Mijnwater Heerlen: Roadmap to 2040

District heating and cooling grid Parkstad Limburg

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About HeatNet NWE

This document has been developed as part of the HeatNet NWE project, which is part-funded through the Interreg NWE programme and aims to increase the uptake of 4DHC networks across North-West Europe. As part of this project, the partners are developing the HeatNet Model, which will help the public sector to begin implementing 4DHC networks, and the Transition Roadmaps, which will outline the partners' experience in developing six district heating pilots across North-West Europe. The HeatNet Guide to Financing is also currently being developed and will give a broad overview of the various sources available to finance district heating schemes.

For further information on these reports and on the HeatNet NWE project, please visit www.guidetodistrictheating.eu.

Introduction

A roadmap is a strategic plan that describes the steps an organisation needs to take, to achieve stated outcomes and goals. It clearly outlines links among tasks and priorities for action in the near, medium and long term.

The six pilot projects of the Interreg NWE Heatnet project were selected to represent a wide variety of locations with a variety of District Heating and Cooling grids (DHC), at different development stages. The goal was is to gather and exchange experience to move to the most advanced grid, identified at that point as the 4th generation.

Mijnwater and the five other pilot projects in Heatnet each wrote a roadmap describing their long-term transition to a sustainable grid, enabling substantial reduction of the collective CO_2 emissions of its customers. The lessons learned at these different pilot projects will be combined into a more universal guide towards sustainable DHC.

While comparing the different situations and grids, it became useful to identify the grid of Mijnwater as an example of a new, 5th generation heating and cooling grid (5GDHC) [1]. This was because its design differs substantially from the more traditional 4th generation DH grid [2]. Both operate at low temperature, which massively reduces the loss of heat during the transport. But in addition, the 5GDHC design enables a new feature: all customers can simultaneously exchange heat and cold among each other. This is combined with a large capacity of thermal storage and an all-electric distributed generation of heat and cold using heat pumps. The result is a grid architecture where heat sources are not anymore the central feature, and the operation can be driven from the demand side.

The Mijnwater grid is a unique and pure example of such a 5GDHC grid that has already reached a substantial scale. This roadmap is therefore not a description how Mijnwater plans the transition to 5GDHC, but rather how the Mijnwater grid will be scaled up to serve the local region. The 5GDHC grid can be powered by all electric distributed generation systems, based on heat pumps near the end user. Although many examples of small 5GDHC grids existed, a review of district heating systems from as recent as 2017 did not yet mention this option [2]. In early 2019 a review article was dedicated to 5th generation heating and cooling systems in Europe [1] .

Since the 5GDHC design is still not commonly known, we start this roadmap with a technical description at a basic level of the physical grid infrastructure. This is followed by a description of the national policy context, the local context in Heerlen and the larger region of Parkstad Limburg. The Mijnwater grid is about 11 years old, and still has a homogeneous design. It was initiated as pilot by the municipality of Heerlen (2002-2008), upgraded to a company with a 5GDHC grid for Heerlen (2012), and adopted by the larger Parkstad region as an important method to enable its energy transition vision for 2040 (PALET). Naturally, such a heating grid brings together local government, investors, consumers, builders, maintainers. A stakeholder analysis gives a good view into how Mijnwater was born and can grow up to a trusted utility company serving the region.

The next section describes the approach of Mijnwater BV for building a grid that is affordable for its customers, allowing them maximum opportunity to energetically improve their own buildings, and resulting in a collective infrastructure that will further reduce energy needs. This should form a solid foundation for being sustainably financed in the long term.

Finally, there is a long-term timeline for this grid and how it will scale up towards 2040, the year in which the PALET plan has as its goal to reach regional energy neutrality.

Mijnwater, the technical picture

Mijnwater 1.0 was initiated and built by the municipality of Heerlen [3, 4, 5] as a 4th generation District Heating *or* Cooling network (4DH, 4DHC) [2]. The idea was to make use of warm water in the abandoned and flooded local coal mine as a sustainable source. In the winter, warm water of 28ºC was fed from the mine into the grid to deliver warmth, while in the summer cool water of 16ºC from a shallower cool source was distributed. This was a '4th Generation' grid in the sense that it made use of a low temperature heat source (or high temperature cooling), and also that it distributed the warmth or the coolth from a central point to the customers. In this phase, there was no simultaneous exchange between customers. This grid started by serving one large office building (national statistics bureau CBS) and a social housing project. However, there were signs that this setup was slowly exhausting the geothermal source, meaning that it could not be scaled up much further. Hence, a new design was made in 2012 by Mijnwater BV.

Mijnwater 2.0

In 2013, the grid was upgraded to 'Mijnwater 2.0', a fully functioning 5th Generation Heating and Cooling grid (5GDHC) [6, 7, 1, 8]. The important new feature was that from that time the grid is able to exchange heat and coolth between all customers, simultaneously, while the mine water system is used to store heat and cold.

Demand driven

In contrast to conventional DHC systems that are based on supply side management, the whole design, operation, and optimisation of the Mijnwater grid is 'demand driven'. Everything starts from the points of demand for warmth or coolth and any residual energy is stored for later use. All physical flows of water and energy are initiated at the points of demand for warmth or coolth. This saves energy by avoiding any unnecessary pumping around as often done in a more traditional DHC grid. As a consequence, we will see that the grid needs no central energy plant or source. This is all made possible by a grid optimised for exchanging energy between customers, by thermal storage at each level and time scale, and by a distributed cloud of heat pumps near the end users that guarantee the right temperature, and also generate thermal energy for the grid.

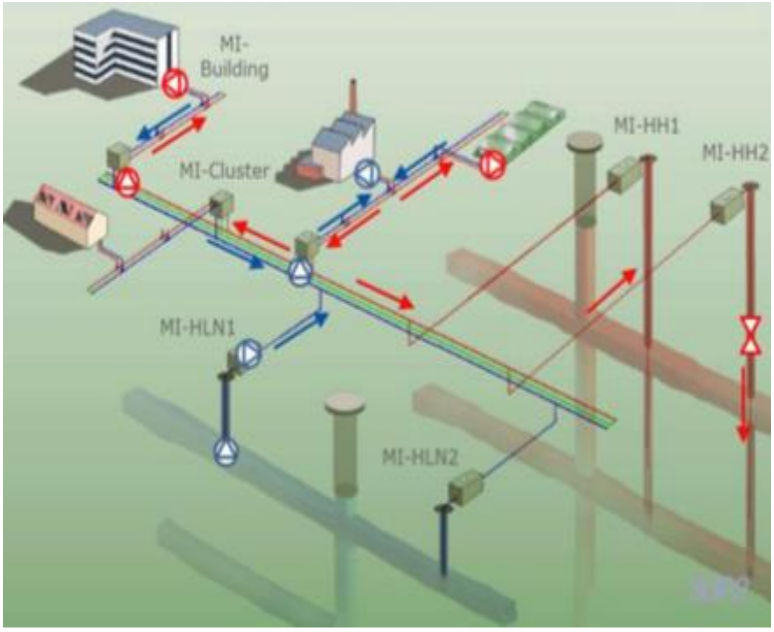


Figure 1 Simple graph to indicate the three levels of energy exchange, and three levels of control, where they connect: the energy station at the buildings (MI-Building), the Cluster Installation (MI-Cluster), and the wells that connect the backbone directly to the mine (MI-Wells).

A two-pipe spine: warm and cool

The basic feature is a conventional two pipe spine, one with warm and another with cold water. However, the direction of flow is not fixed. So we cannot speak of a 'distribution line', to the customers, and a 'return line'. Only at the points of demand, a flow between the two pipes is initiated. Heat can be extracted from the warm water using a heat pump, returning cool water at the right temperature, to the cool pipe. Coolth is extracted the other way round, by rejecting warmth into the warm pipe. This way, customers in need of cooling will automatically provide waste heat to be used by any neighbour needing warmth.

At one end of this two pipe spine, the pipes are connected via a heat exchanger that ensures either that the residual flow of cold water is turned into warm water, or the other way round. The heat is exchanged with a next level in a hierarchy, which could also be thermal storage.

Exchange of energy between consumers on the grid

If one user needs a certain amount of warmth, and the neighbouring one needs exactly the opposite, this will induce two opposing flows from the warm to the cool and back to the warm pipe. In absence of other users there would just be this local loop, and nothing else. In general, the flows will not cancel exactly, and there will be a residual total demand that needs to be absorbed by a heat exchanger at one end of the two pipe spine.

Thermal Storage

An essential ingredient is the thermal storage. The two-pipe spine enables exchange of heat and coolth between nearby locations. The thermal storage enables sharing across time. It separately saves the heat and coolth from the past and makes it available in the future. Together, sharing heat/coolth over the local area and across different times reduces the total energy consumption significantly. Thermal energy is stored in the buildings and hot water boilers (short term), in the water of the grid, and in the mine water (long term).

A 3-level hierarchy of grids

The Mijnwater grid is designed to function at three separate levels, each with independent controls. The previous Mijnwater 1.0 pipe system which has water from the mine running through it, is now the '**backbone**'. It is connected to the mine at two warm and and two cool wells. The wells are bi-directional: this means that water (=energy) can be both extracted and infiltrated. Pressure maintenance and buffer installations at the wells guarantee that the desired flow can always be supplied to the system. The pressure also helps control the dissolved gasses and other substances in the water from the mine. The energy exchange with the clusters takes

Figure 2 Diagram to demonstrate the three-level design of the Mijnwater grid. The elements indicated are an energy station at a large office building (MI-Building), and an example of industry demand for cooling, a greenhouse demanding warmth. The small grey cubes represent the underground cluster installation (MI-Cluster) connecting a cluster with the backbone. Also indicated are the boreholes to the warm (MI-HH1,2), and the cooler (MI-HLN1,2) parts of coal mine tunnel system. The grey boxes are the pumping installations that control pressure at the wells.

place through heat exchangers in the cluster installations.

The backbone has two purposes. On the one hand it connects the cluster grids with each other. But its first purpose is to be a large heat-exchanger connecting the warm and cool wells. It is the thermal interface with the long-term thermal storage of mine water.

In spring 2019, there were four **'cluster grids'**, each connected to the backbone through a large heat-exchanger in a 'cluster installation'. A cluster grid is a two-pipe spine that enables exchange of thermal energy in the local area, and with the backbone.

The Building, or Local Area Grid

Each large building(block) is connected via its own 'Energy station', with heat pumps providing the right temperatures for heating and cooling each building. Simultaneously, the water returning to the cluster grid has the correct temperature. This way, the same heat pumps of the 'Energy Stations' also provide the cluster with thermal energy.

To connect a local neighbourhood of individual dwellings, an Energy Station was designed to serve a 'local area grid'. The dwellings are connected to a system of four pipes at low (15ºC/30ºC) and higher temperature (30ºC/45ºC).

Booster heat pumps.

At the end customers, booster heat pumps produce hot tap water, stored in 120-200 litre buffer tanks. This avoids having long hot water pipes, with resulting heat losses. These are owned, maintained and controlled by Mijnwater.

All electric foundation

Together, the heat pumps of the Energy Stations form an all-electric system that generates thermal energy for the grid. When new buildings or local area grids are connected to a cluster, the generation power automatically scales along with the size of the grid. The mine water that originally was used as a source of thermal energy is now used mainly as long-term storage. The heat used in the winter is replenished in the summer. The thermal mass of the buildings themselves, and the hot water boilers are capable of storing energy on the timescale of a day. The water flowing in the clustergrid, and the backbone also provide some storage during a week, while helping to stabilise the system. The result is a grid that will never run out of energy. It can grow to a much larger size, only limited by the capacity of the grid to transport thermal energy at times of high demand. An example is in the morning, when all offices start work at nearly the same time. This issue is addressed by the next optimisation stage that we call 'Mijnwater 3.0'.

Mijnwater 3.0

The last step in the original design is called 'Mijnwater 3.0', and is still being implemented. Without affecting required comfort levels, it is still possible to optimise the exact timing of demand from buildings. The buildings themselves have a thermal mass, and can store warmth for some time. The water in the grid itself can also be used to store heat for short periods. As an example, large buildings could in principle be heated more slowly by starting slightly earlier in time than requested by the thermostat, to avoid a morning peak from all large office buildings starting their working day at exactly the same time.

The purpose of this optimisation is to reduce maximum peak demand on the grid infrastructure. If a sharp peak is spread over time, the maximum height can come down appreciably. Since the diameter of the existing piping infrastructure always forms a bottleneck in the system, this optimisation of the controlling software will create space to reliably serve a substantially larger number of customers.

At the same time, the (substantial) demand for electricity of the Mijnwater system is shifted and/or spread over time. This can also help stabilise the electricity grid of the network operator, by countering peaks in electricity demand elsewhere, or also variations in electricity generated by wind and solar power.

To conclude: can we define 5GDHC?

It isn't easy yet to define a strict standard, but we could say, based on the Mijnwater experience, that a 5GDHC grid achieves many goals by being 'demand driven'. This property is achieved by an optimised combination of three ingredients, that seem essential.

1. The basic element in the grid is the spine with a warm and cold waterpipe, on which it is possible to simultaneously exchange warmth and coolth between connections. The two-pipe system itself is conventional, but it is optimized for exchanging energy, and the flow of the water is not in one fixed direction.
2. There is sufficiently large thermal storage capacity, so excess energy from the past can be used now, or excess energy from now can be kept for the future. Effectively, thermal storage is like a special 'pipe' that can connect the past with the future.
3. The heat pumps are essential to guarantee the temperature needed by the customers, while also providing the system with a very robust distributed generator of heat and/or coolth.

Being demand driven helps the system to reach a high energy efficiency. Heat pumps deliver the exact temperature the customers need, while the grid feeds the heat pumps with enough energy to ensure high efficiency of the heat pumps. The exchange of heat and coolth helps to reduce the amount of energy needed collectively by the customers on the grid, and averaged over longer times.

The system has a solid energetic foundation based on heat pumps that are located near the points of use. Such a system can grow organically, with new energy stations being added each time a large customer or an area gets connected.

Such an all-electric system provides a path towards complete decarbonization. In 2019, Mijnwater makes use of the Dutch electricity mix, still mainly generated using fossil fuels. At the same time it is easy to make use of waste heat at low temperatures, but also high temperature industrial waste heat can be made useful. It is helpful that the system is robust, and will not easily become dependent on such high temperature sources.

Finally, it is important to state clearly that a 5GDHC grid does need a sufficient volume of thermal storage, but this can be provided in ways that do not need a disused coal mine. So a 5GDHC grid is possible anywhere.

National policy context

This section outlines how the ambitions and goals of national energy and climate policies evolved over time. The structure of national policies is the result of national debates, preferences and initial conditions. Policies build on path dependencies (e.g. domestic reserves of natural gas, lignite or hard coal), the structure of the energy system (e.g. energy mix and infrastructure) and of the economy (e.g. strong industrial base or infrastructure hub function).

Agreement on Energy for Sustainable Growth - 2013

In September 2013, the Agreement on Energy for Sustainable Growth (‘SER Energieakkoord’) was published [9] [10] [11] [12]. This was the result of a grand conference of representatives from business, trade unions, NGO’s, scientists and central, regional and local government. The Agreement on Energy for Sustainable Growth marks the start of the transition to a sustainable future in The Netherlands. The parties to the Energy Agreement will strive to achieve the following four quantitative objectives:

1. An annual reduction of final energy consumption by 1.5%, a total reduction by 100-petajoule (PJ) in 2020;
2. An increase in the proportion of energy generated from renewable sources from 4% to 14% in 2020; and
3. A further increase of that proportion to 16% in 2023;
4. 15,000 jobs, a large share of which will be created in the next few years.

Dutch Climate Agreement – 2019 (soon)

The Climate Agreement (‘Klimaatakkoord’) is the Dutch contribution to "Paris 2015", and it has one central goal, which is to reduce greenhouse gas emissions in the Netherlands by at least 49% in 2030 compared to 1990 [12]. During the past months, the negotiations were held within five sector platforms: built environment, industry, agriculture and land use, mobility, and electricity. These negotiations led to a proposal for each sector platform.

Next to Climate Change, a new driving goal is an organised exit from natural gas. This is to ameliorate increasing problems caused gas extraction in the province of Groningen. A multitude of small earthquakes and tremors are causing great damage to homes and buildings that were never built to withstand tremors, and they even affect the groundwater levels. One of the main agreements by the Sector Platform for the Built Environment [13] was that municipalities will have a central role in transforming the gas-based infrastructure to an alternative energy source. By 2030, 1.5 million homes are to be taken off the gas grid. For 2050, the goal is 7 million homes and 1 million buildings.

Further key points [13] are that geothermal energy should scale to 50 PJ per year geothermal energy by 2030 and more than 200 PJ per year by 2050. In 2021 at the latest, municipal authorities will draw up a local transition vision (‘warmtevisie’) for heat in a careful process with residents and building owners. For each district, the municipal councils are subsequently responsible for a district-based implementation plan for the future sustainable energy infrastructure (‘warmteplan’). This provides guidelines for building owners, network operators, heat suppliers, municipal authorities and other parties to take investment decisions. The original aim was to sign the National Dutch Climate Agreement before the summer of 2019.

When signed, a set of policy tools will be activated at regional and local level. This is known as the Regional Energy Strategies (RES) [14]. On the subject of energy transition, the municipality of Heerlen works together with six municipalities. (From January 1, 2019, the municipalities of Nuth and Onderbanken from the Parkstad region merged with Schinnen to form the new municipality of Beekdaelen.) These are organized in the Parkstad region. This organization is responsible for the implementation of the Regional Energy Strategies in collaboration with relevant stakeholders.

Figure 3: Map of the municipalities of Parkstad Limburg showing municipality boundaries. Most of the densely built areas are in Heerlen, Kerkrade, Landgraaf and Brunssum. The surrounding municipalities of Simpelveld, Voerendaal, and Beekdaelen are more rural with smaller and larger villages.

PALET: PArkstad Limburg Energy Transition

In anticipation of national policy, Parkstad region took an early lead to compose its own policy for the energy transition. The program was named PALET, 'PArkstad Limburg Energy Transition'. Even before the Paris Climate Conference of 2015, Municipality counsels of the Parkstad region put their signature under a common transition vision "PALET 1.0" [15], as well as eight separate municipal plans "PALET 2.0". This has been worked out and integrated in the long-term working plan "PALET 3.0" in July of 2016 [16].

The outcome of PALET 1.0 was clear. About 44% (13 PJ) of all energy demand in the Parkstad region is used for heating in homes, offices, businesses and industry. Research into a regional heating grid was started, as it offers one option to collectively reduce energy consumption, while transitioning to renewable sources.

Heerlen

In 2011, the municipality of Heerlen had a total energy use of 12,355 TJ. Of this, 65% (7,965 TJ) is for buildings, of which 30% are homes, 16% public services, and 19% commercial. Road traffic used 19%, while industry and energy suppliers needed 13%. A small remainder of 3% is unknown, while agricultural energy use is negligible. These proportions were very similar for the whole Parkstad region, that used 29,600 TJ altogether.

The municipality of Heerlen has a substantial and realistic potential to produce sustainable energy. The best opportunities are solar energy and underground storage of heat and cooling. Where possible, wind energy is also an option. Biomass is available, but rather limited in size by local streams of refuse and waste. The figure below illustrates this analysis. After reduction of the energy demand, the remainder could be supplied with about 7026 TJ from sustainable sources.

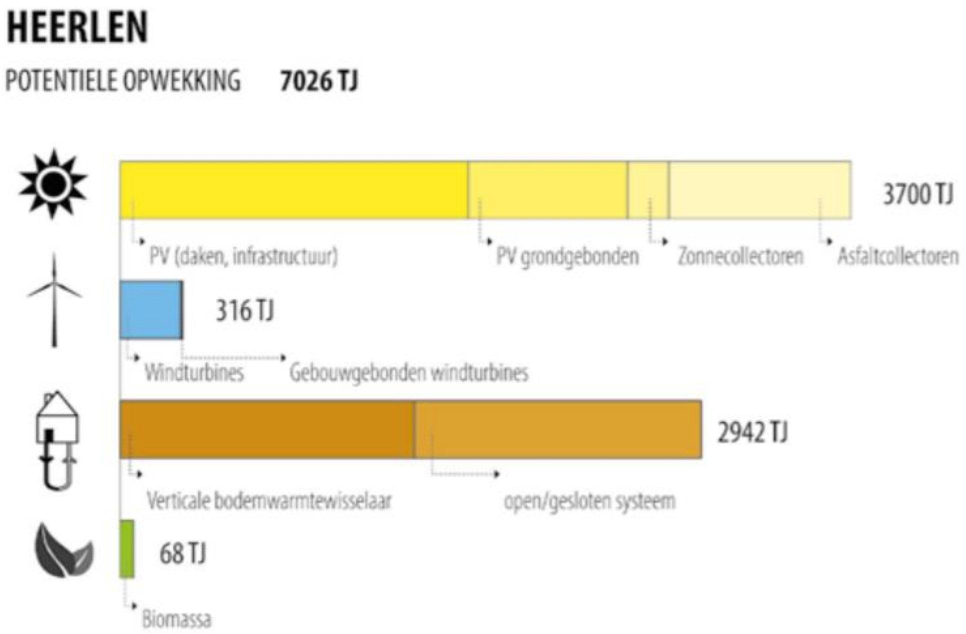


Figure 4 Potential sustainable energy production in the municipality of Heerlen, showing the large potential of shallow geothermal. The potential for solar PV and solar thermal collectors is even larger. There is little space for wind generators, and very little biomass.

Potential for geothermal energy under Heerlen, and Parkstad region

The Town of Heerlen itself initiated research and the first investment, with EU help, to exploit the warmth residing in the water in abandoned coal mine tunnels under the town. This resulted in the Mijnwater grid. In PALET 1.0 and 2.0 a high potential was identified for geothermal heat, as well as Underground Thermal Storage. In Heerlen, this potential was estimated at 7,026 TJ per year. Since sustainable energy sources are also used at a higher efficiency, this should be fully sufficient. Approximately 42% (2,942 TJ) of the renewable energy in Heerlen can be geothermal.

In 2005, the company IF-technology mapped out the potential for shallow underground heat. In 2012, the map was updated by Witteveen en Bos. All of the Parkstad region has medium or high potential, especially for closed-loop systems. This map was limited to shallow geothermal not deeper than 50 m. The source of water in abandoned coal mines is intermediate in depth between shallow (50m) and deep geothermal with high temperature.

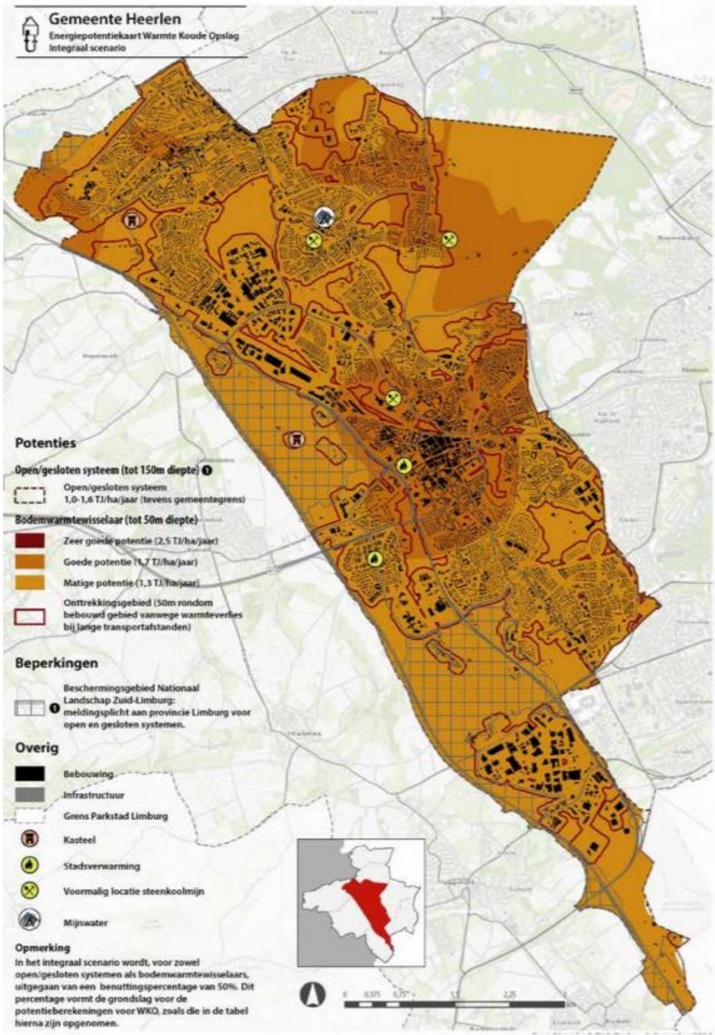


Figure 5 Map of the shallow geothermal potential in the municipality of Heerlen.

The challenges from PALET 3.0

With all this in mind, it has become crystal clear that the Mijnwater 5GDHC grid offers an additional opportunity to reduce energy use: not just at the level of an individual building, but at a collective level of a neighbourhood, a town, or even a larger region like Parkstad region. In PALET 3.0 that summarized and extended the findings of PALET 1.0 and 2.0, an important role was given to the Mijnwater 5GDHC grid. The challenge for Mijnwater is to scale the grid over Heerlen and the municipalities of the Parkstad region.

The figure below, from PALET 3.0, shows how Heerlen is the large core of the Parkstad region, but still represents less than half of the energy consumption. By adding Brunssum, Mijnwater will be active in municipalities representing 50% of energy use. When Kerkrade is added, this increases to 66%. Landgraaf also has a densely built-up area. After that, the remaining municipalities of Parkstad have a more open rural character, with small villages, and isolated buildings. It makes sense for Mijnwater to start with the large municipality of Heerlen, and its large office buildings and educational institutions. It will make sense to subsequently cover the denser regions, and connect small towns nearby. Techniques and procedures will steadily develop, and it is not unreasonable to expect that there will be a way to also connect villages in more open rural areas. An option is also to set up smaller independent island systems in isolated villages, still under Mijnwater management (see maps starting from **Error! Reference source not found.**).

Figure 6 Total energy consumption of the eight municipalities of Parkstad in 2011 (from PALET 1.0). About two thirds of the total 29.6 PJ are for the built environment. In 2019, the municipalities of Nuth and Onderbanken merged with Schinnen, to form the new municipality of Beekdalen. Effectively, Schinnen was add to Parkstad.

Mijnwater Stakeholders

Mijnwater, as owner of a District Heating and Cooling grid, is a publicly owned utility company serving the local community of the municipalities in the Parkstad region. Its purpose is not simply to make a profit, but to roll out the grid such that it can offer its heating and cooling services at affordable rates, while playing an important role in the regional goal of a sustainable transition to energy neutrality in 2040.

The evolution of Mijnwater itself

The **Governance of Mijnwater** itself will also need to evolve as it scales to a stable, sustainable and trustworthy utility that serves the region. The goal is for the whole Parkstad region to become energy neutral for heating and cooling in 2040. Clearly, this will be closely coordinated with the local and regional government and communicated with all other stakeholders.

In the first phase, the Mijnwater system was a sustainability project of the **municipality of Heerlen**. In 2012 it was decided that Mijnwater would be privatized and in 2013 the Mijnwater B.V. was established with the municipality of Heerlen as 100% shareholder.

Since September 25th 2018 the **Limburgs Energie Fonds (LEF)** has become the owner of the company (with the municipality of Heerlen still participating with a loan), and a new governance structure is being considered in light of a significant scale-up of the business. Facing strong growth in demand for the Mijnwater system in the Parkstad region and beyond, Mijnwater is exploring a number of options to fund this forecasted growth.

Mijnwater will remain the owner and grid operator of the different DHC networks. As the organization grows, it may become sensible to subdivide into separate, even independent, parts. The part designing, building, maintaining the infrastructure could become independent, which would free it at some later stage to work on rolling out 5DHC elsewhere. The part coordinating the research, development, cooperation with European partners, might also become a separate entity serving the goals of EU and government development funds.

In addition to new equity from shareholders, Mijnwater is also pursuing new funding from debt markets. With access to new capital from different types of investors Mijnwater should be able to finance the planned DHC-investments for the years 2019-2024. Long term investors demand a structure they can understand, analyse and trust for the long term.

Besides the fact that **municipalities** have their own sustainable objectives, their active role is to facilitate all necessary construction activities, for example for licensing, archaeological research, preservation of natural values, but also the coordination of activities with other utilities. As Mijnwater uses both deep and shallow sources, Mijnwater is obligated to conform to both the Mining Act (**National Government**) and to the **Provincial Rules** for shallow sources (<500 m).

Customers in the built environment

Domestic customers in the Netherlands typically own or use natural-gas powered installations for heating, hot tap water preparation and cooking. The transition to an all-electric system (e.g. electric cooking) will force many people to switch, even if they are reluctant to do so by themselves. Usually these customers are willing to save energy by taking measures (such as replacing glass and/or window frames, cavity wall insulation, etc.) and also to generate sustainable energy, for example with solar energy, although some measures may not be financially feasible.

Building Associations own and exploit almost 50% of the building stock in the Parkstad region. For large scale operations, Mijnwater takes measures in consultation with these building associations, but the individual customer remains central to the implementation and acceptance, e.g. the transition to an induction cooker. The time schedule of large investment is often set by long-term maintenance, or new developments, creating important moments for rolling out the grid.

Larger enterprises, offices and buildings often are equipped with traditional energy sources: gas for heating; electricity for cooling (e.g. supermarkets or data centres). Although the desire for sustainability is not always present, an attractive offer for the customer can be created when connecting to the Mijnwater system. These customers are fairly easily persuaded to join the Mijnwater system because of several reasons:

- No need any more to manage and maintain their own energy generation systems,
- Independency from the future price development of fossil fuels,
- Residual energy can be re-used (think of heat released from the refrigerators of supermarkets and/or from data centres),
- It helps to fulfil regulatory requirements for the environment.

Industrial waste heat, and demand

Medium sized and large industries are high potentials for ‘mining’ residual energy, but often more difficult to understand and connect to the grid, as interventions need to take place in their production processes. The challenge is to seek for win-win situations that, on the one hand, bring benefits to the customer (i.e. by phasing out cooling towers or energy generators, achieving financial benefits, achieving sustainability goals and reducing CO_2 emissions), and on the other hand create a healthy business case for Mijnwater by delivering the required energy to the customer under simultaneous 'mining' of usable residual energy. Once connected, these customers become prosumers. Whoever receives cooling, always automatically provides warmth. And vice versa.

Because the Mijnwater 5GDHC grid has its own reliable all-electric basic heat and coolth generation system, Mijnwater will never need to become dependent on large suppliers of industrial heat. In principle, this gives Mijnwater a strong negotiating position, and the high ground to demand only authentic waste heat, and to facilitate cascading in temperature where possible. If government would for example forbid cooling towers blowing away waste heat, whenever a more sustainable alternative exists, this position would become even stronger [17] [18].

Local Economic Environment: cooperation and development

Other utilities such as drinking water companies, sewer-companies, water authorities, etc. will have their own planning, for example for replacement programs. Once the energy transition is to take place, with drastic excavation works in the streets, it is necessary that all parties involved cooperate in such a way so that the inconvenience for local residents is kept to a minimum.

Electricity is the only form of energy Mijnwater needs. Mijnwater can purchase its electrical energy as a large consumer. This makes it possible to anticipate on variations of the price and thereby produce and store energy at very attractive rates. As Mijnwater wants to be completely fossil free for the energy supply, it generates as much energy as possible sustainably (for example by PV installations) and continuously searches for **electricity suppliers** with the most sustainable energy mix.

By phasing out gas, a situation arises for the existing **gas network operators**, making their gas network superfluous. Mijnwater strives for optimal cooperation to actively involve these network companies in the energy transition for example by carrying out joint civil activities.

For its activities, Mijnwater seeks as many **different hardware suppliers** as possible for, e.g. piping systems and heat pumps, solar panels, contractors for carrying out civil engineering work and installers for the design and realization of the Mijnwater installations. Mijnwater strives for standard designs for the various installations and networks and tries to enter into long-term relationships with suppliers and contractors, in order to make fixed-price agreements and to achieve the highest possible level of uniformity.

Table: Stakeholders in the District Heating and Cooling system in Heerlen

Stakeholders	Roles	Tasks related to role
Mijnwater	System-owner	Initiator of new expansions of the grid, investor, supplier of energy, caretaker of the built environment on the energetic level, asset owner, owner of the permits to exploit both deep and shallow geothermal sources, etc.
	Research and development	Continuous development and improvement of the system with the aim to be able to implement the system as widely as possible throughout Europe
	System operator	Operator and maintenance, manager of the system
Customers	• Domestic customers or small enterprises • Building associations • Larger enterprises, larger offices and buildings • Medium and large industries	Consumers of energy and producers of residual energy flows (=prosumers), Customer representation
Shareholders Investors	• Municipality of Heerlen • Limburgs Energie Fonds (LEF) • External investors	Shareholders and investors with the objective of providing financing in sustainable projects with the primary aim of making the community more sustainable and to reach return on investment as a second goal in the long term
Regulatory bodies	• National • Provincial • Municipal	Develop and implement rules and laws to promote the sustainability of the living environment (from dropping the obligation to connect to gas and the implementation of heat plans in municipalities). Enabling the implementation of new energy systems in the built environment
Other utility companies and network operators	• Gas network operators • Drinking water companies • Sewer-companies • Water authorities	When a new energy system has to be implemented in the existing built environment, this affects all utility companies. Not only physical space must be created, but especially for the gas company, the existing infrastructure has to be removed. In addition, sewage companies and water boards can be useful for storing and extracting energy with water as an energy carrier
Energy suppliers	Electricity suppliers	Because the Mijnwater system is all-electric, the main supplier is the electricity company
Other suppliers, contractors and/or installers	Suppliers	• Installations • Piping • Heat pumps, hydraulic pumps • PV-panels • Hardware
	Contractors and consultancy	• System and grid designers • Project management for installations and civil works • Software developers (such as NODA) • Legal advice • Financial advice and accountancy • Data management and metering
	Installers	• Installations • Measurement and control technology • Software and programming

How to finance a sustainable scaling of Mijnwater grid

In the technical design of the 5th generation heating and cooling grid of Mijnwater, one guiding principle is that all energy flows are driven by the demand at the end user. Similarly, the thinking about how to finance the grid starts with the end-user of the buildings, who in the end must be willing to pay for the grid services. The reasoning is that a financially attractive offer should be somewhat below the cost of the traditional alternative of a gas furnace. The current expenditure on heating (gas, furnace, etc) can be used to invest in a new situation. An advantage for the local economy is that the money that now flows away to pay for fossil fuels will be invested locally. Another advantage is that the Mijnwater system has a stable price, as it is decoupled from the rising prices (including tax) of fossil fuels. But how to make such a transition work?

Eventually, Mijnwater wants to cover all types of buildings. But till now, Mijnwater has had most traction with owners of large office blocks, shopping centres, public buildings, and the building stock of corporations managing a large portfolio of social housing. These parties see the energy transition coming, and they feel a need to react. The time schedule is set by when they do new building development, and the long-term maintenance of their building stock. Mijnwater can work together with such customers to find the best solutions, also financially. Once the time is right, this provides opportunities to roll out the 5GDHC grid to their location. This provides an opportunity to also add smaller customers nearby.

Any proposal by Mijnwater to a new customer starts from the current building conditions [19], and the current costs for providing heating and cooling. The first step is to require from the owner that buildings are built or renovated to a highest reasonable energy label (if possible A+++, or an Energy Index lower than 1.2). Such improvements of the building will reduce the energy needs by about 30%. However, at some point, any further investments at the level of the building become costly. Mijnwater tries to help reduce costs for these building upgrades by initiating collective deals for buying double glazing, insulation, heating systems, solar panels, etc. If banks are willing to provide finance at low interest rates, and local government can help by providing guarantees, this makes the Mijnwater offer even more interesting. Seen from Mijnwater, the buildings must at a minimal be ready for the low temperature heating provided by the grid, but Mijnwater is aiming to connect as many as possible customers with low energy needs. That way, it is possible to connect more customers, that can share the cost of the grid at a lower price.

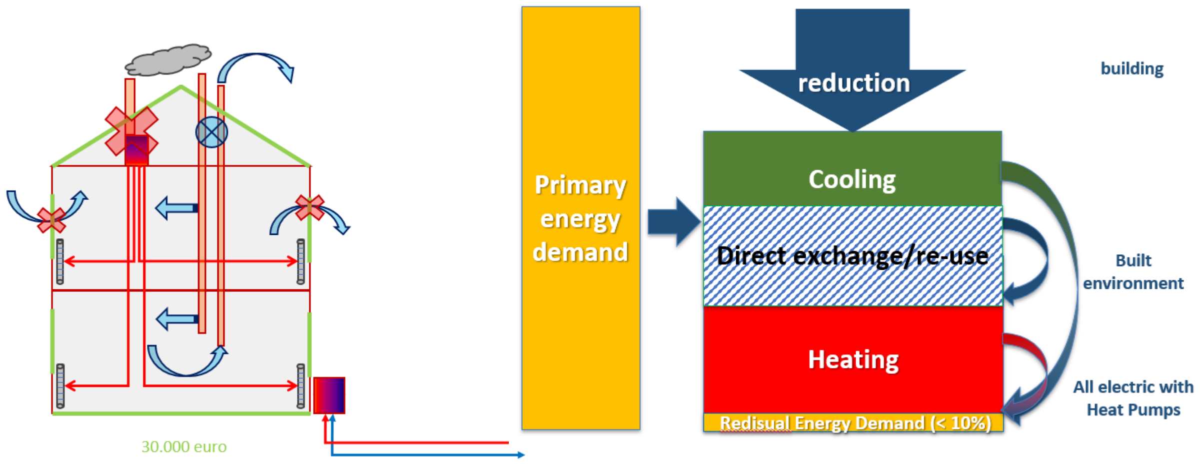


Figure 7 energy reducing measures on building level, combined with a regional grid-strategy to reduce collective energy needs and supply the remainder from all-electric, highly efficient heat pumps, which provides the path towards decarbonization.

At this point it becomes sensible to invest in a new collective capability that resides in the neighbourhood: a grid that can exchange energy for heating and cooling between different buildings and users. Underground Thermal Storage enables exchange of energy across time, even from summer to winter, but also more often at shorter timescales, between moments of availability and need. Energy that was previously discarded as waste heat can now be made useful. This recycling of energy is capable of reducing total energy consumption by a further 30%. The water of the grid also enables efficient water-water heat pumps with a high COP. This results in an electricity demand of less than 10% compared to the energy of traditional heating and cooling systems. In a sufficiently dense built-up area, this will be both energy-efficient and cost-efficient. It will compete with the sustainable alternative of stand-alone zero-energy buildings. Finally, such an all-electric solution enables decarbonization by transitioning to sustainable electricity sources.

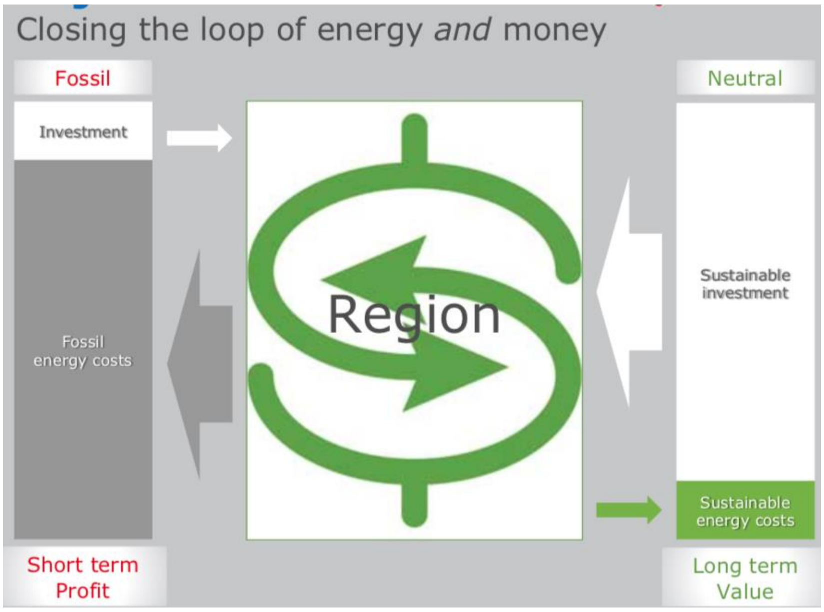


Figure 8 The Mijnwater utility is a way for the local region to eliminate current expenditure on fossil fuels, that leaves the local economy. It is mostly replaced by investing in sustainable local infrastructure, built and maintained largely by locals, thereby nurturing the local economy. The much-reduced energy consumption is all-electric, and can be sourced sustainably, and produced in the local region.

Once such 5GDHC grid infrastructures have been installed, the grid can grow further. The capacity of the system can grow if new customers provide new opportunities to exchange warmth and coolth, and also by gradually improving the efficiency of the 5GDHC grid. But the design also enables scaling up: new customers are served by new energy stations using heat pumps to produce warmth and coolth near the point of use. In this way, future customers will help pay off the initial investments in the basic grid.

However, 5GDHC grids are still a new technology and just beyond prototype stage. Subsidies from various governments are still necessary to make the financial picture add up. This is helping to build value and capacity of the larger community to transform and grow. We gained a lot of valuable experience from communicating with owners and users. Working with the various stakeholders and continually improving our processes while we scale up, and by working with our partners to innovate the way they organize the building-improvements. The experience gathered is not only for the local region, but is a useful base for further deployments of 5GDHC grids, both nationally, and in other countries.

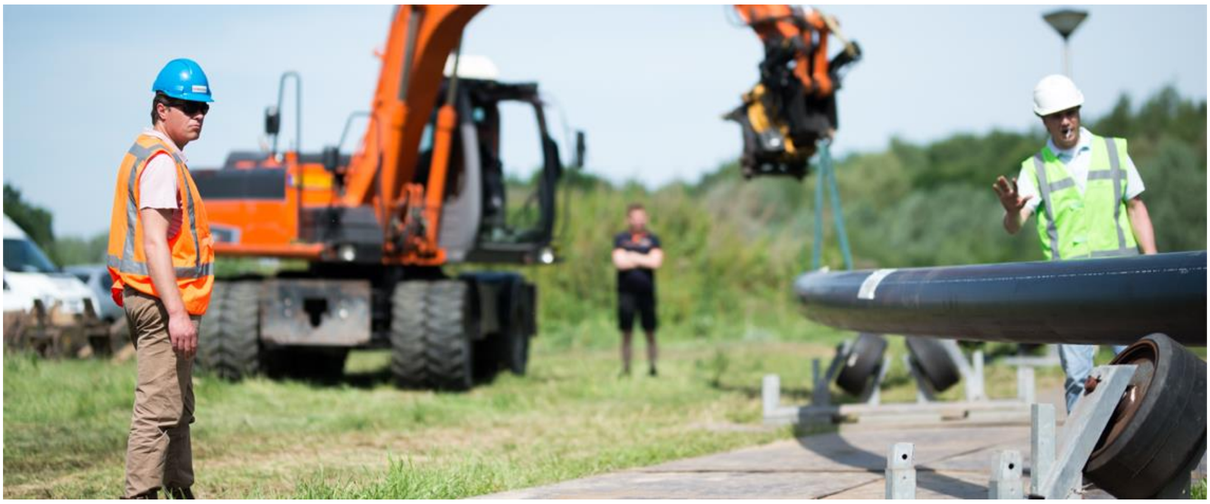
Affordability: example of Brunssum

The next step forward for Mijnwater is to bring the 5GDHC grid to the neighbouring municipality of Brunssum. There was the opportunity to work together with Weller, a social housing corporation, who were already planning to renovate a number of buildings for about 550 apartments in total, while also building new buildings in the centre. This moment enables an integral approach in which savings are possible because necessary maintenance and long-term improvements of the buildings can be implemented together. In the case of Brunssum, the homes currently use the national average of about 1500 m^3 of gas per year. We strive to lower the combined energy costs by about €30-€40 per month.

Creating and growing a market to support 5DHC deployment

Mijnwater BV works together with partners to design and build innovative solutions at the level of buildings, for laying pipelines, and building the installations connecting the cluster grids to the backbone, or the energy station connecting a large building or a local area grid. This extends also to elements of the buildings: prefab energy-delivery systems for heating/cooling, the booster system for hot water, buffers, standards for piping, etc, but even advice about electrical cooking and the proper pots and pans to use. Together we develop guidelines and organizational procedures for budgeting, tendering, and purchase of the necessary products and services. Our guidelines are based on a continually evolving balance between the income that can be generated from our energy services, the financing cost, and the developing market for the products and services we need. Mijnwater BV wants to stimulate the creation and growth of the regional business capacity to produce, build, and install components, to enable the further scale up of our grid. This makes the region more attractive for innovative business, creates jobs, and improves schooling opportunities for the transition from old to new jobs.

Scaling up our 5DHC grid together with the business-ecosystem supporting it is crucial for a sustainable transition based on long-term finance.



Roadmap towards 2040

PALET 3.0 has stated the clear goal that in 2040 the whole area of Parkstad region will be ‘energy neutral’. Energy in fossil form will not need to be imported from elsewhere, and the current expenditure on these fuels will be converted to investments in sustainable energy sources. An important goal is to rejuvenate the local economy and community by establishing this local circular flow of expenditure on energy.

In Heerlen, we also profit from the earlier entrepreneurial initiative taken by the municipality when it was decided to investigate the opportunity of using the water in old coal mines as a source of energy. Heerlen subsequently found the investment and external support to turn it into reality. Mijnwater 1.0 was born. The initiative became an independent entity, Mijnwater BV, which in 2013 upgraded itself to Mijnwater 2.0: possibly the first 5GDHC heating and cooling grid at a substantial scale. It was immediately clear that a next step would be Mijnwater 3.0, in which smart control and various levels of storage capability can help to balance and stabilise the grid, and thereby increasing the capacity of existing infrastructure so it can serve many more customers.

The challenge in Heerlen and the Parkstad region is not to evolve towards a low-temperature 4th generation District Heating grid, since we are already at the stage of a 5th generation grid. The challenge is rather to scale up this grid to serve all of the Parkstad region. In this transition we will need to build the capacity for governance and administration, the capacity of businesses to help design, build and maintain the grid, to standardise innovative components for cheaper production at scale, and the education of people that will do these jobs.

Originally, Mijnwater 1.0 was set up using the traditional 4DHC logic of a heating or cooling grid that distributes the heat or coolth from a central source. Since Mijnwater 2.0, the new 5GDHC grid has a design that starts all thinking from the other side: the points of demand, the customers. The energy stations distributed across the grid are the basic generators of energy, and guarantee the right temperatures. The geothermal source provides storage, and greatly improves the efficiency of the heat pumps in the system.

In 2019, two important steps forward are being taken in the roll-out of the Mijnwater grid. First, there was the investment from Heatnet Interreg NWE in the physical infrastructure for Cluster D (Hoensbroek). The Cluster Installation was built to make the connection with the Mijnwater backbone, and new pipes went into the ground for Cluster D itself. This cluster is different from the other clusters because it connects both to residential areas and to industry. The industry has a demand for high temperature heat, as well as an excess of high temperature waste heat. There is also a swimming pool, needing heat. Any excess heat can now be sent to the backbone. A longer-term challenge will be to implement cascading of temperatures from high to low according to low-exergy principles, leading to more efficient use of the available energy.

The second, larger step, is that Mijnwater is starting up in the neighbouring municipality of Brunssum. The timing was dictated by the long-term maintenance schedule of a large building association, combined with plans for new building development. This is an opportunity to start up the service to Brunssum as a separate small grid, based on smaller local underground thermal storage, and the EcoVat underground tank storage [20]. Temporarily, the system will be supplemented by a mobile energy station making use of air-water heat pumps. The challenge here is to demonstrate that Mijnwater can set up the functioning seed for a new cluster grid, without connection to the Mijnwater backbone. This will be a valuable exercise for any future extension to a disconnected location. Such a connection is likely at a later stage, and Brunssum even has its own good mine water resources. Both borehole and EcoVat storage have features that are complementary to the mine water, which will eventually offer the further profitable exercise of optimising them together.

Long Term Timeline towards 2040

For the coming 5 years, there are already clear plans for deploying the Mijnwater grid to new customers, new municipalities. It is impossible to lay out an exact plan for the coming 20 years. But it is an interesting exercise nevertheless. Imagine what needs to happen to reach the goal of a sustainable heating and cooling grid that covers most of Parkstad region in 2040. Imagine the issues that need to be solved, experiments that will need to be done, and a few possible setbacks that may occur. We are still at the beginning of an exciting story of exploration and creation.

2019-2023

- Brunssum gets its own Mijnwater 5GDHC grid, starting without the mine water connection
- The new EcoVat tank storage concept is stress-tested, in combination with borehole thermal storage
- A study of Mijnwater in the municipalities of Kerkrade and Landgraaf is already underway, and extension of the grid will likely follow the pattern from Brunssum. There is already a tentative map for Kerkrade.
- Connection of industry in Cluster D shows that Mijnwater can absorb and exchange energy from high temperature waste heat. It remains a longer-term challenge to organise a proper cascade of industrial users from high to low temperature. Industry itself could also innovate to reuse more of its waste heat itself, or redesign processes for lower levels of waste heat.
- The maps of the existing Clusters A-D in Heerlen indicate the customers connected already in 2019 (Green) and the substantial increase expected for the coming 5 years (Yellow)
- The Mijnwater 3.0 optimisations of heat storage in buildings and the grid get implemented, lowering peaks in usage of the grid of Heerlen, which allows more customers to get connected, at lower cost
- All municipalities of Parkstad will get clarity about their plan for heating and cooling. Timing is likely set by long term maintenance of large buildings, shopping centres, and the building stock owned by building associations.
- Standard procedures and contracts get developed to a stage that their availability facilitates the first private home owners to be connected to the grid.
- The organisation of Mijnwater increases capacity, is likely to upgrade the governance structure and grow beyond its character of a start-up company. Continuity of purpose will be preserved: as team(s) doing the work, as a trusted service provider, as owner and builder of the 5GDHC grid.
- The best functioning cluster of Mijnwater with the strongest customer base is accepted as a safe asset, used as backing for Green Bonds at very low interest rates. This provides investment capital for further expansion of the grid. With some luck, this is facilitated by the European Investment Bank (EIB).

2024-2028

- Mijnwater will first gain a foothold in all municipalities with dense built environment: Heerlen, Brunssum, Kerkrade, Landgraaf.
- The municipalities to the South-West and North (Simpelveld, Voerendaal, Beekdalen) consist of smaller villages in a more open natural environment. Small separate grids may be a solution. Possibly joined with the larger grid at a later stage. An experiment may help to create clarity.
- A first neighbourhood with only private homes is connected, a local representative council of home owners is formed, and methods are devised to ease the finance of the necessary upgrade of private homes to a level where Mijnwater can easily serve them.
- Solutions are found in cooperation between industry, municipality and Mijnwater for a more optimal cascaded exchange of high temperature waste heat, to better make use of available exergy.

- Possible setback: one industrial source of waste heat ends its delivery. The Mijnwater grid can handle this by reverting to its original all-electric generation using heat pumps, and by leaning a bit harder on the geothermal resource for the following one year. This experience, further optimisation, and lessons learnt further strengthens the robustness of the grid.
- More clusters reach the status of safe asset with stable income. Green Bonds become an important source for low interest investment in further expansion.
- Elsewhere, towns and agglomerations are starting to also systematically transition their old heating grids to 5GDHC. This creates demand for the hardware components of this technology, and gives an impetus to standardisation and mass production.

2030-2034

- Long term maintenance at timescales of 15 years have now provided opportunities for a large fraction of owners of large buildings, building blocks, schools, shopping centres and building associations to coordinate the upgrade of their buildings with a decision to connect with the Mijnwater grid.
- More neighbourhoods with private homes get connected
- Renewable electricity prices have dropped to a level where Mijnwater is able to systematically decarbonise the power used for its grid.

2035-2039

- Buildout continues steadily.
- Large offices, shopping malls, schools nearly all get connected
- A large fraction of homes owned by building associations get connected
- The spread into neighbourhoods with private homes progresses more slowly, but moves ahead
- Standardisation and mass production is starting to make it affordable and easy to connect a small isolated cluster of homes or a farm into a 5GDHC-microgrid, sharing the underground thermal storage. In new buildings, underground storage of heat is becoming a valued feature.

2040

- The Mijnwater grid delivers sustainable heating to most of Parkstad region, and nearly decarbonised
- Heerlen is an example and hub of 5GDHC technology, the governance, and business

Strategies for a long-term transition

At the risk of stating the obvious, here a few general strategies that can be observed at Mijnwater BV.

Government must lead. Local Government have their responsibilities, and goals for climate transition, that can be combined with goals to develop the local region. Local government has the contacts with business, owners of buildings, land, educational institutions, and they are owners themselves. Government has the ability to make policy decisions and agree on long term strategic plans. Government has the power to change the local planning and provide permits for new infrastructure. Government has the connections with local institutions, industry, business, and culture, to help inspire something new. Without buy-in from local government, it is impossible to start a new heating and cooling grid, or even to scale it. For a new innovative grid, it was clearly essential that our local municipality of Heerlen dared to take an entrepreneurial role. Subsequently, it was another leap forward that the larger region of Parkstad adopted the idea that started in Heerlen. Economic predictions or projections mean nothing without commitment to make them reality.

PALET: institutionalise your long-term goal. The Parkstad Limburg collaboration chose to set the goal of energy neutrality for 2040, and plans were made. But it also chose to institutionalise the road towards that goal. The municipalities meet and discuss regularly, and occasionally larger meetings are organized to check the status, renew commitments, brainstorm, and correct course if needed.

Build long-term relationships. Large owners of office buildings, shopping centres, industry, social housing have long term planning schedules for maintenance, and new developments. Keeping relations warm with all these parties allows clarity about when the right moments will come for connecting their building stock to the existing grid. The maps with planned additions for the coming 5 years till 2024 show that the existing clusters in Heerlen are entering a phase of strong organic growth: the fruits of these efforts.

Get the timing right. It is a marathon, with the occasional sprint. When rolling out large infrastructure it is important to know when large customers are ready to move. This is in practice dictated by long-term maintenance schedules, or plans to develop new buildings. Local government can again help, as they are likely to hear about plans long in advance.

Jumpstart a small separate grid. The current strategy to expand in Brunssum is to first start a small, independent 5GDHC grid, even if it temporarily needs support using air-water heat pumps. This is to profit from to the time schedule of a large building association and plans for new buildings.

Develop standards during scaling up to increase efficiency, and lower price. This is not just technical, but also concerns the organisational procedures, contracts with customers and any other repetitive actions.

Have clear values for the long term. If you want to go through a long-term transition during which many things will change, it helps to anchor yourself to a set of stable values that will be appreciated in the long run. These would be more general ethical values like sustainability, the goals of energy neutrality and decarbonisation, or the importance of building a trusted institution, a strong and diverse team of workers, being fair, and relying on long term relationships with the community. They would also be financial, like the goal of recycling investment in the local region, being affordable to customers, and providing a safe investment target for long-term finance. Finally, there can be technical values like the principles of low-exergy, and a demand-driven design to avoid wasting energy. Or founding the system on a basic all-electric energy generation system for robustness, and to enable decarbonisation.

Conclusion

The 5th generation design for district heating and cooling is a real step forward compared to the 4DH paradigm. A radical change beyond further lowering the temperature on the grid. And it isn't just a next technical paradigm. It also essentially involves the way we organize and work together: the customers, the local community, government, business, finance, who all profit, but who all have a role to play as well. Mijnwater BV is constantly searching for the best ways to enhance the services of the new grid technology by well-designed contracts, administration, and the most optimal division of responsibilities between all these parties. We also need to build capacity to do these new things, and even evangelize this new paradigm. Paraphrasing the well-known 'African proverb': you can move fast by building infrastructure, but you can only go far by involving the community.

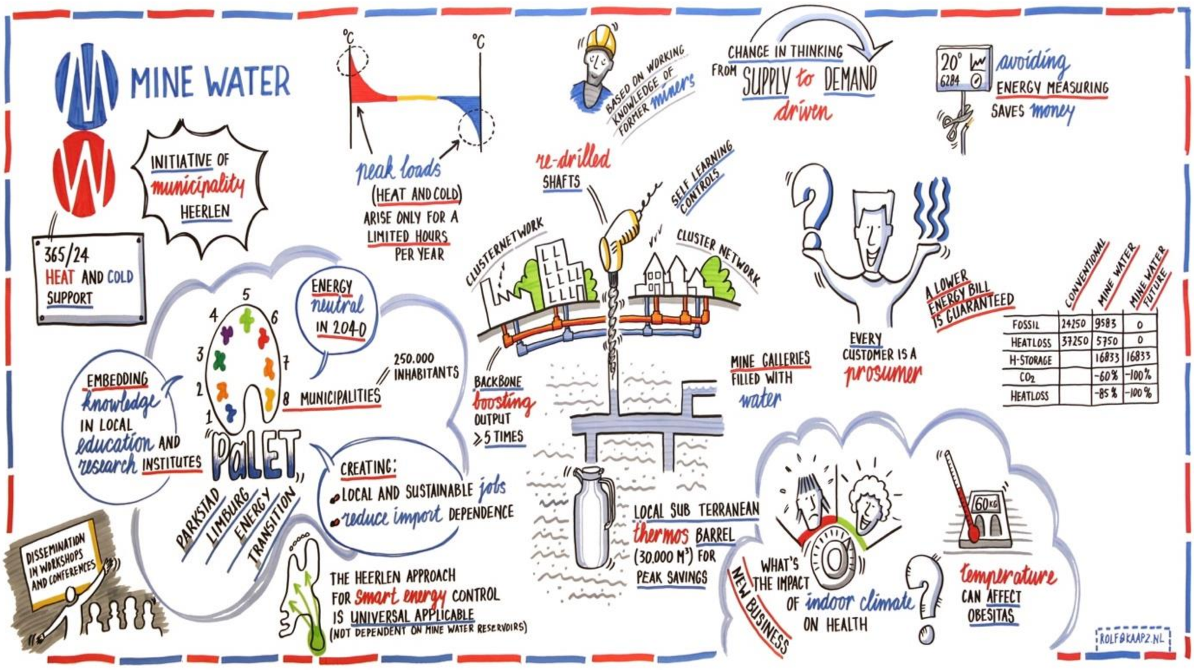


Figure 9: A poster with drawings illustrating various elements in the story of Mijnwater, to help communicate our story.

Appendix A: maps with Mijnwater status and plans, (spring 2019)

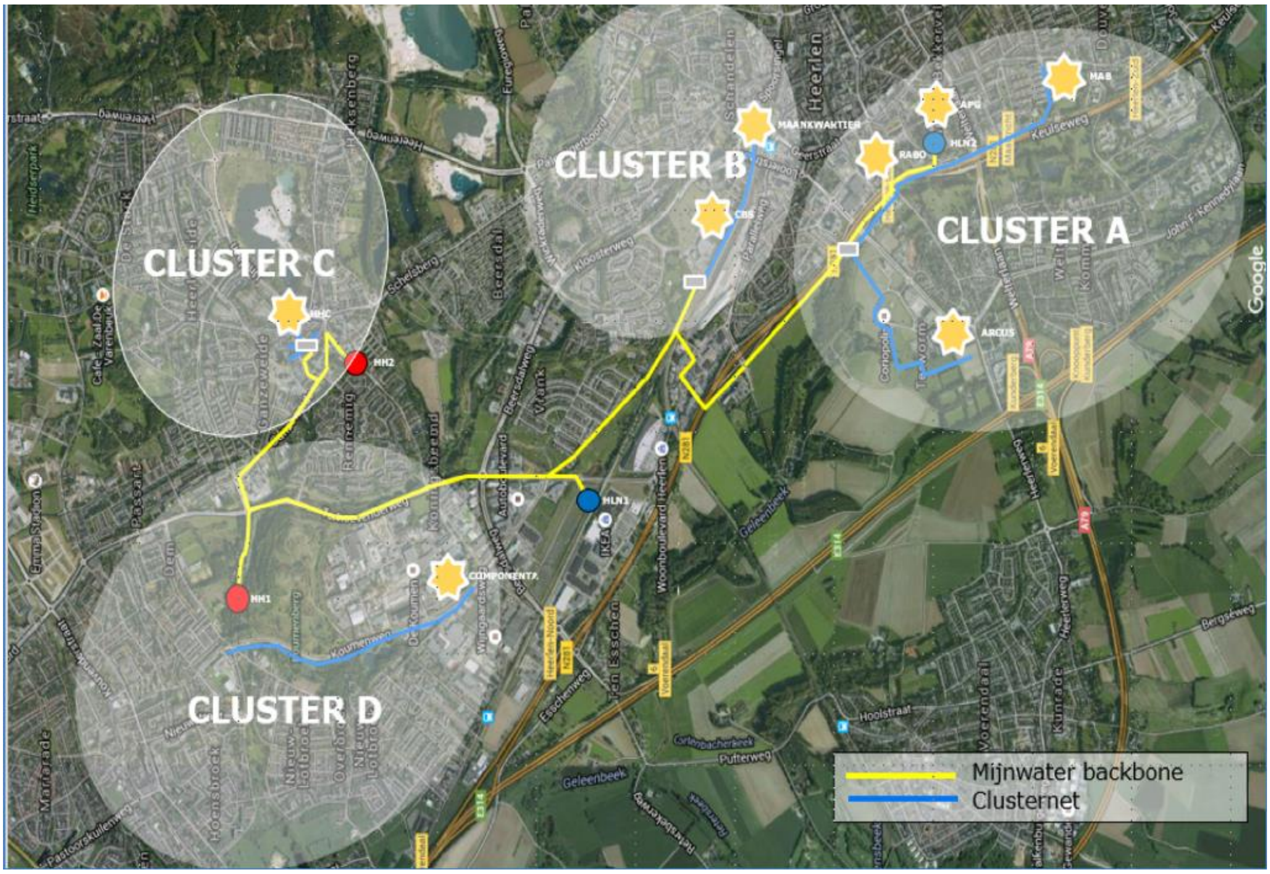


Figure 10. The existing Mijnwater grid in Heerlen, showing the clusters A, B, C, D (North is to the left on this map). The two red dots in Cluster C and D are the wells connected to the warm part of the mine. The blue dots are the cool wells, and the one in the middle is not used in standard operations.

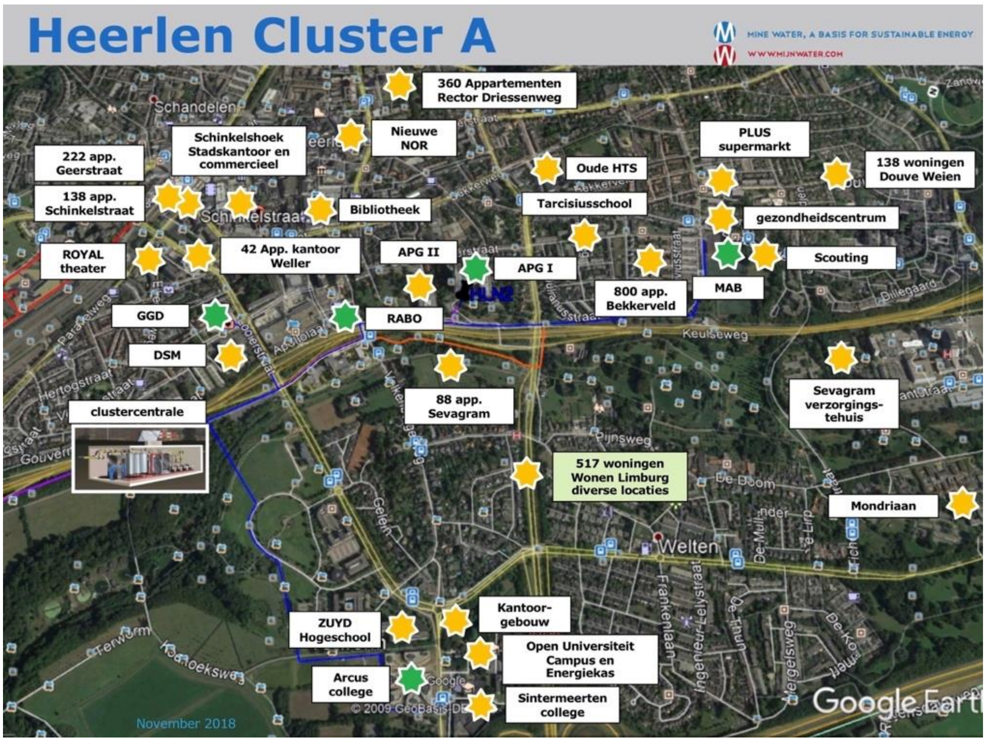


Figure 11: Mijnwater Cluster A in Heerlen. In 2019 it serves four office buildings and the Arcus College (green stars). Many new customers are to join during the coming five years (yellow stars), including 1562 apartments and 655 homes, as well as schools, offices, a medical care centre.

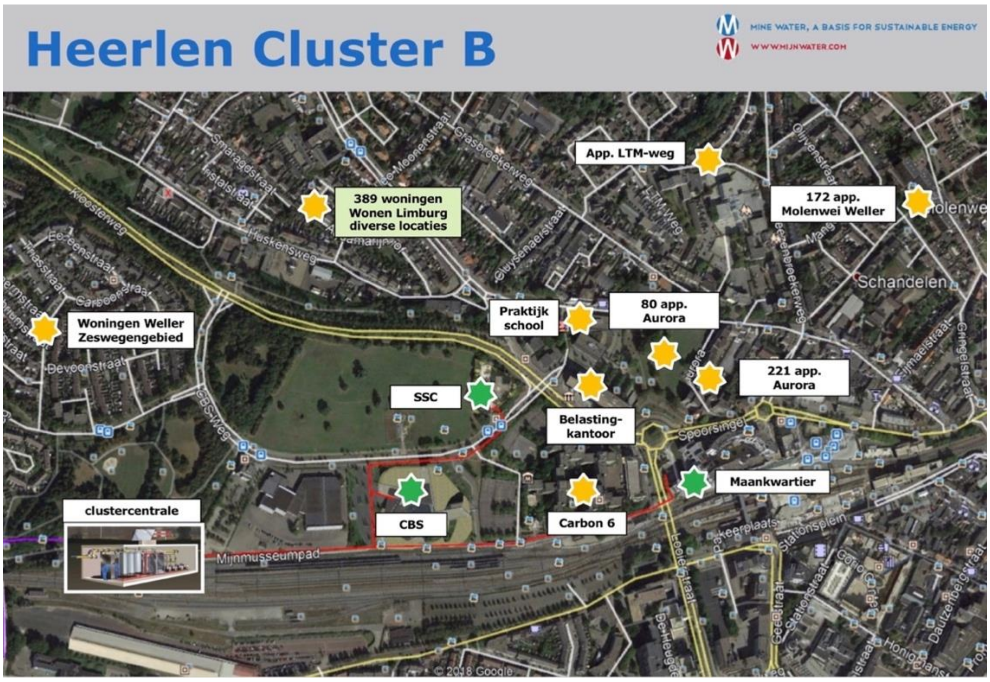


Figure 12: Mijnwater Heerlen Cluster B is currently serving two large office buildings and the showpiece Maankwartier block with shops and apartments, at the railway station (green stars), it will grow significantly in the coming 5 years (yellow stars).

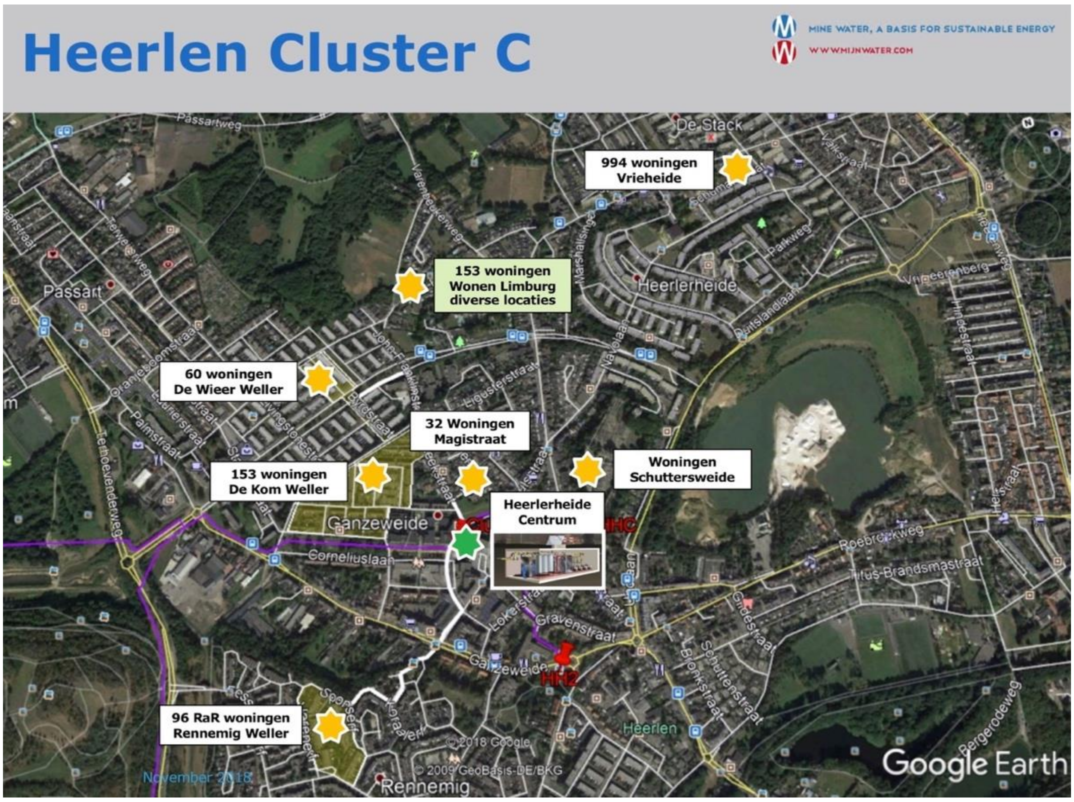


Figure 13: Mijnwater Heerlen Cluster C. Till 2019 only Heerlerheide Centrum is connected (green star), but for the coming years this is to be extended with many dwellings in neighbourhoods nearby (yellow stars).

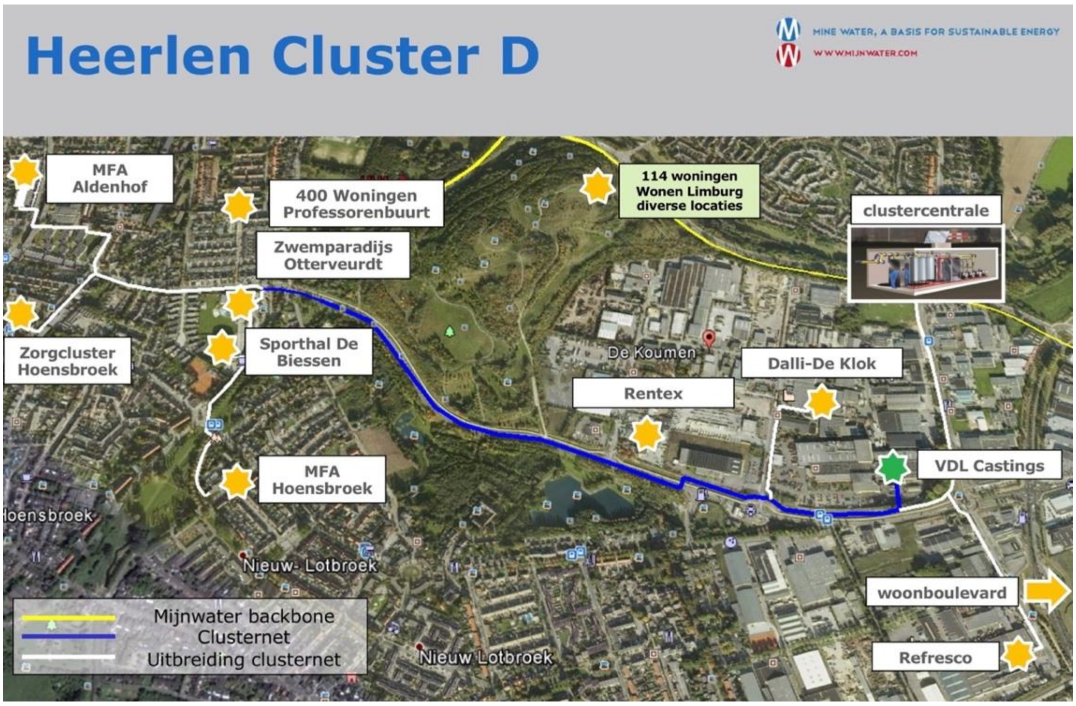


Figure 14: Mijnwater Heerlen Cluster D. On the right is the industrial area, on the left an area with residential neighbourhoods, a swimmingpool, a sports centre and a multifunctional centre that are now being connected. The cluster installation connecting with the yellow backbone has just been finished. The green star for VDL Castings was the first industrial partner in this area to get its cooling coupled to Mijnwater.

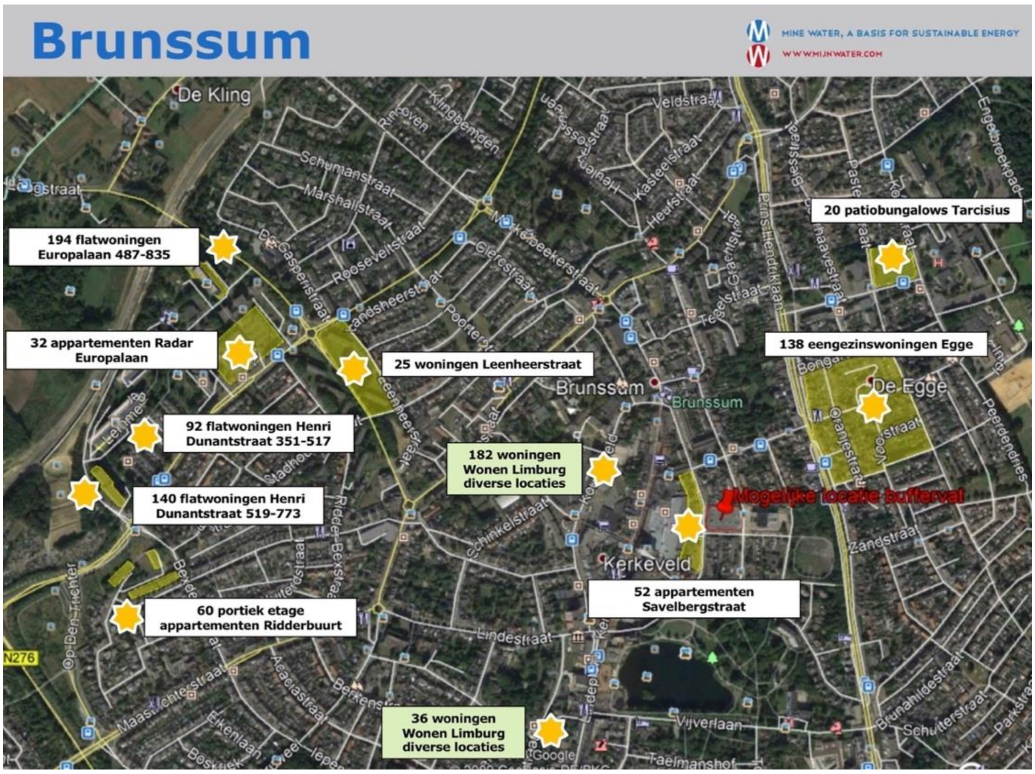


Figure 15: Mijnwater Brunssum. Borehole thermal storage is being tested, or created. Work to connect the yellow stars to Mijnwater services is to start very soon, starting as an island based on local thermal storage. Connection to the mine water reservoir will happen later.

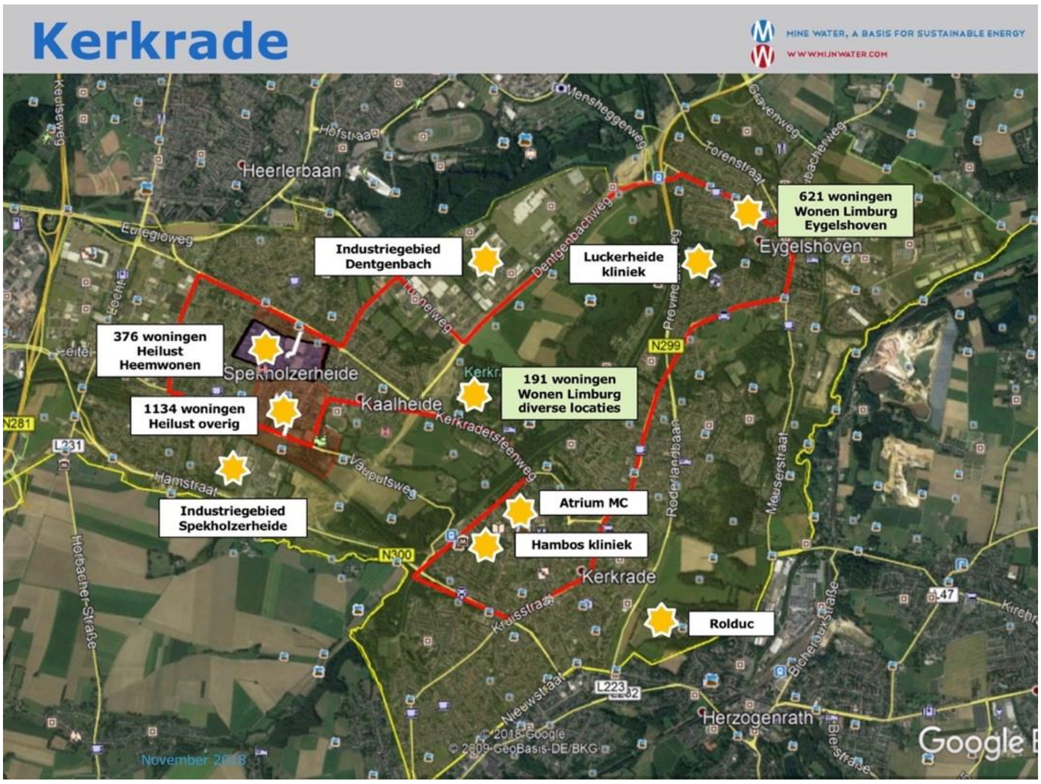


Figure 16: Mijnwater plans for Kerkrade still on the drawing board

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