been recently increasing, as shown by recent master thesis reports (Gonze 2017, Vopat 2017).

After a European benchmarking of the mine water geothermal energy use, the consortium formed by VITO, University of Mons, ABO-Group and Mijnwater B.V. will identify and assess favorable old mine sites in Wallonia and determine the feasibility of surrounding heating networks next to these sites. The project also contains the realization of a business plan for a pilot project and the submission of an action plan to promote this technique in Wallonia.

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TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		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	0.2	0.5	6,825	21,300	0	0	5,926	27,300	8,733	9,800	22,100	62,100
Under construction in December 2019	0.6	1.5										
Funds committed, but not yet under construction in December 2019												
Estimated total projected use by 2020	0.8	2.0										

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

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
Mol	Balmatt	2019	1		B	0.25	0.1	0.01	0.6
Total						0.25	0.10	0.01	0.60

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2019 (other than heat pumps)

1) I = Industrial process heat | H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling) | D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables) | B = Bathing and swimming (including balneology)
F = Fish farming | G = Greenhouse and soil heating
K = Animal farming | O = Other (please specify by footnote)
S = Snow melting

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (°C) - outlet temp. (°C)] x 0.004184 (MW = 10^6 W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) 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

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less, since projects do not operate at 100% of capacity all year.

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)
Saint-Ghislain		D, O	27.2	72.5	30			4.839	21.8	122	0.8
Douvrain		D	26.4	66	40			2.873	20	70	0.77
Geothermia	Ghlin	D	27.8	71	35			4.186	20	103	0.78
Balmatt	Mol	D	40	120	65			9.2	20	145	0.5
TOTAL								21.098	81.8	440	

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 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: (TJ = 10^{12} J)
V = vertical ground coupled
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)
Belgium	12	8	22738	V	4.4	1310	662.891	5.457
Belgium	12	8	4076	H	3.8	1310	113.311	0.000
Belgium	12	10	1359	W	4.7	1310	50.454	2.039
Belgium	12	80	414	V	4.2	1230	111.737	67.068
Belgium	12	120	195	W	4.5	1360	89.107	47.385
TOTAL			28782				1027.501	121.949

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 0.004
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
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
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]	19.978	411.27	0.683
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]			
Other Uses (specify)	1.12	28.73	0.81
Subtotal	21.098	440	0.7125
Geothermal Heat Pumps	284.622	1027.501	0.114
TOTAL			

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)			1		3.6
Production	>150° C					
	150-100° C			1		4.2
	<100° C					
Injection	(all)			1		3.8
Total				3		

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 Prograr
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	11	5	6	6	1	185
2016	12	5	6	6	1	195
2017	12	6	6	7	1	210
2018	12	7	6	7	1	230
2019	13	7	6	7	1	260
Total	60		30	33	1	1,080

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

Period	Research & Development Incl. Surface Explor. & Exploration	Field Development Including Production Drilling & Surface	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999						
2000-2004						
2005-2009	0.26					
2010-2014	14.42	2.7			4	96
2015-2019	8.5	30	2	1.25	80	20