Geothermal Energy Use, Country Update for Belgium

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ABSTRACT

The development and production of geothermal energy in Belgium remains very low compared to other renewable energies. Although shallow geothermal systems represent the major part of the sector in Belgium, the potential of deep geothermal energy is important but still little used. Only four geothermal plants are currently operational and supply heating networks (Saint-Ghislain, Douvrain, Ghlin, Balmatt) and a fifth is under construction (Beerse). Other projects are currently under investigation in Flanders (Turnhout, Herentals and Lommel).

Besides deep and shallow geothermal systems, the geothermal potential of abandoned coal mines of Wallonia has recently been evaluated. Its potential to produce heat and cold (as well as for the storage of thermal energy) is very promising and has encouraged the funding of feasibility studies for pilot projects in this region.

In the scope of speeding up the energy transition, the policies of the different regions continue to support both shallow and deep geothermal projects, through subsidies for research and/or project development and by updating some regulatory constraints.

Belgian scientists from different institutes and universities are involved in several ongoing geothermal research projects, which are briefly introduced in this paper.

1. INTRODUCTION

In Belgium, geothermal energy is mainly produced from shallow systems, although there is a significant but as yet undefined potential for deep geothermal energy.

Shallow geothermal energy is strongly established in the northern part of the country (Flanders), in particular due to the existence of a thicker soft cover (clays, sands) above the Paleozoic bedrock. It is very difficult to evaluate the number of shallow geothermal systems installed in Belgium as well as their capacity. No public organization centralizes this information and the data collected via the professional federations are not exhaustive.

Deep geothermal energy remains fairly marginal but continues to develop from the Dinantian limestone reservoir, present in both Flanders and Wallonia (Figure 1). This reservoir is currently used for heat extraction only.

In Wallonia, deep geothermal energy has been produced for several decades in Hainaut (SW Belgium) by the intermunicipal association IDEA, from three single wells supplying heating networks. These three wells are those at Saint-Ghislain, Douvrain and Ghlin (Figure 1), drilled between 1973 and 1981. The targeted reservoir is that of the Dinantian carbonates. In this area, this reservoir is very thick (>2 km thick) and contains highly permeable levels with karstified zones and brecciated levels. The water produced from these three wells has a temperature of around 70 °C and its salt content is fairly low (1 to 2 g/l), although the wells have reached the productive levels at different depths (1.5 to 2.5 km deep).

2. POLICY DEVELOPMENT FOR GEOTHERMAL ENERGY

2.1 Policy development in 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. These grant the exclusive rights for exploration of and production from a well-defined 3D volume in the subsurface, respectively. The standard validity period of the exploration permit is 5 years, allowing the operator to drill and test wells, and to come up with a production plan, which is required for a production license. Apart from the exploration / production permit, also an environmental permit is needed.

Since the end of 2018 an insurance system for geological risk is in place. The aim of this insurance

system is to should help stimulate investments in deep geothermal energy, which is characterized by high initial investment cost and high uncertainty risk. The insurance covers the geological or exploration risk only. This helps stimulating new projects in Flanders.

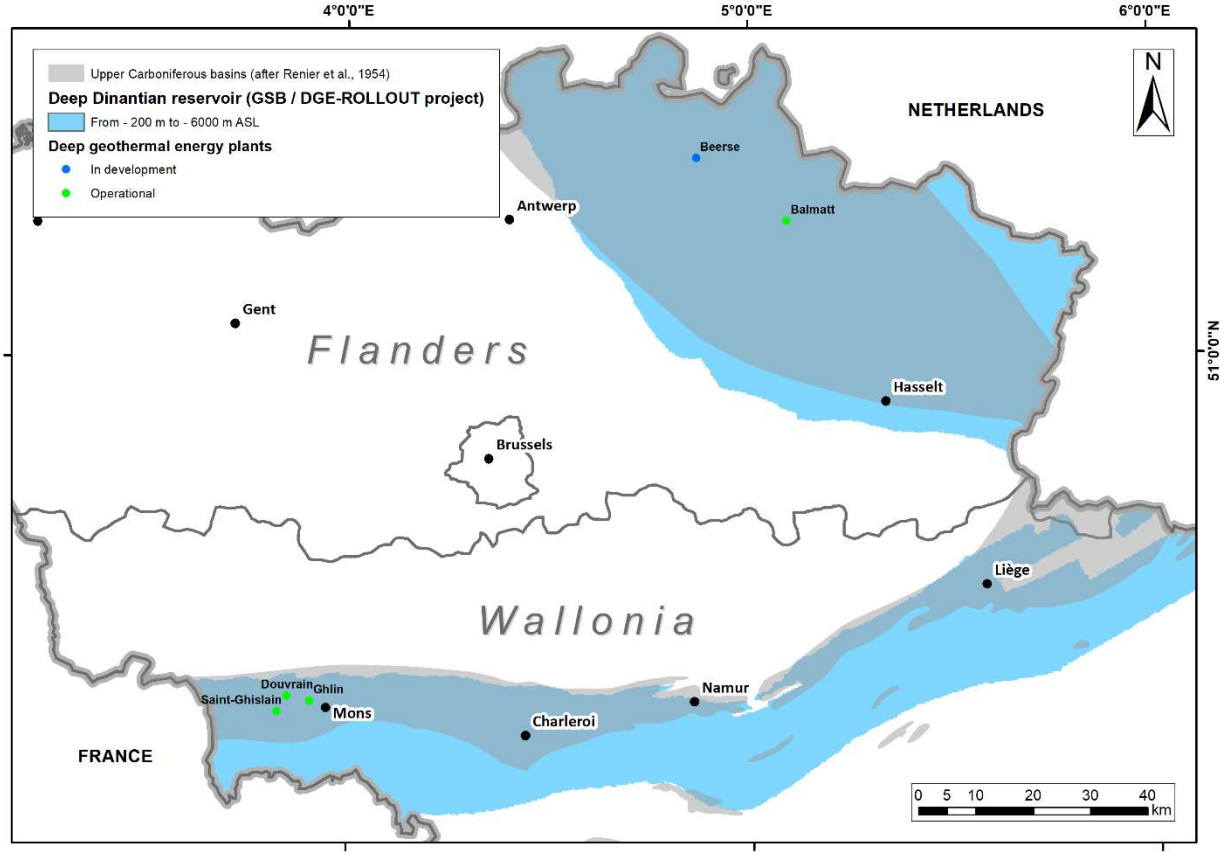

Figure 1: Situation of the Upper Carboniferous basins and the deep Dinantian reservoir in Belgium

2.2 Policy development in Wallonia

According to the latest version of its "Air Climate Energy Plan" ("PACE 2030"), the Walloon Region intended to reach a 23.5% share of renewable energy of the final gross energy consumption by 2030. A new PACE 2030 should be prepared by the end of 2022 and will highlight ambitious goals for geothermal energy following the RePowerEU plan.

In March 2021, the Energy Efficiency Directive (2012/27/EU- ART.14) concerning the strategy for heating and cooling networks powered by cogeneration, waste energy or renewable energy sources was adopted by the Walloon Government (WG).

In March 2022, the final Walloon recovery plan (joint proposal from WG members) was adopted to determine the prioritization of the recovery plan projects. In its third priority, an action program called "Strengthening energy independence and energy transition" (including 6 projects and 1 portfolio), one of the 6 projects is "Support deep geothermal energy and geothermal mining in the Walloon Region" for which a total fund of 25.5 M€ will be devoted.

The regional guarantee system for deep geothermal projects introduced in the previous country update (Lagrou et al., 2019) proposed by WG did not succeed. Nevertheless, this proposal was kept as a major recommendation for the deep geothermal sector deployment in Wallonia.

A shallow geothermal call for projects was launched in spring 2021 with a budget of 7.5M€ (Kyoto Funds and the Walloon recovery plan funds). The call aimed at directly supporting shallow geothermal open and closed projects (≤500 m depth) as well as pilot geothermal mining projects (<1200 m depth). In view of the large number of applicants (18) to the first call, the Walloon Government reiterated this call for shallow and mining projects in July 2022 with a new budget of 22 M€.

The new subsoil decree mentioned in Lagrou et al. (2019) is still under adoption procedure. It will regulate the underground resources exploration and extraction in Wallonia. Within this new regulation, deep geothermal is defined as "*renewable energy whose set of processes allow the extraction of geothermal energy and its recovery, whether thermal or electrical. It is the energy stored in the form of heat under the surface of the solid earth, at depths greater than five hundred meters*". This subsoil decree will detail deep geothermal energy exploration and extraction conditions (with exclusive permits principle) and should be implemented by mid-2023.

For shallow open systems (ATES), some changes in environmental permit classes (especially for the water reinjection) are under evaluation to facilitate the installation of such kind of technology (only one ATES system is currently set up, in the Liège area).

2.3 Policy development in Brussels

Early November 2018, the Brussels Government approved a decree regulating groundwater abstraction and geothermal systems in open circuit. This text was in application in 2019. At the Brussels administration in charge of geothermal energy (*Bruxelles Environment, BE*), about 100 geothermal systems are currently listed in their database (with 17 open systems already permitted or under permitting procedure). Because it was not mandatory to declare closed-loops systems before 2018, it is still complicated to get a proper estimation of installed systems. Thanks to the Brugeo project (ERDF-Brussels funding), the main geoscientific information on Brussels geology, shallow geothermal potential and existing systems is now available through the webtool called BrugeoTool (https://geodata.environnement.brussels/client/brugeotool/home). A clear increase of permit requests was observed since 2019 for various projects: single houses, residential buildings, office buildings, schools, municipality, university, shopping centre, museum. Among them, 12 open systems are installed or in preparation mainly using the Cambrian bedrock as resource.

The short and medium perspectives for the Brussels administration are:

- Agree on a driller certification valid in the two other Belgian regions (2023);
- Set up a dedicated legal framework for closed-loop systems (early 2024);
- Adapt regulations for open systems (some changes are already in place since few months, e.g. a monitoring piezometer must be installed for every open system) (early 2024);
- Put policy measures in place to reach Renewable Energy goals by 2030 in accordance to the results of the large study on thermal energy carriers (benchmarking on renewable heat solutions).

3. DEEP GEOTHERMAL PROJECTS IN FLANDERS

3.1 Operational projects

After a period of suspension of 22 months (July 2019 – April 2021), test operations were started up again at the Balmatt geothermal site in Mol. In the meantime, a number of changes and improvements were made to the geothermal installations in order to cope with the challenges identified during well testing and during the first start-up phase in 2018-2019 (Broothaers et al., 2021). In parallel, the seismic monitoring network was extended.

Between April 2021 and April 2022, nine test phases were carried out, with gradually increasing duration, flow rate and injection pressure (Broothaers et al., 2022). The longest test phase lasted for 4½ months, from November 2021 to April 2022. The connection to the heating grid was reinstalled in August 2021, allowing heat to be delivered to the buildings of VITO and SCK/CEN. Further tests are planned in the coming months.

3.2 Projects under development

Janssen Pharmaceutica has been developing a geothermal plant on their research campus in Beerse (Figure 1). The project targeted permeable zones in the Carboniferous Limestone Group. The first well (Beerse-GT-01) was spudded in December 2019 and drilled to a total depth of 2'725 m MD (2'052 m TVD). This well is intended for injection. A second well (Beerse-GT-01) was spudded in February 2020 and reached a total depth of 2'558 m MD (2'235 m TVD). An extended well test (circulation test) was carried out in the summer of 2020. Positive results were communicated in December 2020, mentioning a production temperature up to 85 °C. Since then, Janssen Pharmaceutica has been working on the surface installations and heating network and intends to bring the geothermal system into operation in fall of 2022. The aim is to reduce CO_2 emissions by 30 %.

3.3 Projects under investigation

The geothermal development company HITA started with the development of three projects in the Campine Basin since 2020. They carried out three seismic surveys to explore the subsurface at selected project locations in Turnhout, Herentals and Lommel. These surveys were initially set up as 2.5D, but processing allowed to come up with a full 3D result. In all three cases, the seismic data were used to construct a 3D static geologic model.

A first survey was carried out in May 2020 on the northwestern side of Turnhout, in the vicinity of the hospital of AZ Sint-Jozef. This project targets the Carboniferous Limestone Group at a depth between 2'000 and 2'500 m, allowing a temperature around 90-100 °C. The resulting geological model served as input for a dynamic model to simulate several scenarios with varying reservoir properties and operational parameters. The goal of the simulations is to evaluate the pressure and temperature impact in the reservoir around the wells. They also provide insights for well planning, the potential output of the geothermal site, and the required license area/volume. For the Turnhout project, the results were subsequently used to apply for an exploration license in the area, which is currently under review by the Flemish authorities.

A second project was initiated in the fall of 2020 with a survey in the area between Herentals and Olen. This project also targets the Carboniferous Limestone Group, and the results indicate it is present at a depth varying between 1'500 and 2'000 m. A temperature around 80 °C is expected. As for the project in Turnhout, dynamic reservoir simulations were performed based on the static geological model. The project will initially focus on delivering heat to a nearby

horticultural area and existing as well as new dwellings in the city of Herentals.

Finally, a third survey was executed in the summer of 2021 in the industrial area of Maatheide in Lommel. The latter tied into a regional 2D survey carried out in 2020 on behalf of VITO in the framework of the Interreg NWE project DGE-ROLLOUT. This allowed exploring the wider area and connecting to existing seismic data and deep geothermal wells in Mol and Dessel. In addition to the Carboniferous Limestone Group, the project in Lommel also targets shallower geothermal reservoirs as the sandstone of the Triassic Buntsandstein Formation or the Upper Carboniferous Neeroeteren Formation. The geological modelling reveals the Buntsandstein Formation is present between 1'000 and 1'300 m depth, where an average temperature of 50 °C is expected. The underlying Neeroeteren Formation may bring the combined thickness of the sandstone interval to 500 m, with a temperature at the base around 65 °C. The Carboniferous Limestone Group is expected at around 4'000 m depth (>150 °C).

4. GEOTHERMAL PROJECTS IN WALLONIA

4.1 Introduction

In Hainaut (SW Belgium), deep geothermal energy is a locally proven resource for heating applications. This resource is under-exploited and the infrastructures that currently exploit it are ageing. However, the development of new projects is struggling to emerge despite the climatic challenges and the local heating needs linked to the population density and the quality of the existing buildings. To encourage the development of new projects in this region, the study of the Dinantian limestone reservoir continues, both for its structure and its hydrogeological characteristics (MORE-GEO project).

Elsewhere in Wallonia, the Dinantian limestone reservoir remains the main target for deep geothermal energy. The global study of this reservoir on the scale of North-Western Europe has been conducted through the DGE-ROLLOUT project (see chapter 6).

The Mijnwater pilot experiment in Heerlen (Netherlands) has shown the value that flooded old coal mines could have for energy production, especially for 5th generation district heating and cooling systems (Boesten et al., 2019). The development of this resource also deserves to be supported in the Walloon Upper Carboniferous coal basin (Figure 1). Therefore, a first study of the potential of geothermal energy from mine water was conducted in 2019-2020 (Harcouët-Menou et al., 2020).

Finally, both the Walloon old mines and the Dinantian limestones of Hainaut are part of the reservoirs on which the DESIGNATE project is evaluating scenarios for the development of deep geothermal projects in Belgium, beside the Dinantian limestones and Cretaceous chalks of Campine in Flanders.

4.2 MORE-GEO

The MORE-GEO project, led by University of Mons, had begun in 2017 and was introduced in the previous Country Update (Lagrou et al., 2019). Despite the abandonment of the "Porte de Nimy" deep geothermal doublet in Mons, this ERDF project continues and focussed on 1) the acquisition and interpretation of data to refine the structure and characteristics of the reservoir and 2) the design of a geothermal resource management tool to promote the implementation of new projects in the region.

The Hainaut2019 2D seismic survey was conducted in the first quarter of 2019. It is composed of 5 north-south profiles of about 20 km each, positioned to supplement the acquisitions of the Mons2012 survey. The global interpretation of the results makes it possible to distinguish two main compartments in the Dinantian reservoir, separated by an important synsedimentary structure: 1) a very thick reservoir, sloping southwards (cf. Saint-Ghislain well) and 2) a thinner and subhorizontal reservoir (cf. Jeumont-Marpent well in France) (Dupont, 2021). Together with direct data, these results have allowed to propose a new geometric model of the Dinantian reservoir (Dupont, 2021) and a delineation of inferred high-transmissivity zones within the reservoir (Dupont et al., 2021a). In addition, the geophysical interpretations led to a revised definition of the Variscan front units in Hainaut (Dupont et al., 2021b)

Geological and hydrogeological modelling of the Dinantian reservoir is still ongoing, updating the various models with the new data acquired and interpretations proposed. These will form the basis for the resource management tools that will be developed over the coming months.

4.3 DESIGNATE

As partner of the DESIGNATE project, funded by the Belgian Science Policy, the University of Mons is developing hydrogeological modelling solutions for use in the simulation tool for geothermal energy exploitation scenarios. The reservoirs considered for Wallonia are the Dinantian limestones of Hainaut and the abandoned coal mines.

4.4 Minewater systems

Initiated and funded by the Walloon Administration, the assessment of the geothermal potential of the old mines of Wallonia has been completed in 2020 by a consortium composed of VITO, University of Mons, ABO-Group and Mijnwater BV. The potential has been calculated in the context of the implementation of a 5th generation network as implemented in Heerlen (NL) for the Mijnwater project. In this type of system, mining reservoirs can be used for heating, cooling and energy storage. The methodology used is based on proxies extracted from mining data such as minimum and maximum mining depths and the number of coal layers mined. A high spatial resolution (0.1 km) was chosen to map the potential at the neighbourhood level.

In order to serve as a decision support tool, a mapping of potential of projects similar to the Mijnwater project was made. In addition to mapping the potential, other tasks were carried out such as modelling a business plan for a pilot project in Wallonia and proposing an action plan to promote the sustainable development of this sector in Wallonia. The main results show that a significant potential exists in the region. Compared to the Mijnwater project and based on conservative assumptions on the state of the old Walloon mines, the total potential has been estimated to 1'690 GWh, which would represent 11 projects equivalent to that of Heerlen (Harcouët-Menou et al., 2020).

In order to develop this potential, the Walloon Administration has launched calls for projects in 2021 to study the feasibility of a pilot mining geothermal project for each of the three most interesting coal basins (Borinage, Charleroi, Liège). The results of these studies are expected in 2023.

4.5 GEOWAL

The Walloon government launch a 2 years-study in 2020 to assess the shallow geothermal potential of the region. VITO, ULiege, GSB, Deplasse and Geogreen worked together to produce technical potential maps which are combined with the economic potential at the surface (heat demand mainly). The project results for the potential evaluation for closed and open systems will be available in October 2022.

5. GEOTHERMAL PROJECTS IN BRUSSELS

In 2019, the Belgian Science Policy approved the project "GeoCamb : Geothermal Energy potential in Cambrian rocks focusing on public buildings" [1] which will run until 2024. The BRAIN-be 2.0 program (Belgian Research Action through Interdisciplinary Networks) funded a budget of 1 M€ for this project in order to support the sustainable exploitation of renewable natural resources and reduce CO_2 emissions. In Belgium, the heating sector counts for 48% of the total use of energy. In this respect, the GeoCamb project focuses on investigating the geothermal potential of the Cambrian basement of the Brabant Massif (BM) in Brussels and its surroundings in order to advise the potential transformation of the main heating source of public buildings. Geological, hydrogeological and geophysical explorations are ongoing in two public case studies and several win-win cases with external partners (Petitclerc, et al, 2019, 2020, 2021). The win-win approach consists of the execution of extra tests and analysis of the monitoring data of existing geothermal projects (both open and closed systems).

Today, the GeoCamb project can rely on 22 sites. In parallel of the geothermal reservoir evaluation, the energy demand of specific public buildings is incorporated in the case-studies to maximise the efficiency of the system. By providing a better knowledge of the Brabant Massif and by demonstrating the efficiency of geothermal systems, the GeoCamb research project will help reducing investment risk, allowing better planning of subsurface resources at policy level and in the end lead to a more secure, carbon-lean and affordable energy cost for the end-users.

6. TRANSNATIONAL GEOTHERMAL PROJECTS

The transnational EU Interreg North-West Europe funded project DGE-ROLLOUT ("Roll-out of Deep Geothermal Energy in North-West Europe") aims to promote the DGE potential of Lower Carboniferous carbonate rocks. The latter occur widespread in the NW European subsurface and are expected to represent a favourable reservoir for hydrothermal energy extraction as it is demonstrated in Belgium, where 3 wells are in exploitation since the 1980's in the Mons basin (Wallonia) and several more recent projects in the Campine basin (Flanders). The Rhenohercynian Basin is investigated following a multi-disciplinary approach. The DGE-ROLLOUT website [2] contains the reports of the different project deliverables.

Belgian exploration will be led by seismic surveys, 2 new profiles of 50 km are scheduled in autumn 2022. 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 CO2 reduction of 25'000 tons/year. 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.

7. CONCLUSIONS

Geothermal energy production remains relatively marginal in Belgium compared to other renewable energies (mainly wind and photovoltaic). Nevertheless, the development of this sector continues, especially for shallow geothermal energy, but also for deep geothermal energy. The development of a fifth deep geothermal plant is underway in Beerse and new projects are under development in Turnhout, Herentals and Lommel. In the meantime, several research projects

[1] https://www.belspo.be/belspo/brain2-be/project_p1_en.stm#GEOCAMB

[2] https://www.nweurope.eu/projects/project-search/dge-rollout-roll-out-of-deep-geothermal-energy-in-nwe/

aiming to precise the geothermal resource and the means to exploit it are underway.

Mining geothermal energy is of growing interest for the production of heat, cold, and for the storage of thermal energy. Its important potential, recently evaluated in Wallonia from the perspective of 5th generation heat network, has motivated the public funding of feasibility studies for the implementation of pilot projects in the most promising parts of the region (Borinage, Charleroi, Liège).

The policies of the different regions continue to support the sector for both shallow and deep geothermal projects, through subsidies for research and/or project development and by updating regulatory constraints.

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Tables A-G

Table A: Present and planned geothermal power plants, total numbers

There are no geothermal power plants in Belgium

Table B: Existing geothermal power plants, individual sites

There are no geothermal power plants in Belgium

Table C: Present and planned deep geothermal district heating (DH) plants and other uses for heating and cooling, total numbers

	Geothermal DH plants		Geothermal heat in agriculture and industry		Geothermal heat for buildings		Geothermal heat in balneology and other	
	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)	Capacity (MW_{th})	Production (GWh_{th}/yr)
In operation end of 2021	25-26	17.69	?	?	?	?	0	0
Under construction end 2021								
Total projected by 2023	33-37	60-100						
Total expected by 2028	50-60	400-450	10-15	?	?	?	0	0

* If 2020 numbers need to be used, please identify such numbers using an asterisk

Table D1: Existing geothermal district heating (DH) plants, individual sites

Locality	Plant Name	Year commissioned	CHP	Cooling	Geoth. capacity installed (MW_{th})	Total capacity installed (MW_{th})	2021 production (GWh_{th}/y)	Geoth. share in total prod. (%)
Saint-Ghislain	Saint-Ghislain	1985	N	N	6	6	13.13	100
Baudour	Douvrain	1985	N	N	4	4	2.86	100
Ghlin	Geothermia	2017	N	N	7	7	0.16	100
Mol	Balmatt	2018	N	N (RI)	8-9	n.a.	1.54	n.a.
total					25-26		17.69	

* If 2020 numbers need to be used, please identify such numbers using an asterisk

** If the geothermal heat used in the DH plant is also used for power production (either in parallel or as a first step with DH using the residual heat in the brine/water), please mark with Y (for yes) or N (for no) in this column.

*** If cold for space cooling in buildings or process cooling is provided from geothermal heat (e.g. by absorption chillers), please mark with Y (for yes) or N (for no) in this column. In case the plant applies re-injection, please indicate with (RI) in this column after Y or N.

Table E1: Shallow geothermal energy, geothermal pumps (GSHP)

The table could not be updated for 2020/2021.

Table F: Investment and Employment in geothermal energy

The table could not be updated for 2020/2021.

Table G: Incentives, Information, Education

	Geothermal electricity	Deep Geothermal for heating and cooling	Shallow geothermal
Financial Incentives – R&D	Yes, if appropriate in certain regional/federal research program	Yes, if appropriate in certain regional/federal research program	Yes, if appropriate in certain regional/federal research program
Financial Incentives – Investment	RC (only in Flanders and for geological/exploratory risk)	RC (only in Flanders and for geological/exploratory risk)	No, except a public call for projects funded for Wallonia
Financial Incentives – Operation/Production	No	No	No
Information activities – promotion for the public	No	Yes, as result of certain R&D projects	Yes, as result of certain R&D projects
Information activities – geological information	No	Yes, as result of certain R&D projects	Yes, as result of certain R&D projects
Education/Training – Academic	No	No	No
Education/Training – Vocational	No	No	Yes

Key for financial incentives:

DIS	Direct investment support	FIT	Feed-in tariff	-A	Add to FIT or FIP on case the amount is determined by auctioning
LIL	Low-interest loans	FIP	Feed-in premium		
RC	Risk coverage	REQ	Renewable Energy Quota	O	Other (please explain)