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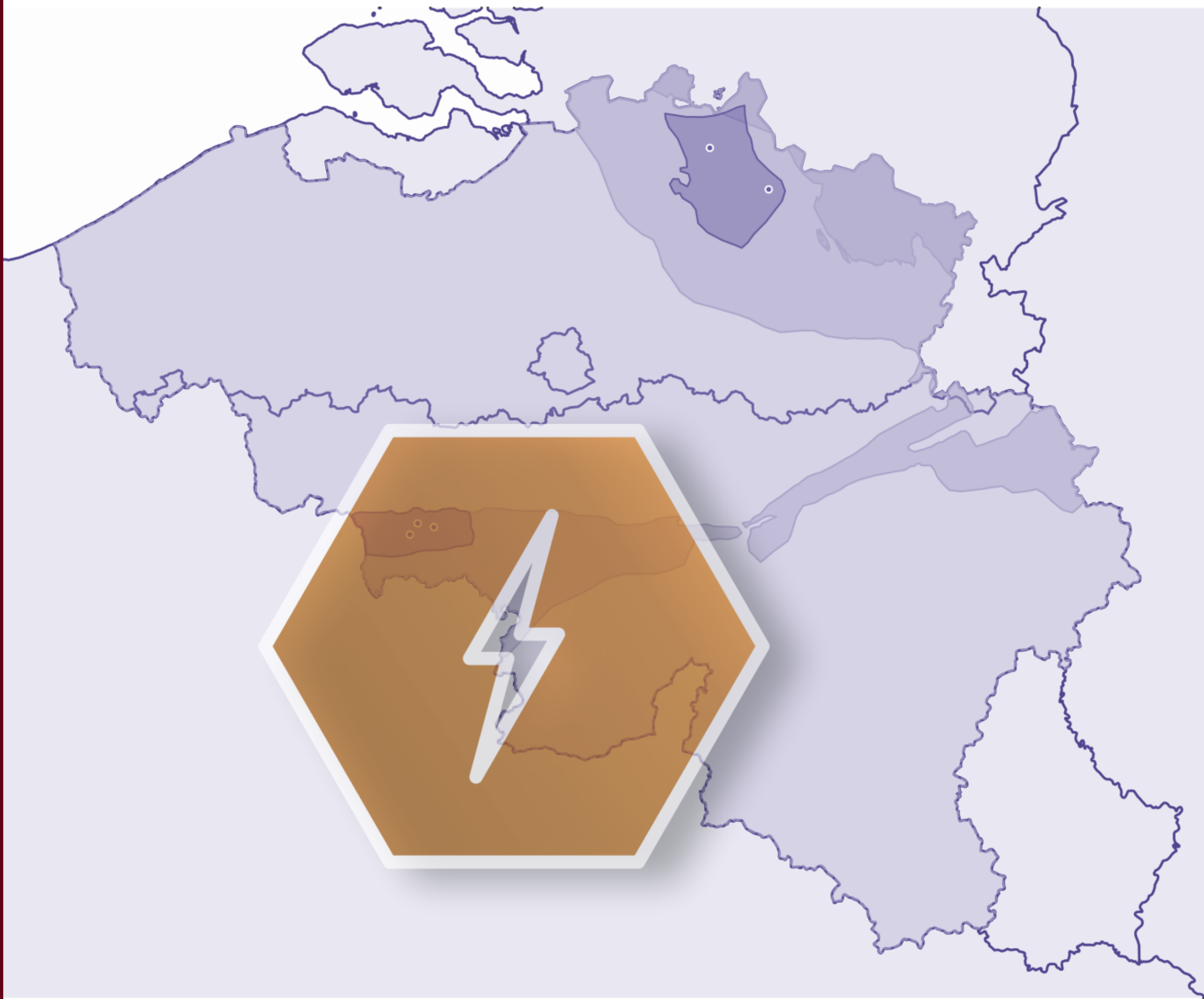

Overview of the geo-energy potential of the Belgian deep subsurface

Kris Welkenhuysen, Estelle Petitclerc, Alejandra Tovar,
Vanessa Heyvaert, Yves Vanbrabant, Kris Piessens

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Opportunities for exploration and exploitation of Belgian geo-energy resources

Highlights

- As climate targets tighten and strategic autonomy becomes imperative, deep subsurface resources emerge as indispensable.
- Belgium's geological diversity geology offers strong potential for CO_2 storage, hydrogen storage, natural hydrogen, and deep geothermal energy.
- Investing in systematic and integrated national geoscientific exploration campaigns that serve multiple applications simultaneously is no longer optional but necessary, as they are essential to transform subsurface potential into strategic assets.

Energy security and climate change have become central concerns for Belgium and Europe. Recent geopolitical events have shown how reliance on external suppliers can expose countries to economic risks and strategic vulnerabilities. Reducing these dependencies requires making better use of domestic and often carbon-lean resources. Belgium's deep subsurface offers untapped potential to strengthen national resilience, support the energy transition, and enhance autonomy.

The Geological Survey of Belgium (GSB), part of the Royal Belgian Institute of Natural Sciences, hosts the country's most extensive geoscientific databases and collections. With a growing emphasis on sustainable and carbon-lean solutions, the GSB is at the forefront of exploring and characterising our subsurface. As Belgium's national geological survey organisation, the GSB harmonises data, provides interpretations, and ensures European alignment through EuroGeoSurveys, the Geological Service for Europe project (GSEU) and other initiatives.

Driven by the Critical Raw Materials Act and Net Zero Industry Act, the deep subsurface has become a crucial domain for four key geo-energy applications: CO_2 storage, hydrogen storage, natural hydrogen and deep geothermal energy. These applications often target similar geological formations, requiring an integrated understanding for optimal use, managing potential conflicts, and guiding coherent policy decisions. It also offers synergy opportunities, using the same investment in exploration and its insights for multiple applications.

A national geological exploration programme is therefore a necessity. Systematic investigation of the deep subsurface, through reinterpretation of existing seismic and drilling data, analysis of wells with deep circulation, and targeted geophysical surveys, will generate the knowledge base needed to underpin multiple applications. By investing in this knowledge, Belgium can transform its deep subsurface from unexplored potential into a well-characterised national asset. This will strengthen energy security, support industrial transition, reinforcing the country's autonomy and help meeting climate targets.

CO_2 geological storage

Highlights

- CO_2 geological storage is the only proven technology with sufficient capacity to permanently contain unavoidable or unaddressed emissions on a geological timescale. It can safeguard industrial competitiveness while contributing directly to climate targets.
- Significant amounts of CO_2 geological storage capacity are likely available in Belgium, estimated at 620 Mt with a large uncertainty range.
- In the Belgian subsurface, the Neeroeteren Formation, Buntsandstein Formation and Dinantian carbonates appear as primary targets for further investigation.
- Next steps are the confirmation of known and suspected dome structures through a targeted geoscientific survey and exploration well drilling, and more general geophysical exploration to reduce uncertainties at formation level.

CO_2 geological storage as crucial solution for unavoidable emissions

Efforts to reduce CO_2 emissions often focus on limiting their production, for example by improving combustion processes or adopting alternative technologies. While effective in some sectors, many industrial processes continue to generate emissions that cannot be avoided with current methods, or for which alternatives remain prohibitively expensive. CO_2 geological storage is today the only proven technology with sufficient capacity to permanently contain these unavoidable or unaddressed emissions on a geological timescale. By doing so, it safeguards industrial competitiveness while contributing directly to climate targets. Importantly, CO_2 storage also enables the achievement of “negative emissions” when combined with technologies such as direct air capture or the use of bio-based fuels. This makes it not only a defensive measure against residual emissions, but also a proactive tool for accelerating progress towards net zero.

In order to reach its legally binding climate targets by 2050, the EU needs to permanently store 250 million tonnes of CO_2 yearly by that time. However, roughly 1.7 Mt of CO_2 is currently stored annually in Europe. While some European countries such as The Netherlands, Denmark and Norway are mobilizing to provide several storage sites, it is impossible to guarantee access and capacity to every country, especially within the time limits of the climate targets. As such, it appears beneficial for every European country to assess potential domestic storage of CO_2. The Net-Zero Industry Act is the latest regulation in supporting CO_2 geological storage, enforcing reporting and data transparency on potential storage options.

In Belgium, developing domestic storage capacity can offer several advantages. Relying solely on foreign storage options decreases Belgium’s autonomy to control its own decarbonization process and cost. This becomes more critical given the fact that Belgium is not on track for achieving its target reduction of 47% by 2030 (55% for the EU). Current plans to build a national CO_2 backbone to transport captured CO_2 in and between industrial clusters, creates a big opportunity to have a full CCS value chain that is complementary to that of exporting CO_2. Domestic storage eliminates effects from foreign policy changes and permitting delays, and with limited transport distance. Abatement costs are expected to also reduce significantly.

With CO_2 geological storage, CO_2 is injected through a well into the deep subsurface where it displaces saline groundwater in the rock pores. A phase change of the CO_2 from gas to fluid-like at a depth of 800 meters increases storage efficiency and security, while multiple impermeable sealing layers prevent upward migration. In Belgium no storage-specific exploration has been performed. With current knowledge, the total available capacity is estimated at 620 Mt, although with a large uncertainty range.

Target areas for CO_2 storage in Belgium

Several geological units show potential for meeting the requirements of depth, capacity, permeability and sealing. Considering its potential for development, a ranking was made of these formations, which are located mainly in the Campine area and the axis Mons-Namur-Liège.

The most promising targets are the Neeroeteren Formation (estimated capacity 18-170 Mt) and the Buntsandstein Formation (12-189 Mt) occurring both in the northeast of the Campine area, and the Carboniferous Limestone Group (Dinantian, 40-1229 Mt), occurring in the Campine area and the Mons-Namur-Liège axis. Additional storage opportunities might be available in the Maastricht and Houthem Formations, the unexploited coal sequences, and the poorly known deep Devonian rocks of the Aisemont Formation. Three potential dome-like trapping structures have been identified that show storage potential: the Loenhout dome structure, currently in use for natural gas buffer storage; the Poederlee dome structure with a likely small capacity; and the Verloren Kamp structure, a largely unknown structure.

Belgium holds potential for CO_2 storage, but additional characterization is needed. More general geophysical surveys will reduce uncertainties on reservoir and sealing properties, and potentially discover new trapping structures. Targeted surveys and exploration wells can confirm existing structures and their reservoir properties.

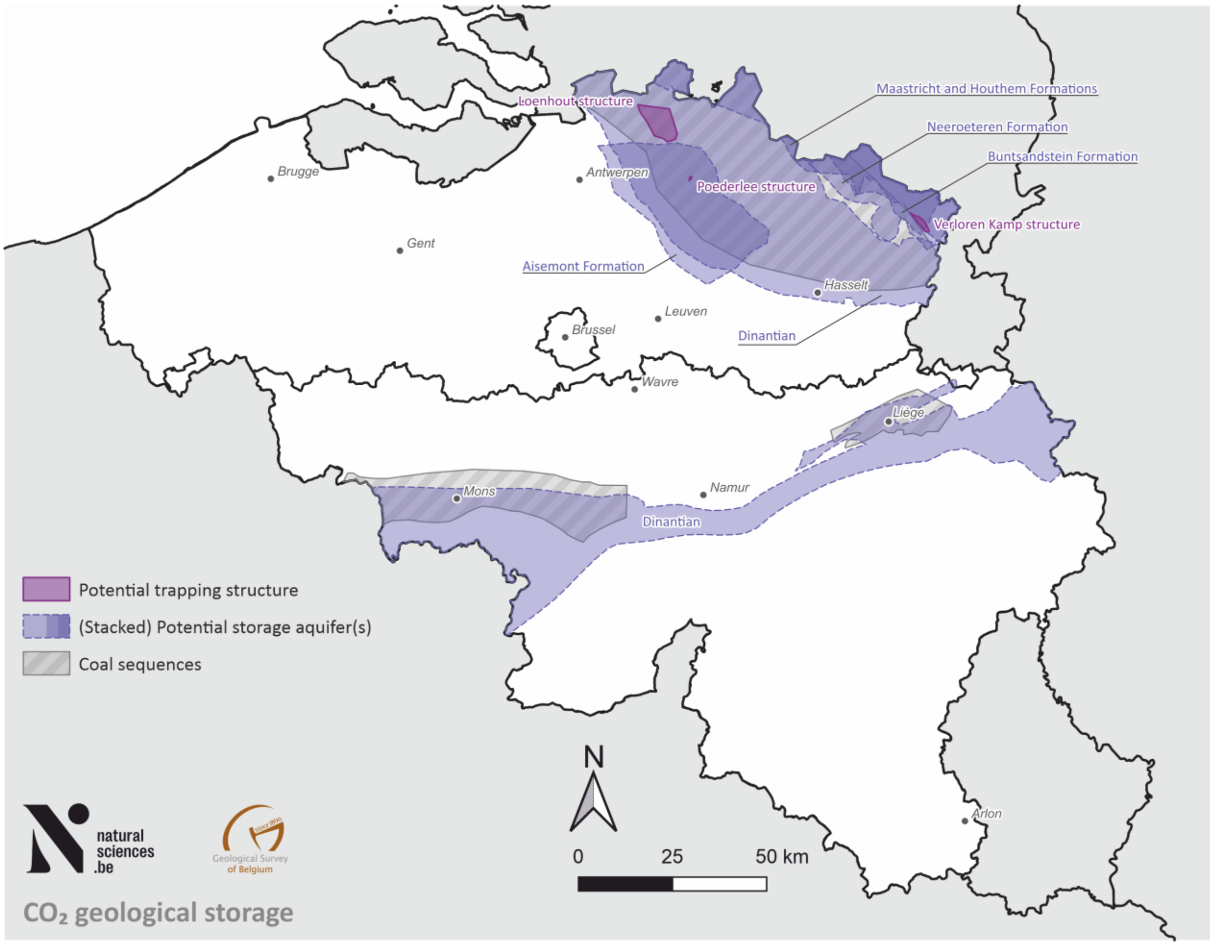

Figure 1. Map of potential CO_2 storage options in Belgium.

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Underground hydrogen storage

Highlights

- Geological buffers become essential for strengthening Belgium's energy resilience.
- The Belgian subsurface shows potential for hydrogen storage sites, the Loenhout natural gas storage is in pilot testing for hydrogen injection.
- Compared to storage of natural gas or CO_2, specific hydrogen gas properties need to be considered for sealing and reactivity.
- Targeted geoscientific exploration is needed to identify suitable trapping structures.

Hydrogen storage for strategic energy assurance

In the pursue of a carbon-neutral society, hydrogen as an energy carrier can play a significant role for Belgium's industry and that of surrounding regions. Any mismatch between energy demand and production, for example due to seasonal heating variations, has a market influence with geopolitical consequences. With large-scale infrastructure being built or planned, geological buffer storage becomes essential to stabilize prices and ensure availability. Temporary storage, very similar to those currently in use for natural gas, can provide peak shaving and reduction of foreign dependency. In fact, a geological reservoir is the only storage type sufficiently large for the amounts required.

Belgian industry is preparing for a significant upscaling of hydrogen production, transport and use. Hydrogen is already an important compound in the chemical industry of Antwerp, and a national transport and transmission grid is underway. The next step is to consider the storage of hydrogen in our subsurface as a buffer. A subsurface natural gas storage, the Heibaart dome structure in Loenhout, is in operation since the early 1980s, providing 7.6 TWh of seasonal buffering. Research and testing led by operator Fluxys is ongoing to confirm potential for conversion to hydrogen storage, with an estimated 2.4-3 TWh capacity. Comparable battery storage would require 5000 large battery parks, each occupying about 1 km^2 of surface space.

Target areas for hydrogen storage in Belgium

Underground hydrogen storage essentially consists of pumping pressurized hydrogen into porous rocks in the subsurface, where it displaces the saline groundwater, and on-demand production. While there is no real minimum depth requirement, a minimum depth of 500 meters is considered here to allow for sufficient sealing formations and a proper trapping structure as containment is key for safety and re-producibility. Potential storage targets are dome-like structures with sufficient porosity and permeability. Due to its high mineral reactivity, composition of the reservoir and sealing rock needs careful consideration.

In the HyStorIES and GSEU projects, several geological formations in Belgium were identified by the GSB that show potential for hydrogen storage. Hydrogen storage potential in Belgium can be categorized in three confidence levels. The Heibaart dome structure represents the first, most confident level, as it is in use for natural gas storage and with ongoing hydrogen storage pilot testing. This structure is assessed to have a hydrogen storage capacity of 2.4-3 TWh. In the second level, two potential dome-like structures are identified: the Poederlee and the Verloren Kamp structure. In the third level with lowest confidence, formations are listed that show a potential match with the basic criteria. In the Campine area these are the Maastricht and Houthem Formations, the Buntsandstein Formation, the Neeroeteren Formation, the Carboniferous Limestone Group (Dinantian), and the Aisemont Formation. In the Walloon Region, these are the Carboniferous Limestone Group (Dinantian), and the Givetian and Frasnian carbonates (Devonian).

The Belgian subsurface shows potential for hydrogen buffer storage with various levels of uncertainty. Further pilot testing in the Heibaart dome structure will show its aptness and stability for large-scale and longer-term storage. A targeted geophysical survey can confirm the geometry of the other assumed trapping structures, and a more general survey in areas of interest is needed to discover favourable circumstances and additional trapping structures in the formations of interest because their potential is largely unknown.

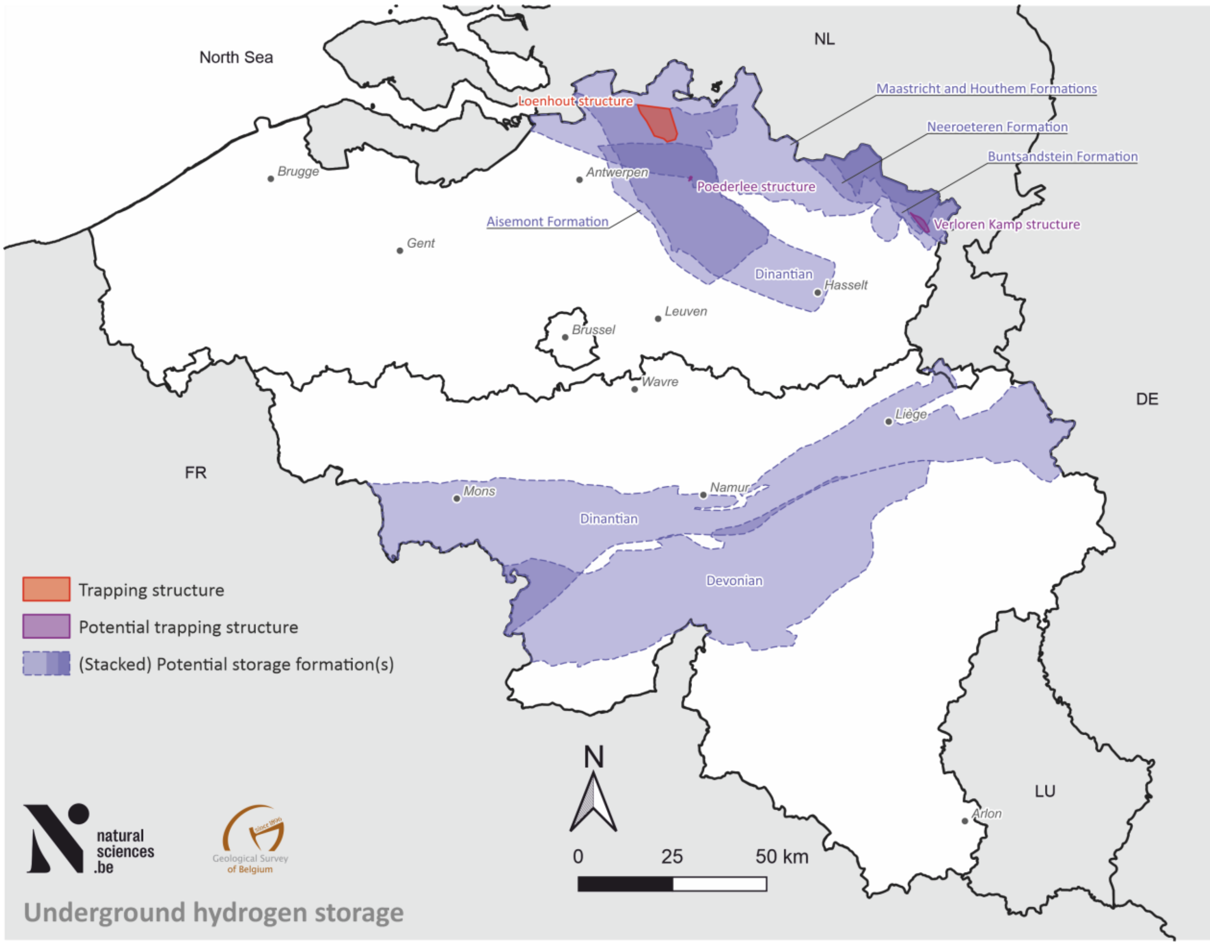

Figure 2. Map of potential underground hydrogen storage options in Belgium.

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Natural hydrogen

Highlights

- Natural hydrogen is a continuously generated clean energy source and holds potential as a domestic resource for Belgium.
- Recent discoveries in several European countries, including geological settings across the French border that extend into Belgium, reinforce this potential.
- Enabling geological conditions exist in Belgium's subsurface, but the presence of natural hydrogen has not yet been investigated.
- A first, general, nationwide geoscientific survey of the subsurface is needed to identify the most promising areas for hydrogen exploration.

Natural hydrogen: a clean energy resource

Natural hydrogen represents the newest addition to the commercial energy landscape. Previously considered a geological curiosity, natural hydrogen emerged as an exploitable resource in 2012 when its economic viability was demonstrated in Mali. Since then, accumulating evidence suggests hydrogen is far more widespread than previously recognised. Recent discoveries in several European countries, including geological settings across the French border that extend into Belgium, reinforce this potential.

Natural hydrogen is a continuously generated, clean energy source, making it a highly strategic resource. This is particularly relevant for Belgium, which hosts the world's second-largest hydrogen transport network beneath Antwerp harbour. Hydrogen serves directly as industrial feedstock and could power heavy transport. Incorporating natural hydrogen would decrease international energy dependence, support industrial decarbonisation, and maintain climate commitments.

Exploration target areas for natural hydrogen in Belgium

Belgium's exceptional geological diversity creates multiple pathways for natural hydrogen generation. The Spa-Malmedy region hosts deep mantle degassing along faults extending potentially into Flanders. The coal deposits, which are present in multiple regions, can generate hydrogen through organic maturation. Iron-rich formations throughout the country enable oxidation reactions with water. Deep granites, particularly in the Brabant Massif, produce hydrogen through radiolysis by naturally occurring radioactive elements. Whilst these generation mechanisms remain incompletely understood, the key message is clear: Belgium's entire territory overlies geological conditions capable of generating natural hydrogen. However, generation alone doesn't guarantee economic accumulation since hydrogen's exceptional mobility means identifying suitable geological traps remains a key exploration challenge.

Belgian geology has been systematically documented since the late 19th century. Throughout this period, hydrogen data were never collected, with one notable exception: the deep Balmatt well at Mol. This drilling unexpectedly encountered hydrogen in measurable concentrations. This single measurement, though not immediately exploitable, demonstrates hydrogen's presence and suggests potential accumulations elsewhere.

Belgium's geological subsurface offers realistic prospects for hydrogen generation, migration from depth, and possible economic accumulation. Such discoveries would represent strategic national importance. The current knowledge gap remains substantial. Priority actions include reinterpreting existing seismic and drilling data to map deep structures and analysing wells where deep fluid circulation occurs. This foundational work will enable targeted geophysical surveys and exploratory drilling.

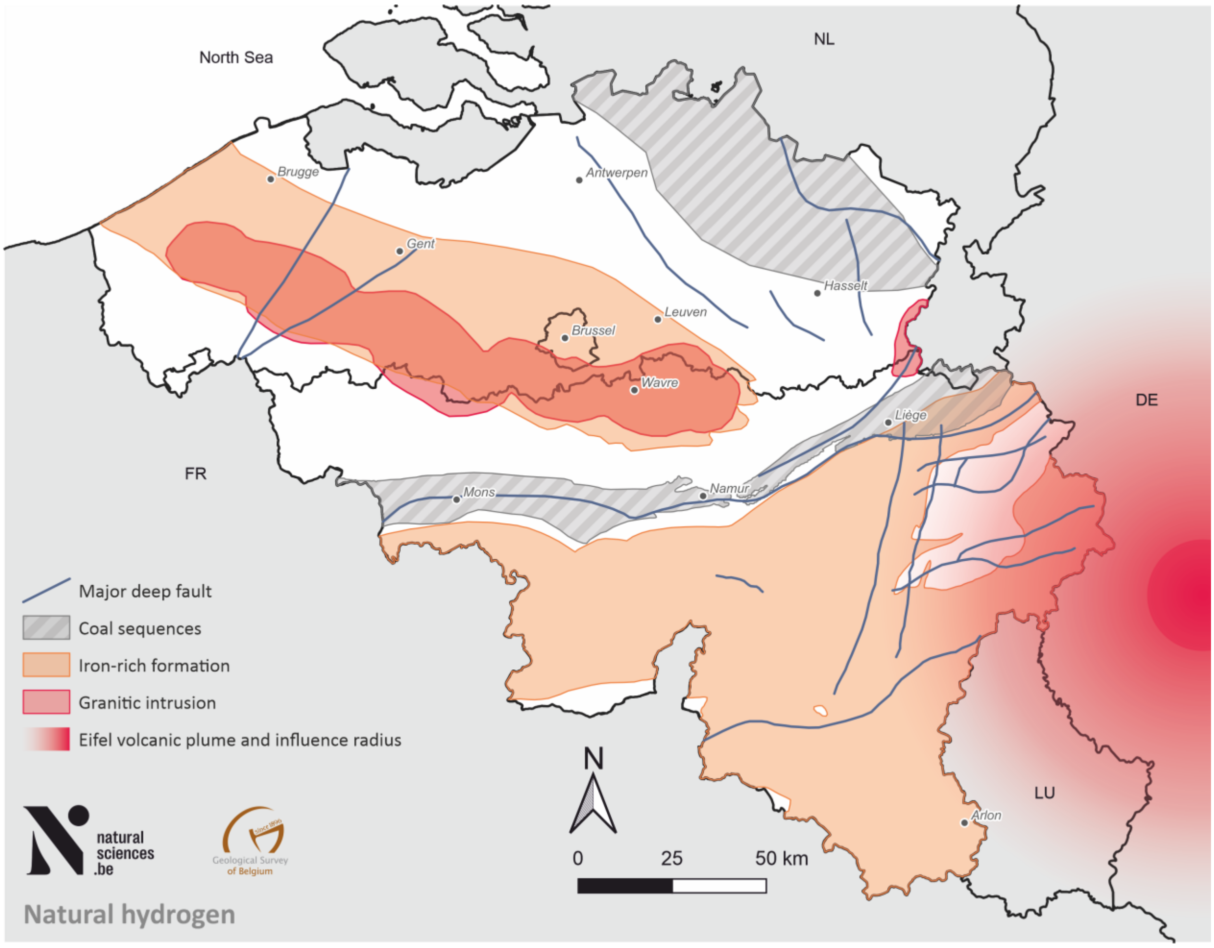

Figure 3. Map of natural hydrogen-relevant geological structures in Belgium.

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Deep geothermal energy

Highlights

- Deep geothermal energy is a strategic domestic energy source.
- Proven operations at Mons, Beerse and Mol confirm the Dinantian reservoir potential.
- About 320 000 TWh of heat-in-place is estimated in the Dinantian of the Mons and Campine areas. The potential in the remaining Mons-Namur-Verviers area is promising but unconfirmed.
- Many other probable reservoirs are untapped, emphasizing the need for further geological exploration and characterisation.

Unlocking local, renewable and continuously available energy

In the 2023 Renewable Energy Directive, the EU set a legally binding target to achieve a 42.5% share of renewable energy in final energy consumption by 2030. Deep geothermal energy (DGE) offers stable, local, and low-carbon heat that directly substitutes fossil fuels and naturally integrates with district heating networks and industrial processes. Across Europe, momentum is building: neighbouring countries such as Germany, France, and the Netherlands have recently adopted ambitious geothermal strategies, backed by strong policy frameworks, substantial public funding, and the deployment of pilot projects and large exploration programs. This regional commitment highlights the need for Belgium to reinforce its own efforts to remain aligned with European dynamics and fully harness its domestic potential.

Heat demand in Belgium is dense, urban, and persistent across seasons, making DGE particularly attractive. Proven deep geothermal resources are present in the Mons area (3 wells), and part of the Campine area (Beerse and Mol wells). By the end of 2024, installed capacity for deep-geothermal district heating, expressed in megawatts thermal, reached 25 MW_{th}, supplying 19 GWh_{th} annually, corresponding to the annual heat demand of about 6000 households and avoiding up to 17 000 tonnes of CO_2 emissions. Including shallow systems (<300 m depth), geothermal represented about 3.3 % of renewable heat in 2023. Looking ahead, expectations are high: Wallonia's PACE 2030 sets a renewable heat target of 15.6 TWh, with deep and mine geothermal ambitiously targeted at 251 GW_{th} in installed capacity, and the Flemish Energy and Climate plan sets a green heat production target of 9.7 TWh. At national level, a more cautious trajectory is foreseen with 35 MW_{th} by 2028 and 50-60 MW_{th} by 2032. With local confirmation of the resource, a subsurface-focused evaluation is thus both timely and necessary.

Target areas for deep geothermal energy in Belgium

Deep geothermal exploitation consists of extracting heat from saline groundwater which gets warmer with depth. Once used, the cooled water is reinjected. Shallow systems operate between 50-500 m depth with heat pumps, deep systems require depths of 1.5-4 km to reach suitable temperatures. More than temperature or depth, rock permeability is critical for sustainable flow rates and the final heat output.

Belgium has two proven deep geothermal plays in the Lower Carboniferous Limestone Group (Dinantian). In the Mons area (Hainaut), long-running wells at Saint-Ghislain (6 MW_{th}), Douvrain (4 MW_{th}), and Ghlin/Geothermia (7 MW_{th}) confirm the productivity of a reservoir at producing 73 °C at 100 m^3/h. The Balmatt doublet in Mol targets a deeper and hotter Dinantian reservoir of about 125 °C, while a second project at Janssen Pharmaceutica (Beerse) has been operational since October 2023. These Dinantian carbonates represent a very large, still under-exploited geothermal stock. Its geological potential for

Belgium, expressed as heat-in-place, was assessed for the Dinantian in the Mons and Campine areas and amounts to about 320 000 TWh, which could supply a significant share of sustainable energy.

Over the past decade, multiple European and national research have assessed Belgium’s geothermal potential within these cross-border initiatives, ensuring its characterization is consistent with the wider regional geological framework. The reservoir immediately surrounding the active projects and ongoing expansion in Mol, Beerse, Saint-Ghislain, Douvrain and Ghlin represent a first and most confident resource level. At the second level, the Dinantian reservoir outside of these proven areas offers strong potential but remains to be confirmed by well drilling. This includes the rest of the Campine area and the Mons-Namur-Liège axis, where geological conditions appear favourable. In the northeast Campine, the Cretaceous, Buntsandstein Formation and Neeroeteren Formation are locally likely suitable as geothermal reservoir. The least confident level lists less characterised formations, which show promising geothermal criteria but remain largely unexplored. These include for example the Devonian carbonates of the Condroz and the Brabant Massif, where fractured basement rocks could provide permeability.

The Belgian subsurface shows significant geothermal potential with varying levels of maturity. Pilot projects and exploration wells will be key to assess reservoir performance, while targeted geophysical surveys can refine the geometry of prospective zones. A broader subsurface characterisation effort is required to define additional favourable reservoirs across the territory, an objective that will be strongly supported by the upcoming WalScan seismic campaign (SPW-TLPE, 2026).

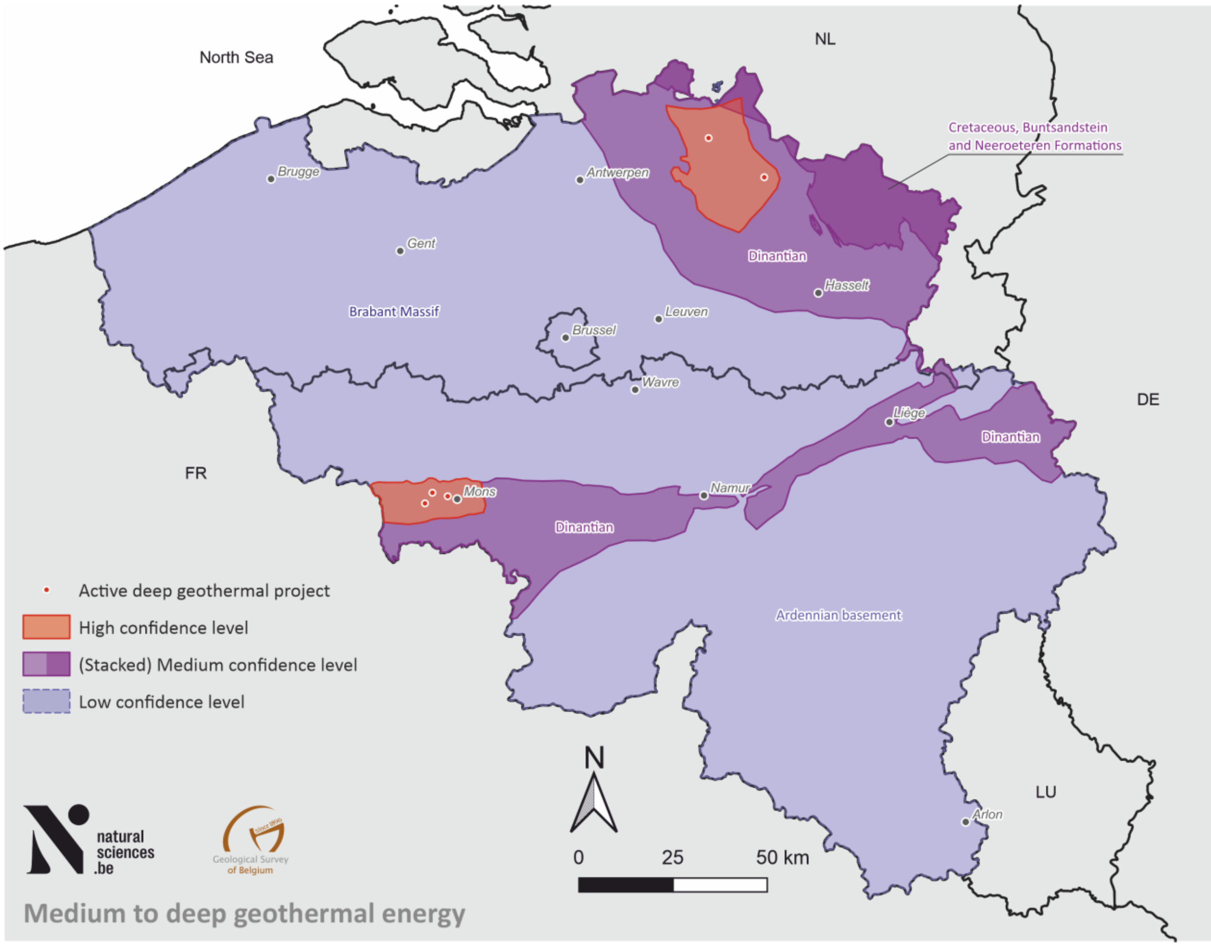

Figure 4. Map of deep geothermal energy options in Belgium.

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