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Country Update for Belgium

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ABSTRACT

Belgium is located in the center of Europe, far from tectonic plate boundaries, volcanoes or other regions of high crustal heat flow. Despite this, over the last 10 years shallow and deep-medium enthalpy geothermal energy has experienced a slow but positive renaissance. Nevertheless, geothermal energy lags behind other renewable energy sources (RES), still making only a small contribution to a rapidly growing renewable energy sector. In this paper we provide an update on the status of the geothermal energy sector in Belgium, with a focus on the developments over the last 5 years. We also discuss the apparent barriers that currently inhibit the industry and the changes that are expected to pave the way for future expansion.

1. INTRODUCTION

Belgium is a small (30,500 km^2) and densely populated country (11.13 million in 2012 from The World Bank, 2014). It is highly industrialized, particularly in Flanders (in the North). Belgium is governed by a federal parliamentary democracy, the level at which international energy targets, and the important European Union 20-20-20 targets, are set. However, primary responsibility for legislation directly concerning geothermal energy (energy policy, nature and environment, business and research) lies with the three regional Governments of Flanders, Wallonia and Brussels.

The ambitious European 20-20-20 goals have played a key role in incentivizing the upward trend of RES (Renewable Energy Sources) and renewing interest in geothermal energy in Belgium. These targets require 13% of the total energy consumption in Belgium to be produced from RES in 2020. In 2011 RES comprised 5.3% of total energy consumption, but current estimates indicate this could be up to 31% in 2020 (Table 1). RES also provides an additional advantage to Belgium since they represent a domestically sourced energy supply in a country that is currently highly dependent on imported energy.

Table 1 Present and planned production of electricity in Belgium. Current and future energy use data compiled from Elia (2014a, b and c). Projected energy use from VITO internal figures.

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables		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 2014	0	0	4968	25068	1308	1278	5926	38393	8398	3692	20600	68431
Under construction in December 2014	0	0	1370	unkown	0	0	0	0	4954	unkown	6324	unkown
Funds committed, but not yet under construction in December 2014	0	0										
Estimated total projected use by 2020	10	66.9	6500	21435.3	117.6	334.7	4,187	33622.3	11067.2	25378.6	21,882	80837.75

The past five to ten years have seen a substantial investment and effort in shallow and medium-deep geothermal research and development (R and D) in Belgium (Table 8). The focus is now shifting towards growth for the shallow geothermal industry, and realization of the first projects for the deep geothermal industry.

Strict rules regarding the renewable energy share of new houses have had a positive impact on the number of GSHP (Ground Source Heat Pumps) being installed in Flanders. In contrast, legislative frameworks in relation to the prospection and exploitation of deep geothermal energy are lacking across the country, though official interpretations of current Flemish subsurface laws indicate that the community owns the deep heat and water (deeper than the depth a landowner can exploit on their own) (Table 2). Deep geothermal projects are currently assessed on a case by case basis but both Flanders and Wallonia are in the process of developing legal frameworks that will provide clarity for the industry and reduce some of the economic uncertainty associated with geothermal projects. This will include updating drilling regulations since there has historically been little need for deep boreholes in Belgium.

Table 2 Policy and legislation relevant to geothermal energy in the Regions of Belgium.

Region	Lead agencies	Legislation	R and D incentives	Investment	Operation and production
Flanders	Relevant agencies belong to the Flemish Ministry of Envirnoment, Nature and Energy (LNE): Flemish Energy Agency (VEA); Flemish Environment Agency (VMM); Flemish Environment, Nature and Resources Department (ALBON); Environmental Impact Service; Environmental Permitting; Gas and Market Regulator (VREG).	In 2013 the Felmish Parliament stated that according to existing laws, deep heat and water are owned "by the community". An official Decree is to be announced in 2014.	Projects from Flemish companies, research centres and organisations can receive financial support, advice and networking for innovative projects (technological or not) from IWT (Agency for Innovation by Science and Technology)	**Ecology Premium.** Grant subsidy for heat and electricity projects; up to 45% for financial support for SMEs for shallow geothermal projects and 35 % for large companies. Total available grant is 1 Mill Euro over 3 years.	**Green power certificates** (90 Euro/MWh for 15 years) (VREG)
		The Flemish Government is working on legislation specific to deep geothermal boreholes.		**Strategic Ecological Suppot.** Deep geothermal energy is eligible for the grant for green technology. The grant is tailor made but requires a minimum total project investment of 3 Million Euro.	
				Useful green heat support. For green heat projects > 1MW/hr. Up to 65 % of project costs for small enterprise, 55 % medium enterprise, and 45 % large company. Up to 1 million Euro per project as an investment. Applicable only if neither green power certificates or ecological support has been granted.	
Wallonia	Relevant agencies belong to the Walloon Ministry of Sustainable Development, Public Service, Energy, Housing and Research and the Ministry of Environment, Spatial Planing and Mobility.	The Walloon Governement is working on legislation adapted to deep geothermal energy.	Funding available for projects on a case by case basis.		**Green power certificates** 20 €/MWh
				Incentive frameworks being developed.	
Brussels	No information				

2. SHALLOW GEOTHERMAL ENERGY

2.1 Geological setting and shallow geothermal potential

The shallow geological setting in Belgium is highly diverse and therefore widely suitable to different GSHP applications. The shallow thermal conductivity has been mapped in Flanders as part of two ALBON projects (Hoes and Gysen 2004 and Robeyn et al. 2011) and more recently as part of the European-wide Thermomap (2013) project. Efforts are now underway by the Belgian Geological Survey to study heat transfer properties for the wider Belgium subsurface in order to improve shallow potential maps and to improve the design of borehole heat exchangers.

2.2 Shallow geothermal utilisation

GSHP comprise by far the greatest proportion of geothermal applications in Belgium (Table 3, 4 and 5). Many new medium to large buildings in the public sector are now equipped with GSHP. The total number of GSHP is expected to increase from 13,085 in 2010 to 22,613 in 2015, with total installed capacity increasing from 157 MWt to 218 MWt. The majority (estimated 80%) of applications are BTES (Borehole Thermal Energy Storage) systems, only 5% ATES (Aquifer Thermal Energy Storage) and the remaining 15% horizontal loop systems (Hoes et al. 2012).

Table 3 Utilisation of geothermal energy for direct heat as of 31 December 2014 (other than heat pumps).

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*	27.778	70	30	N/a	N/a	4.65	19.68	103.8	0.71
Douvrain (Baudour)	D	23.611	65	30	N/a	N/a	3.46	0.9	4.15	0.04
TOTAL		51.389					8.11	20.58	107.95	0.375

D is district heating, O is other – biogas production enhancement.

2.3 Shallow geothermal - discussion

The growth of the shallow geothermal industry over the last 5 years is reflected in and promoted by a growing number of associated SMEs. R and D and training of the workforce for shallow geothermal energy has resulted in the establishment of a growing shallow geothermal market. Regional, national and international programmes were designed to transfer skills and education within the sector and to identify technical and legislative best practice across Europe. Stronger market growth is hindered by weak financial support, which results in relatively high payback times, particularly important for residential buildings. Environmental permitting can also be a problem in certain regions of the country. The foreseen changes to legislation and policy should lead to stronger market growth in the coming years.

Table 4 Geothermal (ground-source) heat pumps as of 31 December 2014.

Locality	Ground or Water Temp. (°C)1)	Typical Heat Pump Rating or Capacity (kW)	Number of Units	Type2)	COP3)	Heating Equivalent Full Load Hr/Year4)	Thermal Energy Used (TJ/yr)	Cooling Energy (TJ/yr)
Belgium	12	8.5	15948	V	4.2	1425	529.8	1.22
Belgium	12	8.5	2990	H	3.8	1425	96.1	0
Belgium	12	8.5	997	W	4.5	1425	33.8	0.915
Belgium	12	95	199	V	4.1	1220	62.8	44.2
Belgium	12	125	83	W	4.4	1175	33.9	35.5
TOTAL			20217			6670	756.4	81.9

[1]Average ground, well water or lake water temperature. [2] V is vertical ground coupled, H is horizontal ground coupled, W is water source (well or lake). [3] Output thermal energy/input energy of compressor. [4] Equivalent full load operating hours per year. Figures are estimations compiled from ATTB (Association Thermal Technics Belgium), drilling and installation companies and governmental services for granting and permits therefore an error margin should be taken into account.

Table 5 Summary table of geothermal direct heat uses as of 31 December 2014.

Use	Installed Capacity1) (MWt)	Annual Energy Use2) (TJ/yr = 10^{12} J/yr)	Capacity Factor3)
Individual Space Heating4)			
District Heating 4)	7.526	94.987	0.38
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying5)			
Industrial Process Heat6)			
Snow Melting			
Bathing and Swimming7)			
Other Uses (specify)	0.581	12.977	0.71
Subtotal			
Geothermal Heat Pumps	198.7	756.4	0.1
TOTAL	206.8	864.4	0.4

"Other Uses" is for production of biogas.

3. DEEP GEOTHERMAL ENERGY

3.1 Geological setting and deep geothermal potential

The diversity of the Belgian subsurface results from a long (550 million years) series of tectonic events and sedimentary basin evolution. The Brabant Massif comprises a large part of Belgium (Figure 1 and 2). The upper part of the Brabant-Massif comprises lower Cambrian to late Silurian fine-grained clastic sediment that was strongly deformed during the Caledonian orogeny. It is generally considered that the deep geothermal potential of the Brabant Massif is small. The sedimentary basins to the northeast (Campine basin) and south (Namur-Dinant basin) of the Brabant Massif provide the greatest potential for deep geothermal energy (Figure 1 and 2). The recognized geothermal resources and hydrothermal processes observed in Belgium are localized in the thick sequences (up to 500 m) of Devono-Carboniferous platform carbonates in these basins, the primary geothermal target. However, the basins differ in structure and characteristics. The Campine basin is an intermediate basin between the Brabant Massif and the Roer Valley Graben (itself an eastward extension of the active Lower Rhine Graben) primarily within the Netherlands. 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 (Dreesen, 1985). The Namur-Dinant basin was affected by compressional tectonics of the Variscan Orogeny, leading to folded and faulted sequences. Anhydrite comprises an important part of the carbonate sequence (Vandenberghe, 1990). Rapid artesian fluid-flow pathways exist primarily along sedimentary breccia zones overlying the partially dissolved anhydrite interval, up to hundreds of meters in thickness (Vandenberghe, 1990), at depths between 1,350 and 2,500 m (Licour, 2012). Deep geothermal potential also exists in clastic Westphalian (Upper Carboniferous) and Meso-Cenozoic sedimentary formations overlying the Brabant Massif and carbonate sequences. Widespread Cretaceous chalks have medium-shallow geothermal potential across much of the north of Belgium. Deep geothermal targets have been mapped for a number of exploration and exploitation projects (Figure 2). The most recent project in the Campine basin, Flanders (Geoheat-APP, Interreg Vlaanderen-Nederland, 2014) better constrained the geothermal potential of four reservoir intervals across the border with the Netherlands. Much of the knowledge of the subsurface of Flanders is from extensive seismic surveys undertaken since the 1950s. In Wallonia the Belgian Geological Survey has also produced a map of geothermal interest areas (300 to 3,000 and 3,000 to 6,000 m) (report not publically available).

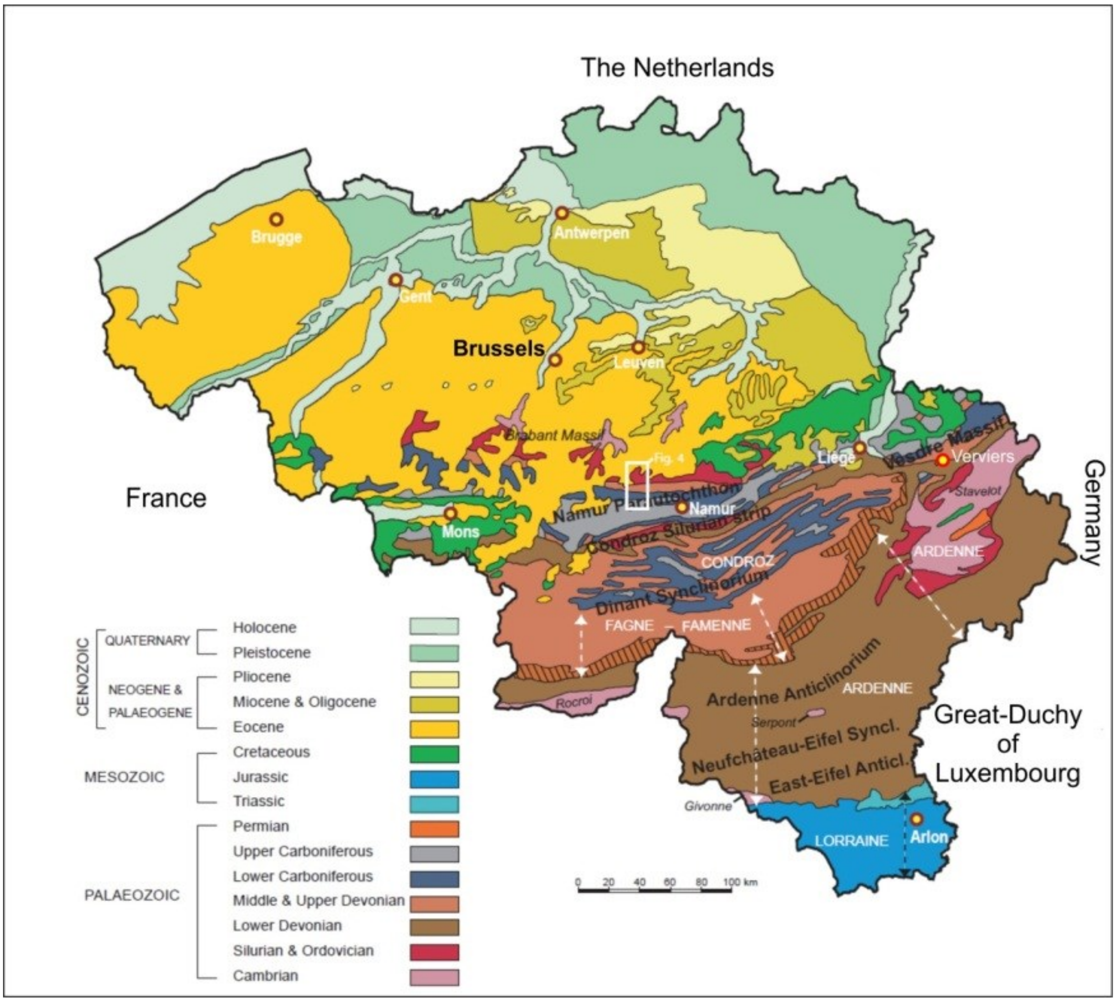

Figure 1 Geological map of Belgium. Lower Cambrian to late Silurian detrital rocks observed in inliers and along some rivers in Wallonia. The detrital and carbonate formations of Devonian and Carboniferous are observed mainly in Wallonia and were explored through former mining activities and boreholes in North-East Flanders (the Campine) and in Wallonia.

The geothermal gradient in Belgium is known only from 23 boreholes in Wallonia and 16 boreholes in Flanders though it is apparently spatially variable (both hot and cold anomalies) (Legrand, 1975; Vandenberghe, 1990). Nevertheless it is clear that there are no large-scale geothermal anomalies. The only warm springs (36°C) emerge in the Chaudfontaine region through a faulted karst system (Figure 2). However Licour (2012) found that natural convection occurs in the Dinant-Hainut basin resulting in a temperature increase at the top of the reservoir and the highest geothermal gradients in the region (up to 42.7°C/km). There also appears to be a rapid increase in geothermal gradient in the Lower Carboniferous in the Campine basin, though data is sparse. Nevertheless, the geothermal reservoirs described above have sufficient permeability at depth to allow for heat exploitation and possibly even electricity generation.

3.2 Deep geothermal utilisation

No new deep geothermal wells have been drilled in Belgium since the 1970s. The St-Ghislain and Douvrain wells in the Hainaut basin (Walloon region) have been providing public buildings with artesian waters of 73°C and 66°C respectively for heating and air conditioning respectively since the 1970s (Figure 2 and Table 5). In 2013 the Douvrain network was developed further and a new customer connected. In Saint-Ghislain a greenhouse and waste water treatment plant also benefit from the geothermal heat through a cascade system. The Ghlin well, Mons basin, also drilled in the 1970s, is now ready to provide water to a district heating network **(**4.65 MWth planned). All of these wells work as production wells, and water is discharged into a nearby river without any re-injection (Table 6).

In the 1970s and 80s three wells were drilled into the low temperature chalk reservoir in Flanders that were used for direct heating of swimming pools (Herentals and Turnhout) and a fish farm (Dessel). None of these wells remain in operation today. The Meer well was also drilled with the Dinantian limestones as a target, but this failed because the overlying Namurian strata thickened dramatically at this point, a fact previously unknown (Vandenberge 1990). A second attempt at this target was made in the Merkplaas-Beerse well for space and greenhouse heating; however flow rates were too low for re-injection into the Dinantian so a semi-doublet was made with re-injection into the chalk. Unfortunately this doublet never materialized as energy prices dropped too low to justify the surface investment (Vandenberge 1990).

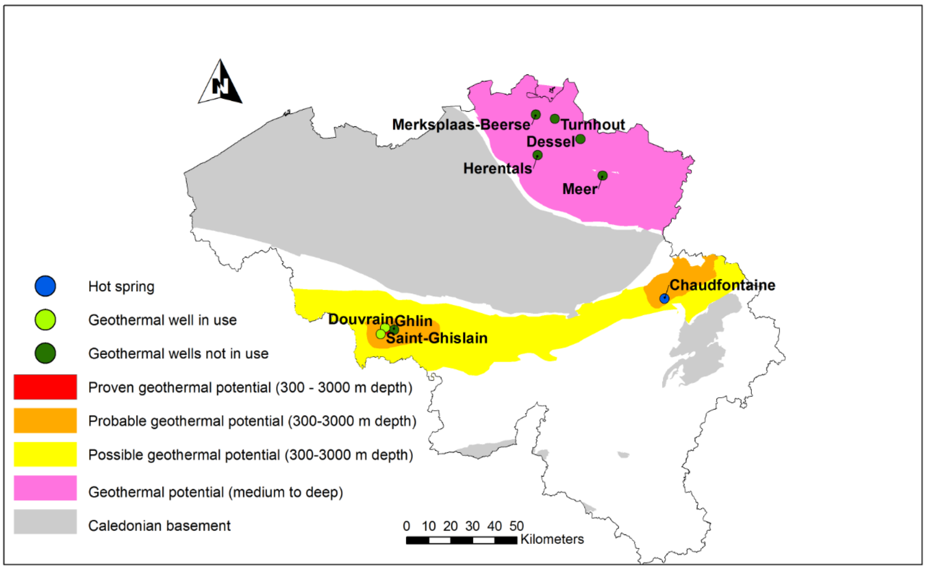

Figure 2 Medium to deep (300-3000 m) geothermal potential map of Belgium. Data from VITO and Geological Survey of Belgium.

Significantly, two major new projects are in progress today both in Flanders and Wallonia. The Balmatt project (Mol, immediately south of Dessel) targets Dinantian Limestones at a depth of 2.8 to 3.8 km (expected temperatures between 120 and 148°C). Up to five wells are planned in order to realize a combined heating and geothermal power production plant with a gross thermal output of up to 48 MW. The first well should be drilled within the coming year. The Wallonian government is supporting two pilot projects near the city of Mons. The first well, designed to provide heating for the station, also targets Dinantian limestones, at a depth of 2.5 km. The second well is for power production, targeting Middle Devonian Limestones at a depth of 4.5 to 5 km. These pilot studies will include assessment of the geothermal potential and identification of obstacles to the development of deep geothermal energy, with a suggested incentive framework. A number of spas in Wallonia also rely on geothermal waters but little is known about the origin. The springs at Chaudfontaine are not utilized for geothermal purposes (Vandenberghe, 1990).

Table 6 Wells drilled for electrical, direct and combined use.

Purpose	Wellhead Temperature	Number of Wells Drilled				Total Depth (km) (Average)
		Electric Power	Direct Use	Combined	Other (specify)	
Exploration[1)]	(all)	0	4	0		1348.75
Production	>150° C	0	0	0		
	150-100° C	0	0	0		
	<100° C	0	7	0		1035.43
Injection	(all)	0	1	0		
Total		0	12	0		1192.09

Table 7 Allocation of professional personnel to geothermal energy in Belgium (estimated).

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2010	7	4	1	0	0	96
2011	7	6	1	0	0	114
2012	7	7	1	0	0	122
2013	8	9	1	0	0	140
2014	9	10	1	0	0	166
Total	38	36	5	0	0	638

1) Government 2) Public utilities 3) Universities 4) Paid foreign consultants 5) Contributed through foreign aid programme 6) Private industry

Table 8 Total investments in geothermal in Belgium from 1995 to 2014 in 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		0.84				100.00
2000-2004						
2005-2009	0.28	0.76				100.00
2010-2015	15.52	4.20	0.61	0.00	4.17	95.83

3.3 Deep geothermal discussion

It is clear that despite being in an intra-continental setting large regions of Belgium have potential for deep and shallow geothermal energy. There is also a corresponding high demand for heat (space and industrial processes) and electricity. The plans for deep geothermal energy indicate that it is currently on the cusp of a take-off similar to shallow geothermal energy, subject to developments in legislation and incentives from the regional governments. In Flanders this has been recognized and precipitated by the Flemish Government as they are in the process of creating a Roadmap for the development of geothermal in Flanders.

The current investment and resulting jobs in deep geothermal research and development (Table 7 and 8) have focused on characterizing the sub-surface potential. Yet a great deal of uncertainty remains due to the lack of deep exploration boreholes that have been drilled, resulting in high geological risk (as demonstrated by the failure of the Meer well in the 1980s). This has led to a bottleneck of geothermal projects at this stage due to the high cost of drilling. It is expected that the drilling of the planned new wells by 2015 will provide better estimation of the subsurface characteristics. This should open up the deep geothermal market in Belgium and aid in the transition from R and D towards pilot installations with a clear market focus.

Another challenge in Belgium is that 60% of the heating demand is in houses and buildings. There is therefore an interdependence of the deployment of heating networks. This is more difficult in Belgium than other countries since many Belgians own their own homes and therefore district heating networks are rare.

4. SUMMARY

In general geothermal energy has been growing slowly in Belgium over the last 5 years. However shallow geothermal installations have been increasing at a faster rate than deep geothermal energy. Shallow geothermal installation development is expected to grow more rapidly as energy obligations for new buildings and renovation are steadily strengthened. Additionally, a minimal share of renewable energy use is obliged since the start of 2014. A difference in deep geothermal development between the regions depends on the geological situations but also the legislative and regulatory environment. The proof of concept in the planned new projects in the coming years will be a critical step for the future development of the geothermal industry.

REFERENCES

Dreesen, R., Bouckaert, J., Dusar, M., Soille, P. and Vandenberghe, N. 1985. Collapse structure at the Dinantian-Silesian contact in the subsurface of the Campine basin, N of the Brabant Massif (N-Belgium). *Dixième Congrès International de Stratigraphie et de Géologie du Carbonifère, Compte Rendu.* **2**. 7-14.

Elia. 2014 (a). Facts and Figures 2013 (online). Available : http://www.elia.be/en/about-elia/publications/facts-and-figures. Accessed 01 December 2014.

Elia (b). 2014. Forecast Changes in Generation Capacity (online). Available : http://www.elia.be/en/grid-data/power-generation/changes-generation-capacity. Accessed 27 May 2014.

Elia (c). 2014. Generating Facilities (online). Available : http://www.elia.be/en/grid-data/power-generation/generating-facilities. Accessed 27 May 2014.

Hoes, H. and Gysen, B. 2004. De warmtegeleidbaarheid van de Vlaamse ondergrond (2004/ETE/R203). VITO Report.

Hoes, H., Peticlerc, E., Declercq, P-Y. and Laenen, B. Geothermal energy use, Country Update for Belgium. 2012. *European Geothermal Congress 2013, Pisa, Italy.*

Interreg Vlaanderen-Nederland. 2014. Geoheat-App (online). Available : http://www.grensregio.eu/2012/11/07/%E2%80%9Cgeo-heat-app%E2%80%9D/. Accessed 15 September 2014.

Legrand, R. 1975. Jalons Géothermiques. *Mémoires pour servir à l'Explication des cartes Géologiques et Minieres de la Belgique, Mémoire* (No. 16) pp 46.

Licour, L. 2012. *Relations entre la géologie profonde et le comportement hydrogéologique du réservoir du Hainaut (Belgique). Caractérisation de l'aquifère dans la région de Saint-Ghislain*. University of Mons, PhD Thesis.

Robeyn, N., Lemmens, B. and Hoes, H. 2011. Bepaling van de thermische geleidbaarheid van geologische formaties en het opstellen van een geschiktheidskaart voor boorgat-energieopslag (TE 2100220).

The World Bank. 2014. Data : Belgium (online). Available : http://data.worldbank.org/country/belgium. Accessed 27 May 2014.

Thermomap. 2014. Thermomap : Area mapping of superficial geothermic resources by soil and groundwater data (online). Available : http://www.thermomap-project.eu/**.** Accessed : 12 May 2014.

Vandenberghe, N. 1990. Geothermal energy in Belgium : An overview. *Geothermal resources council TRANSACTIONS.* **14.** Part 1.