Mine water as a Renewable Energy Resource

An information guide based on the Minewater Project and the experiences at pilot locations in Midlothian and Heerlen
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The Minewater Project is co-financed by the European Union under the framework of INTERREG III B NWE programme.
Foreword

This information guide is based on the Minewater Project and the experiences at pilot locations in Midlothian and Heerlen. It is intended for anyone who has an interest in new renewable forms of energy and for those who may have access to mining areas who wish to explore the possibility of developing a mine water scheme themselves.

The guide briefly sets out some of the key issues confronted and information gathered during the course of the EU-funded Minewater Project through actual and proposed mine water pilot schemes as well as several pre-investment studies. This includes:

- Ways to make initial estimates of technical potential for using mine water as an energy resource
- The issues that need to be addressed by those who would consider harnessing the energy embedded in mine water
- A case study of one of the principal main stakeholders in the pilot scheme, and the regeneration scheme it has championed.

There is likely to be potential for using mine water for integration in local energy networks in many of the mining areas across Europe and beyond.
01 Overview

Abandoned and flooded mines are a good potential source of geothermal energy; they also offer space for storage of hot and cold water. Crucially, the mine water can provide a focus for sustainable regeneration of former mining areas, demonstrating a new renewable energy resource that can deliver heating and cooling for sustainable communities. This can also improve self-image, health, employment and economy thereby helping to restore local pride.

Such schemes can be applied on a neighbourhood scale, by way of a district heating network serving the local community. In order to make use of the geothermal energy in the mine water, other low carbon technologies are typically integrated including heat pumps and Combined Heat & Power (CHP).

The project, funded by the Interreg IIIb programme, is being carried out by an international consortium of partners from the Netherlands, UK, France and Germany, and is led by the Municipality of Heerlen. This project secured the Interreg funding in 2003, and was then revised in 2006.

1.1 Mine water: environmental hazard and energy penalty

Mine water is simply the water that is pumped from mines. In the specific case of the Minewater Project this is water from coal mines.

In coal mines the volume of water pumped exceeds that of the coal dug out. Mine water is a hazard for miners but may potentially prove to be a useful resource for their descendants.

Because of the geothermal heat of the earth this water is warm: the deeper the mine, the warmer the water. For every 100 meters greater depth the water temperature rises by 3°C. At a depth of 800m below the surface the temperature is about 30 – 35°C.

During the time that a coal mine is open a great amount of water is pumped out. This water has been contained in very old geological rock strata, which are millions of years old. It contains many salts and heavy metals, which is normal for water from depths of 500 – 1000m. If it reaches the surface it must therefore be treated with great care; if this water is pumped into local rivers or lakes it will contaminate them.

The company that has permission to mine the coal (has the ‘concession’) is also responsible for treating the mine water. This is very expensive but is economically worthwhile for the mining companies while mining remains a profitable business.

Mining at any specific site usually endures for at least 50 – 100 years depending on the ease of extraction, and the quality and quantity of coal. For all that time water is pumped out of the ground and the water level within a radius of 10 – 20 kilometres around the coal mine sinks. This means that land that was once wet dries out; villages have even sometimes been built in these locations so that the miners can be close to the mines.

When coal mines are closed, there is clearly no revenue stream from coal sales and the expense of pumping water becomes a burden. However, if the pumping is simply stopped there will sooner or later be a problem; usually after several years the water starts to rebound and the water level re-establishes itself. This poses an environmental problem and may even threaten some of the mining villages.

For these reasons, throughout almost all post-mining areas in the European Union, mine water must be continuously pumped out of abandoned coal mines. The member states of the European Union have their own individual rules for the responsibility and liability of mine water. The Minewater Project examines a possible way to harness this water as a useful resource. If successful instead of incurring an energy and financial penalty as the pumps consume electricity, it may prove possible to use the mine water as a revenue-earning energy resource.

1.2 Mine water: new renewable energy resource

The use of geothermal energy is not new. Several methods have been used in a variety of locations. These include using geothermal energy:

- From just under the surface (depths up to 100 m)
- From shallow ground water
- To generate electricity using very hot water or water vapour from deeper than 2 000 m below surface.

Mines provide an intriguing further possibility for the extraction of geothermal energy from medium depths. The loosened rock structure in coal mine locations leads to an intensive heat exchange between rock and mine water. In many cases, this means a new mineable resource ‘geothermal energy’ is easily accessible.

Geothermal energy can be exploited while the mine is still open as well as after closure. During mining operations, a mine water drainage system transports warm water up to the surface. Since the mine water has to be pumped anyway it should be cost-effective to install a heat exchanger and capture the geothermal energy. Invariably, however, the mine water is simply discharged directly into a local river.

Once a mine has been at least partly flooded, there are various ways to set up the system. The most simple alternative is a one-well system. In this case, a heat exchange probe is installed in one of the flooded mine shafts (or boreholes). This probe then extracts heat from the shaft. Whilst the costs of such an installation are relatively low, the output is sub-optimal.

A higher geothermal output can be achieved by installing a two-well system (doublet). One well acts as the source well and the other as the re-infiltration well. Again, mine shafts can act as wells where still accessible. If they are not, wells can be drilled into mine galleries using target drilling. Two-well systems are more expensive, but they can also be used for the cooling of buildings, providing the temperature is low enough. The first European pilot project (in Heerlen, NL) of such a two-well system has been built within the frame of the Minewater Project and is described in this guide.
The Minewater Project: mine water as an energy resource

The Minewater Project was funded by the EU’s Interreg IIIB NWE program. A few years ago an idea was developed in the Municipality of Heerlen, Netherlands, to use mine water as a source of heating and cooling for buildings that were planned above abandoned coal mines (Oranje Nassau 1 and Oranje Nassau 3 coal mines). Heerlen searched for other European partners to set up a European Project and found Midlothian Council, Scotland who had the same ideas for a development location above the biggest Scottish coal mine, near Edinburgh. Subsequently, further partners have also joined the project with the task of carrying out potential and pre-investment studies.

Project partners (Fig. 1.1) include the Municipality of Heerlen (the Netherlands), the leading partner in the project. Other partners include the Midlothian Council (United Kingdom), the housing construction association ‘Weller Wonen’ (the Netherlands), the Building Research Establishment (BRE; United Kingdom), the municipality of Bönen (Germany), Wirtschaftsförderungsgesellschaft Kreis Aachen mbH (WFG; Germany) and Bureau de Recherches Géologiques et Minières (BRGM; France).

Fig 1.1: Signing the Interreg contract

1.3 The Minewater Project: mine water as an energy resource

The Minewater Project comprises a spectrum of studies at different stages that collectively explore the possibility of extracting useful energy from mines that are now closed. It comprises potential and feasibility studies, configured to determine the likelihood of usable mine water resource, and subsequent careful determination of the technical and economic options for harnessing the resource. This includes estimation of the extent and intensity of the mine water resource itself and selecting and designing the system that conveys this energy into the buildings within the local community. The largest deliverable of the project is a fully functional pilot mine water scheme.

Specific activities carried out within the project focus on:

- The live pilot scheme (Heerlen, Netherlands) that will use water from the local mines to heat and cool local communities as part of large new-build developments
- A proposed pilot scheme (Midlothian, Scotland) that has not proceeded but which revealed much useful information
- Pre-investment studies that range from the detailed specific (Aachen, Germany), to a regional assessment (Lorraine, France) and a scoping study for a country (UK).

Mine water has been successfully used for several small-scale projects, but never for a large scale redevelopment. As Riet de Wit, Heerlen municipality Alderman, stated in 2006 “It remains tense and exciting but confidence in the success of the project is growing”.

In the words of Elianne Demollin, project leader, "Yes, it takes a lot of energy (manpower) but confidence in the success of the project continues to grow. If you put it all together – reducing CO₂, restoring the faith of mine workers, and creating more comfortable and healthy living and working environments – we can rightfully be proud of the Minewater Project."
Within the Minewater Project, partners from France, Germany and UK worked on various studies that precede investment in an actual scheme. This section outlines the methods, boundary conditions and technical tools that can be used for the preparation of such a geothermal mine water project.

2.1 Technical tools for preparing a geothermal mine water project

Site identification mapping
Initial technical information for site identification mapping comes from the analysis of maps of the mines and the local geology. Site identification mapping must take into account three factors: demand, supply and favourable technical boundary conditions (Fig. 2.1).

It is possible to obtain an indicative idea of the possibility of utilising mine water by simply matching heating (and cooling) demand to likely sources of warm (and cold) mine water.

Where there are mines in close proximity to built-up areas further conditions for exploiting the mine water can then be investigated. These include the existence of open shafts, depth of the mine water, mine water temperatures, geometry of the mine works and chemical mine water composition.

Modelling
Modelling mainly aims at the prediction of the long term behaviour of the system temperatures. Both analytical and numerical modelling can be applied. Modelling can help to describe the probable development of temperatures in a source well and also help to avoid critical thermal shortcuts between a re-infiltration well and a source well. Moreover, modelling can be applied for estimating the volume (capacity) of the mine water reservoir.

Field investigations
After a suitable site for a geothermal energy plant has been found and some modelling perhaps already carried out, field investigations are necessary to investigate the real technical local situation.

For example, where pipework is still in place in old mine shafts and is to be used for accessing mine water, camera inspections need to be carried out in order to determine their condition and that of the shaft itself.

Pumping tests are useful to study the hydraulic reaction of the reservoir and the thermal and chemical response of the geothermal energy source.

Monitoring
Monitoring is an important aspect of field work activities and a continuous monitoring programme is important for evaluating a geothermal mine water site.

This typically includes measurements of water level in gauges and shafts, water temperature, hydrochemical and geophysical analyses. The example deep logs in Fig. 2.2 show temperatures and electrical conductivities measured within the Von-Goerschen-Shaft in Würselen (Germany) before (21.06.2007), during (20.08.2007/05.10.2007) and after (03.03.2008) a pumping test. During the test, temperatures and electrical conductivities were found to be slightly higher and the graph of the electrical conductivity shows a little bit more disturbance.

Fig 2.1: Site identification mapping

Fig 2.2: Example of geophysical deep log results (WFG)
2.2 High level potential study: UK

Prior to detailed modelling and field investigation, a broad-brush study can be carried out to determine nationwide where potential is most likely to exist. Such a site identification mapping exercise has been carried out for England and Wales, Scotland having already seen a previous similar exercise. There was only very limited coal mining activity in Northern Ireland.

The study set out to examine where heat demands and likely mine water resource coincide. Information was drawn from existing geothermal surveys and coal mine location, from the British Geological Survey and the Coal Authority. This information was then superimposed on heat demand density information for the built environment spanning the whole country.

Two categories of potential location for mine water were investigated. Firstly, where there are already pumped discharges, the flowing water could potentially be used in the manner intended for the Midlothian Pilot. For this, the Coal Authority was able to provide geographical location together with flow rate information based on measured data. The flow rates were used to estimate available heat capacity. From a total of 196 mine water discharges, 25 emerged with an estimated thermal capacity above 1MW. Across the country, the estimated aggregate for these discharges is nearly 90MW.

Secondly, a very rough estimate was made of possible resources in collieries for which the amount of mine water was unknown. The most readily obtainable data that would indicate the size of the coal deposit was the number of men working underground. Mines were divide into size categories, flow rates estimated for each band, and thence used to obtain approximate thermal capacity. As in Heerlen, this resource would be accessed by means of existing shafts or newly drilled wells. Across the country potential accrues to more than 2000MW.

2.3 Technical viability of mine water use in the Aachen area and possible influence on nearby Heerlen mines

The hard-coal mining district of Aachen is situated adjacent to the Dutch mining area of South-Limburg (Fig. 2.3) in which the pilot project of the City of Heerlen is situated. The last mine in the Aachen area was closed in 1992; since 1993 the mine water level has been rising in both Dutch and German mining districts. Although the mines were closed and the shafts were sealed, there still is some pipe work within some shafts (e.g. for degassing or water level measurement purposes) allowing for accessing the mine water reservoir.

Due to the geological setting on the German side of the border and the way the area has been mined, two separate hydraulic zones developed, a western and an eastern province. Within the western province there are close hydraulic connections such that extraction of mine water could affect the mine water level on the Dutch side of the border.

One of the German shafts that could be used as extraction well for warm mine water is the “Von-Goerschen-Shaft” with a depth of about 890 m in the municipality of Würselen (D). Its distance to the Minewater Project pilot in the municipality of Heerlen (NL) is only about 6.5 to 7 km away.

As well as assessing the technical viability of mine water extraction from the Von-Goerschen-Shaft or other shafts within the Aachen area, the WFG study examined the mutual influences of neighbouring geothermal mine water projects. The study was carried out by Engineering Consultants IHS (Ingenierbüro Heitfeld-Schetelig GmbH, Aachen) in close cooperation with the former mining company EBV GmbH.
Hydraulic, physical and chemical measurements were carried out at the Von-Goerschen- Shaft in order to examine the boundary conditions for the development of future geothermal projects. At several shafts across the Dutch-German border line accompanying investigations were performed in order to determine the overall hydraulic impact across the region.

The results of the WFG study demonstrate that there is indeed a hydraulic reaction in the shafts on the Dutch side of the border, at least if the Von-Goerschen- Shaft in Germany is pumped without re-injection of the mine water into the reservoir. The information gathered forms an important geophysical, chemical and technical database for the Aachen area, and its availability reduces the investment risk involved in planning the extraction of geothermal energy. It was proved that there is sufficient warm mine water available from the Aachen hard coal mining district to potentially supply a large number of customers with heat from a sustainable energy resource in the future.

2.4 Potential for using flooded coal mines in Lorraine

BRGM examined the potential for using flooded coal mines in the Lorraine region as a source of geothermal heat for district heating. Consistent with local environmental policy, the objective is to identify where best to launch a pilot project.

The Lorraine Coalfield (Fig. 2.4) extends for 49,000 hectares in the east Moselle region about 30 km from the city of Metz. It includes about seventy municipalities and extends beyond the German border. Between 1818 and 2004, 800 million tons of coal were extracted from 58 shafts in the region. After flooding, the mined area contains a reservoir of several tens of millions of cubic meters of warm water.

Many urban areas in the Lorraine coalfield are located close to the shafts, often built by the mine owners. Several such communities already have district heating networks supplied by an average of 5000 dwellings, these are ideal for exploiting the mine water. Currently, mine gas (methane) accounts for 25% of the fuel used but this will halt when they become completely flooded as expected by 2012.

Geothermal capacity of the Lorraine coalfield

The first stage was a geological study of the Lorraine coalfield; coal layers were studied in order to describe various coal bundles exploited through 58 shafts across the area.

In Lorraine, coal layers are situated under the Vosgian sandstone and are separated from it by a waterproof layer of Permian formation. Coal layers are generally sub-vertical or sub horizontal and were exploited between 120m and 1300m depth, using the long-wall mining method. After exploitation, galleries were either back filled with sand or collapsed using the caving technique.

The estimated total water capacity of the abandoned coalfield is 108m$^3$ at an average temperature at the deepest exploited levels (1200-1300m) of 50°C.

**Scale analysis**

The purpose of the scale analysis is to determine the optimum size for a potential exploitation project taking into account economic and technical constraints. A temperature of 30°C is the minimum useful for integration with existing district heating networks, corresponding to a depth of 800m. This reduces the scope to 15 possible sites. See Table 2.1.

These sites were then examined for their accessibility. The geothermal exploitation of the mine water requires the implementation of at least a doublet of production/re-injection wells. Although access to the reservoir is always possible through new drilling, this would incur too high a cost. This confines the potential to 8 sites at which the reservoir is easily accessible through existing shafts. These shafts are either closed by a short plug of concrete or entirely filled but contain observation and/or degassing pipes giving access to the lowest gallery.

Two further criteria complete the final selection of the potential sites: reservoir volume and proximity of a district heating network (within 1km). Two sites fulfil all the criteria:

- Freyming-Merlebach: Vouters 2 (production shaft), Cuvelette Nord (re-injection)
- Forbach: Simon 5 (production shaft), Simon 3 (re-injection)

**Environmental evaluation**

Important environmental concerns include:

- Impact of heat exploitation on the hydro-thermal behaviour of the reservoir
- Chemical composition of the water; mine water contains toxic compounds, carbon dioxide and methane. Care must be taken to avoid releasing potent greenhouse gases and causing aquifer pollution.

**Table 2.1: Scale analysis**

<table>
<thead>
<tr>
<th>Name</th>
<th>Site</th>
<th>Depth</th>
<th>Volume of Reservoir</th>
<th>End of flooding</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wendel 3</td>
<td>Petite Roselle</td>
<td>850 m</td>
<td>15,6 Mm$^3$</td>
<td>Expected 2011</td>
<td>7000</td>
</tr>
<tr>
<td>Marienau</td>
<td>Forbach</td>
<td>850 m</td>
<td>5,5 M m$^3$</td>
<td>Expected 2011</td>
<td>23 000</td>
</tr>
<tr>
<td>Simon 3</td>
<td>Forbach</td>
<td>850 m</td>
<td>18,6 M m$^3$</td>
<td>Expected 2011</td>
<td></td>
</tr>
<tr>
<td>Simon 5</td>
<td>Forbach</td>
<td>1050 m</td>
<td>22 M m$^3$</td>
<td>Expected 2011</td>
<td></td>
</tr>
<tr>
<td>Vouters 2</td>
<td>Freyming-Merlebach</td>
<td>1250 m</td>
<td>40,2 M m$^3$</td>
<td>Expected 2012</td>
<td></td>
</tr>
<tr>
<td>Cuvelette Nord</td>
<td>Freyming-Merlebach</td>
<td>1250 m</td>
<td>40,2 M m$^3$</td>
<td>Expected 2012</td>
<td></td>
</tr>
<tr>
<td>Reumaux</td>
<td>Freyming-Merlebach</td>
<td>1036 m</td>
<td>8,6 M m$^3$</td>
<td>Expected 2012</td>
<td></td>
</tr>
<tr>
<td>Faulquemont</td>
<td>Créhange</td>
<td>960 m</td>
<td>8 M m$^3$</td>
<td>1989</td>
<td>4 000</td>
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Preliminary system design
In order to identify the appropriate hydronic technology suitable for long-term exploitation of mine water, a preliminary system design has been developed by considering the geothermal plants currently operating in the Paris basin together with the site-specific information collected. Some of the main requirements are:

- A dedicated plug in order to thermally separate the pumping room from the water column when a shaft diameter > 1m is used
- Due to variable hydraulic losses in the network, the use of 3 separate types of pump, for production, circulation and re-injection.
- For heat exchangers and pumps, titanium components instead of stainless steel (notably 316L type) due to the presence of NaCl and other chloride brine.
- PVC and high density polyethylene coated pipes for mine water transportation.
- Ongoing monitoring of water level and the installation of a stand-by pump in order to prevent accidental contamination of the sandstone aquifer.
- Chemical monitoring of the mine water (at least every 3 months).

Cost benefit analysis
In order for the capital investment and likely return for initiating a mine water project to stand a chance of being viable the following elements are necessary:

- Close proximity of the mine to the heat production plant (within 1 km)
- Heat demand ≥ 40 GWh, per year
- The use of existing shafts (no new well drilling)

Table 2.2 gives some indicative costs.

<table>
<thead>
<tr>
<th>Investment</th>
<th>Costs (M€)</th>
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<tr>
<td>Heating plant and geothermal loop assuming pre-existing infrastructures</td>
<td>0.7</td>
</tr>
<tr>
<td>Shaft equipment</td>
<td>1</td>
</tr>
<tr>
<td>Piping for new installations for providing medium temperature hot water</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>5.7</td>
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<table>
<thead>
<tr>
<th>Maintenance</th>
<th>Costs/year</th>
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<tbody>
<tr>
<td>Equipment</td>
<td>0.1</td>
</tr>
<tr>
<td>Energy</td>
<td>0.6</td>
</tr>
<tr>
<td>Contingency (20%)</td>
<td>0.15</td>
</tr>
<tr>
<td>Total</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Income (assuming a sale price of 45€/MWh and a 40GWh installation) 1.8
Fig 2.4: Lorraine ore fields (Yellow = salt, Ochre = iron and Grey = coal)

Fig 2.5: 3D representation of the reservoir
Fig 2.6: Temperature changes versus time (continuous exploitation)

Fig 2.7: Temperature changes versus time (cyclic exploitation)
There are two basic options for exploiting mine water; with the 2 original pilot schemes these were both represented: drilling and/or pumping from depth (Heerlen pilot scheme) and using water already reaching the surface (Midlothian pilot scheme). These options are considered in this section; even though the Midlothian pilot did not proceed, technical and economic analysis was carried out.

3.1 The Heerlen Pilot Scheme

The city of Heerlen lies in the south of the Netherlands in the province of South Limburg. The city grew primarily because of the exploitation of local coal deposits. The coal mines subsequently closed leaving the area with high levels of unemployment, and local pride damaged.

The city has an overall policy, Parkstad Limburg, for reducing energy consumption and consequent carbon emissions by integrating new and more sustainable types of energy. The Minewater Project is an important element of these plans.

Following the closure of the mines, water has flooded into voids left behind where coal was mined. Consequently there are now large reservoirs of water in the mines beneath Heerlen. These are located at varying depths with temperature increasing with depth. Harnessing these reservoirs for energy supply forms the basis for the Minewater project.

The pilot project concept was to make use of warm and cold water from the closed mines for heating and cooling buildings by means of district heating and cooling infrastructure. Under the centre of the city the reservoir water is relatively cool and there is enough for current and predicted future cooling requirements. Reserves of warmer water are much smaller, and are found under the northern part of the city. However, the idea is to replenish these by re-injecting water heated by industrial processes and also water that has been used for cooling buildings (and has consequently warmed up).

As the project progressed the concept was refined into using these reservoirs as a large scale cold/heat storage system. The first phase is the provision of heating and cooling to Heerlerheide Centrum.

Innovative technical concepts have been developed, including a design strategy for the buildings and their heating and cooling systems so that these match as nearly as possible the available temperatures of the mine water. This mode of heating, using very low temperatures (between 27°C and 32°C) is known as a 'low exergy' system. By minimising the supplementary energy required, a CO₂ reduction of 50% is estimated compared with conventional solutions.

The progress with the Heerlen pilot is the result of several years of preliminary work. Initial studies were carried out to deduce the viability of this concept. This included:

- An examination of the local geology and the former mines (Fig. 3.1)
- Obtaining knowledge of the mining galleries and shafts
- Making a computer model of the geology and infrastructural lay-out of the mines
- Evaluating the likely extent of the resource
- Developing building energy systems that can make optimal use of the resource
- Engaging the whole community, many of whom are former miners
- Assembling a team of interested partners including the developer.

Fig 3.1: Schematic of the Oranje-Nassau I mine
Minewater as a Renewable Energy Resource

Location: Heerlerheide Centre

- 350 dwellings
- 3800 m² commercial buildings
- 2500 m² public and cultural buildings

- 11500 m² health care buildings
- 2200 m² educational buildings
Potential customers

Existing CBS office
43500 m²

New CBS office
21000 m²

Existing APG office
4100 m²
3.1.1 The energy concept at Heerlen

The fundamental task involved with the pilot project has been to match the buildings demand with the available energy supply, and to balance the cooling and heating sources, from the deep (warm) and shallow (cold) wells. This involves both the establishment and maintenance of the required temperature levels and buildings energy demand, and the volumes and temperatures of mine water that can be extracted.

The buildings’ energy demands were minimised through:

- High levels of insulation and mechanical heat recovery
- District heating and cooling networks: the aggregate demands are significantly less than the sum of each building’s individual demand
- Thermal storage: this can smooth the demand profile.

Issues that were addressed on the supply side include:

- The amount of renewable energy available from the mine water
- Low or zero carbon supplies that could best complement the mine water
- Minimising the size of supplementary heating or cooling equipment eg heat pumps and condensing gas boilers, and maintaining high running hours.

3.1.2 Geology

The coal bearing strata in the Limburg area mostly slope in a north-south direction, sinking deeper towards the Northeast. The volume mined and the subsurface infrastructure of the four combined ON-mines accrues to approximately 10-11 million m$^3$, most of which has been filled with water.

The deepest excavated coal layers within the former Oranje-Nassau (ON) concession are found at the northern limit in the vicinity of Heerlerheide (HH), with the shallower mines located beneath the centre of Heerlen (HLN).

Specifically, mining took place to a depth of 800m in the ON III mine (location 1 Heerlerheide) and it is here that the water is at it warmest (~ 34°C).

In the former ON I mine (location 2 Heerlen centre, Stadspark Oranje Nassau) the mining was far shallower so that it is here, at a depth of 250m, that the relatively cool water (< ~ 18°C) is to be found.

3.1.3 Energy from mine water: developing the approach

The initial process of locating the best sources of warm and cool water involved gathering together detailed information about the mines and carrying out a geological study. Details of the local geology were obtained together with maps of the old mines, and former miners still living in the area were contacted. This enabled estimates to be made of reservoir location and water temperature and chemistry.

These estimates were used as a basis for flow modelling analysis from which the initial concept was devised. It was only due to the very high level of accuracy of this modelling exercise that the Heerlen pilot has been able to adapt successfully. Suitable sites for drilling were identified and this enabled flow tests, chemical tests and temperature measurements to be carried out. The mined-out areas and their porosity were also explored to improve the modelling of the reservoirs. (Fig. 3.2).

Most of the original estimations of mine water potential focused on SON (Stadspark Oranje Nassau area). However, when it became clear that no imminent development would be happening here, attention turned instead to Heerlerheide. At Heerlerheide plans for a major regeneration were well underway; community and political support for the inclusion of the mine water project grew rapidly.

There was little time to accurately establish equivalent information for the new site. It soon became clear, however, that the desired flow of the warm mine water was simply not available by means of straight drilling in mined panels. Only 15-20m/h could be obtained; much more is needed.

The strategy for obtaining warm mine water was consequently modified. Instead of pumping the water from the mined panels, water would instead be extracted from the stone-drifts. This would require a highly specialised drilling technique, and the target zone would be restricted to 2.5m x 4.0m at a depth of 700m. This proved far more costly since a specialist drilling team was required together with steerable drilling equipment.
A further problem then arose because of the connection of the stone drifts with shallower cooler areas by the intermediately positioned former ON-III main shaft. Although the flow rate would increase water would inevitably be drawn from cooler areas. The geologists estimated that within only 14 days water from the main shaft would reach the production well. There would be no way to avoid this; as the geologists point out, the mines were constructed for coal production, not optimised for the mine water extraction!

One option to resolve this would be to drill several new wells for extraction, but this would have been too expensive. Instead a fundamental change was made to the project. The original scheme based on a purely geothermal use of the minewater, was adapted to one of large-scale heat and cold storage with a warm water buffer zone established between the hot and cold wells (Fig. 3.3). This involved the drilling of another well (HH2) where reused water will be reinjected and stored for ‘buffering’. This water would comprise the (now heated) water after it has been used for cooling, and / or warm water from local industries injected at a greater depth.

Water used for heating that has been sufficiently cooled off, will be reinjected at shallower depths in the Heerlen wells. Depending on the temperature at which this is done in the intermediate temperature well HLN-3 or one of the cold wells HLN-1 or HLN-2.

The HLN-3 well was the result of a further stage, when it emerged that the return water would not always be warm or cold enough for direct reinjection into either a cold or a warm water zone (via either the cold production wells (HLN-1, and HLN-2) or the warm water buffer well (HH2). So this 5th well (HLN-3) was drilled to specifically store intermediate temperature water and also as a way to get rid of excessive amounts of water in the event of unexpected problems.

Further tests reveal the likely success of this approach with availability of enough warm water at 28°C and flows over 80 m³/hr possible.

Further issues still confront the engineers because the cooling waters should not come into contact with the warmer waters at times and places not anticipated (short-circuiting).

3.1.4 Issues with mine water

Mine water tends to be mineral-rich because it emerges from depth and it is warm. A number of specific issues arise:

- **Scaling** – This is caused by carbonates due to pressure and temperature differences. A dedicated sensor monitors the build-up of scale. However, the low pH value of the water restricts this problem.

- **Corrosion** – Mine water usually contains substantial quantities of dissolved iron (pyrites). This reacts with oxygen to form ferrous oxides and hydroxides. A possible solution may be to prevent the infiltration of oxygen by sealing the wells with oil (several metres thick) floating on top of the mine water within the wellbores. An ‘oxygen-scavenger’ injection device may be installed in future in the production well.

- **Bacterial corrosion** – Sulphate may be used in future for reducing the build-up of bacteria.

Table 3.1 shows pump test results from two wells that demonstrate the likelihood of scaling and corrosion problems.

![Fig 3.3: Schematic cross section of the underground conditions as anticipated in the mine water plan](image-url)
Remark

HH1
- As anticipated
- High chloride and very little floating
- No problems.

Unit
- High iron content
- Requested quantities
- Install pump at 1 March 2007
- 21 February 2007
- Ph = 7.8
- Surface pipelines
- No specific problems
- Assessment
- As anticipated

HH2
- Table 3.2: Table pumping tests
- Table 3.1: Water data acquisition from wells Heerleheide 1 and 2

Minewater as a Renewable Energy Resource
- Pumping energy balances
- wellbores.
- level rise in the Heights of water
- Temperature cold water wells
- Temperature hot water wells Heerleheide
- Permeability of reservoir
- Max. pumping volume hot water wells
- Salt concentrations
- Minerals
- Acidity
- Pumping quantity cold water wells
- Temperature cold water wells
- Heights of water level rise in the wellbores.
- Setting of pressure balances
- Consumption of pumping energy
- Consumption of pumping energy is much higher than expected at HLN-1 and HLN-2.

Table 3.1: Water data acquisition from wells Heerleheide 1 and 2

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit 1</th>
<th>Unit 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of sampling</td>
<td>21 February 2007</td>
<td>1 March 2007</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>μS/cm</td>
<td>7.380</td>
</tr>
<tr>
<td>pH value</td>
<td></td>
<td>6.21</td>
</tr>
<tr>
<td>E value measured</td>
<td>mV</td>
<td>-149</td>
</tr>
<tr>
<td>Eh value</td>
<td>mV</td>
<td>65</td>
</tr>
<tr>
<td>Q2</td>
<td>mg/l</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>32.1</td>
</tr>
<tr>
<td>Total hardness</td>
<td>°dH</td>
<td>21</td>
</tr>
<tr>
<td>Total hardness</td>
<td>Mmol/L</td>
<td>3.8</td>
</tr>
<tr>
<td>Filterable solids</td>
<td>Mg/L</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

Table 3.2: Table pumping tests

<table>
<thead>
<tr>
<th>Property</th>
<th>Result</th>
<th>Remark</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature hot water wells Heerleheide</td>
<td>32° - 28 - 32°C at 700 metres depth</td>
<td>Minor water level decline during pumping</td>
<td>Temperature as expected, ample supply for Heerleheide.</td>
</tr>
<tr>
<td>Permeability of reservoir</td>
<td>100% in the stone-drifts and open galleries. In collapsed galleries and mined-out zones estimated between 10 and 60%</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Max. pumping volume hot water wells</td>
<td>105 m³/h</td>
<td>Very little floating material in all wells at both pump tests</td>
<td>Requested quantities can be supplied</td>
</tr>
<tr>
<td>Salt concentrations</td>
<td>High chloride and sulphide</td>
<td>As anticipated</td>
<td>No specific problems anticipated; corrosion effects will be managed.</td>
</tr>
<tr>
<td>Minerals</td>
<td>High iron content</td>
<td>As anticipated</td>
<td>Surface pipelines will be regularly cleaned.</td>
</tr>
<tr>
<td>Acidity</td>
<td>Ph = 7.8</td>
<td>As anticipated</td>
<td>No problems.</td>
</tr>
<tr>
<td>Pumping quantity cold water wells</td>
<td>220 m³</td>
<td>Requested quantities of 250 m³ can probably be achieved</td>
<td></td>
</tr>
<tr>
<td>Temperature cold water wells</td>
<td>HLN 1 = 16 °C</td>
<td>HLN 2 temperature high, probably due to inflow of warmer water via shaft ON-I</td>
<td>HLN 2 temperature high, probably due to inflow of warmer water via shaft ON-I</td>
</tr>
<tr>
<td>Heights of water level rise in the wellbores.</td>
<td>HH1 decline at higher delivery levels, HH2 not pumped!</td>
<td>As anticipated.</td>
<td>Install pump at sufficiently great depth; so a little deeper.</td>
</tr>
<tr>
<td>Setting of pressure balances</td>
<td>Needs little setting time; so large reservoir capacities.</td>
<td>Dependent on distances / open connections</td>
<td>As anticipated.</td>
</tr>
<tr>
<td>Consumption of pumping energy</td>
<td>Consumption of pumping energy is much higher than expected at HLN-1 and HLN-2.</td>
<td>Abnormal consumption at HLN-2 due to large counter-pressure from an undersized district heating pipe</td>
<td></td>
</tr>
</tbody>
</table>

3.1.5 Pumping testing

For the provision of warm water a 692m well (HH-1) has been drilled into an old, still open transportation gallery near the northern (warm) limit. A first flow test lasting 18 days has been successfully accomplished, demonstrating that at the surface a water supply of at least 28°C is amply available, with a maximum flow rate of 100 m³/h. This latter flow regime was maintained for the last 2 days of the test duration.

The second well (HH- 2) has been drilled into a stone-drift at a depth of 702m. The purpose of this well is the re-injection of used and therefore warmed-up former cooling waters. This will provide a buffering effect against the shallower cool waters in the realm of the ON-III main shaft.

Pumping tests carried out in 2006 and 2008 also focused on a wider set of mine water parameters including chemical and hydrological properties as well as flow rates and temperatures. Some of these are shown in Table 3.2.

3.1.6 Using the water

The water is drawn up and distributed through the district heating and cooling pipe networks. For transporting the warm water the standard district heating approach is followed: pre-insulated pipes to minimise heat loss with a leak monitoring system that detects moisture to within 1 metre. The return and the cold water supply pipes do not need insulation.

Since even the warm water is well below the limiting temperature of 80°C for using plastic pipes this is the material used for the heat networks. There is another important reason for using plastic rather than steel, the normal (and more expensive) alternative: the mine water is highly corrosive.

Although the potentially corrosive effect of the mine water is restricted by taking measures to exclude oxygen, it is nevertheless essential that the pipe material is corrosion-resistant and also has low abrasion values even when the fluid being carried is abrasive. High grade polypropylene meets these requirements.

The very high specification of modern district heating pipes means that the risk of contamination from mine water leaking is minimal. In particular, the embedded leak detection system works by observing very small ingress of water leaking is minimal. In particular, the embedded leak detection system works by observing very small ingress of moisture before a physical leak occurs. A significant leak is more likely to occur where two pipes are joined; however the welded joints should protect against this.

For the heat exchanger titanium, a highly corrosion-resistant metal is used.

For the district heating and cooling pipes, maintenance points have been installed so that cleaning devices [“pigs”] can be pumped through the pipes to counter scaling problems.
3.1.7 Buildings designed for low temperature heating and high temperature cooling

The buildings themselves are designed to have a low heating and cooling demand. Specifically, this involves constructing the buildings with very good thermal insulation and small ventilation losses, integrating mechanical ventilation with heat recovery, and limiting summer solar gains by means of effective shading. The characteristics of the buildings are summarised in Table 3.3.

Limiting the heating and cooling demands in this way means that most of the remaining demand can theoretically be met by low exergy sources (this means heat demand is met by means of a low temperature heat supply, and the cooling demand by a high temperature cooling supply). It was estimated that the mine water from different depths at Heerlen can be used to contribute significantly to these demands with only small temperature increments (and hence energy) required from supplementary systems.

Table 3.3: Characteristics of buildings designed for low temperature heating and high temperature cooling

<table>
<thead>
<tr>
<th>Building Regulation NL</th>
<th>Practice 2007 NL</th>
<th>Mine water Lowex</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal insulation</td>
<td>Thermal insulation</td>
<td>Thermal insulation</td>
</tr>
<tr>
<td>Envelope Rc = 2.5</td>
<td>Envelope Rc = 3.0</td>
<td>Envelope Rc = 4.0</td>
</tr>
<tr>
<td>Glazing U = 3.0</td>
<td>Glazing U = 1.5</td>
<td>Glazing U = 1.2</td>
</tr>
<tr>
<td>Ventilation</td>
<td>Ventilation</td>
<td>Ventilation</td>
</tr>
<tr>
<td>No system requirements</td>
<td>50% ME/50% MVHR</td>
<td>MVHR efficiency = 95%</td>
</tr>
<tr>
<td>Air tightness</td>
<td>Air tightness</td>
<td>Air tightness</td>
</tr>
<tr>
<td>qv 10 &lt; 200 (n50 = 3)</td>
<td>qv 10 = 100..150</td>
<td>qv 10 &lt; 62.5 (n50 &lt; 1)</td>
</tr>
<tr>
<td>Emission system</td>
<td>Emission system</td>
<td>Emission system</td>
</tr>
<tr>
<td>No requirements</td>
<td>Radiators</td>
<td>Floor heating and cooling</td>
</tr>
<tr>
<td>HVAC system/efficiency</td>
<td>HVAC system/efficiency</td>
<td>HVAC system/efficiency</td>
</tr>
<tr>
<td>No requirements (but in EPR)</td>
<td>Condensing boilers</td>
<td>Mine water with heat pumps (boiler back up)</td>
</tr>
<tr>
<td>EPC dwellings</td>
<td>EPC dwellings</td>
<td>EPC dwellings</td>
</tr>
<tr>
<td>0.8</td>
<td>0.8</td>
<td>0.5</td>
</tr>
</tbody>
</table>

3.1.8 The heat and cool networks

The extracted mine water will be transported to local energy stations by a primary energy grid. In these energy stations heat exchange takes place between the primary grid that extends from the wells to the energy station, and the secondary grid that runs from the energy station to each of the connected buildings. The secondary energy grid provides low temperature heating (35 – 40°C) and high temperature cooling (16 – 18°C) supply and one combined return (20 – 25°C) to an intermediate well. The function of this return water is to maintain a buffer zone between the warm and cold wells.

The overall concept (Figs 3.5 and 3.6) is for five well locations and energy stations connected by three pipelines of 7 km each. Warm water is transported from the warm wells located in Heerlerheide in the north and cold water is transported from the shallow (Heerlen 1 and 2) wells in the southern region. The ‘three-pipe system’ also has a common return pipe to take the combined return water to the fifth well for reinjection.

Fig 3.5: Schematic view of the energy concept
Minewater as a Renewable Energy Resource

At first it had been hoped that the mine water would be at such useful temperatures for both space heating and cooling that, through low exergy design, no further energy input from more conventional low carbon technology would be required. However, for both the heating supply and the cooling supply it has proved necessary to include a heat pump.

Although this means that the ratio between renewable mine water energy and electricity is not as favourable as had been hoped, heat pumps are themselves a low carbon technology so that the overall system should still achieve impressive carbon savings.

A more serious problem is the emergence of the water for cooling at a higher temperature than expected. This together with much higher than expected pump consumption are teething problems that are under investigation.

There also remains the need for domestic hot water (DHW). This must be raised to a much higher temperature (at least 60°C) in order to avoid problems from legionella. Initially there were plans to achieve this by means of a centralised combined heat and power (CHP) engine, but it was felt it would be more effective to heat the DHW on an individual building basis. The load profile of the health care centre (not connected to the mine water system) was individually suited to the application of CHP, but that of the residential buildings was not so these were instead equipped with individual gas-fired condensing boilers.

The design principles for the buildings that have minimised their energy demand also means there is a significant amount of time when the buildings require neither heating nor cooling. Overall the energy demand for the redeveloped areas is quite small. This conflicts with the overall need to recover money invested by means of energy sales unless the cost levied per unit of energy is very high. This dilemma faces all new developments where a very good environmental performance is being achieved through a combination of minimising demand and expensive low carbon technologies to produce a diminished supply.

The overall system will be controlled by an intelligent energy management system including telemetering of the energy uses/flows at the end-users.

3.1.9 Minimising demand: Low Exergy and Building Design

As with many of the renewable energy systems that are now being implemented more rapidly than ever before, the use of the mine water energy is limited by the nature of the resource itself. However, if we are able to make use of available renewable energy resources, we can conserve fossil fuels for situations where there is no alternative.

In the vicinity of Heerlen the highest temperature mine water that can be readily accessed is 32°C. The use of water at this temperature requires a specialised approach. Specifically, it calls for an attempt to match as well as possible the energy demand to the available supply.

High grade fuels such as fossil fuels and, even more so, electricity are extremely versatile and concentrated. They can be converted to many other energy types for an enormous range of mechanical purposes and industrial processes requiring 100s of degrees. It is not therefore thermodynamically smart to use such fuels for temperature elevations of several 10s of degrees.

Conversely water at 32°C is not at all flexible in its range of useful applications. As an energy resource it is very low grade. Yet even as a preheat for a conventional heating system where water is heated from 10°C to 80°C, it could potentially contribute 30% of the required temperature rise. This enables fossil fuel use to be reduced with consequent conservation of valuable resources for
applications where there is no alternative, and reduces the associated carbon emissions.

If we then design the building and heating equipment to be capable of using water at much lower temperatures then the potential saving increases. The scientific name that is used to define grade or quality of energy is ‘exergy’.

Building design aspects:
• Low ventilation rate
• High insulation
• Thermal storage and or mass

System aspects:
• Focus on underfloor, wall and ceiling heating, with even distribution of heating surface.

3.1.10 Customers of the Heerlen Mine Water Scheme

The first customer is the Housing Association Weller specifically through the regeneration scheme at Heerlerheide Centre. Further schemes (Table 3.4) will come on line in due course, with the Heerlen APG head office scheme connecting imminently. The pipes have been designed to cater for the extra mine water flows that will be needed when the clients that are anticipated connect to the network.

Heerlerheide Centre
The regeneration of Heerlerheide Centre includes new build residential (330 dwellings), commercial (floor area 3,800 m²) and public (16,200 m²) buildings, including new health care and educational facilities.

The first new building and construction activities in Heerlerheide Centre started in 2006 and will be completed by 2011. Most of all the buildings that are planned as part of this development will be connected to the mine water heating and cooling networks. They will all be confined to a very compact area so that the length of the energy distribution pipes is minimised. The principal stakeholder in the Heerlerheide development is the Housing Association Weller. This scheme and the role of Weller in delivering it is described further in the case study later on in this Guide.

Heerlen APG head office
This development involves the improvement of a large existing building, the APG head office of floor area 60,000 m². The total building envelope has been refurbished to a level better then the current Dutch Building Decree requirements for new buildings.

The mine water will be used for providing both heating and cooling. The building will be designed so that low temperature heating and high temperature cooling can be used for all the offices. The APG building will have a direct connection to the mine water wells and will have its own energy station that will be equipped with heat pumps to ensure the office temperature stays within the required range.

The glazing system will be designed with low transmissivity in order to limit solar radiation in summer; this makes it possible to use high temperature cooling, most of the time directly from mine water.

Projected demands (heat and cold) from these and other future customers are summarised in Table 3.4.

Table 3.4: Total demand for mine energy from water per hour and per year (data from September 2008)

<table>
<thead>
<tr>
<th>Customers current &amp; potential future</th>
<th>Floor area in m²(GFA)</th>
<th>Hot water</th>
<th>Cold water</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum delivery m³/h (= hour)</td>
<td>Volume m³/yr</td>
<td>Maximum delivery m³/h (= hour)</td>
</tr>
<tr>
<td>EC Heerlerheide</td>
<td>48</td>
<td>144,000</td>
<td>86</td>
</tr>
<tr>
<td>APG</td>
<td>41,000</td>
<td>26</td>
<td>66,000</td>
</tr>
<tr>
<td>SON, CBS new</td>
<td>22,000</td>
<td>28</td>
<td>70,000</td>
</tr>
<tr>
<td>SON, CBS old</td>
<td>43,500</td>
<td>65</td>
<td>163,000</td>
</tr>
<tr>
<td>Total</td>
<td>167</td>
<td>443,000</td>
<td>472</td>
</tr>
</tbody>
</table>

NB: CBS will probably be connected to the mine water system

3.1.11 Conclusion

Abandoned and flooded mines can be reused for a new sustainable energy supply for heating and cooling of buildings. The Minewater Project in Heerlen shows that the temperature (about 30°C) found at 700m and the temperature of the shallow wells (16°C – 18°C at 250m) can potentially make a significant contribution to the heating and cooling requirements of buildings provided they are very well insulated, have energy efficient ventilation systems and have systems designed to use moderate temperatures like underfloor/ wall heating.

However, the systems are not without their problems, since it is difficult to exactly predict in advance what the temperature and volume flows will be. This is because one commonly does not know precisely which parts of the mine (infrastructure) are still open and which are not. For the Heerlen pilot this meant nothing less than changing the whole original purely geothermal philosophy of the system. Instead of direct provision of warm water, the warm reservoir is used for a combination of large scale cold / heat storage in addition to the geothermal supply.

3.2 The proposed Midlothian pilot

The shaft of the disused Monktonhall Colliery is near the proposed centre of Shawfair. This shaft could be used to access a resource of warm water for driving a heat pump to provide heating to a district heating network. The technical viability of any geothermal energy source depends on satisfying three criteria:

• Is the water source hot enough to provide useful energy?
• Is there sufficient water available for the life of the project?
• Can the water be abstracted at a sufficient rate to provide the net power required by the project?

Preliminary studies indicated that these 3 criteria are satisfied.
Midlothian is located in Scotland just to the south of Edinburgh. It also lies on one of Scotland’s major former coalfields that produced millions of tonnes of coal annually and employed thousands miners. All the pits are now closed.

The area immediately to the south east of Edinburgh has been earmarked for development. Known as the South East Wedge, it comprises land under the auspices both of the City of Edinburgh and Midlothian. The need for thousands of new homes is a measure of Edinburgh’s growth and prosperity not least because of the effect of devolution of power to the Scottish Parliament.

A key strategic element within the South East Wedge development is the proposed new town to be known as Shawfair. It covers the part of the South East Wedge that lies within Midlothian Council’s boundaries.

The Shawfair Local Plan was adopted on 25 September 2003. It provides detailed land use planning guidance as to how the proposal to build a new settlement of about 4000 houses plus associated community, commercial, employment and transport facilities is implemented. The development footprint will be over 450 acres.

A joint venture company, Shawfair Developments Limited has been formed between Miller Homes and Midlothian Council to deliver the new town over a 15-year period.

Construction work has begun on Shawfair Park: however, by May 2008 only the first 1.5 acres had been constructed comprising three buildings for use as offices – one at 500m², one at 740m² and one at 1000m².

Midlothian and Shawfair

One of the key objectives Midlothian Council has for Shawfair is for it to be developed in a sustainable way. As well as the wider environmental drivers, there are additional local factors: the South East Wedge is situated in Edinburgh’s green belt, so that greenfield development needs to be particularly sensitively devised. Also, this is a former coal-mining area with attendant remediation issues; Shawfair itself includes the former Monktonhall Colliery. Monktonhall closed in 1998 leading to concerns over the potential impact of rising mine water led the Coal Authority to avoid pollution from the flooded mines.

Monktonhall Colliery was one of the deepest coal mines in the UK at approximately 900m. A previously commissioned study established that the temperature of water in Monktonhall varies from 37°C at its deepest and emerges at 13°C.

The decision was made to focus analysis on using the surface water at 13°C. This approach was pursued because both equipment capital cost and running cost would be higher for pumping the warmer, deeper water. It was also concluded (in Midlothian though not in Heerlen) that the temperature of 37°C would not be directly useful for heating.

Having decided not to use the warmer mine water temperature directly, the actual temperature of the mine water feed is less important than its consistent temperature and availability. The mine water can provide a substantial supply of continuous constant temperature water; no other surface water source has this attribute. Studies have concluded that a constant stream of mine water at 13°C could be maintained under all conditions.

When the mine was operating water was being removed at a rate of about 128kg/s. Since closure, the water level has been maintained with a pump rate of about 100kg/s. Particularly since the area being drained by the pump at Monktonhall now extends to include other mines that would have formerly had their own pumps, it is concluded that at least 100kg/s could be pumped without recirculation.

In order to investigate the possibility of using mine water as a local energy resource for Shawfair, Midlothian Council commissioned a preliminary analysis from a local mining expert regarding the potential size of the resource followed by a technical options appraisal to compare a number of possible heating systems. Finally, a business case analysis was carried out to determine economic viability.

The proposed Shawfair development lies above the mine workings from several collieries. Crucially, its footprint includes the former Monktonhall Colliery where water is being pumped by the Coal Authority to avoid pollution from the flooded mines.

In order to satisfy the magnitude required for the whole of Shawfair once built, mine water would need to be pumped at a rate well above this. The potential mine water resource beneath the whole South East Wedge area is large and extends to a number of collieries. These are likely to be interconnected such that the area drained by Monktonhall may be sufficient to service the full Shawfair development and beyond. This would involve a recirculation scheme the details of which have not been fully explored.
The size of the Shawfair development after three full phases was estimated to require a heating demand of 25MW, although this estimate would since have decreased because of increasingly stringent requirements for new buildings.

However, the detailed analysis progressed by considering just the first phase, since the data were better known, and the available grant finding could in any case only extend this far. Such a scheme would require a much smaller flow rate; indeed the integrated system that was then examined involved a flow rate of 30kg/s.

### 3.2.4 System design

The planned first phase of Shawfair includes 555 dwellings, 12000 m² of office development and a 15000 m² school. The estimated aggregate heating load to service this development is approximately 3000 kW.

A range of options were considered to provide this heating demand. These options include various arrangements of heat pumps and combined heat and power (CHP), feeding a district heating network to distribute the heat from a single energy centre to all the connected buildings.

These heat pump and CHP options were also compared with a base case scenario (gas-fired boilers). Both the economic and environmental performance were examined.

The heat pump would be designed to raise the temperature of the district heating return water from 40°C to 60°C, with CHP integrated in the system to raise this to 80°C to supply the district heating network. It was assumed that the heat pump would be supplied with 30kg/s of mine water to the evaporator, making use of the abundant and consistent availability of mine water at 13°C. The mine water could be discharged at the surface to a water treatment facility (reed beds) or discharged at a nearby shaft.

In order to maximise the running hours of the heat pump and minimise the capital expenditure the analysis was based on a single stage vapour compression heat pump sized to meet the base heat demand. The coefficient of performance of this heat pump is assumed to be approximately 5.

The CHP unit used in the analysis was a spark ignition engine designed to run on natural gas. These engines achieve a high electrical efficiency, retrieve heat effectively and can perform with high overall availability (over 90%).

The extent to which low carbon heating plant reduces carbon emissions depends on the assumed emissions factors. This is particularly important when comparing heat pumps and CHP because the former uses electricity while the latter generates it.

There are differing views regarding the applicability of these efficiency factors, and this can affect the apparent best environmental solution. The favoured option (Fig. 3.7) would achieve an impressive reduction (possibly the best, depending on the assumed emission factor) in carbon emissions, and appeared economically viable given grant availability.

This scenario posits a 1500 kW gas-fired CHP engine and a 450kW vapour compression heat pump. The heat pump would supply 1500 kW, to raise the temperature from 40°C to 60°C using the mine water supply, with the CHP generating electricity to both run the heat pump and for...
Despite the clear technical feasibility for a mine water scheme at Shawfair, the scheme did not actually proceed. There were several reasons for this that, taken together, were perceived to present too great a risk to the Council.

One of the key elements is the difficulty of timing. Unlike Heerlen, which has proceeded through redevelopment of an existing site, Shawfair will be a completely new town. All infrastructure and construction is to take place on empty brown and green field land. By mid 2006 there was still no procurement exercise to secure a private sector partner to deliver the project. It was foreseen that it would not be possible to adhere to the time constraints of major grant funding streams, including Interreg. In hindsight, with only a very small development completed by mid-2008, it seems that it would indeed have not been possible to make use of the capital grant from Interreg.

Despite having secured substantial funding support, there still remained a significant funding gap amounting to approximately 3.5 million, itself a risk the council would be reluctant to take.

There were, however, also key differences in project structure: at Heerlen the developer was actually a driving force behind the scheme. In particular, with a heat network requiring an ESCO to run it, the developer simply decided to form its energy company. By contrast for Shawfair the developer was not on the scene at the inception of the project, and viewed the requirement to deploy the unusual mine water and district heating supply system as a financial and marketing risk.

The developer was also reluctant to commit to not having a gas supply installed. This reflects the usual expectations of potential purchasers, although opinions may have been revised had the subsequent very sharp energy price rises been known at the time. They would also need to agree to specified construction phases. Latterly the first major phase, originally to be sited adjacent to the mine water discharge at Monktonhall, was moved to a different location.
The calculation of the reference energy-costs is subject to many discussions and points of view, due to different interests. For the Minewater Project the reference energy costs (including conventional cooling) are calculated at the level of the actual building decree. The individual consumption of cooling is not metered, but charged at a fixed rate. In this way, metering costs are avoided, and residents can start cooling as early as possible to get the maximum effect from the limited capacity of the floor cooling, also returning heat into the mines (heat storage). A standard tariff for low-exergy cooling is not yet available in the Netherlands.

For private households mine water energy can be supplied at competitive prices. For larger commercial and public buildings this is not the case (yet). The reason for this is that these large consumers enjoy lower prices for conventional energy. Furthermore, most of the larger buildings in Heerlen to which mine water energy will be supplied do not have full low-exergy systems, since these are existing buildings which are being redesigned. As a result of the latter, these large consumers cannot take full advantage yet from low temperature heating and high temperature cooling.

Another topic in the price discussion is the assurance of the continuous supply of minewater energy of the same quality. To avoid supply risks the large consumers invest in back-up systems which are relatively expensive. The energy savings will not offset the capital cost of these back-up systems.

Economic benefits will also occur because of the integrated design, especially by combining heating and cooling in the same supply system (i.e. floor heating and cooling, good thermal coupling of building components). This avoids the investment cost of a separate cooling system.

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The economic value of heat and cold from mine water is expressed in an energy unit price that is determined by three factors:

- The running costs of the mine water company, including electricity for the well pumps and transportation, maintenance, replacements and administration.
- The cost of upgrading low valued heat and cold by heat pumps and gas-fired boilers.
- The reference energy-cost as a limit for the tariffs for the heat and cold.

Fig 4.1: Business model, Heerlen
The delivery structure has been devised to have the following elements:

1. The municipality of Heerlen has not taken on the role of an energy company. Risk to instead be transferred to the specially formed production company Corio Energy.

2. The municipality of Heerlen to have 100% ownership of Corio Energy (with concession, mine water well and pumps and primary heat network).

3. Corio Energy (to be started up) to be a holding company for 4 companies with its own management. Although owned by the council, future participation by other parties is also possible.

4. Corio Energy to be responsible for obtaining the mine water and supplying it to locally-based ESCOs, currently Weller Energy at the Heerlerheide site. The primary product comprises 208m³/hr warm water at 28°C and 500m³/hr cool water.

5. Weller Energy (and any other participating ESCO) has full responsibility for supply contracts with end-users to supply them with electricity, heat and cooling, ensuring they pay ‘not more than otherwise’ (that is not more than if they had conventional energy systems).

6. Corio Energy, Weller Energy (and any other – if any – participating ESCO) are not permitted to make a profit during the first 5 years of operation.

Intended customers are the owners of buildings designed according to the principles of low exergy, and large complexes with stable demand for heat and cold, in the vicinity of the main district heating infrastructure. Currently these include Weller Energy, APG, CBS and potentially other sites including several educational institutions (Arcus College, Hogeschool Zuyd, Open Universiteit and Sintermeerten College). Weller Energy is already supplying the Heerlerheide site in this way, and APG and CBS are strong potential customers. Large connections in Stadspark Oranje Nassau are anticipated in 2010 and 2015.

Thus the business plan is founded on expansion as Heerlen pursues its intention to become a ‘climate-neutral’ city. However, developments must be financially viable: the mine water scheme must be able to generate sufficient cash flow to recoup net investments (these exceed €4m) over a period of 30 years. This assertion is made on the basis of continuing sharp rises in energy prices of 7% during the first ten years, (by comparison mine water costs, being mostly fixed costs, barely rise), significant residual value of the infrastructure, and no significant mine water well exhaustion.

4.2 Midlothian

Midlothian Council’s preferred delivery model involved procuring a private sector partner, an Energy Services Company (ESCO) to design, build and operate the project. Although the market for ESCOs remains small, a preliminary marketing exercise identified two possible market-leading ESCOs.

The effective participation of the key stakeholders is vital and in this case these included the developer, the Coal Authority, other third party land-owners, as well as the council.

The Coal Authority owns the land so its permission has to be secured, and their permission is required to use and then discharge the mine water. District heating pipes need to traverse land owned by third parties, so their permission is also required.

The structure of the relationships between the key parties had to comply with various requirements:

- The council’s risk transfer requirements
- The developer’s preferences regarding their perceptions of marketability
- The need for an economic return for the ESCO
- Conditions of grant award authorities
- All relevant regulatory requirements.

This lead to the following features of the proposed delivery structure:

1. The Council to have no direct nor indirect stake in the ESCO, not receiving any profit earned nor directly exposed to the risks, these being transferred to the private sector.

2. A fully-owned council Special Purpose Vehicle (SPV) to hold the physical assets of the Energy Centre and the heating and wire networks, maintaining council ownership.

3. A lease or licence agreement to be put in place between the council SPV (or the council directly) the private sector partner allowing the latter access to these assets.

4. The council SPV to pass grant funds and developer contribution funds to the private sector partner in the form of capital contributions in line with contracted milestones.

5. The private sector partner, probably through the ESCO, would enter into supply contracts for purchase and sale of electricity and for the purchase of gas, and enter into supply contracts with end-users to supply them with electricity and heat.
Lack of appetite to participate on the part of the developer together with identification of significant risks led Midlothian Council to withdraw. A funding gap was identified which would become much worse if the Interreg grant schedule could not be complied with. Also, the monopoly element makes developers nervous about marketability.

The district heating system operator would supply heat and electricity to the development and properties connected to the system would not be connected to mains gas. To protect consumers, each would be metered with tariffs set 5-10% below conventional supplies, through a Service Level Agreement with the ESCO.

Lack of appetite to participate on the part of the developer together with identification of significant risks led Midlothian Council to withdraw. A funding gap was identified which would become much worse if the Interreg grant schedule could not be complied with. Also, the monopoly element makes developers nervous about marketability.
In general the ownership of mine water is not well defined. However, it is important to consider ownership issues together with necessary licences, permits and liabilities. In the Netherlands, but not in Scotland, the geothermal resource embedded in the water is specified in law.

5.1 Heerlen

Issues that had to be addressed in Heerlen include those that are:

- Specific to mining and mine water – these are set out below and often involve set periods for objections that must be factored into the overall project timescale, together with time to address any objections.

- More general buildings-related issues; these are not specific to the use of mine water and are not mentioned here, but must be properly addressed.

- Related to European tendering procedures; these are not specific to the use of mine water and are not described here. It should be noted, however, that these procedures can be time-consuming and therefore impinge on delivery where there are tight deadlines in place.

During the coal mine closure programmes (1960/70s) in the South Netherlands, the responsibility of mine water was removed from the mining companies to the Dutch State; this is carried out by the Dutch Mining Authority.

5.1.1 Ownership of mine water

The Dutch Mining Law, introduced on 1 January 2003, sets out rights and responsibilities concerning all mining activities. The holder of a permit, granted by the Minister of Economic Affairs, is authorised to search and use natural resources 100 meters or more below ground even when he is not the owner of the topsoil. The owner is obliged to give consent for this.

The holder of such a permit is not the owner of the mine water but is responsible for the treatment of this water and obliged to ensure this water does not pollute the environment.

The environmental law (Wet Milieubeheer) is applicable to mining activities. Any company that explores natural resources needs to have an environmental permit and is liable for damage to environment, including damage as a result of inadequate treatment of mine water.

5.1.2 Ownership of the natural geothermal resource in mine water

The Dutch Mining law defines geothermal heat as a natural resource. All natural resources are owned by the Dutch State. As such, natural resources more than 100 metres below ground are not owned by the owner of the real estate but by the Dutch State.

The State can give consent to a third party to search for and/or exploit these natural resources. The ownership of the natural resources for which such a permit is granted by the Minister of Economic Affairs, transfers from the Dutch State to the holder of the permit.

5.1.3 Mining law

Minerals are owned by the State. The ownership transfers to the mining company by exploitation. Geothermal heat has no owner. According to the former legislation, the mine itself becomes the property of the mining company. This ends when the concession ends. According to present legislation the ownership of the mine remains with the State.

Key issues with legislation include:

- The Mining Law Mijnbouwet dates from the 31 October 2002. The exploitation of geothermal heat at a depth below 500 m is licensed by the Mijnbouwet.

- For the exploitation of geothermal heat below 500 m, an exploration licence from the Minister of Economic Affairs is needed. This licence grants the exclusive right to explore within the stated area, and gives a preference for the exploitation licence.

- For the drilling a “Mijnbouwmilieuvergunning” is required, issued by the Minister of Economic Affairs. This licence has environmental aspects. Parts of the Wet Milieubeheer are applicable to this but a separate licence based on this is not required.

- After the presence of geothermal heat is proved, the Minister can issue an exploitation licence. Heerlen council has applied for such a licence (Winningsvergunning).

- Besides an exploration licence a licence based on the Wet Milieubeheer is needed for a permanent mining installation. The licence stipulates environmentally sound exploitation.

- For any buildings a building licence is required and the use of the ground must be in accordance with the ‘Bestemmingsplan’ (Development Plan). This is determined by the city council and is based on the ‘Wet op de Ruimtelijke (Ordering)’ the Town and Country Planning Act.

5.2 Midlothian

Midlothian Council identified a solution that does not require any drilling activity. They did not therefore need to research into drilling rights.

Land in Scotland is owned a coelo usque ad centrum – literally from the heavens and to the centre – by which the owner of the top soil owns everything beneath it in a straight line to the earth’s core. In theory, one can therefore drill with impunity provided the activity remains within the ownership footprint. Furthermore, it is an established principle of Scots Law that the owner of the

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1 Report of discussion in Dutch Parliament, MvT 26 219, number 3, page 50 and 51
In each case the proposal to site the works in a former mineworking site will be helpful in getting planning permission granted. In any event, planning permission will be required for the other sections of the project so this should not be seen as solely a drilling issue.

The Coal Industry Nationalisation Act 1946 in effect removed some of the property rights referred to earlier. Under that Act all interests in coal mines and unworked coal were transferred to the National Coal Board (now the Coal Authority). Investigations into the ownership of the mine water itself suggested that because the ownership of the coal was transferred to the Coal Authority, the subsequent void left after the removal of the coal also belonged to them as did the water which has seeped into the void.

Accordingly, the owner of the surface will no longer have any right to work the coal, interfere with the mine workings or extract the water within unless it obtains Coal Authority’s consent.

In the case of the Shawfair Project, the Coal Authority has a non statutory responsibility for control of the rising mine water. Accordingly, at present, the Authority pumps the water from the mine and discharges via a series of pipes into reed beds on the surface. The Midlothian system would have taken a loop from the pipes above ground, extracted the heat from the water and then return it to the pipes for discharge into the reed beds

Although this proposal has its own set of environmental issues, it avoids the need for drilling and its associated difficulties.
6.1 Weller

Weller is a Housing Corporation that was formed from origins within government some 80 years ago. Although now operating in the private sector Weller has maintained its public face, retaining the high degree of social responsibility enshrined in its mission statement.

Currently Weller owns 10,000 houses, from which it draws annual rental. However, as rental houses are not profitable some of these are sold; Weller has been able to initiate innovative new projects from the proceeds of these sales.

In Heerlerheide centre 350 dwellings will be supplied with district heating by 2013.

Weller has its own energy company to supply these district heated dwellings. The local district heat tariff is linked to the average price customers pay for gas. This ensures that residents do not pay more for district heat than they would for heating a home with an individual boiler. Cooling demands are also on the increase, so the aim is to fulfil these as well.

Weller puts sustainability at the top of its agenda: as well as the energy aspects, sustainable building materials are used including, for example, wood that is fully certificated as coming from sustainable sources. This policy is consistent with the aims of the Dutch government’s Community Energy Programme, which aims to deliver projects in the range of 35 – 40 GJ in a sustainable way leading to projected savings of 10GJ.

Weller’s activities also contribute to the overall condition of residential areas in the Netherlands, specifically that there are practically no bad quality neighbourhoods to be found.

Weller is a mission-driven housing association ‘offering housing is a means to an end: offering services to the individual customer for an optimal experience of living with respect for humanity, environment and society.’ The development at Heerlerheide is a good example of Weller putting into practice its aspirations.

6.2 A new vision for Heerlerheide

Heerlerheide is a district within the city of Heerlen, comprising 22,000 residents in 9,700 dwellings. Following the closure of the mines, the area has suffered from deprivation and poor self-image. The centre had suffered from a fragmented shopping area and a poor traffic structure. This has lead to many of those who can choosing to leave the area and the image of the area consequently deteriorating. A primary goal for the regeneration scheme for the centre is to reverse this trend, and to deliver a new and positive vision for the future that attracts new people and commercial investment.
In 1996, together with local government, Weller started a major new initiative to renew and redevelop the centre of Heerlerheide. Previous attempts to transform rundown areas in the region have sought to green the former industrial landscape, but in erasing the mining past they have also damaged local identity and pride. A fundamental aspect of the plans for Heerlerheide is therefore to restore local pride, and part of this is to acknowledge local heritage.

Weller captured their vision for the redevelopment of Heerlerheide with the terms ‘binding and booming’, specifically meaning to stimulate:

- The binding of people
- The booming of commercial services.

Although the use of mine water was not originally part of the redevelopment of Heerlerheide, its integration into the scheme has acted as a powerful symbol of this vision. To once again be obtaining energy from the mines has caught the imagination of local people, so that they have become willing and enthusiastic participants in the difficult task of revitalising the community.

6.3 What’s Involved

Initially, Weller already owned 2,000 dwellings and 3,500 m² of commercial space in the centre of Heerlerheide. The planned town centre redevelopment is based on both new build residential (350 dwellings), commercial floorspace (3,800 m²), together with community buildings (16,200 m²) including an educational complex, library, community centre and residential care home. A high quality environment is planned with innovative dwellings and green areas with parking space located underground. Currently approximately 80% of the dwellings in this area are social housing; the new development will comprise a 50:50 split.

The first new building and construction activities in Heerlerheide Centre started in 2006 and are due for completion by 2013. Figures 6.3 and 6.4 demonstrate the imaginative architecture that reflects the innovation applied to the scheme as a whole. Weller decided that all the buildings planned for the regeneration of Heerlerheide would be connected to the district heating and cooling scheme based on mine water. Part of the original masterplanning exercise was to ensure that all these buildings would be constructed within a very compact area which reduces the expense for energy distribution.

6.4 Organising the Heerlerheide Scheme

Weller has formed a joint cooperation with the Municipality of Heerlen; this has led to agreements regarding investment:

- A public private partnership involving a total investment of €75 million, with €32 million invested by Weller (€5 million of this being unprofitable rentals) and €15 million provided by Heerlen Council.
- Implementation of energy efficient designs incorporating high insulation values, very low temperature heating (low exergy principle), and integration with Heerlen’s Minewater Project.

Weller has, as the main investor, decided to form its own energy company Weller Energy Ltd. Wholly owned by Weller, it will be responsible for the supply of heating and cooling energy services to all customers who are connected to the scheme. It will facilitate the process of securing customers for the scheme and provide a guarantee to all real estate developers involved in this development.

Weller Energy Ltd. has consequently managed the construction of the Heerlerheide energy centre and distribution grid. In the energy centre the mine water is brought to the necessary heating and cooling levels by heat pumps. As with all district heating networks, the system is fuel flexible so that with only minor modifications it can also operate without the mine water resource.
6.5 Customer service

The heating and cooling from the energy centre is delivered to the individual buildings by means of the district heating and cooling networks.

All the dwellings at Heerlerheide (Fig. 6.5) are serviced with floor heating and cooling. The calculated seasonal average supply temperature for the floor heating is 35°C; this fits perfectly with the principle of very low temperature heating.

The low temperature floor heating can only work properly if residents understand it. Weller has taken great care to provide clear information about the system. Information sources include a guide, brochure and personal advisors.

The dwellings are built to a high specification of thermal insulation and are also tightly sealed. The dwellings are therefore also serviced with mechanical ventilation with high-efficiency heat-recovery (80% efficiency).

Domestic hot water is provided by pre-heating the cold water with the same supply (35°C) used for the central heating, and then further heating the water up to 70°C with high-efficiency condensing boilers located in each building. This pre-heating provides about 30% of the annual demand for hot water. Residents are restricted to electricity for cooking. In Fig. 6.6 the combined heat-load duration curve for Heerlerheide is shown.
Using the mine water

The masterplan for the redevelopment of the run-down centre of Heerlerheide commenced in 1996, and initially had nothing to do with mine water – it was simply another regeneration project being developed by Weller. The buildings would in any case have been very energy efficient.

However, the development is perfectly placed for inclusion with the mine water scheme. Specifically, Heerlerheide is situated on the concession of the ON III pit in a relatively deep mined area between the two warm wells (30ºC–35ºC). The use of mine water as part of the energy supply has lead explicitly to the adoption of the low exergy principle together with high levels of insulation.

The peak heating demand is about 2.2 MW; this is about 20% lower than traditional heat loss calculations would suggest. This is because of internal gains and storage of heat in the building fabric. The high thermal specification for the dwellings also means there is likely to be approximately 2000 hours per year when heating and cooling demands are zero. This is good for the residents who will benefit from low energy bills, but makes life difficult for the energy supplier.

The maximum cooling demand is about 1 MW and was originally intended to be mainly covered by the mine water with the heat pumps running in reverse mode.

The four heat pumps in the Heerlerheide energy centre have a combined peak capacity of 700 kW, and are able to supply up to 80% of the annual heat demand. The remaining 20% heat demand is supplied by gas-fired condensing boilers. With a total capacity of 2.7 MW these also provide full back-up for the system.

With the mine water providing substantial pre-heating, the heat pumps are required to provide only a small temperature increase. This enables the heat pumps to work very effectively, with a high coefficient of performance (COP). Specifically an average COP of 5.6 is anticipated, potentially rising even higher under the most favourable circumstances.

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**Fig 6.6: Annual load-duration curve Heerlerheide**

**Fig 6.7: Heerlerheide redevelopment birds-eye view**
For anyone wishing to examine the potential for a mine water energy system there are a number of important issues to address, including:

**Technical**
- How big is the mine water resource?
- Is the mine water resource accessible?
- Is there a thermal demand nearby?
- How well can the thermal demand be matched to the available supply?

**Community**
- Are all community stakeholders fully informed and 'on-board'?
- If not what is the strategy for bringing this about?

**Legal**
- Who owns the minewater?
- Who has responsibility for the minewater?
- What licences are necessary?

**Economic**
- What is the capital cost?
- What is the running cost?
- Is there a financial return over the life cycle?
- Can the likely increases in energy costs over the long-term be considered?
- Are the sources of finance able to take a long-term view?

**Organisational**
- Are the developers ‘on-board’?
- What organisational structure could deliver such a scheme?
- Negotiating with energy companies
- Who will take on the risk of such schemes?

**Environmental**
- Is there a flooding problem?
- Is there a pollution risk?
- Could the scheme alleviate these problems?
08 Using mine water – lessons so far

The Minewater Project will reveal if this innovative idea is feasible on a large scale. "There is still is a long way to go, but every step – like reaching the drifts – brings us a bit closer to success," Alderman (of Heerlen) Riet de Wit says.

The principal lessons emerging from the Minewater Project include:

- Abandoned and flooded mines can be reused to contribute as a new sustainable energy supply for heating and cooling of buildings. The Minewater Pilot in Heerlen shows that mine water can be part of an integrated approach that also includes the design of the buildings. Specifically the buildings and their services need to be capable of utilising low temperature heating (e.g. through underfloor heating) and high temperature cooling.

- The wells and end-users should be located as close as possible, thus avoiding necessary permits (archaeological, flora and fauna, civil infrastructure) and minimising costs for the pipe infrastructure.

- The balance between types of buildings and their tenure (e.g. social housing, private housing, commercial buildings) influences the economics and thus feasibility of the project, so needs to be taken into account properly at an early stage of the project.

- Projects of this magnitude inevitably pose risks, particularly when assessed in conventional financial terms. It is essential to consider the widest perspective when assessing the project including environmental and social benefits. This is not easy because attributing explicit financial value to these issues is not an exact science.

- The value and thus success of mine water projects predominantly depends on an integrated approach to the different related aspects. Projects should stick to this broad concept at all times, from initial decisions regarding the development through to negotiations with ESCOs.

- Attitude to sustainability is important. The success of the project depends on the successful engagement and flexible approach of the major stakeholders from the beginning. An effective marketing strategy is essential in order to secure this, explaining concepts such as district heating and low exergy, as well as the innovative nature of the mine water concept itself.

- The opinions of local end-users need to be taken into account at a very early stage of the project. It is best to start communication and explanation of the mine water project right at the beginning. Previous local experiences are ‘mines’ of valuable information.

- Projects of this nature are inevitably complex, possess a variety of ‘unknowns’, and present unforeseen hurdles as they progress. It is important to reach a certain critical mass and momentum, with all the involved parties on board and motivated. Although new problems and remaining risks should not be ignored, it then becomes desirable to focus on opportunities rather than hurdles.

- Legal issues have sometimes proved to be confusing, ambiguous and inconclusive. The project team feels this is best dealt with in a pragmatic way, focusing on the opportunities to make the use of the heat of the minewater possible.

- Reducing the risk of project plans changing during the execution of the project, will reduce the risk of losing funding. Unfortunately this can be very difficult to achieve.

- Exploiting the opportunity of using the mine water is easier if it fits in with both political and social aspirations. Currently, for example, the timing is ideal because environmental drivers are very strong at local, national and international levels.

- Timing of the phases in project development is also important. If these are not favourable, financial constraints can become the major influence instead of the project itself being the driving force itself ‘surfing the waves of society’.

- The Minewater Project is a renewable energy project. However, it cannot be successful without the positive participation of experts in other fields eg mining authorities and local mines knowledge, drilling companies with the right skills and machinery.
Appendix A: Community and heritage at the pilot locations

Heerlen

Coal mining is the root of the city of Heerlen. Before the mines came to the area there was a network of small villages separated by farmland. Today the city is using 21st century technology to revitalise an area that has suffered decades of neglect.

Heerlen’s history starts at the end of the nineteenth century, and the impact of mining is still very visible in the landscape of the whole area. The mines were closed relatively early, because of competition from the Dutch gas industry in Groningen, and cheaper production facilities in other countries. The city is still recovering from the impact of the closure of the mines; but a new energy market is starting to develop on the ruins of the old mines.

Until the end of the 19th Century the province of Limburg was mainly an agricultural area with small villages separated by farmland and little water creeks. Coal mining was practiced for centuries, but was only technically feasible through shallow pits in areas where the coal layers reached the surface. Many concessions to extract coal were given to small entrepreneurs under the (originally French) mining law from 1815. Investment, however, was very high and the names of many of the early concession areas illustrate the way that speculation dominated production – ‘Proserpina’, ‘Limburgs Toekomst’ (future of Limburg) and ‘Concordia’. This changed in 1911, when the Dutch State bought their concessions for the large amount of almost 2 million Dutch Florins.

The Staatsmijnen (state mines) started their activities in 1902. The first office was the living room of the first Director and some rented rooms in the village of Heerlen. The challenge was to drill almost 200 metres through the carboniferous stone layer. Loose sand layers made this job even more challenging.

Several mineshafts were made between 1902 and 1907, and in 1916 the first useable coal was distributed in the Netherlands. However, it was very difficult for the Dutch mining industry to be competitive on the world market. The Netherlands had no tradition of protecting the home market, and markets in the US, Germany and the UK were difficult to access. To compete, the Dutch mines had to be very innovative and cost-effective.

Mine workers had to be brought in from other countries during the early years; while highly educated engineers and mine managers were recruited from Holland, which had a mining university in Delft with a very good reputation. The people for the heavy work came from all over the world, but many were also recruited from the local agricultural communities. They became the ‘koempels’ – the local word for mineworker.

Social life in the new mineworkers’ villages was organised by the mines and the traditional Catholic Church together. The society was organised with strict rules according to a fixed hierarchical system. For the local community the mines and the service-providing companies were the past, present and future, offering on the one hand income, social stability and safety, and on the other hand a one-way route towards hard labour without a chance to escape.
When there were strikes in the UK during the Depression of the 1920s, the Dutch State mines continued to be productive. In the 1930s the production of the mines increased, with less workers earning less money. After World War Two the Dutch mines flourished along with the economy; building a new society on the ruins of Europe. However, in 1959 the production of gas in the north of the country heralded the beginning of the end of the coal industry in the Netherlands. In 1965 Joop den Uyl (Minister of Economic Affairs) visited Limburg carrying the message that the mines had to be closed. He promised new work for all miners.

The mines were closed one after the other and new enterprises were founded. Many of them were not ready for the competitive markets and survived only two or three years. The miners lost their jobs, and the villages around Heerlen lost their economic basis.

After the closure of the mines Heerlen became a shrinking city. The economy did not offer enough jobs to prevent young people from leaving the city.

The Domesday scenario was that second-rank companies and illegal trades would dominate the image of the city and thus accelerate the shrinking process – Parkstad Limburg was heralded as the ‘green’ alternative:

- The old mining villages will be transformed into neighbourhoods in a green network of farmland and natural areas.
- The neighbourhood around the railway station – for years the symbol of deterioration, with drugs addicts in dark empty streets – will be renovated in an ambitious plan to create a new centre for the old villages.
- There are plans to attract new economy companies to a combined German/Dutch trade area exactly on the border of both countries.

Against this background Heerlen is taking the bold step to reuse the old mine shafts for the heating of the new or renovated buildings.
At the end of the Nineteenth Century the big Lanarkshire companies expanded to the east. Smaller family businesses could not match these aggressive entrepreneurs, and one by one they were swallowed up or amalgamated with others to form local coal companies. It was only in the Twentieth Century that the small-scale coal industry in Mid- and East Lothian became one of the centres of Scottish coal mining industry.

In 1947 the National Coal Board took control of the pits. In order to meet the needs of post-War industry, the Coal Board looked for new coal resources and found these in the Esk Basin. The small villages in Midlothian suddenly grew, with a large influx of people from the west. The County Council faced both housing and social problems. New showpiece pits at Bilston Glen and Monktonhall were among many other new mines in the area. Since closure of the mines there is now a large area of brownfield land around the site itself, but all the colliery buildings have been demolished and the site has been levelled. There is considerable vegetation covering the site; some of it having been planted to screen operations while the colliery was working, and some natural growth.

The monks of Newbattle Abbey are known to have been digging coal from the ground in the Thirteenth Century. After the Reformation and the dissolution of the monasteries (1536-1540), mining was taken over by the big landowners. They developed the pits as commercial enterprises. Thanks to coal, the Forth Estuary became one of the busiest trading areas in the British Isles and a centre of the salt industry.

The pits and salt pans were dangerous and unpleasant places. To make sure that there were enough people to do the work, the Scottish Parliament passed a law in 1606 that tied colliers and salters to their overlords – like serfs or slaves. The law was not repealed until 1799, and it affected the relationship between landowners and miners long after.

The iron industry came to Lanarkshire when hot blast smelting was invented. Coal fuelled this new industry, and thousands of miners were needed. Many of the jobs were filled by Irish immigrants and other European refugees who were fleeing famine.

In Lanarkshire and West Lothian the new booming business created a revolution in the old master/slave relationship. In Midlothian and East Lothian the old order held sway. The old landowners operated cartels to keep prices artificially high. The city of Edinburgh’s answer was to build the Union Canal to bring in coal from the west.

In 1840 a Parliamentary Commission found many women and children being used to carry huge loads of coal out of the steep mines in the central and eastern region, but they found hardly any in the western region. They criticised this remnant of slavery and new legislation in 1842 banned women, and girls and boys under ten from working underground.

Coal has been mined in Midlothian for centuries. The industry brought prosperity for some, but working conditions for miners were tough and dangerous. Now the region faces a cleaner, ‘greener’ future...

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At first the Coal Board was welcomed by miners, but this changed rapidly when the economy changed during the late 1950s and the 1960s. Small pits were shut first and closures in Midlothian had cost 5000 jobs. Through the 1970s Bliston Glen and Monktonhall kept output high, but the closures continued until, by the time of the last great national strike in 1984, they were all that was left.

Monktonhall burst briefly into life again in 1992 and survived for another five years.

The remains of the former pit of Monktonhall are situated beneath the centre of the new development plan – Shawfair. In considering the mine water concept, the vision was that Monktonhall could symbolise the transformation of Scotland’s ‘black diamonds’ into a sustainable new energy source for the Twenty-first Century.

This disused mine is now flooded, and the water temperature varies from 13°C-35°C. The flooding is a hazard, and without careful management, the mine water could cause subsidence, flooding and damage to properties. Using the mine water to heat buildings would help to avoid these problems, but it could have had other benefits.

Over the next 15 years, some 4400 homes and 30 hectares of commercial development will be constructed at Shawfair. This development involves a wide range of organisations, including the local authority (Midlothian Council), other public agencies, private developers and the local communities.
Additionally, the project has numerous observers. These observers are professionals and/or interested parties located in Europe. Clearly, their involvement exemplifies the significance of the project of a European level. The observers include:

- Geothermische Vereinigung e.V. (Germany)
- Stichting Platform Geothermie (the Netherlands)
- LEG Stadtentwicklung GMBH & Co. KG (Germany)
- The Department of Fundamental Geology at the University of Silesia (Poland)
- Energie-Cités (France)
- TNEI Services (United Kingdom)
- Bureau de Recherches Géologiques et Minières (BRGM, France)
- Senter Novem (the Netherlands)
- The Vlaamse Instelling voor Technologisch Onderzoek (VITO, Belgium)
- The Province of Limburg (the Netherlands)
- The Geological Institute at the Bulgarian Academy of Sciences (Bulgaria)
- The Faculty of Technology
- Policy and Management Economics of Infrastructure at the Technical University in Delft (the Netherlands)
- The Department of Civil Engineering and the Department of Mine Engineering at Leuven Catholic University (Belgium)
- Faculté Polytechnique De Mons (Belgium)
- Fraunhofer Institut Bauphysik (Germany)
- Applied Geophysics at Aachen University (RWTH, Germany)
- Fachhochschule Bochum (Germany)
- University of Wageningen (WUR, the Netherlands)
- The Dutch Open University (OU, the Netherlands)

Further Information
The Minewater Project website can be found at www.minewaterproject.info