BUREAU D'EXPERTS
PH. DEPLASSE & ASSOCIES S.P.R.L.

TECHNICAL ENGINEERING &
MAINTENANCE CONTROL

Support for the Cap Construction Cluster for the analysis of the Heerlen pilot project

Consultancy and report writing assignment

ANALYSIS OF THE WORKING OF MIJNWATER B.V. AND POSSIBILITIES TO DEVELOP SUCH A MODEL IN WALLONIA

REPORT

Avec le soutien de la Wallonie

Author : Nicolas Cuvelier
Reviewer and strategical Input : Gaëtan Durvaux
Field visit and technical support : Stéphane Barbier & Philippe Deplasse

Summary

Following a call for proposals of 21 June 2019, Deplasse & Associés was entrusted with the following assignment: "*SUPPORT FOR THE CAP CONSTRUCTION ASBL CLUSTER FOR THE ANALYSIS OF THE HEERLEN PILOT PROJECT AND PRODUCTION OF A REPORT FOR THE "HEATNET NEW" INTERREG PROJECT*".

This report is the assignment deliverable and fulfils the main requirements of the specifications, namely "*can such a project be transposed into Wallonia and under what conditions"?*

The city of Heerlen, in the Limburg region in the Netherlands, launched a district heat and cold distribution network pilot project fifteen years ago. As the city is located in a former coal mining area, where there are currently a large number of abandoned flooded mines. As the water present in the flooded mines is maintained at a constant temperature by the geothermal gradient, it represents a source of heat and cold that can be used to supply buildings. Initially, the Heerlen network simply provided heat and cold to the buildings connected to the network.

But the limits of this model rapidly become apparent, in particular because of the gradual exhaustion of the source and the focus of the project shifted to a network for exchanging heat and cold between connected buildings. Heat was transferred between the network and buildings using heat pumps, as soon as an user consumes heat, the pump it reinjects cold into the network (and vice versa). This cold or heat reinjected into the network can then be used by another user, and if that is not the case, it is then reinjected into the mines for longer term storage (inter-season).

As the ranges of temperatures used for the provision of heating and cooling are "temperate" (28°C for hot water and 16°C for cold water) the distribution related losses are substantially limited. But these temperatures also make it possible to integrate sources of renewable and waste heat into the network. These various points make the Heerlen project the first fifth generation heat network to reach such a scale.

The Heerlen network currently makes it possible to reduce the CO_2 emissions of the buildings that are connected to it by 65%. The gradual integration of renewable electricity will result in a reduction of the carbon footprint, with carbon neutrality as the final objective.

Many factors have facilitated the implementation of this project, including inter alia the technical skills of the team that designed the installations, nut also the commitment of the local authorities to the project, the Dutch energy and legal context, as well as the availability of local and European funding. These factors taken together have made this project a success, not only technically but also commercially/financially.

This type of heat network, based on exchanges of heat and cold between connected buildings and using abandoned flooded mines for long-term storage purposes, represents an innovative technology that has numerous potential applications, in particular in Wallonia. The presence of abandoned mines that have been flooded in Wallonia (more specifically along the Sambre and Meuse), combined with the current energy transition and similar objectives of reducing CO_2 emissions, represents a context favourable for the development of projects similar to the Heerlen project.

As the success of this project is the result of years of work and adjustments, numerous lessons can be learnt from it, and certain pitfalls can be avoided. Additional studies will be necessary to establish an action plan with the aim of transposing this type of project, in particular regarding the availability of resources and heat and cold demand near to potential resources, but there are very real development opportunities.

We will see however that the Dutch and Walloon contexts differ in some aspects, but other factors are common to both regions. The transposition of this successful project from one region to another is therefore not a trivial task, but some adjustments, not only at legislative level, but also at administrative and promotional levels, can make it feasible.

We take the opportunity of this report to review the legislative aspects of geothermal energy in the Walloon Region.

The development potential of this type of project is therefore very real, in particular for the achievement of the objectives of reducing CO_2 emissions, and therefore merits serious consideration.

Table of contents

Introduction

On 11 May 2019, the highest level of CO_2 in the atmosphere on earth since the beginning of mankind was recorded. A count of 415 parts per million[1] (PPM) in the atmosphere was recorded, that is the highest ever threshold measured in earth for 3 million years[2]. The climate emergency inherent in this increase of CO_2 in the atmosphere therefore requires an effective response involving a drastic reduction in greenhouse gas emissions in the coming years.

This reduction requires alternatives to fossil energies to be put in place in all domains, including for the heating and cooling of buildings. The residential sector alone represents almost 14% of greenhouse gases in Wallonia. Making the energy consumption of our buildings greener is therefore one of the great challenges of tomorrow[3].

In the city of Heerlen in Netherlands, Mijnwater B.V. took over an esco from the municipality of Heerlen. The objective of Mijnwater is to connect building in the city of Heerlen on it's heating and cooling network. This project relies on the geothermal resources of former coal mines under the city to supply a fifth-generation heat and cold network. As this project uses a renewable heat resource that considerably reduces greenhouse gas emissions, it is relevant to analyse it and study its potential transposition in Wallonia with a view to achieving the region's greenhouse gas reduction targets.

In order to reduce its impact on global climate change, Belgium is committed, via the signing of the Paris Agreement and the implementation of the country's climate energy plan, to reducing its greenhouse gas emissions. The heating of buildings alone represents around 20% of these emissions. Therefore, the reduction of the carbon intensity of this sector is a major challenge for the future. In addition, as Belgium does not have any natural gas resources, it is currently fully dependent on imports of such gas. It is therefore necessary to develop alternatives to this in anticipation of the increasing scarcity of this resource and the resultant increase in prices.

Therefore, the aim of this study carried out at the request of the Cap Construction ASBL Cluster is to provide hard evidence in order to enable politicians in Wallonia to determine the advantages of the Heerlen project and the feasibility of transposing such a project in Wallonia.

This report will therefore examine the technical and legal feasibility of such a transposition in Wallonia. However, given the limited information on the cost-effectiveness of the project we will not be able to make a judgement on this aspect. Nevertheless, we would be prepared to carry out a specific study on this aspect on the basis of recent data acquired in the various calls for proposals in which we have participated.

To comply with the target determined in the Paris Agreement and the climate energy plan, Wallonia must develop geothermal energy as a renewable heat resource. As geothermal energy on mining sites represents a resource that is potentially available in Wallonia, the implementation of projects similar to that of Heerlen is therefore a means of achieving this target essential for the development and future of the region.

For the purposes of this study, a research plan was put in place, consisting of several phases, with first of all the collection of data and studies already carried out on the subject and the related points. Several meetings with key stakeholders in the Walloon ecosystems were organised in order to identify specific points of interest to be addressed as part of the study on the transposition of this successful model from one region to another.

To identify the factors that contributed to the success of the Heerlen project, but also to identify the barriers and obstacles encountered during its implementation, an on-site visit and interviews with the various local stakeholders and participants were organised. These enabled us to collect data from different perspectives, from the point of view of not only the operator, but also the local authorities and end consumers.

[1] co2.earth/daily-co2

[2] Atmospheric Carbon Dioxide Concentration Across the Mid-Pleistocene Transition, Bärbel Hönisch, N. Gary Hemming, David Archer, Mark Siddall, Jerry F. McManus. *Science,* 19 Jun 2009, Vol. 324, Issue 5934, pp. 1551-1554.

[3] PACE 2030

The data collected were then analysed on the basis of the bibliographic resources previously collected and on the consortium's experience in this domain.

The objective of this report is therefore twofold. Initially, it will be to determine the advantages of a project such as that of Heerlen in order to reduce greenhouse gases and reduce dependency on imports of fossil energies, and then to highlight the factors that made its implementation possible. Once this analysis has been completed, we will then examine the feasibility of transposing such a project in the Walloon Region, and determine the measures that could optimize such a transposition.

In this report, we will start by defining the relevant context. We will address the general problem of the reduction of greenhouse gas emissions, and the definitions of the various concepts addressed.

We will then address the energy issues and the characteristics of the energy market in the Netherlands. This will enable us to establish the framework within which the Heerlen project came about. We will then describe the various aspects of this project by looking at its development over time, as well as the various technical, financial, strategic and legal factors that have contributed to its success.

Once the characteristics of the Heerlen project have been clearly defined, we will examine the feasibility of transposing such a project in the Walloon Region. We will therefore begin by comparing the Walloon and Dutch situations, followed by a state of play analysis of geothermal energy and heat networks in Wallonia, as a presentation of various measures that could facilitate the development of geothermal energy by/and heat networks in Wallonia.

1. BACKGROUND AND CONCEPTS

1.1. General context

In a world where energy needs are increasing and where fossil energy sources are becoming scarcer and are the source of atmospheric pollution that has an impact on health and on the climate, there is growing awareness of the need for alternatives to these polluting energies. Against this backdrop, the development of these clean energy resources is flourishing, especially as these are renewable.

1.2. Geothermal energy, a clean and renewable energy

1.2.1. Definition

Geothermal energy is defined as "energy stored in the form of heat beneath the surface of solid earth"[4]. In fact, the deeper we go beneath the earth's surface, the higher the temperature. This phenomenon is known as "geothermal gradient" and corresponds on average to an increase of 3°C every 100m. This geothermal energy can potentially be captured via the circulation of a fluid, naturally present (water table) or injected, under the surface. This fluid will then heat up (capture the energy present), and by bringing it to the surface, we can extract the thermal content stored, which can be used directly for thermal needs, or can be partially converted into electricity.

There are several different types of geothermal energy depending on the way in which the fluid will be used (directly or indirectly), its temperature (very low, low, medium or high), its original depth (surface or at depth) and the energy contained in the fluid (very low, low, medium or high)[5].

The differentiation is generally made between:

- Very low-temperature geothermal energy: the heat-transfer fluid (water or air) is captured at temperatures below 40°C. It is drawn from the soil surface layers at depths of generally between 10 and 1,000m. This geothermal energy is generally used for heating, cooling and supplying domestic hot water to buildings, but generally requires the use of heat pumps. It is the type of geothermal energy that is used in the Heerlen project.

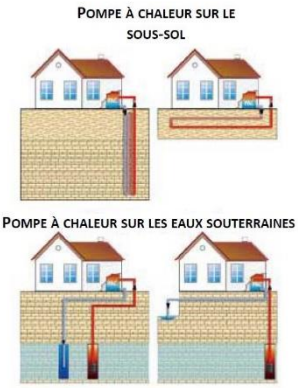


Figure 1 Source BGRM

- Low-temperature deep geothermal energy: the fluid (water) is captured at greater depths, generally between 1,000 and 2,500 m, and its temperature is therefore higher, between 30°C and 90°C, and this heat can be used directly for heating via the use of heat exchangers. It is this type of geothermal energy that is used for the Saint-Ghislain heat network.

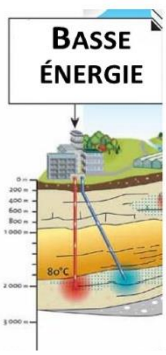


Figure 2 Source BGRM

[4] DIRECTIVE 2009/28/EC
[5] BRGM : Bureau de Recherches Géologiques et Minières

- Medium-temperature deep geothermal energy: the fluid (water or wet steam) is captured at depths of between 2,500 and 5,000 metres at temperatures of between 90°C and 150°C. As the quantity of energy present in the fluid is higher, this can be used as both a heating source and can also be partially converted into electricity. It is this type of geothermal energy that is used on the Mol drilling site.

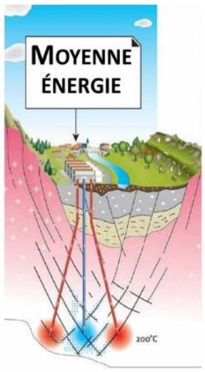


Figure 3 Source BGRM

- High-temperature geothermal energy: this type of exploitation of geothermal energy is based on the presence of magma pockets near the surface. This fluid is captured in the form of steam at high temperatures (above 150°C) and can be used to supply heat and produce heat. This type of geothermal energy is not present in Belgium, because of the absence of magma fluids in the country.

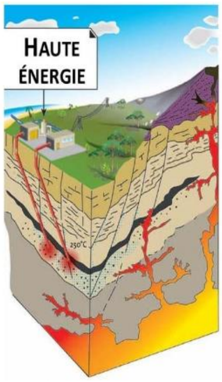


Figure 4 Source BGRM

1.2.2. Availability and renewable character

Geothermal energy has many characteristics that make it an energy that has substantial potential for the future, whether as a source of heat or for transformation into electricity.

It has the advantage of being available round-the-clock throughout the year, regardless of the weather. In addition, it is virtually inexhaustible and its development does not produce greenhouse gas and has only a very limited environmental impact.

These characteristics make it a source of energy for the future, in which government investment can create significant added value. Being a pioneer in this type of technology helps to boost research and innovation and can be a major source of jobs and income for the future.

1.3. Heat networks, source of reduction of greenhouse gas emissions

1.3.1. Definition

A heat network, also referred to as a district heating network, is a system of central heating at the level of a group of buildings, a district, or even a city[6]. A heat network therefore consists in supplying a group of buildings using a centralised production system using a boiler shared between these buildings. Its aim is to provide heat to the buildings for heating, domestic water, industrial processes or other purposes.

1.3.2. Heat networks as tools for reducing greenhouse gas emissions

Heat networks have been identified as a means of contributing to the reduction of greenhouse gases, since these networks make it possible to recover: waste energy (energy recovery units, plants, etc.), geothermal energy, solid

[6] International review of district heating and cooling, Sven Werner, Energy 137 (2017) 617e631

biomass (pellet, cogeneration, etc.), and other sources of green heat. Therefore, the CO_2 impact of the sector is increasingly favourable, and can be improved even further by adding other low carbon sources[7].

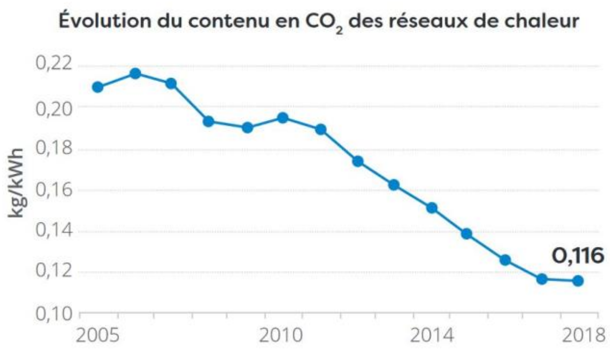


Figure 6 Change in the CO_2 content of heat networks (SNCU 2019)

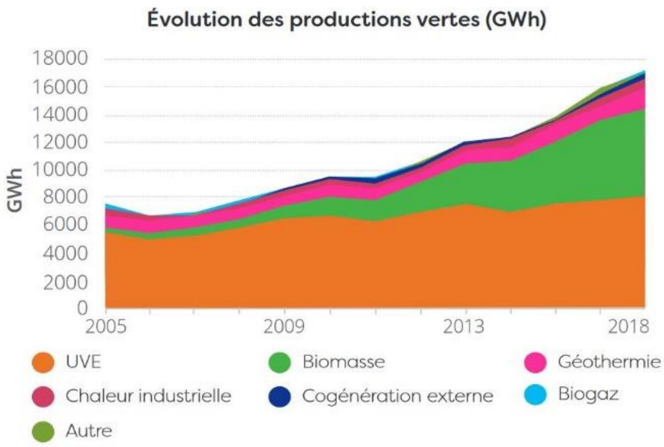


Figure 5 Renewable and recovered energy used by heat networks (SNCU 2019)

As these graphs shows the CO_2 footprint of heat networks has decreased sharply in recent years[8], in particular through the integration in these of an increasingly large share of renewable energies. These networks are spreading in Europe, and Wallonia has a significant development potential, but a series of bottlenecks still need to be addressed in order to enable this development to move up a gear.

Spurred on by the European Union, successive governments have put in place the legal framework (heat networks decree, geothermal guarantee fund, energy communities, etc.). However, as we will see, a lot of work still needs to be done for the development of such networks.

1.3.3. The different generations of heat networks

The principle of a heat network, consisting in transporting heat to buildings to heat them, is an old concept, but in respect of which the techniques used have changed over time, and several generations of heat networks have followed one another[9].

[7] PNUE, réseaux urbains de chaleur et de froid, libérer le potentiel de l'efficacité énergétique et des énergies renouvelables
[8] SNCU : Syndicat National du Chauffage Urbain
[9] H. Lund et al. / Energy 68 (2014) 1e11, 4th generation district heating,

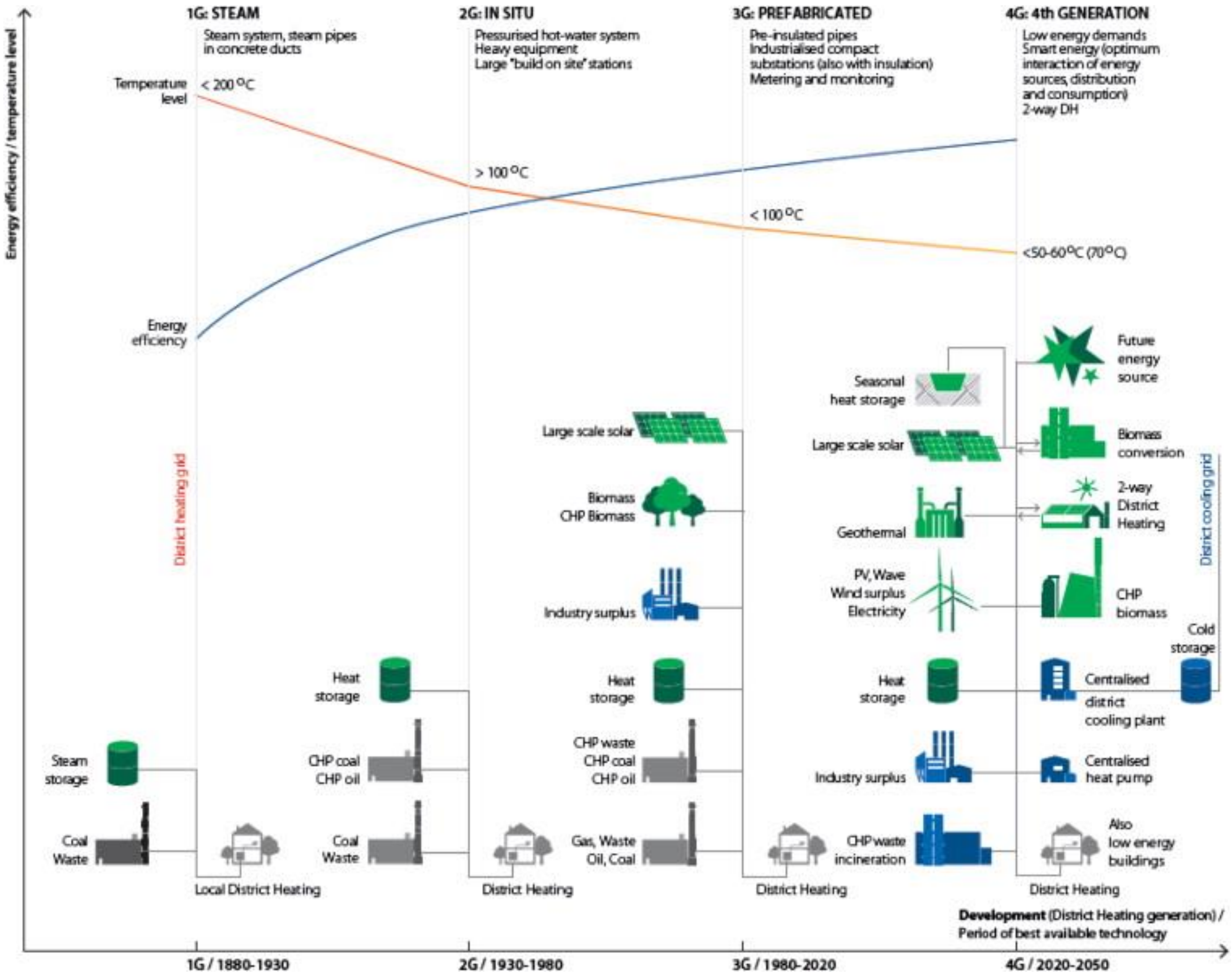
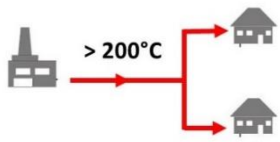


Figure 7 Generations of heat networks (Source: Lund et al. 2014[10])

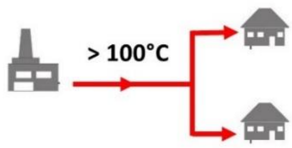
1.3.3.1. 1st Generation District Heating & Cooling (1GDHC) Network

The first-generation district heating & cooling network was based on the high-temperature distribution of steam (200°C) in uninsulated pipes (concrete) for the purpose of a local heating network.



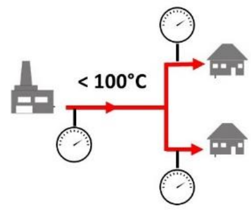
1.3.3.2. 2nd Generation District Heating & Cooling (2GDHC) Network

The second-generation district heating & cooling network is based on pressurised superheated water (>100°C) as a heat carrier, for the purposes of urban heating.



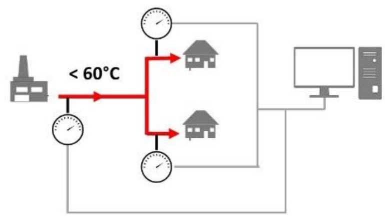
[10] Lund et al., 4th generation district heating (4GDH) integrating smart thermal grids into future sustainable energy systems, 2014

1.3.3.3. 3rd Generation District Heating & Cooling (3GDHC) Network



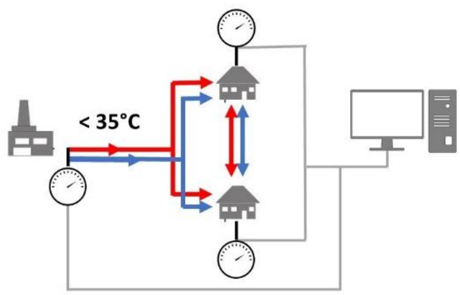
The third-generation district heating & cooling network is based on a network of distribution through insulated pipes, with compact sub-stations, and the introduction of a system for monitoring the heat distributed. The heat temperature is lower than in the previous generation (lower than 100°C). This is the case in particular of several existing Belgian sites, such as the F site in Saint-Ghislain and that of UCL in Woluwe.

1.3.3.4. 4th Generation District Heating & Cooling (4GDHC) Network



The fourth-generation district heating & cooling network is based on the distribution of heat at a lower temperature (<60°C) to buildings with low energy needs (heat insulated). The distribution network uses a customer driven smartgrid, which matches energy sources (which may be decentralised) with distribution and consumption. The reduction of the distribution temperature allows the use of lower temperature heating sources, which facilitates the integration of renewable heating sources (solar, biomass, cogeneration, etc.) in the system.

1.3.3.5. 5th Generation District Heating & Cooling (5GDHC) Network[11]



The fifth-generation district heating & cooling network uses low-temperature water (<35°C) to provide hot and cold simultaneously. The network's low temperature facilitates the use of waste heat from industry and the service sector, as well as that from low-temperature renewable energy sources. One of the major innovations of this fifth-generation district heating & cooling network lies in the fact that the various parties connected to the network can simultaneously exchange heat and cold between them. This, combined with large storage capacities, results in a network whose sources of heat and cold are no longer the cornerstones of the system.

1.3.4. HeatNet NWE project

Interreg HeatNet NWE is a project supported by the European Regional Development Fund (ERDF). Its objective is to respond to the challenge of reducing CO_2 emissions in North-West Europe, via an integrated approach intended to integrate renewable sources of heat with low CO_2 emissions, in particular fourth generation district heating & cooling networks. To that end, six heat and cold pilot projects are being supported and analysed in the United Kingdom, Ireland, Belgium, France and the Netherlands.[12]

[11] *S. Buffa et al. Renewable and Sustainable Energy Reviews 104 (2019) 504–522, 5th generation district heating and cooling systems, a review*
[12] nweurope.eu

2. THE DUTCH ENERGY SITUATION AND THE MIJNWATER PROJECT IN HEERLEN

2.1. Energy issues in the Netherlands

2.1.1. Heat carrier

Historically, natural gas was for many years the main heat carrier in the Netherlands, because of the country's significant reserves. In 1959, a natural gas field with reserves of 2,820 billion m³ was discovered in the province of Groningen, in the North of the Netherlands. The existence of this natural resource in the country has led to natural gas being used as the main energy carrier for buildings and industry in the Netherlands.[13]

However, the development of gas gradually resulted in reservoir pressure depletion, with as a consequence surface subsidence, increased seismic risk and damage to surface areas (stability of buildings). These seismic events were observed in the 1980s, with an increase at the beginning of 2000 (29 seismic tremors in 2011).

In 2018, this situation forced the Dutch authorities to decide to phase out the use of gas in Netherlands, initially in 2030, very probably earlier (towards 2025).

Alternatives are therefore being developed to offset the end of this production, with the aim of avoiding dependency on gas imports from other producer countries. In this context, heat networks, which already represented 4.4% of the supply of heat to Dutch households in 2017, are seen as one of the solutions to this problem.

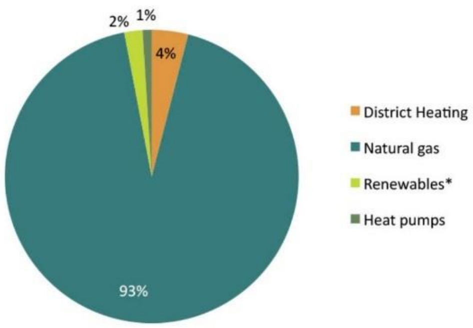


Figure 8 Proportion of the various heat carriers in the Netherlands
(Source: euroheat.org)

2.1.2. Energy transition and CO_2 policy

As part of the planned low carbon energy transition, the Dutch target is to reduce the CO_2 emissions of residential buildings by 80% by 2050 (COP21). This policy is ambitious, but some municipalities, such as the conurbation[14] of Parkstad, are going even further. The latter has put in place the PALET (PArkstad Limburg Energie Transitie) plan with the aim of achieving carbon neutrality by 2040.

Alongside the above measures, the Netherlands has decided to establish an ambitious policy of phasing out the use of gas for residential use by 2050, as part of a low carbon energy transition approach intended to reduce the CO_2 emissions of residential buildings by 80% by 2050 (COP21). This goal of abandoning the use of gas for domestic use will be offset to a large extent by going all-electric (via the use of heat pumps), but also by connecting dwellings to district heat networks.

[13] Euroheat.org
[14] Grouping of several cities within the same geographic unit

The abandonment of gas as a heat carrier is therefore moving the Netherlands to a system where the main heat carrier will be electricity. This transition will increase electricity demand, with the risk of a fivefold increase in the electricity grid load.

Heat networks are therefore a good alternative to ease demand on the electricity grid. Up to 3 million homes are estimated to be powered by a heat grid similar to that developed by Mijnwater[15].

2.1.3. Typology of consumers

2.1.3.1. Domestic

Typically, Dutch users use gas for heating, domestic hot water and cooking purposes.

The difficulty of the energy transition for these users therefore lies in switching from gas to all-electric (e.g. induction cooking). Domestic users generally support energy saving measures, such as insulation (windows, walls, etc.) and are willing to generate their own renewable energy (solar), but the costs involved in these measures remain the main decision-making factor.

2.1.3.2. Businesses and offices

The biggest businesses, offices and buildings traditionally use gas for heating and electricity for air-conditioning. They are often less focused on sustainable energy

However, there are incentives to encourage consumers to modify their heat supply, in particular no longer needing to maintain and manage their energy facilities, an end to dependency on fossil energies and further price increases, the use of residual energy (heat emitted by supermarket refrigerators or data centers), and the possibility of satisfying environmental requirements.

2.2. Presentation of the Mijnwater's project in Heerlen

2.2.1. Location

The municipality of Heerlen is located within the conurbation of Parkstad, in the Dutch province of Limbourg. It is located in a coal mining area whose coal resources were extracted up to the 1970s.

2.2.2. History

2.2.2.1. Origin of the project and the city's mining past

As the sub-surface coal resources were mined during many years, the region has many mine shafts and galleries that are currently flooded. In 2003, an employee of the municipality of Heerlen, the energy and sustainability coordinator Elianne Demollin-Schneiders, came up with the idea of using this mine water as a source of heat for buildings. Once the feasibility studies had been carried out, an estimated reserve of 8 million m³ of water was located in these former cold mines. As this deep water is naturally heated by geothermal features, it is therefore a potential source of thermal content, and this geothermal potential has been estimated at 7,026 TJ/per year in Heerlen, which is the equivalent of the average annual consumption of around 1,000 Walloon household, or the energy released by burning ±195,000 m³ of natural gas. However, the potential of the mine water is not limited solely to heating buildings, because the water in shallower depth strata is colder, and can therefore also be used for cooling buildings when necessary.

[15] Duurzaam tweede leven voor Limburgse mijnen, J. van Bockxmeer

The municipality of Heerlen therefore decided to launch a pilot project with the objective of supplying the city's buildings with heat and cold. That is how the Mijnwater 1.0 project came about.

2.2.2.2. Mijnwater 1.0

Mijnwater 1.0 is a pilot project, without any specific profitability or development objectives. Its aim was to assess the feasibility of supplying buildings with heat and cold using the water in former coal mines.

In 2005, five shafts were drilled to reach the reserves of water at the required temperatures. To that end, the authorities relied on the help of former miners who showed them the best places to drill.

Two of these shafts were used to pump hot water (28°C) at a depth of 700m, while two others were used to draw cold water (16°C) at a depth of 250m. The fifth shaft was used as a return shaft to reinject water into the mines (at a depth of 350m) after having extracted the heat or cold. From these shafts an 8 km-long network of underground pipes was put in place to distribute the mine water to the buildings. This system of pipes used to transport water from the mines was called the backbone.

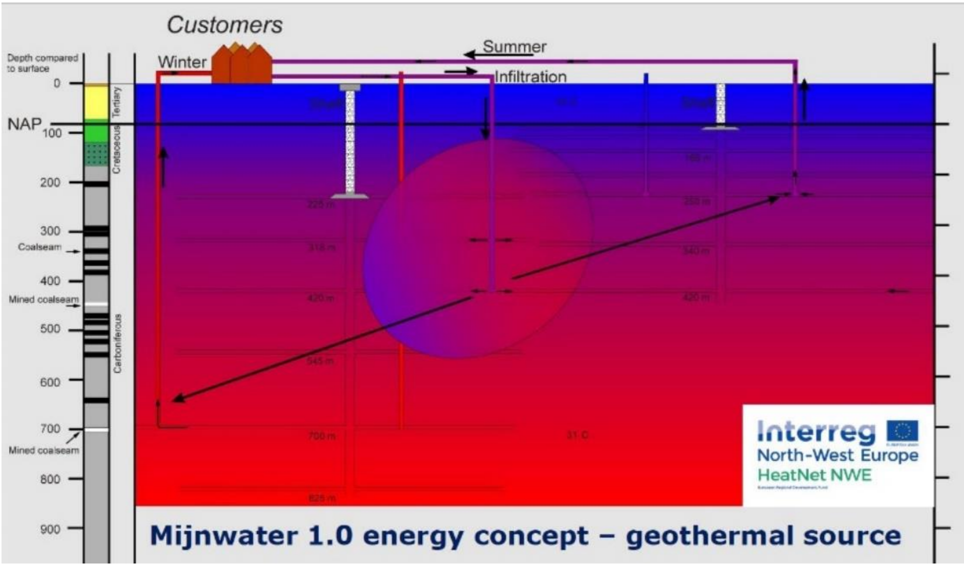


Figure 9 Principle and geothermal reservoirs of the Mijnwater 1.0 project

And in 2008, the first buildings were connected, and a surface area of almost 50,000 m² was then supplied with heat in winter and cold in summer from the mine water, creating the first geothermal mine water facility in the world.

Each building has an installation comprising a heat pump, which enables it to obtain heat (or cold) at the required temperature according to its needs.

It should be noted that during this stage of the project, the buildings are supplied only with heat in winter and cold in summer, but never both of them simultaneously. Moreover, there are no exchanges between buildings. It is therefore still a fourth-generation district heating and cooling network.

However, it was found that this direct use of mien water as a source of heat and cold was gradually exhausting the mining resources, in particular the reserves of cold water. A new operating method therefore had to be examined, which gave rise to the Mijnwater 2.0 project.

2.2.2.3. Mijnwater 2.0: towards a system of heat exchanges between consumers

The transition to version 2.0 of the Mijnwater project involved several essential changes from version 1.0, not only from a technical point of view, but also as regards the philosophy of the project. It involved the switch from a pilot project intended solely to examine the feasibility of an idea (supplying heat to buildings using mine water) to a possible alternative to gas as part of the energy transition being implemented in the Netherlands.

In this context, it was necessary to increase the number of network connections, but the gradual depletion of the resources present in the mine water meant that this was not possible, so it was necessary to fundamentally change the functioning of the system. The project therefore switched from a system drawing thermal energy from the mines to supply buildings to a system based on the exchange of heat and cold between buildings, with the mines being used henceforth only for inter-seasonal storage[16].

The system is based on the principle of clusters: parallel networks were added to the backbone. They are composed of a hot water circuit and a cold-water circuit. The heat and cold are exchanged between the backbone and the cluster's circuit via a heat exchanger. The buildings are then connected to the cluster's circuit with which they will exchange heat and cold via installations including a system of heat pumps.

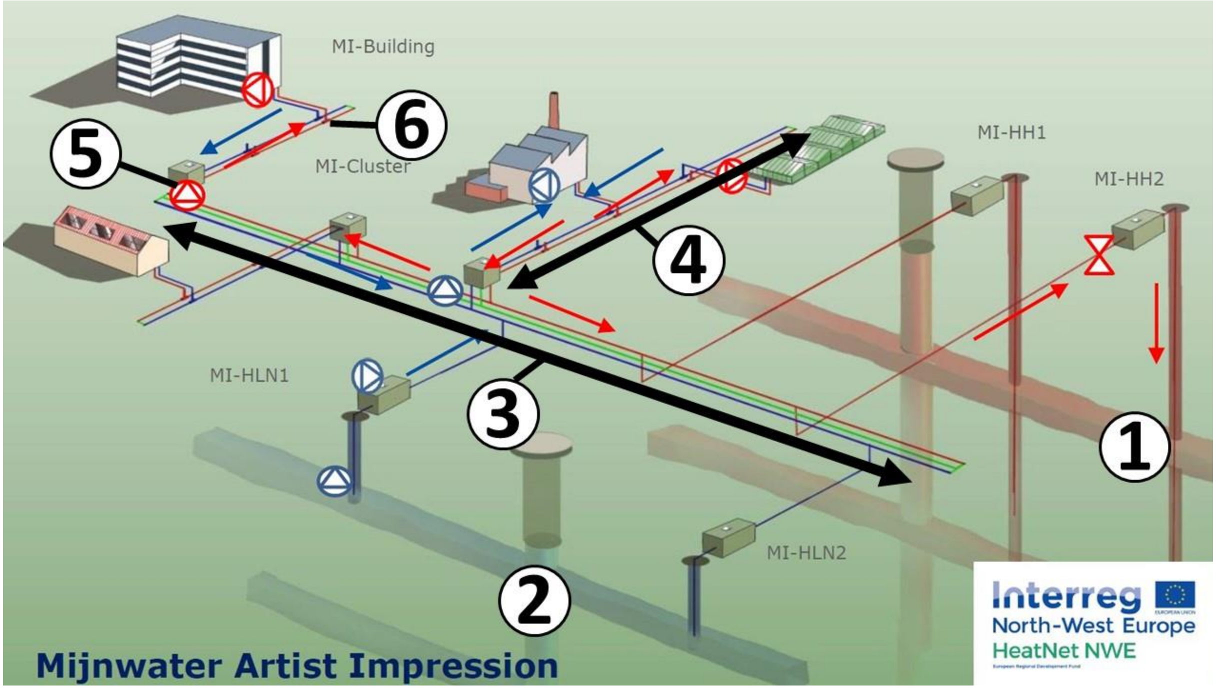


Figure 10 Principle of the Mijnwater 2.0 project
(1= Hot reservoir, 2= Cold reservoir, 3= Backbone, 4=Cluster, 5=Heat exchanger, 6=Heat pumps)
Source: Mijnwater

[16] René Verhoeven et al., Minewater 2.0 project in Heerlen the Netherlands: transformation of a geothermal mine water pilot project into a full scale hybrid sustainable energy infrastructure for heating and cooling, Energy Procedia 46 (2014) 58-67

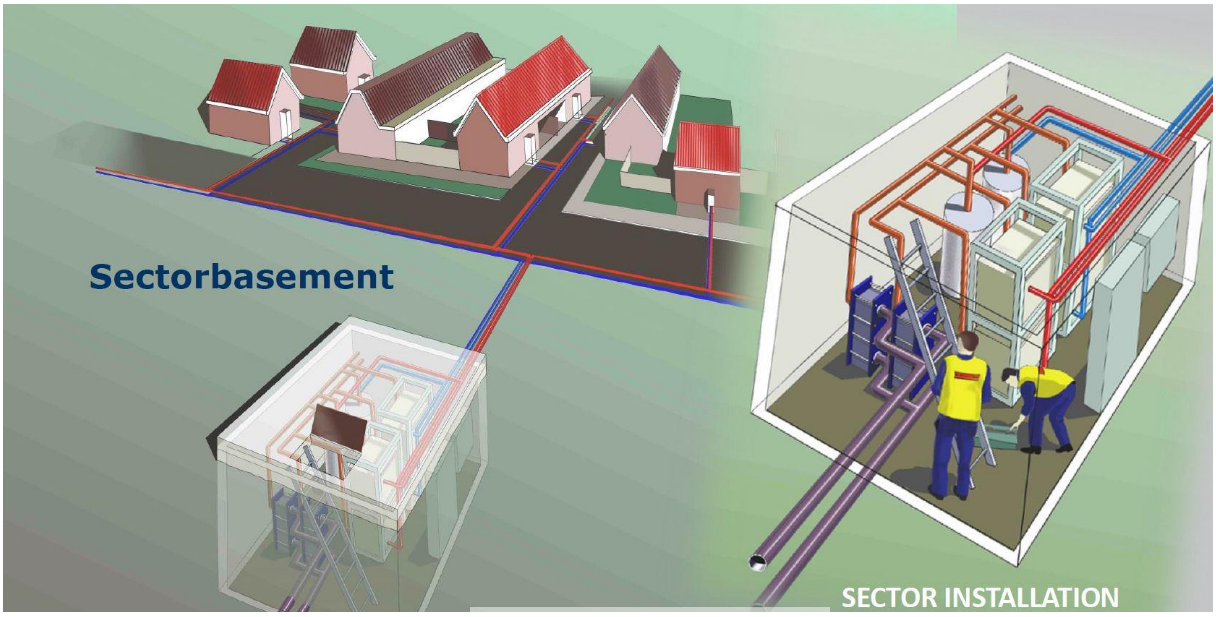
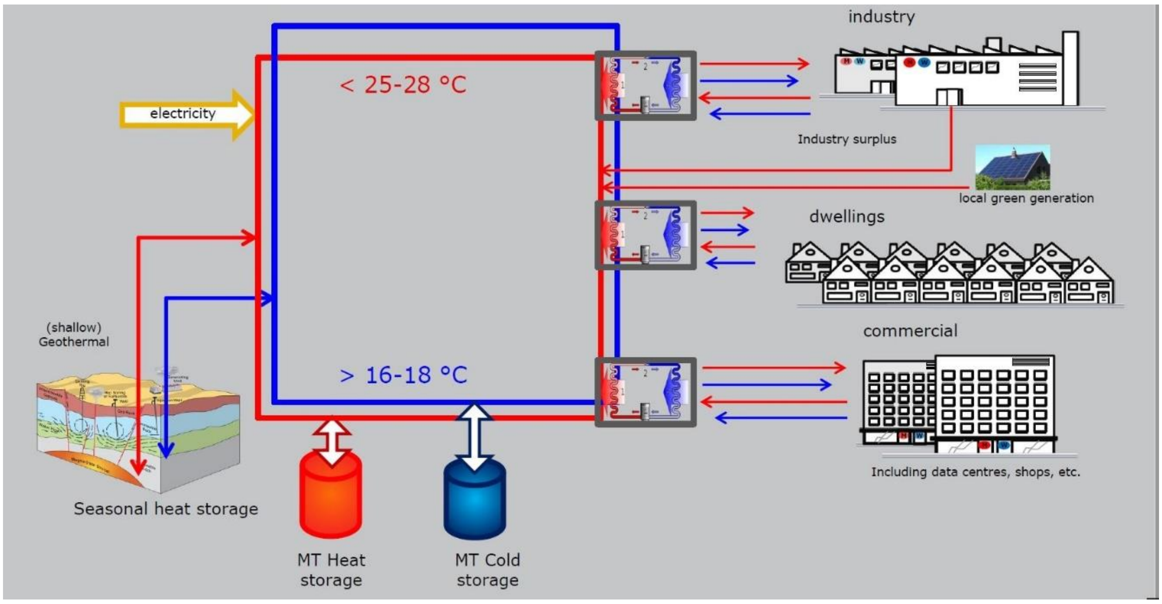


Figure 11 Heat exchanger between the backbone and the cluster (Source: Mijnwater)

In this configuration, any building that consumes heat on the network will automatically supply cold to it, and vice versa, it will release heat into the network when it extracts cold from it. This heat or cold reinjected into the network can then be used to supply other buildings according to their needs. And if this energy is not used by other buildings, it is then stored in buffer storage tanks on a short or medium-term basis, or is reinjected into the mines via the backbone for long-term storage (inter-seasonal). The most important component of the system then becomes the exchange capacities (of heat and cold) between companies, residential buildings and commercial buildings.



Therefore, the use of the shafts may be different: a heat shaft will be used to extract hot water from the mines, while the other will reinject hot water for inter-seasonal storage. This will also be the case for the cold shafts, and the fifth shaft which was used initially to return used water is no longer necessary.

This configuration has a significant advantage: it allows the network to supply heat and cold simultaneously, which means that it can cater for buildings having different heat and cold requirements, or that need to be supplied with heat and cold simultaneously.

There are currently four clusters connected to the backbone, to which there are eleven connections for a surface area of 200,000 m² supplied by the heat network, including 330 apartments.

It is estimated that at the current time around 50% of the heat and cold needs of the buildings are covered by the exchanges between buildings, with the rest being supplied by the mines, but offset by inter-seasonal storage.

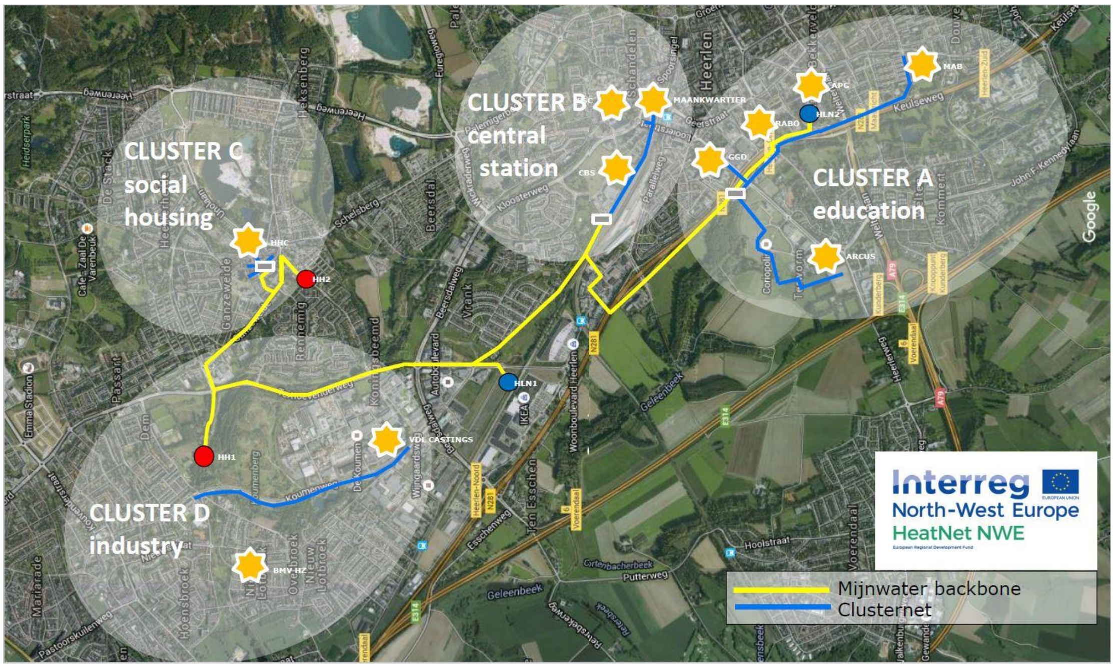


Figure 12 Network of the Mijnwater 2.0 project in Heerlen

2.2.2.4. Mijnwater 3.0: predictive integration of data

The next step for the project was Mijnwater 3.0.

The principle is a system, based on consumer demand, which recognises demand patterns according to the climate and past observations. It is therefore be possible to anticipate energy needs based on weather forecasts and consumer demand. This will make it possible to improve the efficiency of the distribution of hot and cold water, and better integrate the use of other sources of hybrid energy. For example, heat can be stored in buffers when this heat is produced (e.g. solar), knowing that such heat will be used later. It is also be possible to adjust the temperature of buildings according to the activity of their occupants, or take advantage of the high thermal inertia of buildings to heat them before demand spikes and cut the heat supply of buildings temporarily so that heat is supplied where it is required.

The use of electricity of renewable origin (via wind farms or the installation of photovoltaic panels) for the operating of the installation would make it possible to reduce even further the CO_2 impact of the network, making it even more sustainable.

2.2.3. Legal form and staff structure

Mijnwater B.V. is a public enterprise. It belonged initially to the municipality of Heerlen, and is now wholly-owned by the province of Limbourg via the Limburg Energie Fonds (LEF).

This enterprise has around twenty employees, divided between the following roles:

- network design
- network implementation
- network maintenance

2.2.4. Changes to the decision-making structure over time

The pilot nature of the project means that economic profitability was not the initial priority. The objective was to check the technical feasibility on a small scale. The technical success of the project during its development points to its eventual profitability. This potential recently led to a former banker being recruited to consolidate the financial objective of the project.

2.2.5. Activities carried out internally vs. externally

The technical development has been mostly carried out internally, while the technical facilities have been developed externally. Billing of users (owner occupants or tenants) is outsourced to a specialist company.

2.3. Technical aspects

2.3.1. Heat supply and exchange system

The heat network developed in Heerlen by Mijnwater is a low-temperature heat distribution network (28°C for the hot water used as a source of heat). This feature is interesting since it not only avoids a large part of the distribution related heat losses, but also makes it possible to integrate into the network sources of heat emitting at a relatively low temperature, such as the heat produced by heat pumps when these produce cold, or waste heat.

In addition, this configuration makes it possible to integrate renewable sources of heat into the system, such as waste heat from industry or that produced by solar heating panels.

In this configuration, the backbone has a twofold role: it links the clusters, and makes it possible to reinject heat or cold into the mines for inter-seasonal storage.

Mijnwater 2.0 also integrate an intelligent monitoring system (smartgrid) which takes account of the temperature required in buildings, the return temperature on the network and the outside temperature to optimise the various flows of water in the clusters and in the backbone. The system can therefore automatically adjust to consumer demand so that the only energy consumed is for the operation of the pumps, which ensures a very high level of network performance.

These factors make the Mijnwater 2.0 project an exemplary model of a 5th generation district heating and cooling network.

The network is based on three levels that exchange heat between them: the backbone that draws and reinjects hot (or cold) water from and into the mines. As the water extracted from the mines is corrosive, the materials making up the backbone must be corrosion-resistant. The piping system is therefore composed of synthetic materials and stainless steel (type 316). The water is extracted from the mines in a way that ensures that the pressure is at least equal to 2 bars at the level of the exit points so as to avoid the degassing of the solution gas in the mine water. The pumping in the mines is therefore regulated by the pressure within the backbone.

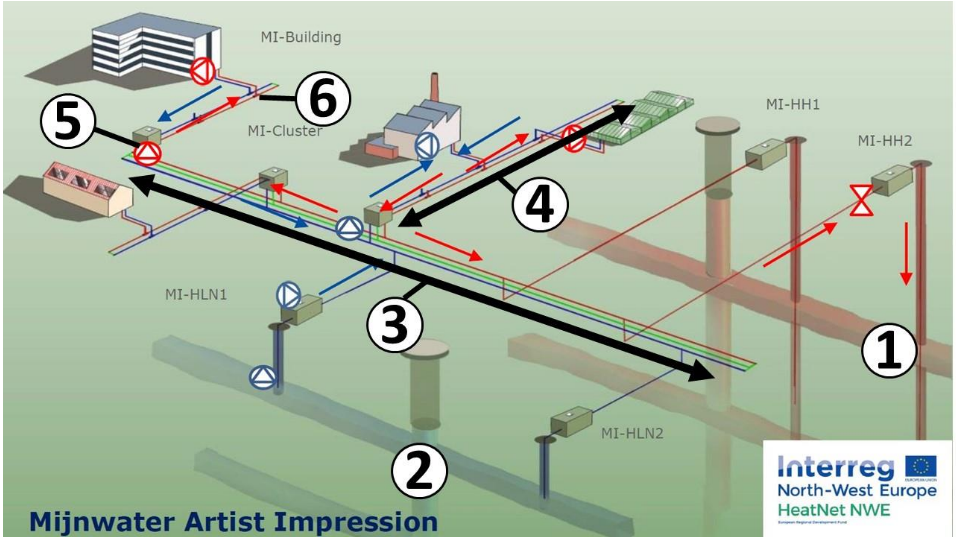


Figure 13 Principle of the Mijnwater 2.0 project
(1= Hot reservoir, 2= Cold reservoir, 3= Backbone, 4=Cluster, 5=Heat exchanger, 6=Heat pumps)
Source: Mijnwater

The cluster grids on the backbone are independent piping systems that carry heat from the backbone to the buildings supplied by the network and transfer heat between buildings. The heat is exchanged between the backbone and the cluster grid via a heat exchanger. The mine water is therefore not on the cluster network, which avoids the need to use corrosion-resistant materials. A single heat exchanger is used to exchange both heat and cold. It is a pump, located on the backbone side, which sends hot water to the heat exchanger when required by the cluster, and the resultant cold water is sent to the backbone's cold-water pipe (and vice versa when the cluster requires cold). To optimise the exchange of heat, the flows of water on both sides of the exchanger must be identical. The pumps sending water from the backbone to the heat exchanger are therefore regulated according to the flow measured at the level of the cluster.

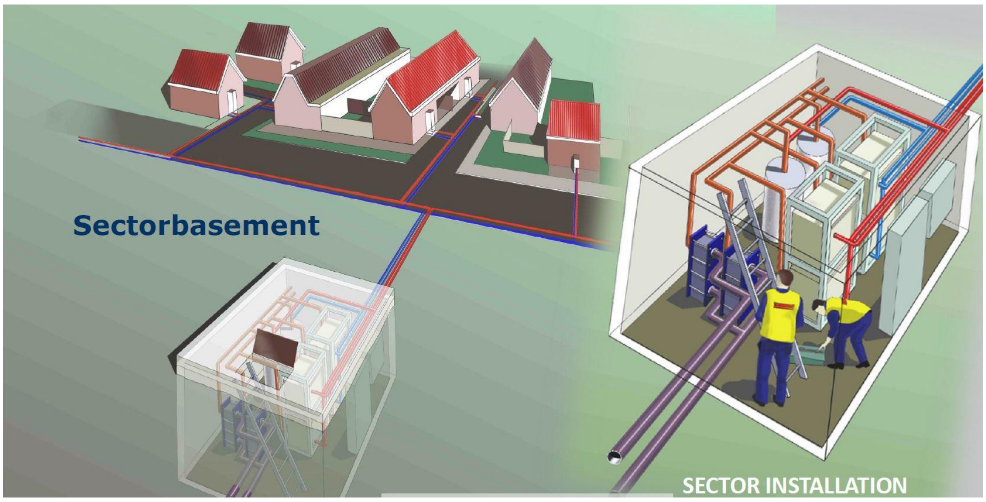


Figure 14 Heat exchanger between the backbone and the cluster
(Source: Mijnwater)

The last level of exchange of heat is between the cluster network and the buildings connected to it. This exchange is operated via an installation with two heat exchangers supplied by pumps next to the cluster, which enables heat and cold to be delivered simultaneously to the building. The heat and cold supplies operate independently thanks to signals from the installations on the cluster side and from the building part. It is important that the network reinjection temperature is regulated so as not to destabilise the network (the network re-injection temperature is moreover one of the connection conditions). The temperature of the return heat must not be too high (<14°C) for the return line of the heating circuit, and must not be too low (>30°C) for the return line of the cooling circuit of the building. The installations located between the cluster and the buildings are therefore regulated according to the temperature. For each building, a system of heat pumps is then used to transfer the water at the necessary temperature for the building.

2.3.2. Heat storage

Heat storage is an important element for the operation of the system.

It is necessary in particular to store the excess heat for subsequent use, but also to establish a reserve so as to smooth demand in the event of a sudden increase in demand (when there are peaks in demand).

Heat storage is divided between several units across different levels of the network and provides for storage on different time scales.

The mines are the first level of storage. They have a capacity of 8 million m³ and the temperature there is constant according to the depth (in the absence of external flows), which makes them excellent long-term storage tanks. In the Mijnwater project, they are used for inter-seasonal storage. The cold from the heating of buildings in winter, and which is not re-used for other buildings in the network at that time, is returned to the mines to be stored until summer, when it will be used to cool buildings (and vice versa for the heat produced in summer).

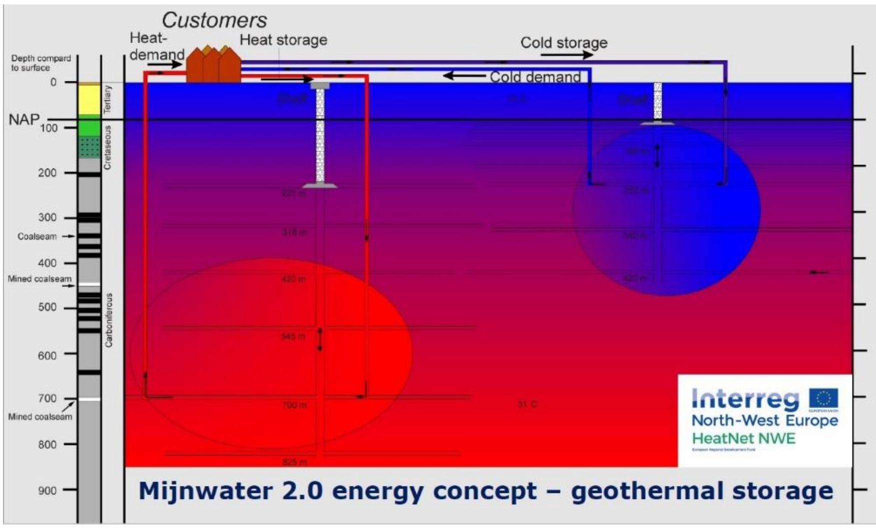


Figure 15 Mijnwater 2.0: Circulation within the backbone and storage in the mines (Source: Mijnwater)

The cluster provides a second level of storage consisting of a 70m³ tank. It levels out changes in heat supply and demand within the cluster and therefore avoids excessive demand on the backbone and mines reserves.

Thirdly, the buildings are the last level of storage. Each building contains a buffer storage tank of 0.2 m³ for the building's storage needs. But the building itself can also serve as a storage place, since if it well insulated it can retain the heat for a certain period. The buildings can then be heated in advance (for example, a few hours before the opening of offices) so that this heat is not mobilised on the network during demand spikes (for example, in the morning for consumption for domestic heating and showering).

2.3.3. Remote management

The entire network is managed remotely via a central monitoring system. All these installations are inter-connected via the Internet, which enables them to interact with each other according to the system's different parameters.

This remote management system has a twofold role. The first is operational: it enables the various heat exchangers, pumps and heat pumps to interact, according to supply and demand for heat, so as to optimise the delivery and storage of this heat. It is also a means of logging these parameters so as to be able to adjust them if necessary, whether as regards the technical setup or at the level of the installations.
The second role is to monitor the installations. The central monitoring system detects specific errors and outages, and also makes it possible to rapidly send warning signals to the appropriate service in order to respond rapidly and efficiently to any system malfunctioning.

2.4. Economic aspects

2.4.1. Subsidies

2.4.1.1. Premises

Initially, the pilot project was financed by the municipality of Heerlen. It financed all of the stages necessary to get the project off the ground, including for the various feasibility studies, setting up the initial teams and the expenses for drilling and putting in place the heat network.

More recently, the province of Limbourg has also been integrated into the project funding. In total, the estimated amount invested by these two stakeholders is between 20 and 25 million euros.

2.4.1.2. European

Various European programmes have participated in the Mijnwater project, in particular Interreg HeatNet NWE, D2Grids, Horizon 2020, Life4Heatrecovery and OPZuid.

The estimated total amount of funding provided by these various subsidy programmes for the project is between 25 and 30 million euros.

2.4.2. Contractual relationship with consumers and pricing

2.4.2.1. Contract

Mijnwater does not propose a standard contract for the supply of heat and cold to end users. The terms and conditions governing each connection are discussed beforehand with future users. Several points can be adapted where applicable. The type of pricing proposed can also be negotiated with the consumer (see point 2.4.2.2).

The contractual terms and conditions depend in particular on:

- The type of occupation of the building: residential, service, industrial
- The building's heating and cooling needs
- The building network's heat supply capacity (waste heat, heat and cold needs regardless of the season, etc.)
- Whether or not there is green electricity in the building (photovoltaic panels, cogeneration, etc.)

A specific contract for each new connection is established in the light of these factors.

2.4.2.2. Pricing

The pricing, in the same way as the contractual specifications, varies according to the profile of the connected building. However, there are some guiding principles.

To be attractive, the price of Mijnwater's heat offering must be lower than the cost of heat supplied by the dominant carrier, namely a connection to the gas network with an individual boiler. With this in mind, Mijnwater's aim is to propose an offering whose cost is 10% lower than that of gas (predominant heat carrier). It is to be noted that gas is increasingly less frequently regarded as the benchmark, and that offerings are gradually more likely to be compared with an Air/Air or Air/Water heat pump type installation.

The network connection costs are always assumed by the owner.

The pricing of heat consumption can take two forms. It can be linked to the actual heat consumption of the building. That is the case in particular for residential type buildings and domestic connections.

For service type buildings and connections, Mijnwater prefers to base its pricing on the surface to be supplied with heat and cold. This pricing per m² avoids the costs inherent in heat metering, and is particularly interesting for Mijnwater if the building is correctly insulated.

There is no established prosumer pricing model. This is determined on a case-by-case basis.

2.4.3. Taxation

The only taxation that we have identified is that relating to the deterioration of roads at the time of the installation of the piping of the backbone and clusters. This is a one-off tax at the time of installation, there is no highways tax.

2.5. Strategic aspects

2.5.1. Network connection technical conditions

One of the technical prerequisites for connecting to Mijnwater's heat network is that the building must be correctly insulated (if possible, A+++). However, the fact that a building is inadequately insulated is not an obstacle to connection if the applicant plans to make such an improvement at a later date (during a major refurbishment project).

This prerequisite is strategic since it reduces the building's energy demand, and facilitates more connections for the same heat availability. As some of the pricing models are proportional to the floor area heated (and not to consumption), it is very much in Mijnwater's interests that such consumption is as low as possible.
Moreover, low heat demand reduces the size of the heat pumps supplying the buildings and therefore the related costs.
Lastly, so as not to disrupt the network, it is important that the temperature of the water returned to the network remains below 15°C. Therefore, a low-temperature heating system is necessary, while it remains essential to ensure that the building is well insulated (in order to limit the energy required).

Mijnwater owns all the installations up to the building (including heat pump). All other installation (like floor heating are for the building owner). The fact that Mijnwater owns all of the installations considerably facilitates maintenance, problem solving, and the management and delivery of heat to consumers.

2.5.2. Relations with external stakeholders

2.5.2.1. Relations with the project's partners

Mijnwater is more interested in developing partnerships than in outsourcing. Their philosophy is based on all of the stakeholders being committed and responsible for the outcome of the project. They use call for proposals, but the final selection is not based solely on the price, but also takes into account the partner's expertise and commitment to the project.

Generally speaking, Mijnwater is responsible for planning and design, while the various partners are responsible for the installation and the implementation of the plans developed by Mijnwater. This modus operandi ensures a certain consistency in the installations, which greatly facilitates maintenance and problem solving.

2.5.2.2. Relations with local authorities

As the Mijnwater project was initially undertaken by the municipality of Heerlen, before Mijnwater B.V. was subsequently purchased by the province of Limburg, the relations between the authorities and Mijnwater have always been very close. The municipal and provincial authorities are therefore stakeholders in the project, and relations with these partners are therefore regular and strong.

2.5.3. Types of procedure used for the conclusion of the various contracts

We were unable to obtain this information during our interviews.

2.5.4. Factors having convinced consumers and prosumers to participate in the project

2.5.4.1. Selling points

To overcome any negativity on the part of the various users of the network (seer point 2.1.3), Mijnwater has developed various strategies and arguments on several levels.

The first of these arguments is pricing. The cost of the heat proposed by Mijnwater is 10% below the price of heat obtained via a traditional gas installation. However, the price argument generally needs an additional explanation since the price of the heat generated by the network can sometimes seem more expensive than that produced by a gas installation, because the purchase and maintenance costs of the gas installation are often forgotten by users, and only the gas consumption is taken into account by them. It is therefore necessary to estimate the TCO in order to make an objective comparison.

A second price argument is that of the stability of the price of heat over time. As the heat derived from the Mijnwater network is not linked to fossil energy prices, apart from inflation, it remains stable over time, unlike the fossil energy prices which are subject to taxes and excise duties and which will inevitably increase in the future.

Another strong argument is that of the reduction of CO_2 emissions as a result of connecting to the network. This argument is particularly weighty not only for individuals for whom the ecological aspect is important, but also for businesses that are required to reduce their CO_2 impact or face sanctions.

An argument that is sometimes underestimated concerns the absence of roof-top technical installations, since a connection to the Mijnwater network eliminates the need for chimney pipes installations and roof-top refrigeration units. The resultant free space can be used for another purpose (terrace, additional floor, etc.) which, in areas where the value per m² is high, is a powerful argument.

Lastly, the money previously spent on fossil energies is now invested locally. This argument has become even more powerful in the Netherlands since the announcement of the closure of the Groningen field, and the resultant need to import gas.

2.5.4.2. Publicity

In the same way as the challenges of energy transition, heat networks as an alternative to traditional facilities are often largely ignored by the general public. It is therefore necessary to communicate on these subjects in order to ensure that potential future consumers are better informed of the ins and outs of the situation.

Mijnwater communicates with the general public via various channels, in particular by organising information sessions, meetings with the project's stakeholders, by setting up a website posting information on the project, via regular newsletters, and by organising mediation meetings when there are disputes or misunderstandings.

2.5.4.3. Industrial waste heat and heat demand

Medium-sized and large industrial buildings have a high potential as a source of heat via their residual energy (waste heat). However, it is often more difficult to convince them to connect to the network, since an intervention on their production process is necessary to recover this residual energy. It is therefore necessary to find a win-win solution: so that the prosumer derives some benefit from it, either financially, or through the achievement of environmental targets or by reducing its production of CO_2. Furthermore, Mijnwater needs to be able to achieve a balance between supplying the necessary energy and collecting the residual energy.

Another difficulty lies in supplying heat adapted to business processes. As it is a low-temperature network, it is very difficult to achieve the temperatures needed for these processes with this type of network. The potential of businesses lies mainly in their ability to provide heat or cold on the network (capacity as prosumer) rather than in their capacity as a consumer for the network.
Once connected these users become a prosumer: a party that receives cold always automatically supplies heat to the network.

At the time of writing this report, there is not yet any industry supplying waste heat connected to the network, but the connection of an ironworks with cold needs for its various processes is being studied.

2.6. Legal aspects

Various pieces of legislation influence and regulate the development of heat networks and the supply of heat in the Netherlands.

2.6.1. Gas Act

Because, until recently, the Netherlands had large gas resources, gas was favoured for the production of heat in buildings, to the point that it was compulsory for buildings to be connected to a gas network if there was one close to the building.

The planned phasing out of the Groningen field and the ambitious policy of the Netherlands for reducing CO_2 emissions and ending the use of gas for domestic heating resulted in an amendment to the Gas Act being adopted which abolishes this connection requirement and prohibits connection of new houses and smalls companies from 01/07/2018. A new legislation has been settled to create a new, clear and simple regulatory framework for the Dutch electricity and gas market, based on European law. This legislative package, referred to as "STROOM" (Streamlining Optimization and Modernization) has been putted in place on may 2015[17].

2.6.2. Bouwbesluit

The construction decree (Bouwbesluit) defines the codes to be complied with in the construction sector in the Netherlands. It clearly defines the standards, in particular those relating to the supply of gas, electricity and heat. This decree also lays down technical connection conditions to be respected, including the obligations to be connected to the gas network (repealed) or the heat network.

[17] L. Wildeboer et al., STROOM; the new electricity and gas act in the Netherlands, CMS legal 2020

The various obligations and standards are clearly and unambiguously defined in this decree, so that each of the stakeholders of the various networks can refer to them to establish technical conditions and rules applying to network connections.

2.6.3. Energieakkoord

The energy agreement (EnergieAkkoord) is a plan, established in 2013, between the Dutch government and dozens of organisations and interest groupings in order to promote energy transition in the Netherlands. The signatories to this plan undertake to achieve various targets, in particular reducing national energy consumption by 1.5% annually, with the objective of achieving a total reduction of 100 petajoules (PJ) in 2020. It also aims to increase the proportion of renewable energy from 4% to 14% in 2020, and 16% in 2023[18].

2.6.4. Klimaatakkoord

The Dutch climate agreement (Klimaatakkoord) consists of a series of measures intended to reduce CO_2 emissions in order to comply with Paris Agreement of 2015. This law project, which is due to enter into force in 2021, consists of a series of measures intended to reduce by 2030 CO_2 emissions in the Netherlands by 49% compared with 1990.

One of those measures' objective is to reach a reduction of 3.4 million tons of domestic CO_2 emissions, which corresponds to disconnecting more than 1.5 million households from the gas network by 2030, for more environmentally-friendly alternatives, such as heat networks. The target for 2050 is to disconnect more than 7 million households and one million buildings.

A heat fund (Warmtefonds) will also be set up. Between 50 and 80 million euros will be set aside every year to subsidise the insulation of private dwellings and low-carbon heating installations.

The reduction of CO_2 emissions will naturally be based on the gradual phasing out of gas as a source of heat. This means increasing the network availability of renewable heat. The government's goal is therefore to withdraw between 30,000 and 50,000 existing homes form the gas network. Furthermore, from 2021, 75% of new buildings must not be connected to the gas network[19].

Other measures target businesses, in particular the introduction of a CO_2 tax for large companies, and a tax increase on the natural gas used by businesses.

These measures are intended to drive initiatives to reduce CO_2 emissions and offer alternatives to gas. Geothermal energy is also spotlighted in this agreement; the target is that it should represent 50 PJ by 2030 and 200 PJ by 2050.

Municipalities are also given significant responsibilities in this regard. They must establish a plan for the transition of heat sources, in collaboration with local stakeholders (Warmtevisie), and develop a project to implement this plan for future renewable energy infrastructures (Warmteplan). The idea is to establish guidelines for the various stakeholders in the sector (owners, DSO, heat suppliers, municipal authorities and others) so that they can plan their future developments and investments in a reasoned manner. In this regard, Heerlen is part of the conurbation of Parkstad, which has developed its own Warmtevisie and Warmteplan.

2.6.5. Warmtewet

The "Heat Act" (Warmtewet) consists of a series of measures intended to legislate on rules on district heating, the supply of heat and therefore to heat networks. Its aim is to provide protection to the people connected to a heat network, whether for businesses or homes, in particular by combatting excessive pricing. For people connected to

[18] Iea.org
[19] Bakermckenzie.com

a heat network, the lack of choice for heat supplier and, therefore, the lack of competition, easily lends itself to abuses. Legislation is therefore necessary to establish a framework for this situation.

This Act lays down in particular maximum prices for the heat supplied, the conditions under which user can disconnect from the network, compensation if the heat supply is interrupted, the regulation of heat metering, the establishment of a disputes committee, etc.

Therefore, the criteria to be taken into account when calculating the maximum price for heat are clearly defined: they must be based on the price that the consumer would have to pay to obtain the same heat via another carrier.

2.6.6. PALET

The PALET (for PArkstad Limburg EnergieTransitie) is an energy transition plan put in place by the conurbation of Parkstad. It consists of an analysis of the region's energy situation, as well as proposals for an efficient energy transition.

As regards the city of Heerlen, it has been estimated that 7,026 TJ of the 7,965 TJ used for buildings can potentially be supplied by renewable sources, the bulk of which would be solar, but more than 40% could be provide by geothermal energy. In this regard, it quickly became apparent that heat networks, in particular the Mijnwater project, represent a conceivable alternative for the supply of heat to buildings as part of the transition to cleaner energy. It has therefore been integrated into the most recent versions of the PALET, with a new challenge in view: increasing the scale of the project to other municipalities in the conurbation of Parkstad[20].

2.7. Roles of the pubic authorities

2.7.1. Roles of the municipality

The municipality of Heerlen has played a key role in this project.

First of all, it was the project initiator: it was a municipal employee, the energy and sustainability coordinator Elianne Demollin-Schneiders, who came up with the idea of using mine water as a source of heat for buildings. The municipality then undertook the necessary project feasibility studies and, once the findings of these studies were available, it then recruited the competent team to implement the project.

The municipality has also participated in the project's financing, above all during the initial development stages, when the project did not yet have European subsidies. In particular it financed the feasibility study of the project to develop the heat contained in mine water, as well as the establishment of the technical teams for the practical implementation of the project. It was only after these phases that Europe became involved in the financing of the project. In total, the municipality of Heerlen has invested around 25 million euros in the project.

Lastly, the municipality of Heerlen is also a customer of the network, since several of its buildings are directly connected to the Mijnwater heat network, in particular a sports centre and several schools. In addition, the municipality has undertaken that all future municipal buildings will be connected to the network.

2.7.2. The province's role

The province of Limburg has not played a direct role in the development of the Mijnwater heat network. However, it has played an important role in providing information and acting as an energy transition facilitator vis-à-vis the general public.

[20] PARKSTAD LIMBURG ENERGIETRANSITIE (PALET) PALET 2.0 - HEERLEN

This role involves among other things setting up offices open to the public where citizens can find information on issues relating to reducing both energy consumption and CO_2 emissions. The province will also promote the insulation of buildings by informing citizens of the different prices and grants available for insulation.

In general, in the Netherlands, energy saving incentives are based on subsidies for those that make such savings and non-energy efficient behaviour is penalised by high energy prices.

3. Adaptation of the Mijnwater B.V. model to Wallonia

3.1. Comparison of the situation in Wallonia and the Netherlands

Situation in the Netherlands	Identical situation ?	Situation in Wallonia
Determination not to be dependent on foreign energy suppliers		
The Netherlands has long been relatively energy-independent via the Groningen gas field (they also imported gas from Russia to combine it with gas from Groningen in order to reach a good calorific value). There is a real determination to remain independent vis-à-vis foreign energy suppliers.		Belgium, and therefore Wallonia, is already heavily dependent on foreign energy suppliers. In addition, via the capacity remuneration mechanism (CRM), the dependency on gas for electricity will increase in the coming years.
Presence of geothermal resources in mines		
The mining past of certain Dutch regions, and the end of mining, has resulted in the flooding of shafts and galleries by groundwater. As this water is heated by geothermal energy, it represents an exploitable healing resource.		Wallonia also has a mining past. Therefore, the same types of situations exist there, but this issue needs to be studied in-depth. Such a study is being carried out in part by Vito and UMons at the request of the SPW.
Primary energy ratio (PEB) favourable to heat networks		
The primary energy ratio of the heat produced by the Mijnwater's heat network is set at 2 in the Netherlands, but there is a project to modulate this value based on the source of heat. This makes it possible to obtain a favourable PEB (Energy Performance) certificate, which encourages the installation of this type of heat carrier.		In Wallonia, the primary energy ratio of heat networks has been set at 2, regardless of the source of the heat, which is very detrimental to the development of this type of project. This situation is very often raised by real estate developers interested in the matter and results de facto in the choice of gas, where applicable, or air/water heat pumps in all development districts. This issue was under review by the previous minister. It is important not to lose sight of it since it represents a major obstacle.

Owners of large real estate portfolios		
In the Netherlands, many buildings have a single owner. This configuration facilitates exchanges between heat suppliers and consumers, by reducing the number of participants.		This situation also exists in Belgium (social housing companies, etc.) The number of Belgians owning their own home (72% in 2015 but decreasing) is higher than in Netherlands (66%), but this does not have any real impact on the choice of network. The complexity depends more on the way in which co-ownership works (Federal law), since co-ownership management tends to be very passive unless forced to act because of legislation or an imminent danger to the building.[21]
Support of the local and provincial authorities		
The success of this project (at least during its initial phase) is due to a large extent to the support of the local authorities (the municipality of Heerlen) which has provided financial and logistical support for the project. Without this local commitment, it is very unlikely that this project would have been implemented. The province of Limbourg has become one of the project's stakeholders, in particular since the purchase of Mijnwater B.V. by the Limburg Energie Fund. The province of Limbourg sees the Mijnwater project as a technology of the future which will benefit not only the province, but also the rest of the country, even internationally. It is therefore an investment that is equally interesting from a financial point of view.		In Wallonia, there are already heat network projects that have been supported and initiated at local level by the authorities (City of Charleroi ERDF Project, Tibi Project, Urbeo ERDF Project in Herstal, etc.). It is even the case for the majority of them (55% according to a TWEED study). The local authorities are therefore also involved in the Walloon Region. On the other hand, the guidelines ate regional level are certainly less clear.

[21] ec.europa.eu

Commitment to moving away from fossil energies as a heat source		
The need to find alternatives to fossil energies is a not a problem specific to the Netherlands. However, the end of the development of the Groningen gas field, together with the determination not to be dependent on imports, have led the Netherlands to phase out completely the use of gas as a source of domestic heat, and therefore to find alternatives.	±	In Wallonia, there is no such determination to completely stop the use of gas as a source of domestic heat. However, it is to be noted that this determination did not exist in the Netherlands at the time of the first phase of the Mijnwater 1.0 pilot project. In addition, as global reserves of fossil energies are limited, it will be essential to envisage a transition to other energy resources in the coming years.
Opposition of gas DSOs		
During the implementation of the Mijnwater project, the distribution system operators (DSO) have not blocked the development of the project, probably for two reasons: at the start of the project, the scale of it did not represent a real threat for gas DSOs, and the legislation relating to PALET prohibiting the connection of new buildings to the gas network, the heat network therefore did not represent a direct competitor for them.		In Wallonia, heat networks are seen by the gas DSOs as an alternative to their product and therefore as a potential source of a loss of earnings. They therefore regard heat networks as business competitors. However, this statement must be nuanced, since in the discussions on the heat networks decree, the largest DSO in Wallonia took an interest in the matter with a view to potentially becoming a stakeholder. This point seems interesting since it would reconcile the environmental interest with the individual interest of the DSO.
Image and public knowledge of heat networks		
Except for the regions where heat networks are already established, the general public is generally unfamiliar with such networks. However, the presence of heat networks in some large cities (Amsterdam, Rotterdam) gives them a certain positive publicity.	±	In Wallonia, in general, heat networks remain unknown at the current time. They developed to some extent between the 1930s and 1980s with a view to capturing the waste energy of steel works, but the gradual disappearance of this activity, coupled with a lack of maintenance of the networks, means that they tend to have a poor image (Socageth in Charleroi, Sambreville Network, Intervapeur, etc.). On the other hand, they have clearly attracted renewed interest over the last ± 5 years among technicians in the sector, developers and maintenance companies.

		There would however appear to be an important need to communicate positively on the subject if the aim is to get citizens to take an interest in hat networks.
Possibility of making it mandatory to connect to heat networks		
During the installation of the Mijnwater heat network, the municipal authorities imposed this system as source of heat for the domestic heating of new buildings in Heerlen. In general, in the Netherlands, it is mandatory in almost all cases for buildings to connect to a heat network is there is such a network within 40m of the building.		This point is a recurring request from the sector at roundtables on local planning regulations. Moreover, it is in line with Directive 2018/2001 (protecting investment by limiting the right to disconnect) subject, as provided for in article 24 of the obligation for the DSO to accept new suppliers of thermal energy (waste heat, renewable energy, etc.).
Availability of public funding		
The Mijnwater project has benefitted from significant public funding, especially at the outset, first of all from the municipality of Heerlen, and then from the province of Limbourg	±	In Wallonia, there are heat network support mechanisms. They are mainly investment grants, tax deductions and green certificate mechanisms. The regional authorities also support heat networks via the allocation of European funding (ERDF) as is the case for the district heat networks of Charleroi and Herstal.
Significant reliance on gas as a source of heat		
In the Netherlands, gas was by far the most widely used source (<90%) for domestic heating.		In Wallonia, the situation is not as homogeneous. The energy source for domestic heating varies considerably depending on the location and type of building (urban or rural) and strategies to promote the usefulness of heat networks therefore needs to be more varied[22].

[22] Directive efficacité énergétique 2012/27 – Art. 14 – Stratégie de réseaux de chaleur et de froid alimentés par des cogénérations et des énergies fatales – PWC Deplasse ICEDD

Proportion of social housing in the real estate stock		
Social housing represents a large proportion of Dutch real estate[23][24] (30%) and the conditions of access to such housing are flexible: in the event of an increase in the household income, the household can stay in social housing, but the rent is adjusted accordingly. Social housing companies are therefore important contact points when installing a heat network.		In Belgium, social housing represents a far lower percentage of total real estate (7%). Social housing companies are therefore less important as a contact point for the implementation of heat networks.
Determination to reduce CO_2 emissions		
The Netherlands has a target of reducing the CO_2 emissions of residential buildings by 80% by 2050. The conurbation of Parkstad (which includes Heerlen) wants to go even further, and wants to achieve carbon neutrality by 2040.		Wallonia is also determined to reduce CO_2 emissions, in accordance with the climate energy plan, which refers to heat networks and geothermal energy.
Sources of renewable energy		
The low temperature of the Mijnwater heat network means that it is easy to integrate renewable sources of energy, such as solar heating panels, wind power, geothermal energy and waste heat.		This type of heat source is also present in Wallonia. In 2015, it was estimated that around 8,400 GWh[25] of renewable heat were produced in Wallonia (biomass, solar, heat pumps, geothermal energy)

[23] Bdpeurope.com
[24] oecd-ilibrary.org
[25] apere.org

Taxation of large companies in respect of their CO_2 emissions and gas consumption		
The klimaatakkoord defines the taxation of companies having high CO_2 emissions. Such measures encourage companies to take steps to reduce their emissions, for example connecting to less polluting heat sources, which drives the development of environmentally-friendly alternatives, such as heat networks.	±	In Wallonia, sectoral agreements enable companies that hit their targets for the reduction of CO_2 emissions in order to obtain financial and administrative benefits, in particular increased subsidies for energy auditing initiatives, exemptions from contributions and excised duty reductions[26][27]. However, there are no repressive measures for companies with excessive CO_2 emissions.
Obligation to connect to a heat network		
In the Netherlands, it is mandatory to connect to a heat network if there is one within 40 metres of the building, and this requirement is mentioned in the municipality's heating charter.		In Wallonia, this obligation can be imposed via town planning rules. However, for such a requirement to be imposed there must be the necessary political will. The idea of a mandatory connection to a heat network is especially interesting in the light of article 24 of European Directive 2018-2001 which sets out the disconnection conditions to be respected, in particular the need for an alternative leading to a significant improvement in energy performance.

[26] Rise.be

[27] agoria.be

3.2. Geothermal energy in Wallonia

Geothermal energy has a potential that has not really been developed in the past in Wallonia. Since 2010 there has been renewed interest in this resource, resulting in new studies on this subject and its potential. Geothermal energy is moreover referred to as one of the alternatives to fossil energies in the Climate Energy National Plan, with estimated renewable heat production of 11 GWh in 2030[28] in Wallonia. The target for 2030 is for 25% of heat consumption to be covered by renewable sources of heat, including geothermal energy, via the establishment of heat networks.

To facilitate the development of geothermal energy and provide a framework for such development in Wallonia, several legislative texts are in the process of being produced or approved. These include a preliminary draft decree establishing a geothermal energy guarantee scheme, which was approved by the Walloon Parliament at first reading on 24 January 2019[29]. The aim of this decree is to establish a regional geothermal energy scheme and a guarantee fund. This guarantee would provide for compensation for projects where the geothermal energy obtained after drilling is less than the projected theoretical volume.
A subsurface preliminary draft decree is also pending, with the aim of establishing a clear and precise framework for subsurface activities, including geothermal energy which at the current time is not governed by any regulation. This decree would establish a clear legislative framework in order to reassure the various stakeholders that have sometimes been reluctant to enter the market because of the lack of legal certainty. This preliminary draft decree was approved at first reading by the Walloon government on 6/12/2018[30].

3.2.1. Geothermal energy potential in Wallonia

As can be seen on the map below, Belgium is not in an area where high geothermal energy is achievable, because of the absence of a high level of seismic or volcanic activity on its territory, and the absence of magma movements in its sub-soil.

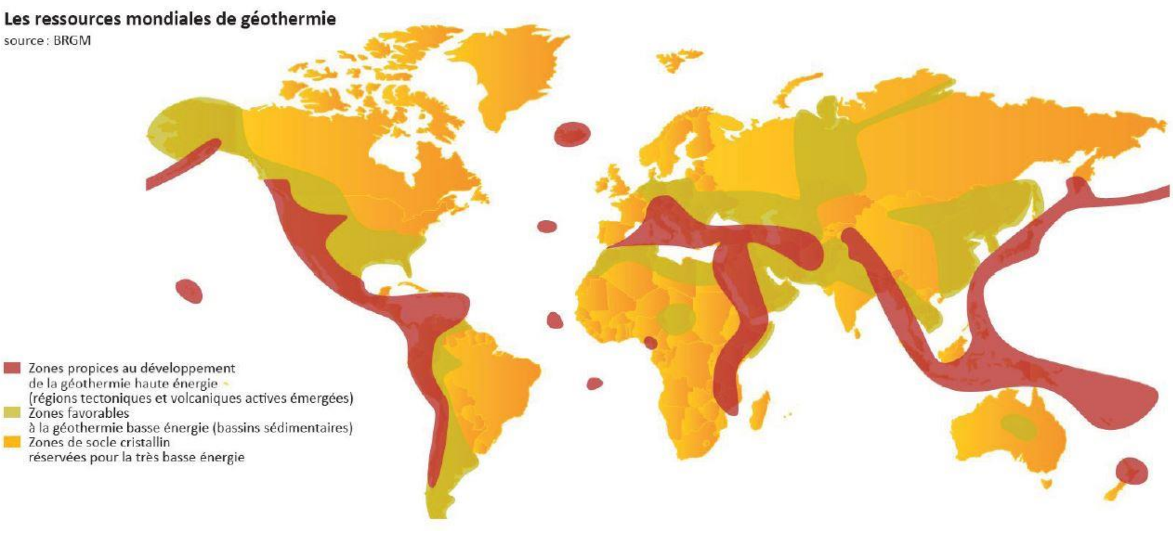


Figure 16 World geothermal energy resources. Source: BRGM

To identify more accurately Wallonia's geothermal potential, a study was carried out by the Royal Institute of Natural Sciences on behalf of the Wallonia Public Service (SPW – DGO4) in 2011. This study used existing information and cross-tabulated data from different sources (geological maps, deep boreholes, geological cross-sections, seismic data, gravimetric data, hydrogeological data, etc.) in order to identify the areas in Wallonia with geothermal

[28] PNEC 2021-2030
[29] Gouvernement.wallonie.be
[30] parlement-wallonie.be

potential. This potential is determined not only by the presence of subsurface resources, but also by the presence of potential users of this resource on the surface. Although the electricity obtained from high-temperature geothermal energy can potentially be transported over long distances, this does not apply to the heat obtained. The potential users of future geothermal sites must therefore be located close to such sites. Therefore, the density of the population on the surface was also taken into account for the location of future geothermal energy production sites in the study carried out by the Royal Institute of Natural Sciences.

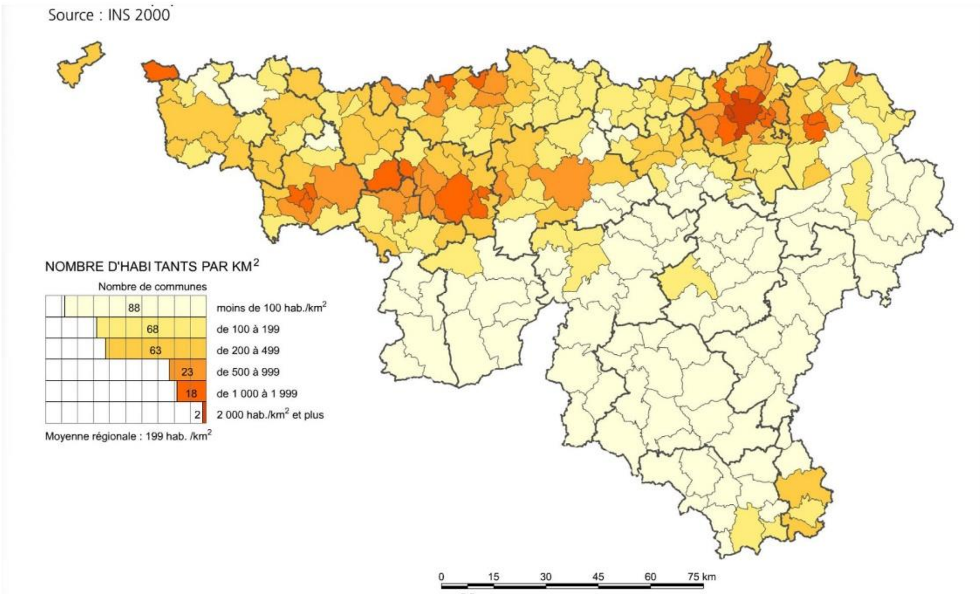


Figure 17 Number of inhabitants per km² in Wallonia. Source: INS 2000

As the above map shows, the areas of high population density in Wallonia are mainly concentrated along the Mons-Liège axe, and they are therefore areas to be prioritised for the development of geothermal projects.

The soils identified as suitable for the developments of geothermal energy in Wallonia are composed of Devonian and Carboniferous limestone, these formations being aquifers already recognised and harnessed in geothermal energy.

These factors have been used to produce two maps representing, on the one hand, the areas of interest for deep geothermal energy and, on the other hand, areas of interest for shallow to medium-depth geothermal energy.

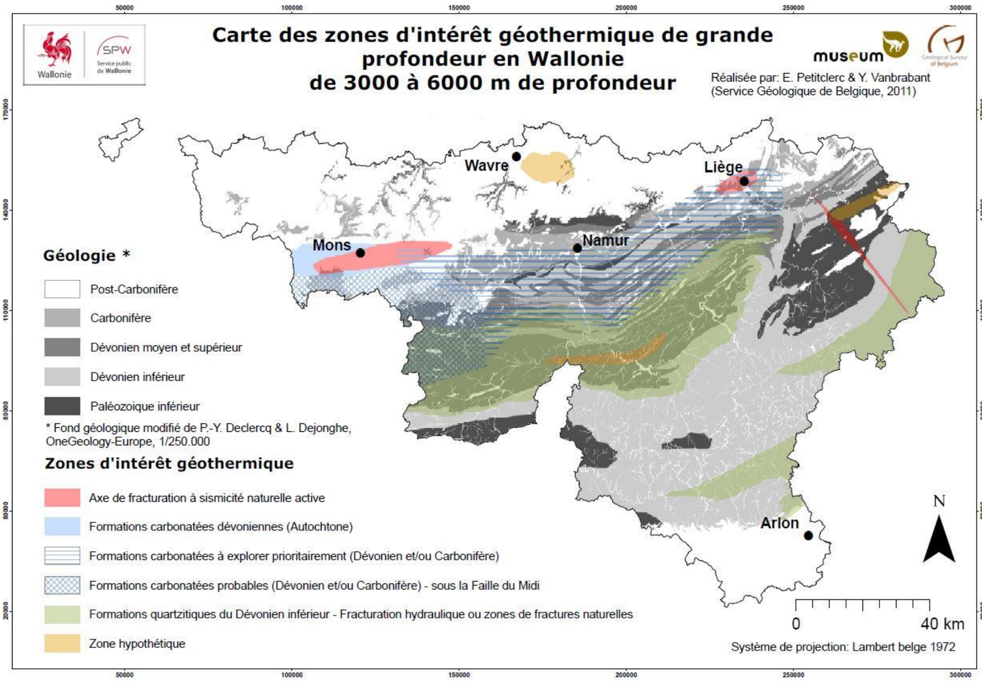


Figure 18 Map of areas of interest for as regards deep geothermal energy in Wallonia. Source: enregie.wallonie.be

On this map, an area of interest formed of limestone soil dating from the Devonian and Carboniferous ages along the Mons-Liège axe, along the geographic formation called the Faille du Midi. This area should therefore be explored as a matter of priority for the development of deep geothermal shafts. However, a second factor also needs to be taken into account, namely the cementing which occurs naturally within deep fractures and which will gradually reduce their permeability and, therefore, their interest in terms of deep geothermal energy.

However, as there is seismic activity in the areas this considerably slows this cementing phenomenon and, accordingly, these seismic areas are of interest for geothermal development. In Wallonia, three areas of this type have been identified in the regions of Mons and Liège, and in the Verviers-Trèves (Trier) axis. These three areas are therefore regarded as priority areas to be explored for deep geothermal energy.

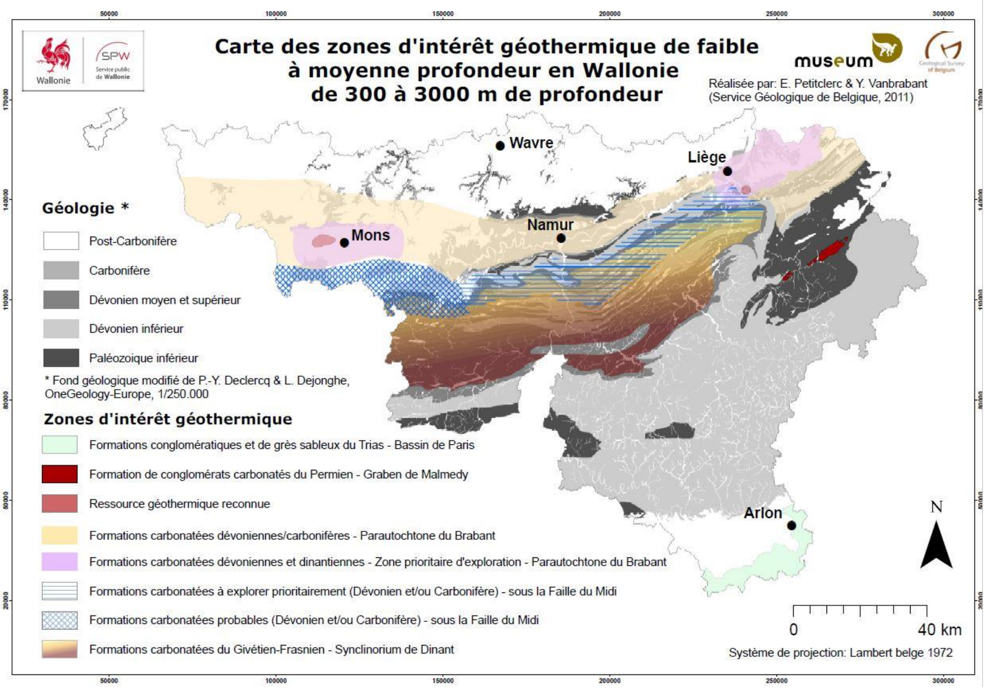


Figure 19 Map of areas of interest as regards shallow and medium-depth geothermal energy in Wallonia. Source: enregie.wallonie.be

For shallow and medium-depth geothermal energy, Devonian and Carboniferous limestone strata also need to be taken into consideration as being the geological formations that are of the most interest for this form of geothermal energy. The above map shows the presence of this type of geological formation along the Mons-Liège axis, going from Tournais to Verviers. The development of shallow and medium-depth geothermal projects is therefore conceivable in this region. The presence of a thick layer of Carboniferous limestone, and the presence of a recognised and exploited reservoir of geothermal energy (Saint-Ghislain) make the Mons region an area to be prioritised for the development of geothermal projects. Data drawn from soil probes in the Liège region, and the presence of the thermal site of Chaudfontaine also make the Liège region an area suitable for the development of shallow and medium-depth geothermal projects.

At the current time, a mission, led by the Royal Institute of Natural Sciences, as part of the DGE-Rollout project, is currently being carried out in order to establish two seismic reflection profiles within the area between Mons and Liège. The aim of this mission is to determine the precise structure of the soil so as to better assess the potential of the subsurface and reduce the risk factors, with a view to developing geothermal projects.

As there was a period in Wallonia's history of significant coal mining activity, it has many currently abandoned mines on its territory. The map below contains an inventory of abandoned coal mines, and their depth, in Wallonia.

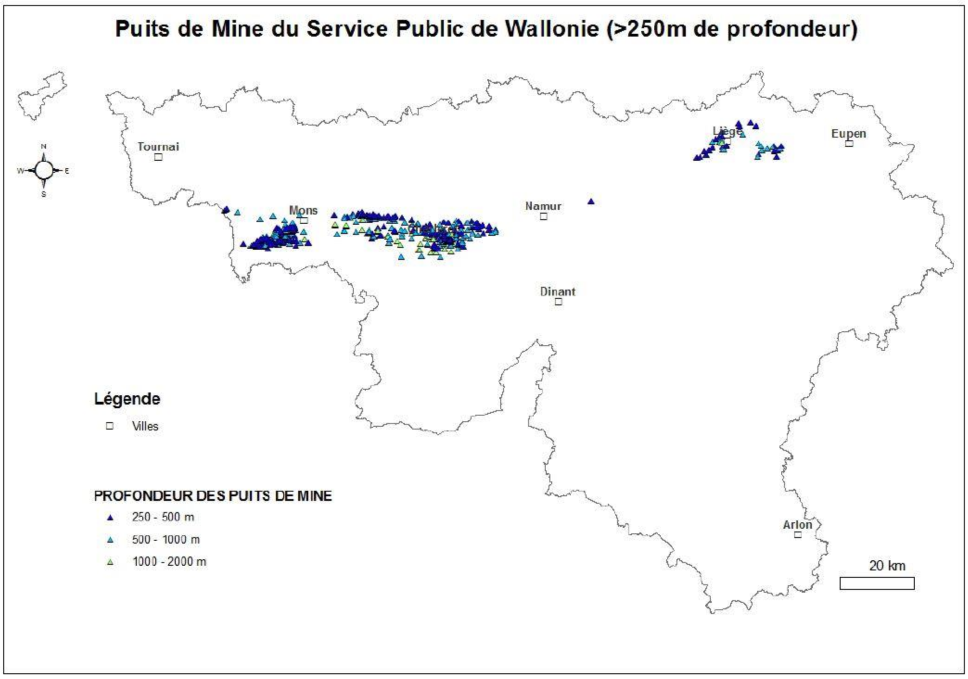


Figure 20 Location of the probes of the Geothermal Platform of Wallonia (> 250 m of depth). Geological map of OneGeology

Unfortunately, no study has yet been completed to analyse the geothermal potential of the former mines in Wallonia. However, a study of this type is currently being carried out by the Flemish Institute of Technological Research (*Vlaamse Instelling voor Technologisch Onderzoek,* VITO) in partnership with the Mons University (Umons), on behalf of DGO4. The aim of this study is to establish the potential of these former mine shafts with a view to developing a geothermal project, with a coupled heat network similar to the Heerlen project. The findings have not yet been published, but there seem to be three areas of interest, in the regions of Mons, Charleroi and Liège.

3.2.2. State of play regarding geothermal energy in Wallonia

At the current time, geothermal resources are only exploited to a limited extent in Wallonia. Two regions have been recognised as having underground hot water resources: the Mons basin and the region of Chaudfontaine.

The existence of these resources in the Mons basin has been known since 1975, when a geological exploration probe revealed a source of flowing water (artesian water) at a temperature of 73°C. The idea of harnessing this resource gradually developed and, in 1985, work began to develop the site. This supplied heating to a 6km district heating network, supplying a hospital, three schools, a swimming pool and 355 dwellings, with a total capacity of 16.7 GWh.

A project led by IDEA, an intra-communal structure, and financed by Wallonia and Europe (via the ERDF) is currently being carried out in Mons, with the aim of drilling a geothermal dipole in the centre of the city, to supply in particular a hospital. The drilling of the two shafts to a depth of 2,500m is due to be completed by spring 2020, with supply coming on stream in 2023[31].

There are also two other geothermal shafts in the Mons basin: in Douvrain and Ghlin. The Douvrain shaft releasing water at 67°C, was drilled in 1979 for geothermal development purposes. The Ghlin shaft dates from 1981 and today supplies heating to a 40 ha business park, as well as heat for industrial processes, thereby preventing 2,600 tons of CO_2 emissions[32].

[31] Renouvelle.be
[32] Idea.be

There is also a source of hot water in Chaudfontaine (36.6°C) which is used in particular in bottling plant processes.

As for very low-temperature geothermal energy, this has been exploited in various individual heating projects within "Canadian shaft" type installations. The principle of these installations is to use the underground heat to heat dwellings in winter and to benefit from the relative cold of the ground in summer to cool buildings, via the use of a heat pump[33].

But to date, there is no large-scale exploitation of low or very low temperature geothermal energy. However, the aim of the study carried out by VITO in partnership with UMons on behalf of DGO4 is to determine a site for carrying out a pilot project similar to the one developed in Heerlen.

3.2.3. Obstacles to the development of geothermal energy in Wallonia

As seen above, geothermal energy is a clean form of energy that has real potential as an alternative to fossil energies. Accordingly, the limited presence of this technology in Wallonia is symptomatic of the presence of obstacles and barriers to its development in the region. A study commissioned by the Wallonia Public Service, and carried out in 2011 by Ecorem S.A., VITO, and the Geological Service of Belgium, has analysed these obstacles and barriers and has put forward ideas for overcoming them[34].

It is not enough to have sufficient scientific knowledge and a suitable legal framework for geothermal projects to be a success. One of the most important factors for the viability of such a project is its cost-effectiveness. For that to be possible, it is necessary to ensure that the income generated makes it possible to recoup the significant expenses involved in installing the facility, in particular investment expenses (exploratory drilling, development drilling, heat networks), as well as the administrative expenses (permit, risk study, impact study, etc.). There are many obstacles along the way to successfully implementing geothermal projects and they must be overcome.

The abovementioned study carried out in 2011 has identified obstacles at several levels: legally, financially, in terms of risks and potential impacts, and at the level of social acceptance.

3.2.3.1. Legal obstacles

From a legal point of view, the main obstacle is the lack of a clear, specific legal framework established especially for geothermal energy in Wallonia, whether at the level of environmental and town planning legislation, or at the level of legislation governing mining activities. Although most activities related to geothermal energy (drilling, extracting water, etc.) may be indirectly covered by such legislation, the legislative texts do not provide a specific geothermal framework. However, such a framework is essential to foster and implement geothermal projects, while limiting and potentially controlling any negative impacts of this type of project.

a. Environmental legislation

At the level of environmental legislation, geothermal projects have similarities with groundwater mining projects. However, various adaptations necessary in order to establish a clear framework at the level of environmental legislation have been identified. The main ones are:

- A change to the name of the headings of the environmental permit dealing with drilling operations so that they clearly include geothermal projects.
- An extension of the period of validity of provisional environmental permits beyond 12 months to enable various pilot tests to be carried out, or making renewal easier.
- Defining a specific heading for the geothermal reservoir stimulation phase. We will see below that this geothermal project implementation phase is a potential source of nuisance, and that a specific heading would be useful to define it.

[33] parlement-wallonie.be
[34] Étude des obstacles à la géothermie profonde, Ecorem, VITO, Geological Survey of Belgium, 2011.

- The conditions relating to the preservation of the aquifers when extracting groundwater are a problem for geothermal projects since they specify that the quality of the water must be protected. But during geothermal projects, the composition of the geothermal waters may vary following injections of surface water, phenomena of precipitation, or temperature changes. A distinction between water intended (or potentially intended) for human consumption and geothermal water (unfit for human consumption because of its chemical composition) could be established so as to have fewer restrictive requirements for the protection of the quality of the water for geothermal aquifers.
- Consideration should be given to the factors to be taken into account in environmental impact studies so that such studies reflect the actuals impacts of a geothermal project.
- Lastly, it would be relevant to have specific headings for the production of electricity and the production of heat in a geothermal facility.

b. Legislation on mining activities

Geothermal projects have many points in common with mining activities. The extraction of heat from the subsurface can be compared to the exploitation of a subsurface resource or service. Moreover, geothermal energy falls explicitly within the scope of mining legislation in many countries. The concept of concessions included in mining legislation is an important factor which could apply to geothermal projects. It deals with the concept of the ownership of the substances present in the subsoil, and distinguishes between that ownership and that of surface ownership. An additional analysis comparing the concept of concessions and permits should be carried out in order to identify which aspects could be the most interesting for geothermal projects. The potential implications of geothermal development for surface owners also need to be analysed with a view to examining whether the latter should potentially be paid a fee.

For the development of geothermal energy in Wallonia, it is necessary to put in place appropriate legislation integrating a comprehensive, long-term vision of geothermal energy. In particular, a stable framework is necessary in order to reassure investors, and sustainable management of geothermal impacts is essential for long-term management purposes.

According to the analysis carried out in 2011, the most reasonable approach would be to integrate geothermal legislation into existing mining legislation, by including references to environmental legislation as regards environmental specifications.

Pending substantial legislative amendments to integrate geothermal energy, and in the light of the current legal framework that can be used to govern deep geothermal projects, it would be interesting to modify some aspects of current legislation to facilitate a controlled, reasonable implementation of future geothermal projects, by including the changes proposed here above.

3.2.3.2. Financial obstacles

The main financial obstacles to geothermal projects are the significant investment costs and the risks associated with the various project development phases. Geothermal energy requires significant exploration work to locate the resource, deep drilling operations to reach the resource and the development of installations for its extraction. These are just some of the many stages which each represent a risk. These risks and their perception by potential investors are an obstacle to the development of geothermal projects, especially as the highest risks are during the initial stages of the project, which are among the most expensive. It is important therefore to reduce as far as possible the different forms of risks by using in particular appropriate scientific and financial tools.

The main obstacle identified is the geological risk, that is to say the risk of not obtaining the projected resources once drilling has been competed, because the quantity and quality of the resources in the reservoir reached are insufficient.

Additional risks also need to be taken into consideration, in particular changes that may occur during exploitation, such as changes at the level of flows or the composition of the heat transfer fluid, or changes or damages that may affect the structure of the installations.

To minimise the financial, risks and encourage investment in geothermal projects, several actions are recommended for the Walloon region:

- Putting in place financial and guarantee mechanisms to minimise risks.
- Developing a database containing full information on soil types and their geothermal potential, as well as existing geothermal installations.

It is to be noted that the development of geothermal projects similar to that of Heerlen is based on the exploitation of geothermal reservoirs whose capacity (the volume of mining galleries), depth and location are known. The geological risk and the additional risks are therefore considerably lower for this type of project.

3.2.3.3. Obstacles associated with potential risks and impacts

The major geothermal risk, in particular as regards deep geothermal energy, is the seismic risk associated with the development of the geothermal field.

These earthquakes can occur during different stages of the project, whether during drilling, stimulation, hydraulic testing or exploitation. Fault and plate movements may have different origins, but are generally caused by subsurface pressure differences as a result, for example, of pumping and the reinjection of fluid in the underground reservoirs, which can cause pressure to build up, leading to fault movements and, therefore, to earthquakes. But the most critical stage in terms of induced seismicity is the stimulation phase, which consists in artificially increasing the porosity of underground rocks when this is too low, in particular by hydraulic fracturing. This stage is not always necessary, but is indispensable for the development of geothermal projects in crystalline rocks.

Although the earthquakes resulting from putting in place and exploiting geothermal installations are generally low in magnitude, they have a very significant impact on public opinion, and can be negative for the image of geothermal energy in the eyes of the population. That is the case in particular in Mol, where the operation of a deep geothermal power plant provoked earthquakes in the summer of 2019. As a result, operations were shut down for the time needed to identify the causes of these earthquakes, which made the headlines[35].

To limit the risks associated with induced seismology, the following recommendations have been put forward:

- Establish a reaction plan
- Aggregate seismic and geological data in a database accessible to future project developers
- Demarcate areas where the development of geothermal installations is (strongly) inadvisable

It is to be noted that the development of geothermal projects similar to that of Heerlen does not imply either deep drilling or the stimulation of geothermal reservoirs. The risks associated with induced seismicity are therefore considerably reduced for this type of project.

Other risks are also associated with geothermal exploitation, including among others the risks associated with ground movements which may occur because of pressure differences within geothermal reservoirs. This phenomenon therefore needs to be taken into consideration when developing a geothermal project.

The risk associated with the contamination of the groundwater aquifers and surface water by geothermal water should also be noted. The water extracted via geothermal exploitation is, by its concentration of dissolved chemical elements, unfit for human consumption. The discharge of this geothermal water outside its reservoir may be a source of surface or underground water pollution. The pressure differences caused by exploitation may also

[35] Rtbf.be

provoke underground water movements which may result in geothermal water entering groundwater tables containing water potentially fit for consumption.

It should be noted that a project to exploit geothermal resources present in former mines such as that of Heerlen does not involve surface discharges of geothermal water, and that as the geothermal water circulates freely in former galleries, the pressure differences in the reservoir are lower than in a traditional geothermal project.

3.2.3.4. Risk associated with social acceptance

There is always the risk with the development of new technologies that they will be badly perceived by the general public, for various reasons, including in particular a lack of knowledge of the technology involved and its impact on the environment or human health, or because of negatives experiences in other regions, or even unfounded rumours. The approval of the technology being a fundamental requirement for the development of new projects, social acceptance is a factor that cannot be ignored. This public approval will in particular have implications during the public consultation stages, for example during permit granting stages. But it also influences the NIMBY (*Not in My Backyard)* factor which is very frequently associated with the development of new technologies.

It is therefore important to put in place a proactive information policy targeting the general public in order to avoid a technology or project having a negative image, that can sometimes lead to them being halted, as was the case notably for a geothermal project in Basel in Switzerland, which was halted as a result of the earthquakes caused by its exploitation.

Similarly, the tremors felt in the region of Mol due to the operation of the geothermal power plant there caused considerable consternation in the local community, and led to the temporary closure of its facilities.

To promote social acceptance, several approaches are conceivable at the level of the region.

- Clear political support avoids showing the seeds of doubt that can be created by governmental disagreement on the technology. In addition, clear support sends a signal to researchers, businesses and investors that the investments made today will be supported and valorised in the future.
- Putting in place a clear and appropriate regulatory framework enables all of the specific aspects of a technology to be taken into consideration, and is a guarantee that all of the implications of such a project have been properly taken into account in order to limit any negative effects, whether in terms of the environment, safety, or human health.
- The existence of administrative instruments of social participation gives citizens the feeling that their voice has been heard and that they can have an impact on their environment. Obviously, this type of instrument is only relevant if the opinions expressed are effectively taken into consideration.
- Lastly, keeping the community informed via contract points (offices, websites web, etc) facilitates a clear dialogue with the population and avoids the fake news phenomenon. In addition, knowledge of all the ins and outs of a technology or a project puts information into perspective.

The existence of pilot projects is an excellent way of demonstrating how a technology or project works in practice. The development of this type of project therefore showcases a technology to the population and answers their questions.

3.2.4. Measures taken to develop geothermal energy and new projects in progress in Wallonia

In the previous point, we referred to various obstacles to the development of geothermal energy in Wallonia. As the report that identified these obstacles dates from 2011, some steps have bene taken in the meantime or are currently being implemented to overcome these obstacles.

3.2.4.1. Geothermal guarantee scheme

A preliminary draft decree introducing a geothermal guarantee scheme was approved at first reading by the Walloon government on 24 January 2019.

The aim of this decree is to establish an insurance policy covering the geological risk, that is to say the risk that the geothermal resource obtained after drilling is not as expected, in order to create an investment climate favourable to the development of geothermal energy in Wallonia[36].

This decree has two sections:

- The establishment of a regional geothermal guarantee system covering the risk and providing compensation, where applicable, on the basis of the opinion of a technical committee.
- The creation of a geothermal guarantee within the Kyoto fund with a specific budget earmarked for compensation purposes. To be eligible for such compensation, investors contribute to the compensation fund via the payment of a premium proportional to the cost of the project.

The regional guarantee will thus cover all of the development drilling expenses, and almost all of the upstream development costs, that is to say the expenses incurred in order to ascertain whether the actual resource corresponds to expectations[37].

This decree still needs to be approved at second reading by the Walloon government.

3.2.4.2. Subsurface preliminary draft decree

A subsurface preliminary draft decree with the aim of establishing a clear and precise framework for activities and installations developing subsurface resources was approved at first reading by the Walloon government on 06/12/2018. As geothermal energy can be defined as the exploitation of subsurface resources, in particular as regards deep geothermal energy, this decree addresses the provisions relating to geothermal energy as part of the environmental law, and established a precise framework for it. This preliminary draft decree governs the related seismological risks, whether upstream of drilling, or concerning the operations relating to production testing. It lays down several measures and rules to be complied with in connection with a geothermal exploitation project:

- The organisation of a public information campaign before drilling starts.
- The establishment of a seismic monitoring network, at least six months before drilling starts, and during the test phases and throughout the period of exploitation.
- The signing of an agreement between the project initiators and the Royal Observatory of Belgium (institute with responsibility, among other things, for seismological studies in Belgium) on the subject of seismic and geodetic data[38].
- A ban on exceeding a pressure of 100 bars during circulation and reinjection tests.
- The reduction of injection pressures at the end of the hydraulic testing so as to rebalance the constraints within the geothermal reservoir.
- The establishment of a seismic threshold, set at a magnitude of 1.5 on the Richter scale, above which increased vigilance needs to be put in place.
- The establishment of a seismic threshold, set at a magnitude of 2.0 on the Richter scale, above which all operations must be stopped immediately.

This decree would therefore establish a favourable environment for attracting investors that are still reluctant to enter the market because of the current legal vacuum. The second reading of this preliminary draft decree was initially scheduled for 14/03/2019, but has been postponed and is still pending.

[36] parlement-wallonie.be
[37] gouvernement.wallonie.be
[38] astro.oma.be

3.2.4.3. DGE-Rollout project

The DGE-Rollout project is a European project intended to support the expansion of deep geothermal energy in North-West Europe to supply high-temperature heat in order to reduce greenhouse gas emissions[39]. For Belgium, this project is in progress, under the supervision of the Geological Service of Belgium[40], and has several potential benefits for Wallonia, in particular:

- Providing the necessary impetus for the development of the deep geothermal energy sector in Wallonia, by adopting a European approach while responding to the region's specific needs.
- The production of two 2D seismic profiles facilitating an investigation of the deep structure of the subsoil in Wallonia in areas of strong energy demand.
- Enhanced knowledge of the Walloon subsoil in order to better assess future deep geothermal projects on its territory.
- Enhanced knowledge of the Walloon subsoil so as to reduce the risks inherent in the development of deep geothermal projects and attract national and foreign investors, and improve the scaling of projects.

3.2.4.4. Géotherwall project

The Géotherwall project is a project initiated by the IDEA (inter-communal body) in Mons, financed by Wallonia and Europe (via ERDF)[41]. Its aim is to drill a geothermal dipole in Mons to supply heating to buildings, in particular the hospital Ambroise Paré, via a heat network. These shafts will be drilled to a depth of 2,500m and drilling is due to start in 2020. The aim is to obtain a water resource at 70°C with a projected flow of 150 m³/h, and estimated energy production of 7 MW[42]. The projected consumption covered by this new renewable source is between 10.5 and 14 GWh per year, which corresponds to the needs of 700 housing units, and would result in an estimated CO_2 saving of 3,514 tons a year.

This drilling will be monitored by Mons University (UMons) so as to collect data covering in particular:

- Information on the geothermal reservoir, inter alia the petrophysical, hydraulic and thermal properties.
- The opportunities and threats relating to the land, on the surface and at depth, with a view to designing and sizing the geothermal facilities.
- Geophysical imaging data obtained through direct observation and measurements in shafts. These will facilitate the matching of seismic facies and geological structures.

3.2.4.5. Determining the geothermal potential of abandoned former mines in Wallonia

The aim of this project, carried out by VITO in collaboration with UMons and the consultancy Deplasse & Associés, is to establish the potential of these former mines with a view to developing a geothermal project with a coupled heat network similar to that of the Heerlen project. The potential of the various areas has been established by determining the volume of the potential reservoir and the temperatures potentially reached within it. The study is ongoing, and the findings have therefore not yet been published, but there seem to be three areas of interest, in the regions of Mons, Charleroi and Liège.

[39] nweurope.eu
[40] naturalsciences.be
[41] Idea.be
[42] Idea.be

3.3. Heat networks in Wallonia

3.3.1. State of play regarding heat networks in Wallonia

There are several heat networks of different sizes in Belgium. Unfortunately, there is no cadastre of heat networks in Wallonia. The development level of such technologies is therefor quite uncertain.

But more than 100 biomass heat network projects have been studied in six years in Wallonia alone, with the support of the facilitator[43] (this type of projects may evolve towards the collective self-supply of electricity). And it is very likely that many heat networks have never been identified.

However, a study[44] of the Tweed cluster in 2011 identified 35 networks in Wallonia and highlighted the following elements:

- 63% of the heat networks have a length of less than 1 km.
- 66% of the heat networks generate power of less than 1 MW.
- More than 55 % are derived from projects initiated by the public authorities (municipalities).
- Average size of the projects, ±400 KWth.
- 70% of the projects use biomass as their source (biomass-fired boilers, biomass CHP facilities, biomethanization, mainly of low power units).
- Several large-scale projects (Gas***-Geothermal energy-Waste heat) of more than 5 MW (Sart-Tilman, Louvain-la-Neuve, Enerwood).
- Scarcity of projects of more than 1km and/or integrating more than two consumers.
- No waste incinerator at this time but a project is in progress for those of IDEA, Tibi and Intradel (Urbeo).

Even if this study is not very recent, it reveals that district heating network have still a significant growth potential. The existing ones at the time of the study are globally small sized (in terms of length and power), and servicing few customers. The majority of them are using biomass to generate heat, and those using geothermal energy are rare/absent.

It is clear that a new study could be very useful to establish an up-to-date cadastre of the district heating development in Wallonia. But we can already say that a large-scale district heating using geothermal energy from the mines as heat source, as the one developed by Mijnwater in Heerlen, would be a ground-breaking innovation.

[43] Source: Rural Federation of Wallonia
[44] Tweed, Réseaux de chaleur en Wallonie, 2011

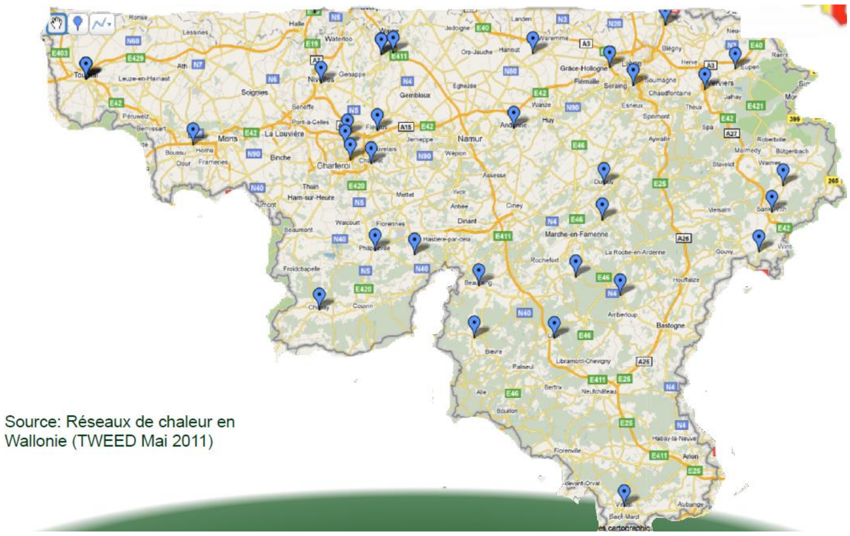


Figure 21 Heat networks in Wallonia (Source : Tweed 2011)

In the past, several major, high-capacity heat networks, linked mainly to steel works were present in Wallonia, including in particular those of the Verviers (Intervapeur), Charleroi (Socageth), Saint-Ghislain and Châtelet.

But the failure to properly maintain some of them, combined with a lack of funding/anticipation for renovation work, led to some of them being shut down, and created a negative image around heat networks in Wallonia. Other networks have been maintained and are gradually being renovated, in particular on the university sites of ULg (Sart-Tilman) and UCL (Louvain-la-Neuve and Mons). But there is still a large potential for the heat networks in terms of meeting heat demand. More than 940 statistical sectors[45] in Wallonia have a linear need of heat in excess of 2,000 kWh per year per meter, which is generally used as a reference to identify the cost-effective threshold of a heat network.

To establish a functional and economically viable heat network, it is important to match demand for heat (for heating, domestic hot water, etc.) and the supply of heat (waste, geothermal, etc.). The Heerlen project, if it can reach economic equilibrium, demonstrates that the focus should no longer be solely on heat, but also on cold. The need for cold (which corresponds to a supply of heat) would balance the exchanges of heat/cold between the network's customers.

As the mapping of heat supply is taking clearer shape thanks to the studies commissioned by the Region over the last 10 years (biomass potential, cogeneration potential, waste energy potential, etc.), the mapping of heat and cold demand is however incomplete and still to be developed.

We will take stock of the situation regarding the availability of the resource and the mapping of needs in the following sections.

3.3.2. *Availability of the resource*

Heat resources can come from different sources. By cross-tabulating these resources with a map of the density of heat needs it is possible to identify statistical/geographical spots having a development potential for a heat network project development. The results of this kind of study can be presented in maps as shown just below.

[45] Source: Ulg 2012 and PWC-ICEDD-Deplasse "complete evaluation of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling networks" within the framework of the transcription of article 14 of Directive 2012/27/EU.

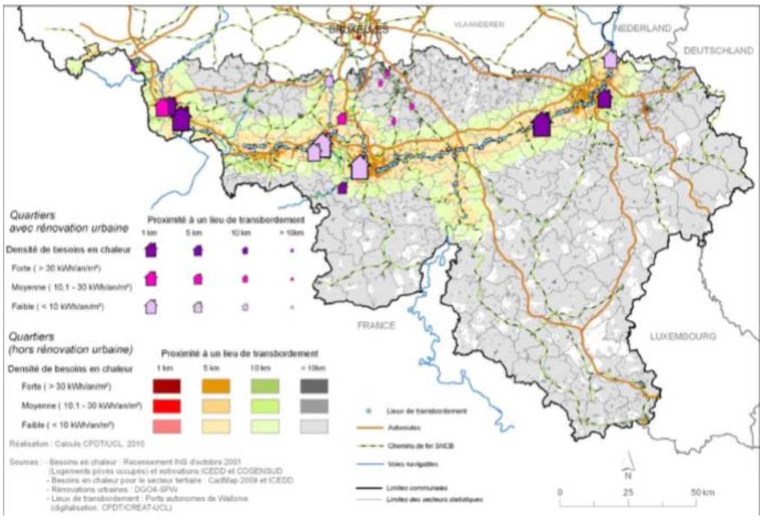


Figure 22 Relevance of location of heat network supplied by non-native wood (UCL 2010)

The heat resources can be from variable origins, generally, they include at least:

- The availability of biomass.
- High-temperature waste energy.
- The availability of a geothermal resource at mid-depth or deep.
- The availability of gas for high-yield cogeneration.
- The availability of biogas (livestock effluents, biomethanization, water treatment plants, etc.).
- The geothermal energy from former mine shafts and the recovery of gas from mines.

On the initiative of Europe (transposition of Directive 2012/27/EU on energy efficiency), the Walloon Region has commissioned numerous studies over the last ten years in order to determine this potential. The maps and illustrations below are some examples of the findings of these studies:

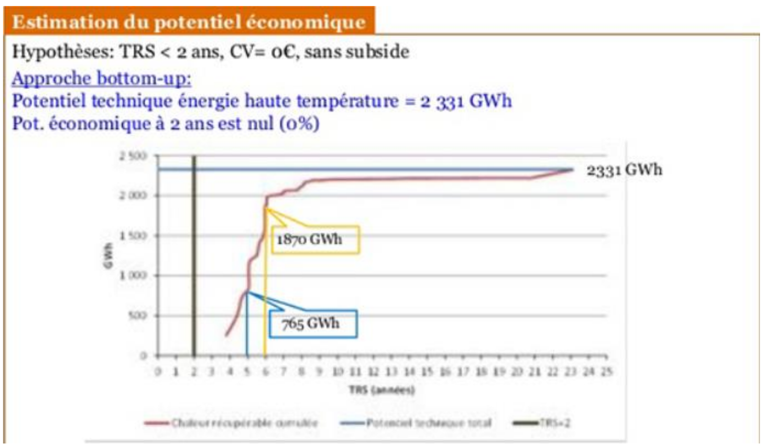


Figure 23 Economic potential of the recovery of waste heat (PWC 2017)

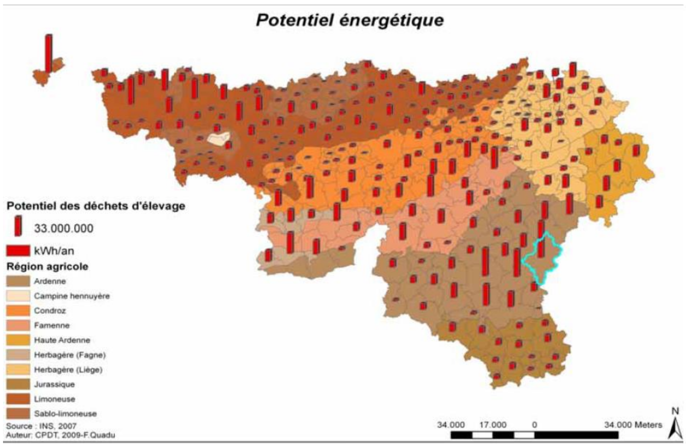


Figure 24 Energy potential of livestock effluent

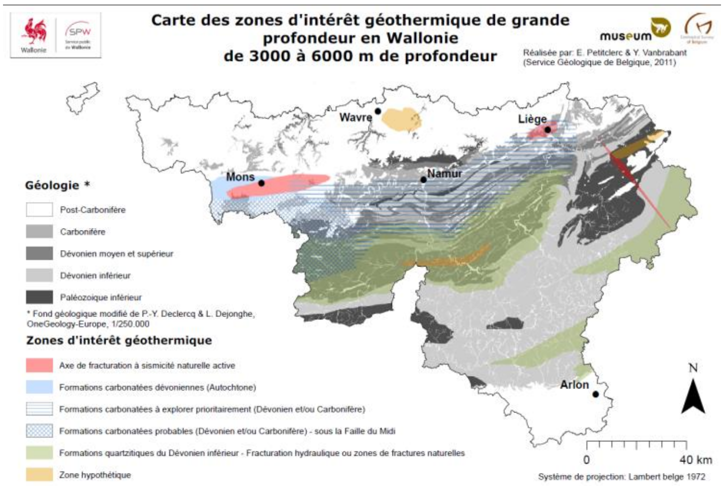


Figure 25 Area of deep geothermal interest in Wallonia

These studies have also made it possible to gradually put in place the support and regulatory framework necessary for the development of this type of network. But there is still work needed to achieve this goal.

3.3.3. Characteristics of heat demand.

The technical and economic feasibility of a heat network depends to a large extent on **density of the sector(s) to be supplied**: with constant thermal features and building usage, a network's efficiency increases in line with the connection density of users. If the optimisation or relevance of such a network automatically depends on a certain intensity of urbanisation (in the same way as dedicated public transport corridors for example), the scheduled improvement in the insulation of buildings will inevitably reinforce this requirement.

The viability of the heat network increase as the urbanisation is favouring **mixed usages** within districts: residential accommodation does not consume heat (or air conditioning) at the same time as a retail outlet or offices. This kind of configuration will "smooth" the curve of heat needs (over the day and over the year). This smoothing is a positive element for the economic equilibrium of a heat network. The presence of a few buildings with significant needs (hospital, swimming pool, shopping mall, etc.) in an area with fewer needs (newer/well insulated housing) is also very positive for the development of a heat network.

Civil engineering represents, according to the ADEME, approximately 28% of the cost of setting up a district heating network. Therefore, **an area of urban renewal is a very interesting opportunity** for putting in place such an infrastructure. Almost 50% of these civil engineering costs can be avoided when streets need to be renovated: placing two pipes in an existing district is not twice as expensive.

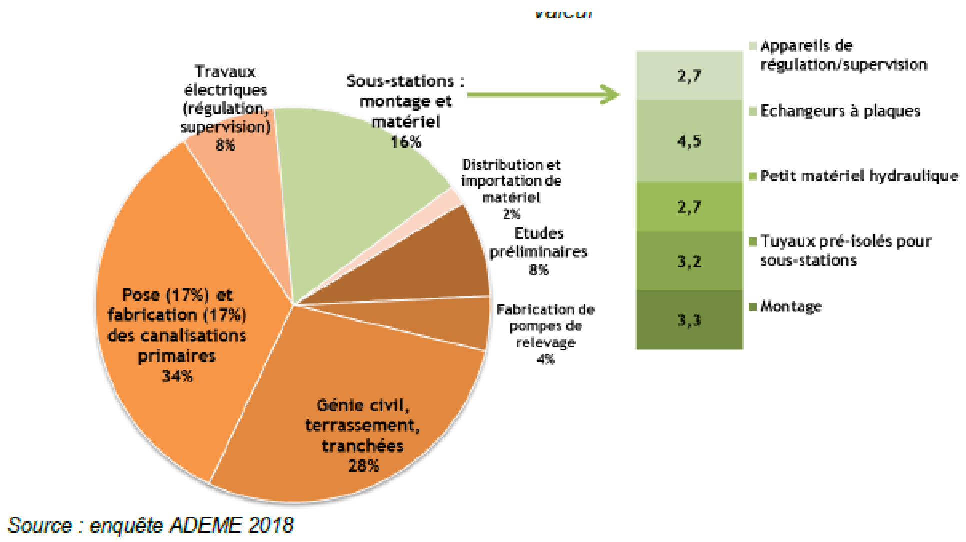


Figure 26 Cost repartition of setting a heat network (Source : Ademe 2018)

The most recent study on the potential of heat networks and high-efficiency cogeneration (PWC/Deplasse/ICEDD 2017) highlights a major problem that is confirmed in the energy-climate 2030 plan (December 2018) which specifies on page 133:

"The estimated technical potential of heat networks is based on a bottom-up approach starting from situations favourable to the development of a heat network in order to estimate a qualitative potential. At the time of the study, data are available at the level of the territory of a municipality and they cannot be used to extrapolate favourable situations at the level of a district or a street, for example."

There are therefore heat networks in Wallonia but the general public knows relatively little about them (they are often owned by a public entity for its own needs).

In the next section we will present a SWOT analysis of heat networks which, other than the abovementioned technical considerations, explains both the interest and relative inertia of the sector.

3.3.4. SWOT analysis of heat networks in Wallonia

Strengths	Weaknesses
• **Low CO_2 emissions:** as heat networks integrate sources of heat of renewable origin, they can contribute to a reduction of the energy sector's CO_2 emissions. The new well insulated pipes and the fact that the installations operate at a lower temperature strongly limit network losses. • **Recovery of waste heat:** heat networks recover the waste heat of businesses to redistribute it to other buildings. This heat which was previously lost can therefore be re-used, thus limiting energy waste. • **Alternative to fossil energies:** heat networks are an alternative to heat generated using fossil energies, especially if the heat provided to the network is of renewable origin and has low CO_2 emissions, as is the case for that obtained from mines. • **Maintenance costs are lower than for an individual facility:** the pooling of costs involved in the maintenance of installations results in economies of scale versus those of individual installations. • **Destressing for users:** the pooling of the supply of heat enables users to free themselves from maintenance and fuel supply constraints in respect of their heating installation.	• **Cost of setting up the network:** launching the project and setting up the installations requires a significant investment (CAPEX). Although this cost needs to be kept in perspective given the network's lifespan, the amounts involved remain substantial. • **Lack of choice of supplier:** the people connected to a heat network are not in a position to choose their heat supplier, which some people may find unacceptable. • **Need for long-term investment:** as the CAPEX is high and the network's lifespan is long, the time it takes to obtain a return on investment will be equally long, which may be dissuasive for investors if their interests are not supervised/protected. • **Complex projects with numerous participants:** heat network projects involve a large number of participants, not only at the technical, administrative and legal levels, but also, and not least, from the point of view of the number of network users. • **Collective dependency on the network:** as numerous individuals and business are connected to the same network, in the event of a network failure, the impact will be felt on a larger scale.

Opportunities	Threats
• **Objectives for reducing CO_2 emissions:** as Belgium has ratified the Parris Agreement, it must reduce its CO_2 emissions by between 80 and 95% compared with 1990. Heat networks offer an opportunity to achieve these targets. Moreover, the Air Climate Energy 2030 Plan provides for support for heat networks from the point of view of green heat measures[46]. • **Need for an alternative to fossil energies:** fossil energy resources are not inexhaustible, alternatives to these energy sources must be found before they run out, but also in anticipation of an increase in their cost because of the increasing scarcity of such resources. The preliminary draft thermal decree specifies that heating and cooling are regarded as a key sector with a view to reducing carbon intensity. • **Reduction of dependency on energy imports.** • **Non-recovery of waste heat:** many businesses produce heat that is currently lost. Heat networks represent a way of recovering this waste heat, and therefore the energy used to produce it. • **Presence of flooded mines:** as Belgium has a mining past, it currently has a large number of mine shafts on its territory, and some were flooded after their closure. Belgium therefore has a potential geothermal resource.	• **Low price of fossil energies:** the current price of fossil energies is relatively low, especially in the light of the CO_2 emissions they generate. These low prices are an obstacle to the development of alternative sources of energy, such as heat networks. • **Waste heat not considered as form of energy in its own right:** at the current time, waste heat is not considered as a form of energy in its own right. Its non-use is therefore not seen as energy waste, which impedes its potential recovery, in particular via heat networks. • **Opposition of gas DSOs:** heat networks are currently seen as a source of financial losses by gas distribution network operators, and these DSOs therefore tend to put a brake on the development of heat networks. • **Difficulty of procedures for obtaining permits:** the multiplicity of heat sources (each requiring a specific permit), plus the permits and difficulties relating to the road works necessary for installing networks make administrative formalities fastidious. • **Unfavourable primary energy ratio:** the primary energy ratio currently attributed to heat networks (set at 2) is extremely unfavourable for them, and tends to nip the various projects in this regard in the bud. • **General lack of awareness of heat networks:** there is a lack of awareness of heat networks in Belgium, not only among the general public, but also at the level of politicians and the energy sector. Therefore they are not always considered as a possibility in various projects undertaken. • **Lack of transparency of public support** Unclear public support could be interpreted by the citizen as a lack of confidence in this kind of technologies.

[46] Plan Air Climat Énergie à l'horizon 2030 (PACE 2030)

3.4. Factors and measures that could facilitate the development of geothermal energy by/and heat networks in Wallonia

Some simple measures could considerably facilitate the development of geothermal energy by/and heat networks in Wallonia. We have seen in the previous points that the political class has shown an increased interest in geothermal energy in recent years, which has resulted in the implementation of various projects and legislation favouring the growth of this technology. However, some measures could still be taken to develop this technology. That is also the case as regards the development of heat networks, which is essential for the growth of geothermal energy, in particular as regards the transport of heat to end users.

Here are some measures that could facilitate the development of geothermal energy by/and heat networks in Wallonia.

3.4.1. Change to the primary energy ratio of heat networks

The certification of the energy performance of buildings (PEB) consists in carrying out an overall assessment of the energy performance of a building using a defined calculation method. One of the resulted obtained at the time of this certification is the primary energy consumption of the building in question and its installations. To obtain this primary energy consumption, real consumption is relativized using a primary energy ratio specific to the energy source used, which takes account all of the transformations necessary, as well as transport related losses before delivery to the end consumer. The point of those calculation is to place the various energy sources on an equal footing.

The primary energy ratio of heat networks in Wallonia is currently set at 2, which is very disadvantageous for their implementation. This is all the more surprising given that heat networks are potentially a source of reducing CO_2 emissions when the heat is from renewable sources or waste energy.

In comparison, this ratio is 0.7 in Flanders, and the stakeholders want to see this ratio reduced further according to the sources of heat fed into the network.

3.4.2. Creating contact points within the administration

The current limited development of geothermal energy and heat networks in Wallonia is due, at least in part, to a lack of knowledge of the subject, not only technically, but also from a legal and administrative point of view. Project initiators may be discouraged by the various obstacles standing in their way, which can lead to potentially viable and interesting projects being abandoned. By providing assistance, whether at administrative level, or in terms of technical or methodological advice, the authorities could foster the development of these projects.

In addition, this lack of knowledge may have an impact on legislation, since it is likely that this ignorance is behind the legislation unfavourable to the development of heat networks, in particular as regards the determination of its primary energy ratio.

3.4.3. Taxation of the consumption of fossil fuels

As the prices relating to the consumption of fossil fuels are currently very low, the alternatives to such fuels seem very unattractive. An increase in the tax on the consumption of energy using fossil fuels would therefore boost the development of alterative systems, such as geothermal energy and heat networks.

In addition, the financial resources that such a tax would generate could be reinvested in CO_2-saving projects, such as the geothermal projects associated with heat networks.

3.4.4. Establishing a system of subsidies for the development of geothermal energy and heat networks

As described in point 3.2.4.2, a decree establishing a guarantee system is in the process of being adopted by the Walloon government. However, a system directly subsidizing geothermal projects and heat networks would obviously foster the development of these by reducing the relatively high cost of putting in place such installations.

3.4.5. Establishing a system for recovering waste heat

At the current time, a large proportion of waste heat is not reused. This represents a loss of energy that could potentially be recovered, in particular via a heat network. To promote the recovery of this energy, a system of recovery bonuses or a tax on waste heat not recovered could be put in place.

3.4.6. Systematically examining the possibility of installing a network during road works

One of the obstacles to the development of heat networks identified is the high cost of installing infrastructures, in particular the development of an underground pipe network. One way of reducing the costs inherent in putting in place a heat network would be to take advantage of planned roadworks to install the necessary pipework for the heat network. One solution would be to systematically examine the possibility of installing a heat network when planning roadworks. Moreover, this would be in line with point 5 of article 18 of the Directive 2018-2001.

3.4.7. Making it mandatory to supply part of the heat necessary for a building via renewable energy sources.

As the National Energy Climate Plan (PNEC) provides for an increase in the renewable energy share of Belgian consumption, the introduction of measures making it mandatory to include a proportion of renewable energy in the heat consumed by buildings would appear to be a concrete means of achieving the plan's objectives. Furthermore, this type of measure would help to recover renewable energy, in particular that linked to geothermal energy and heat networks.

3.4.8. Involving DSOs in development processes

Renewable energies and their development are too often perceived by DSOs as a source of financial losses. Generally, therefore, they are not in favour of the development of such networks, and in some cases are even clearly opposed to them. Yet, as fossil fuel resources are finite, their business sector will have to change in the near future, and it is very much in their interest to start this transition as soon as possible. Involving them in the development of heat networks in Wallonia would make them stakeholders in this transition rather than an obstacle.

3.4.9. Financing the network

As this type of project involve drilling operation, the installation of infrastructure on existing roads, and the numerous technological installations, involves significant CAPEX. The long payback period can discourage some investors, especially since the resource is not guaranteed until exploratory drilling has been carried out. Consequently, the setting up of a geothermal guarantee mechanism would make it possible to pool this risk and make investors less reluctant.

Another way would be to separate investments linked to the heating network infrastructure from those linked to the production of heat. The cost of heat transport infrastructure being one of the determining points for the profitability of a network, the pooling of these costs would improve the profitability of the most expensive projects.

3.5. Legal context

In this chapter, we will highlight certain legal issues that may arise during the implementation in the Walloon Area of similar projects as the one developed in Heerlen. However, an in-depth study by people specialized in energy-specific legal matters is likely necessary.

3.5.1. Mining and water legislation

Extracting geothermal energy is similar in many ways to the exploitation of mineral resources and could fall under the scope of the mining legislation. In addition, as the exploitation of geothermal resources involves interactions with groundwater, water legislation must also be taken into account. If the circuit is of the "open" type, pumping in a first basin and reinjection in a second one implies significant consequences, in particular at the level of the chemical composition of the water contained in these basins. But also at the level of the aquifers groundwater crossed by geothermal installations, for which the water is potentially intended for human consumption.

The water pumped within the geothermal installation can therefore require purification before its reinjection This operation can be extremely expensive, and harm the profitability of such a project, or even have a negative impact on the image of this type of facilities for citizens. Also, the potential seismic impact linked to reinjection into the basement is an issue that can lead to the shutdown of installations (even if geothermal plan in Baudour works for more than 20 years without any problem).

One way to solve this problem would be to set up a closed water system, with the presence of surface exchangers allowing heat exchange between the water from the mines (circulating in a closed circuit) and the distribution water present in the backbone. In that case, mining and water legislation would probably not be applicable.

3.5.2. Soil legislation.

The installation of heat transport infrastructures (piping) below roads and private grounds implies to refer to the right of the ground legislating this type of installations. Attention should be paid to the legal owner of these lands, whether public or private. The installation of the heating network in the public domain may have to be the subject of a state authorization (road permission) or a state concession, which may involve urbanism charges.

For public land, several competent authorities may be encountered (municipal, regional, national), and for a same road, there may be several road managers. This "puzzle" of competent authorities is really a brake on development of heating district network.

Likewise, the establishment of a heating network in the private sector must be the subject of an agreement (easement, long lease, purchase of land, etc.) with the owners of the lands crossed.

3.5.3. Heat Network Decree

The heat networks decree, legislating the various aspects relating to the establishment and operation of a heating network, was validated at first reading in the Walloon parliament, and still needs to be validated at second reading. This decree provides for specific legislation relating to the distribution of heat via thermal networks, in order to clarify the still unclear aspects of it.

3.5.4. Protected customers

Potential protected customers should also be taken into account, namely customers for whom federal or regional legislation provides protection status.

3.5.5. Network property

Regarding the specificities of each of the parts, and in order to split the risks and constraints, it could be interesting to divide the ownership of the network into 2 distinct parts: the part linked to the production (extraction) of heat (part connecting the mines to the clusters) and the distribution part (from backbone to buildings). This kind of network splitting could be done by splitting the funding of these network parts, as mentioned in point 3.4.9. This kind of funding mechanism could remove some barriers linked to the cost of the network, which will most probably increase the development of heat networks in Wallonia.

3.5.6. Statutes of the various stakeholders

Consideration should be given to the legal status of the various actors involved in this type of project. In particular at the level of the company providing the heat, the network operator, and the consumer/prosumer.

3.5.7. Network management

The development of a project similar to the one in Heerlen requires the establishment of a network manager. The management of such a system is relatively similar to that of electricity or gas networks. Therefore, involving the DSO already present in Wallonia could be interesting, especially as this would prevent them from obstructing this type of project, which could be perceived as a potential source of income loss.

However, certain specificities linked to this type of network, in particular in terms of supply assurance, imply the establishment of specific contractual conditions.

3.5.8. Fare management

It would be important to clearly define the appropriate structure for managing the tariff component of this type of network. It would seem that at the Walloon level this is part of the competence of the Energy Administration (DGO4), but a clarification would be necessary. If the tariff management is the competence of Energy Administration, it ensures that all the tools are in the hands of the minister to support his policy for developing green heat. This could avoid blocking situations like those observed between the CWAPE and the Ministry regarding the prosumer tariff.

3.5.9. Invoicing and VAT

Several legal factors must be taken into account in order to set up an appropriate billing system. This is particularly the case for the situation in which billing is based on consumption, which implies the installation of meters, which must be calibrated. Work must also be done on VAT liability. Since consumers are automatically suppliers of heat, the resale of heat to the network must be the subject of a reflection on the value added present. Since large consumers (and suppliers) are generally taxable businesses, the question does not arise for them. On the other hand, individuals re-injecting the heat complementary to that consumed are not always so, and a non-discriminatory mechanism is therefore to be foreseen. For this, compensation seems to be possible: the difference between the heat consumed and the heat injected could be charged. However, it becomes more complex if the costs of heat and cold differ, or if a consumer produces more heat than he consumes.

3.5.10. Heat supplier choice

This type of heat network may appear as not allowing for a choice about the heat supplier. However, the European Directive 2018-2001 frames this type of infrastructure by allowing the multi-source, and by setting clearly defined exit conditions.

3.5.11. Connection obligation

The obligation to be connected to a heat network is a particularly effective measure for ensuring the development of such networks. This type of obligation was introduced during the development of the Louvain-La-Neuve heat network in 1972, with good results. If it is properly managed, with the possibility to opt out on valid grounds (alternative with the same ecological potential and with financial advantages), it can ensure enough connections to make the network cost-effective, without appearing despotic or being detrimental to real estate projects in the area of the heat network. This requirement can be imposed via town planning rules, making a heat network connection mandatory, but this type of measure requires a strong political will.

In addition, the European Directive 2018-2001 sets forth strict conditions for disconnecting from a heat network. Point 2 of article 24 allows users to disconnect if the network is not an efficient heat and/or cold network, and point 3 of the same article specifies that users can only disconnect from a heat and/or cold network for an alternative that improves energy performance.

3.5.12. Need for implementation of a strong exit strategy

In order to avoid inconvenience due to an unexpected end to the exploitation, it seems necessary to establish clear conditions governing this exploitation. In the case of a problem which puts an end to exploitation (geological, hydrological, environmental, seismic or other), the conditions are then defined from the outset, avoiding unexpected investment losses or recourse to arbitration. In addition, the installation of secondary heat sources (solar thermal, biogas/gas cogeneration, or other) allows for the supply of back-up heat to the grid, or even the replacement of mines as the main source of heat if it is no longer usable (for any reason).

3.5.13. Legal thinking about lifting barriers to the development of this type of network

Certain obstacles to the development of heat networks based on mining geothermal energy could be removed through the introduction of appropriate legislation.

This is particularly the case for the definition of the primary energy ratio of heat grids, which is currently set at 2[47], which greatly hinders the development of such networks. Since the majority of new constructions in Wallonia are carried out by professional promoters, those will seek to achieve the best technical-financial balance for their projects. They will then turn to other more cost-effective technologies, even if they are less environmentally friendly. The modification of this primary energy ratio therefore seems to be a priority for the development of this type of network.

In order to improve the profitability of this type of network, and thus facilitate its development, consideration should be given to the decoupling of investments linked to the production of heat from those linked to the transport of heat (cf point 3.4.9), so as to envisage CAPEX with a new vision.

Similarly, the recovery of fatal heat is not currently cost-effective because of the costs associated with the installation of heat recovery equipment at heat generating facilities, but also and above all because of the cost of heat transport infrastructure from the fatal heat source to the heat network. Moreover, since fatal heat is not considered to be an energy in its own right, the promotion of its use is nearly absent in Wallonia. A support mechanism for green heat seems necessary so that economic profitability no longer prevails over ecological quality.

Other measures could also be put in place, such as an obligation to supply part of the heat via renewable sources, or a mechanism for global support of green heat.

[47] In the Walloon software which define the energy label of a building

3.6. Methodology for the development of a heat network using former mines in Wallonia

Putting in place a heat network similar to that developed by Mijnwater in Heerlen is conceivable in Wallonia, provided that the region adheres to a certain methodology. As a prerequisite it will be necessary to carry out a real market study, and to take account of the financial and profitability aspects in the development of the project.

It is necessary to build on the experience gained from the Heerlen pilot project, in particular through the direct development of a heat network using mines for long-term storage purposes rather than as a source of heat and cold, or as regards the support of the authorities for the project.

In any event, a certain methodology is desirable for the studies to be carried out upstream of the implementation of the network.

3.6.1. Identifying sites having geothermal energy potential on mining sites

As the Heerlen heat network is based on the exploitation of geothermal resources and the storage of heat and cold in former mines, it is necessary to identify the geographical areas where such resources are present in Wallonia.

3.6.1.1. Importance of the temperature

For the installation of a heat and cold exchange network to be technically possible, the temperature of the heat and cold sources present needs to be sufficient to be exploitable. As these temperatures are determined by the geothermal gradient, they are relative to the depth reached during the mining operations. It is therefore necessary to identify the sites where the maximum depth reached during the mining operations makes it possible to obtain water that is sufficiently hot to be used as a heating source, but also where the minimum depth makes it possible to obtain water that is sufficiently cold to be used as a cooling source.

Potential sites must therefore have at the same time a minimum depth and a maximum depth that satisfy these conditions.

3.6.1.2. Importance of capacity

The identification of former mines having minimum and maximum depths so as to be able to obtain water at the necessary temperatures is a good start, but the quantity of water needs to be sufficient to supply a heat network without the resource being exhausted. The volume of water therefore needs to be sufficient. As this is linked directly to the ore extracted from the mine and therefore the space left free, it can be determined using data from that period, showing the volume of coal mined, or the number of seams (or galleries) which were mined at the time.

Mons University, in collaboration with VITO, is currently mapping the mining sites with geothermal potential, which could potentially be developed to put in place a heat network.

3.6.2. Identifying heat and cold supply and demand

Once the resource has been clearly identified, it is necessary to examine the consumer aspect of the project, since consumers are at the heart of the project, and without them the project would be meaningless. However, this is probably one of the most difficult stages in the implementation of the project, since it involves convincing potential consumers that are neither especially interested in this type of project nor familiar with the ins and outs of such a project.

In order to make things easier, it is useful to reduce the number of contacts. To that end, when searching for consumers for a future heat network, it is interesting to prioritise exchanges with parties that own large areas of real estate, such as social housing companies, owners of shopping malls, managers of public buildings and large real estate portfolios, and owners of offices blocks. Once the potential consumers have been identified, it will then be necessary to estimate the spatial and thermal density of the future network, and identify precisely the typology of the network's future users.

3.6.2.1. Quantifying the demand for heat and cold

After having identified the mining sites having geothermal energy potential, it will then be necessary to identify and quantify the heat and cold demand near such sites.

To ensure that such a network is cost-effective, there must be enough consumers connected to it and the heat demand of such users must be sufficiently high. Similarly, it is necessary to ascertain the needs of the consumers connected to the heat network so as to ensure that it is correctly sized to establish consistent specifications, ensure profitability and minimise costs.

One of the difficulties lies in the fact that it is low-temperature network, which implies that the connected buildings can be heated with these low temperatures, and therefore that they are well insulated. This criterion raises two issues.

The first is that the quality of the insulation of buildings in Wallonia is not in general sufficient for this type of heating[48]. To connect these buildings to the network, a prior insulation campaign would be necessary, and this insulation is not always possible depending on the type of buildings.

The second difficulty lies in the fact that well insulated buildings will, by definition, consume less energy. To achieve a certain level of profitability for the heat network, it will therefore be necessary to have a large number of consumers connected to the network, or connect large consumers to it in addition to small residential consumers.

3.6.2.2. Determining the spatial density and the thermal density

The presence of potential consumers on the site of a future network is necessary for its development, but these consumers still need to be located sufficiently close to each other, since the proximity of the network's users makes it possible to reduce the size of the network's installations. This in turn cuts installation and maintenance costs. Smaller distances between users will also reduce heat losses during transport. The greater the spatial density, and above all the thermal density, the more cost-effective the network will be.

3.6.2.3. Identifying the typology of consumers

Quantifying demand is not enough on its own to put in place a heat network that is not only energy-efficient but also financially viable. The typology of consumers also needs to be taken into consideration, in particular as regards the temporality of demand, the type of demand and the required temperatures.

The timing of consumer demand varies. For example, domestic users will be more likely to require heat in the morning and in the evening, whereas an office building will need heat during the day. The age pyramid within an area also needs to be taken into considerations, since households composed of retirees will not have the same heat demands as a household composed of workers.

The type of heat required also differs. In general, a residential property will require heat in winter and cold in summer, whereas a commercial building will require cold on a more regular basis during the year. In addition, the heat and cold demands of industrial consumers are very specific and must be taken into account on a case-by-case basis.

Lastly, the temperature required for connected buildings also needs to be taken into consideration. A well-insulated building can be heated at a low temperature, whereas a badly insulated building will require high temperatures to

[48] Enquête sur la qualité de l'habitat – L'isolation thermique des logements en Wallonie, CEHD 2015

heat it. In addition, for the industrial sector, each process requires a specific temperature and the processes therefore need to be assessed individually.

A varied group of users will make it possible to spread heat and cold demand over time, which reduces the total energy to be supplied at the same time, and therefore enables more consumers to be connected, provided that they have different consumption profiles.

In addition, different consumer profiles optimise heat and cold exchanges between users, since if one user needs heat while another needs cold, they can exchange the cold and heat resulting from their own consumption. The more consumer demands differ, the more the exchanges between them are efficient, and the lower the demand on mining reserves.

3.6.2.4. Identifying users with surplus cold and heat

For a network to function efficiently, the users connected to it must have surplus and/or cold which they can feed into the network. These users, called prosumers, therefore supply heat or cold to the network, which will then be used by other consumers on the network. These prosumers are important for the network's viability, in particular during periods when demand is relatively homogeneous. For example, in winter, heat demand is high, whereas cold demand is relatively low. The presence of a prosumer supplying heat to the network will therefore counter-balance this high heat demand.

The integration of this heat, which was previously lost ("waste heat"), means that this "free" resource is injected into the network. The network therefore requires fewer external sources of heat, which reduces its CO_2 impact. It is important however to remain cautious in relation to the longevity of the industry. As the lifespan of a heat network is around 50 years, there is a need for companies supplying heat to be present throughout the total life of the network. Stable heat suppliers over time, such as waste incinerators, should therefore be prioritised.

In the absence of these prosumers, the heat or cold demand that is not counter-balanced by exchanges within the network will be drawn from the mining reserves, which can lead to these becoming exhausted, as was the case during the first phase of the Mijnwater project.

4. Conclusions

Geothermal energy, coupled with heat networks, represents a solution for the future. These combined technologies contribute to a more rational use of energy and a reduction of CO_2 emissions

The use of water in flooded mines as a source of heat and cold, and for the long-term storage of heat, makes this combination of technologies even more interesting, since it makes it possible to avoid most of the risks inherent in deep geothermal energy. It also reduces the use of fossil fuels, responsible for the bulk of the sector's CO_2 emissions. Even if the determination to avoid being dependent on fossil energy suppliers is not as strong in Wallonia as in the Netherlands the projected end of fossil resources is encouraging the authorities to look at possible alternatives.

Lessons can be learnt from the Heerlen pilot project. Particularly the viability of a project based on exchanges of heat and cold, with storage in the mines rather than a direct exploitation of the resource present in the mines. But it also highlights several needs that provides support for heat network projects. In particular, the need for clear legislation, the need for investment by the authorities (at both local and national levels) and even the need to integrate a financial and cost-effective component when preparing the project.

The presence of former mining sites in Wallonia suggests that the development of this type of project could be feasible in Wallonia. But studies of the geothermal potential of the flooded mines, as well as supply and demand of heat in the surrounding area, are necessary to ensure the viability of the projects.

There are some differences between the situation in the Netherlands and that noted in Wallonia. The energy context in the Netherlands, in particular the determination to move away from gas as an energy carrier, has been a major factor in the success of the Heerlen project. However, as global gas reserves are finite, available stocks will inevitably decline, which will be accompanied by an increase in fossil fuels prices. The financial weight of gas consumption in Belgium will therefore become increasingly important. It would therefore be appropriate for Belgium, and therefore Wallonia, to take advantage of the planned energy transition to grasp the opportunity offered by this type of innovative project to build a more economically- and environmentally-friendly future. Nevertheless, some measures need to be adopted with a view to facilitating the development of projects of this type. These include in particular legislation on the supply of heat and the installation of heat networks. Particularly as regards the primary energy ratio of heat networks in Wallonia, or the price and low taxation of fossil energies despite their high CO_2 impact. These aspects are real barriers to the development of heat networks and need to be revised to put in place consistent legislation that is favourable for such projects.

As the real estate stock in Wallonia is not particularly well insulated from a thermal point of view[49][50], an insulation campaign should be a perquisite to connecting buildings to a heat network, if the network is not to be limited to new buildings. However, because of the configuration of some old buildings, it is not always possible to insulate them without incurring excessive costs.

It is also important to increase knowledge of heat networks in Wallonia, not only among citizens but at the level of the authorities and professionals in the sector. The promotion of this type of project, in particular via successful pilot projects, would restore the image of heat networks in the eyes of the various stakeholders, which would be a positive factor for their development. In this regard a project similar to the one carried out in Heerlen would be interesting to highlight the possibilities offered by heat networks, while at the same time offering an opportunity to capitalise on Wallonia's mining heritage.

[49] Stratégie wallonne de rénovation énergétique à long terme du bâtiment – Climact, 3E, BPIE, 2017
[50] Enquête sur la qualité de l'habitat – L'isolation thermique des logements en Wallonie, CEHD 2015

Designating contact persons or establishing a dedicated service within the administration, with the aim of informing citizens, the project's sponsors, but also the political class about the opportunities offered by heat networks, and the various approaches and premiums available to develop such networks, would be a factor that could spur the development of heat networks in Wallonia.

Heat networks using geothermal energy from mines therefore have a cost-effective and environmentally-friendly potential, which makes them interesting for Wallonia's future energy development. But a strong political will is essential in order for this potential to be realised. The significant cost of this type of project requires a long-term vision, and decision-making on a case-by-case basis according to local parameters.

5. Thanks

We would like to thank the people from Mijnwater B.V. that we have met during the interviews in Heerlen, namely Herman Eijdems, Louis Hiddes, Angélique Palmen, Sjoer Parren and René Verhoeven.

We also wish to thank Volmar Delheij from Stadregio Parkstad Limburg, Eric Jan Reemers from the Municipality of Heerlen and Jack Gorgels from Weller Wonen for answering our questions during the interviews in Heerlen.

We also would like to thank Me Guy Block and Me Elvira Saitova from the law firm Janson for their assistance for the legal part of the rapport.

Finally, we would like to give a special thanks to Joyce Bongers from Mijnwater B.V. for her review of this document and to Benoit Hofer from Cap Construction for the supervision of this mission.

6. Bibliography

- Belgian Government, Plan Air Climat Énergie à l'horizon 2030 (PACE 2030).
- Belgian Government Plan National intégré Energie Climat Belge 2021-2030 (2018).
- BRGM, 2008. Production de chaleur par géothermie – l'expertise du BRGM. Géorama, 20, (2008).
- Buffa S., Cozzini M., Antoni M. D., Baratieri M.,Fedrizzi R.., 5th generation district heating and cooling systems, a review, Renewable and Sustainable Energy Reviews 104 504–522 (2019).
- Brummer N., Bongers J., Mijnwater roadmap to 2040, (2019).
- CEHD, Enquête sur la qualité de l'habitat – L'isolation thermique des logements en Wallonie, CEHD (2015).
- Climact, 3E, BPIE, Stratégie wallonne de rénovation énergétique à long terme du bâtiment, (2017).
- Dutch Government, Energie akkoord.
- Dutch Governement GAS act.
- Dutch Government, "Warmtewet" (2019).
- Ecorem, VITO, Geological Survey of Belgium Étude des obstacles à la géothermie profonde (basse et haute énergie), (2011).
- European Directive : Energy Efficiency (2012/27/EU).
- European Directive : Promotion of the use of renewable sources (2009/28/EC).
- Hönisch B., Gary Hemming N., Archer D., Siddall M., McManus J. F., Atmospheric Carbon Dioxide Concentration Across the Mid-Pleistocene Transition, Science, Vol. 324, Issue 5934, pp.1551-1554 (2009).
- Lund H, Werner S, Wiltshire R., Svendsen S., Thorsen J. E., Hvelplund F., Vad Mathiesen B., 4th generation district heating (4GDH) integrating smart thermal grids into future sustainable energy systems, Energy 68 (2014).
- Nijpels E., "Presentatie Voortgang: Klimaatakkoord," (2018).
- Parkstad Limburg, "PALET 3.0: Parkstad Limburg energietransitie," (2016).
- Peticlerc E., Vanbrabant Y., Développement de la plate-forme Géothermique de la Wallonie, (2011).
- Praktijkboek Bouwbesluit 2012, M. Van Overveld, P.J. Van Der Graaf, S. Eggink-Eilander, M.I. Berghuis (2011).
- Programme des Nations Unies pour l'Environnement, réseaux urbains de chaleur et de froid, libérer le potentiel de l'efficacité énergétique et des énergies renouvelables
- PWC Deplasse ICEDD, Stratégie de réseaux de chaleur et de froid alimentés par des cogénérations et des énergies fatales (2015).
- Syndicat National du Chauffage Urbain (SNCU), Enquête nationale sur les réseaux de chaleur et de froid (2017).
- Tweed, Réseaux de chaleur en Wallonie, (2011).
- Ulg and PWC-ICEDD-Deplasse "complete evaluation of the potential for the application of high-efficiency cogeneration and efficient district heating and cooling networks" within the framework of the transcription of article 14 of Directive 2012/27/EU, (2015).
- Van Bockxmeer J., Duurzaam tweede leven voor Limburgse mijnen, (2019)
- Verhoeven R, Willems E., Harcouët-Menou V., De Boever E., Hiddes L., Op 't Veld P., Demollin E., Minewater 2.0 project in Heerlen the Netherlands: transformation of a geothermal mine water pilot project into a full-scale hybrid sustainable energy infrastructure for heating and cooling, Energy Procedia 46 (2014).
- Werner S., International review of district heating and cooling, Energy 137 (2017).
- Wildeboer L., Van der Weijden C., Feld J., STROOM; the new electricity and gas act in the Netherlands, CMS legal (2020).