CASE STUDY

The use of mine water in district heating systems – an example from Heerlen, Netherlands

The district heating system in Heerlen, the Netherlands makes use of an innovative approach: using mine water from a former coal mine as a geothermal heating source and for energy storage.

The system is one of the first so-called 5th generation district heating and cooling (5GDHC) grids, an integrated heating and cooling system that uses a multitude of energy sources, technologies and digital tools to provide flexible supply specifically designed for the city's fluctuating needs. Heerlen's unique approach to its 5GDHC is an example of how to make use of the legacy of coal mining to generate significant benefit.

DESCRIPTION

Location: Heerlen, Netherlands

Type of action: Implementation of 5th generation district heating and cooling using former coal mine as a source of heat and for underground energy storage

Actors: Local and regional government, district-owned power company

Financing conditions: EU funds, municipal and district grants, private investments

KEY POINTS

APPROACH

Developing a state-of-the-art 5th generation district heating and cooling grid, and integrating the former underground coal mines into this system as an energy source and for storage

Decreasing dependency on fluctuating oil and gas prices, and producing local, sustainable and affordable heating and cooling

ACHIEVEMENTS

Reducing CO_2 emissions by 65%, and eliminating the local use of fossil energy for district heating (keeping in mind that there is still dependence on the overall Dutch energy mix, which in 2023 relies mainly on fossil fuels)

Setting up a cloud structured grid, which includes multiple levels of control and decentralised energy generation that can exchange heat and cold, all with use of excess heat and prosumers instead of consumers

Integrating short-, mid- and long-term energy storage using former underground coal mines

Implementing a low-exergy design aimed to provide the right temperature, at the right place, for the right application

ENABLING CONDITIONS

Securing strong financial support through local and EU funding

Having municipal support, good communication channels in place, and social acceptance

Working in the context of a company (owned by the region) made it easier to attract funding than if it had been a municipal project

Building technical knowledge and capacity within the company

Controlling not only the grid, but also end-user power stations in the buildings, which enabled efficiency optimisation and automated system control

Thinking in creative, inventive and pragmatic ways

CHALLENGES

Finding financial support

Requiring a lot of investment of capacity and money into research and development, and still facing unexpected barriers, because this was a completely new approach

Choosing the right drilling location for wells

Technically executing the project due to lack of experience with this innovation among construction companies

Convincing consumers to change to a so-far unproven H&C solution

European Commission

Introduction

In Heerlen, the Netherlands, the coal mining era (which ended in 1974) left behind an underground network of tunnels and shafts – a legacy that still requires maintenance and eternity costs. In the pursuit of finding new purposes for the coal mines, the City of Heerlen began exploring the possibility of using the heat captured underground for its district heating. From the first exploration to today, the whole project has undergone an intensive development process, which can be described in three main stages:

1st stage: the pilot

From 2003-2008, a pilot project was developed with the support of the European Interreg IIIB NWE programme and the EC-REMINING-lowex project, and was carried out by several international consortia of partners from the UK, the Netherlands, France, and Germany.

The pilot included two hot wells in the northern part of Heerlen, which reached depths of 700 metres below the surface to extract hot water, and a temperature of about 28°C. On the other side of town, two 250m-deep cold wells were created for the extraction of cold mine water with a temperature of about 16°C. A fifth well was used to inject the used cooled-down warm water and the used warmed-up cold water (18-24°C) back into the system.

At the pilot stage, the system provided both heat in winter and cooling in summer to two buildings: the Central Bureau of Statistics (22,000m^2 large), and the Heerlerheide Centrum, a complex with shops, office and apartments (about 30,000m^2). This relatively easy system also comprised a bivalent energy station with heat pumps for base loads, and gas boilers and chillers for peaks.

2nd stage: upgrading the system to a thermal smart grid with energy storage

Once the pilot proved that it was possible to use mine water for district heating, the municipality decided to expand the system. During that time, the province of Limburg (in which Heerlen sits) decided to become climate-neutral by 2040, which made the project of greater interest for the whole region. However, the system up to that point used mine water purely as an energy source, with limited capacity for further expansion, since the water simply needs time to reach the extraction temperatures again after being pumped back to the ground-level.

To avoid overusing the heating source, while still scaling up the system, the project opted to investigate using mine water for energy storage instead of as an energy source. Accordingly, starting in 2013, the process was changed quite significantly so that mine water was heated up (for heat storage) and cooled down (for cold storage) before being pumped back into the ground via bi-direction wells.

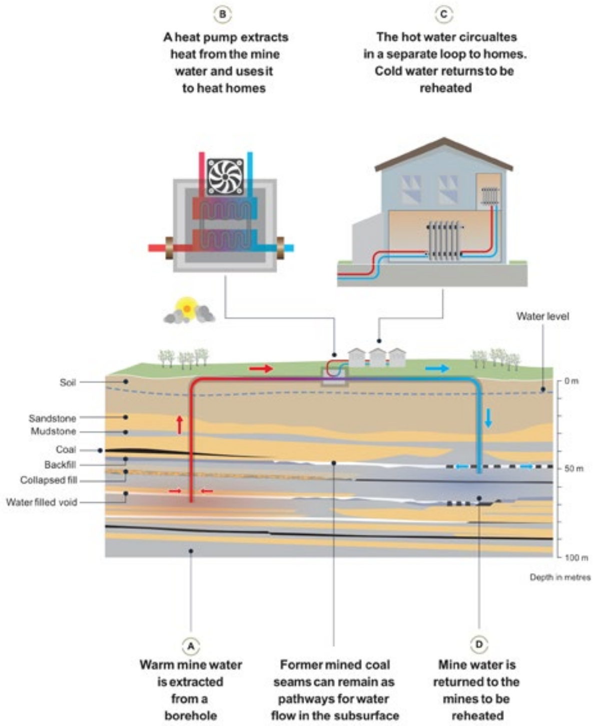

FIGURE 1: THE PRINCIPLE OF MINE WATER USAGE AS AN ENERGY SOURCE FOR DISTRICT HEATING SYSTEMS EXPLAINED. DEPTH INDICATED IS JUST AN EXAMPLE, THE SHAFTS IN HEERLEN REACH 250M (COLD WELL) AND 700M (HOT WELL).

Source: British Geological Survey

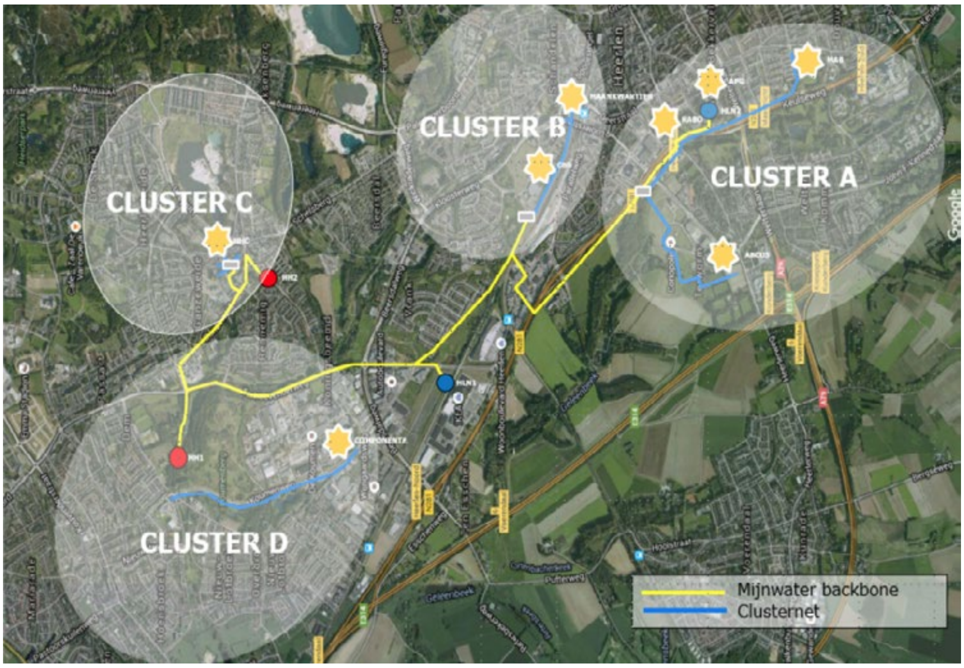

FIGURE 2: A MAP OF HEERLEN MUNICIPALITY SHOWING THE CLUSTERS, PIPE NETWORK AND HOT & COLD DRILLING WELLS, THE LATTER INDICATED BY RED AND BLUE DOTS.

Source: Van Oevelen Vanhoudt 2020

Additionally, the system was upgraded to a "thermal smart grid" (or thermal hydraulic cloud network), which provided heating and cooling with higher efficiency due to an instant heat and cold exchange. This was fully automatic, demand-driven and interconnected between consumers and the renewable sources in the area. Furthermore, no more gas was used in the system for peak energy supply.

The upgraded 2nd stage of the Mijnwater project provided heat for 200,000m^2 of building equivalents in four connected cluster grids, with a newly installed capacity of 4 MW for heating and cooling (see figure 2). Three of the four new clusters also made use of excess heat from a data centre, a supermarket and from industry to provide further input to the grid via heat pump installations. In all cases, the excess heat was primarily used by distinctive consumers themselves; but, in times of additional surplus heat, it was discharged to the cluster grid to be used by others.

Overall, the newly created cluster network was designed in accordance with the "low-exergy-principle". In other words, preferentially using low valued energy close to room temperatures, and delivered by sustainable energy sources, and designing the grid to run on rather low temperatures to prevent greater energy losses. In practice, this means that the temperature in the grid stays at about 25°C, cascades up to the temperatures required by end users (maximum 45°C for new buildings with a high energy efficiency standard, and 60°C for renovated buildings), always providing the lowest temperature needed by the consumer. For domestic hot water, each building had an additional booster heat pump to provide warm water at 65°C. For example, in 2017/18 the grid delivered 5.1 GWh/a of heating, and 5.2 GWh/a of cooling, with an electricity input of 2.3 GWh/a.

3rd stage: optimising the control system and providing energy storage for different time periods

While the system was already quite advanced by its 2nd stage, the Mijnwater project is continuously being further developed and refined. It became clear that there was room for further optimisation, especially to avoid large peak demands, particularly early in the morning when all office buildings began to need heating. Decreasing peak demand would allow more customers to connect to the grid, and thus lower H&C end prices.

To realise further optimisation, a self-learning and adaptive intelligent control framework – which uses multiple control strategies like cell/cluster balancing, peak shaving and interaction with the electricity market – was set to be developed as part of the European-funded, Horizon 2020 project "STORM". However, the effort required to develop such a system was underestimated, and therefore results were not as promising as expected. To realise this top-level control framework, further development will be needed.

In addition, the Mijnwater energy storage system will be expanded to provide more effective integration of short-, medium-, and long-term (seasonal) energy storage needs.

Key challenges

Mijnwater's business case is based on long-term investment with a time horizon of 20-30 years for installation components and 50 years for pipes and construction works. Financing these new types of regionally-based energy provisions is a complex process. Many financial institutions are not yet capable of adequately estimating the risks of these new technologies, and therefore it was a challenge to find financial support for the project, especially in its early phases. However, through step-by-step expansion and proof by results, Mijnwater was able to build up trust and increased the bankability of its approach.

Another challenge was finding contractors capable of designing and implementing such innovative technology. The work on-the-ground required very specific insights into integral operation and energetic performance. In the past 10 years, the project incurred financial losses due to improper design and failed execution of the concept. As a result, service contractors aiming to work with Mijnwater B.V. now have to provide references and demonstrate experience with at least 4GDHC grid installations.

At the beginning of the 1st and 2nd phases, it was a challenge to convince consumers to switch to the new, "unproven" heat supplier. Mijnwater requires end users to occupy a building with high energy efficiency standards, so some existing buildings needed to first invest to at least ensure the building was ready to work with low-temperature heat, and to upgrade insulation and ventilation with heat recovery. This has minimised energy losses and enabled Mijnwater to connect as many buildings as possible to the grid. Mijnwater tries to lessen costs for these building upgrades by initiating collective deals for buying double glazing, insulation and other needed materials. Plus, to convince potential customers to switch from their current heat supply to Mijnwater, from phase two onward the company offered a price reduction of approximately 10% compared to the existing alternative, which in the end convinced many consumers to switch, together with the argument that Mijnwater can deliver heating and cooling at fixed prices over time that are independent from the volatile and international oil and gas markets.

Enabling conditions

As this was a completely new approach, a lot of capacity and money went into research and development in order to realise the Mijnwater system. Together, the Municipality of Heerlen and later the Province of Limburg invested around €20-25 million, and mobilised another €25-30 million from various EU programmes. Choosing the drilling locations was very important, and therefore €50-150,000 were invested into a feasibility study to explore the subsurface of the area and to gain digital geo-referenced data.

The success of this project, at least during its initial phase, can be largely attributed to the support of the local authorities, specifically the Municipality of Heerlen, which also provided financial and logistical support. Without this local commitment – including strong and transparent communication about what the project was going to do, how it works and why it was seen as a good idea – it would have been unlikely that the project would have been implemented. The social and historical context were further factors that enabled the project's social acceptance. Furthermore, former miners were actively involved in the planning stage and were consulted to identify suitable locations for the wells.

Another crucial enabling condition for the Mijnwater project was changing the organisational structure from a municipal project, to a district-owned enterprise. A company structure made it easier to attract private investments, as investors were more familiar with this structure and were more convinced that a company could operate with long-term ambitions, especially when compared to projects, which risk losing support after the initial project end-date. Furthermore, building-up technical knowledge and capacity within the company has been crucial to cope with the new and high-tech 5GDHC concept. A detailed commissioning protocol was helpful to avoid costly mistakes and performance flaws.

To advance from a 4GDHC to a 5GDHC, it was important that the ownership and operation of the grid, storage, and decentralised energy stations (heat pumps) in the connected buildings allowed for systemic optimisation and effective overall operation of the energy infrastructure.

Finally, creative, inventive and pragmatic thinking was a driver of the process within the developing team, who approached problems as challenges instead of barriers.

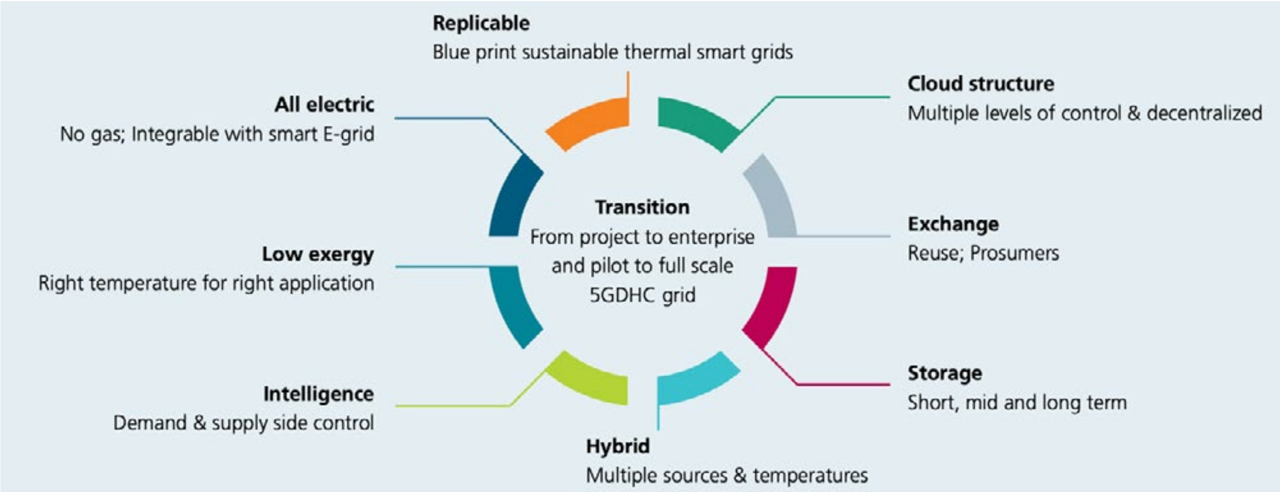

FIGURE 3: SUMMARY OF KEY ELEMENTS OF THE MINE WATER 5GDHC SYSTEM.
Source: Fraunhofer IEG

Achievements

Over the course of the last few years, Mijnwater B.V. gained international attention for its innovative approach of using mine water for district heating, and developing a modern 'low-exergy' interconnected grid system. By applying an 'energy-efficiency-first' principle right from the start, the approach set a compelling example about gradually building up a 5th generation district heating and cooling network that provides a blueprint for future district heating and cooling solutions.

Currently, Mijnwater B.V. contributes to achieving a 65% reduction in CO_2 emissions for heating and cooling of connected properties in the region when compared to the average gas heating and electricity-run cooling solutions. Thanks to the continued development of the system, mine water energy is now an essential part of the city's 2040 renewable energy master plan, and has been included in the Parkstad Limburg Energy Transition (PALET) strategy for the Parkstad Limburg region. In the long-term, the plan is to further scale-up the system across Heerlen, including for clusters of private homes, and to optimise cascaded use of energy between consumers and producers. Eventually, the concept should also be adopted by other municipalities in the region, including (micro-grid) island solutions for rural clusters with only a few buildings.

The concept has also been taken-up as a best practice within the D2Grids project, which will build five European pilot sites in Bochum (Germany), Brunssum (the Netherlands), Glasgow (Scotland), Nottingham (England), and Paris-Saclay (France) that will serve as examples for the realisation of 5GDHC systems, and will improve its commercialisation potential. In Brunssum, which neighbours Heerlen, Mijnwater B.V. is directly involved as the executing company building up the new, independent heating and cooling island grid for residential housing complexes.

Further reading

- Mijnwater website
- In-depth case study about Mijnwater 5GDHC Grid
- Mijnwater Heerlen: Roadmap to 2040
- More insights into excess use and integration in Heerlen

Academic papers about the Mijnwater approach and technical solutions

- Boesten, S., Ivens, W., Dekker, S. C., and Eijdems, H. (2019): 5th generation district heating and cooling systems as a solution for renewable urban thermal energy supply, Adv. Geosci., 49, 129–136
- Verhoeven, R., Willems, E., Harcouët-Menou, V., De Boever, E., Hiddes, L., Veld, P. O. T., and Demollin, E. (2014): 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, Enrgy. Proced., 46, 58–67
- Walls, D.B.; Banks, D.; Boyce, A.J.; Burnside, N.M. (2021): A Review of the Performance of Minewater Heating and Cooling Systems. Energies, 14, 6215

Initiative for coal regions in transition

The Initiative for coal regions in transition is led by the European Commission.

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