The Mine Water Project Heerlen, the Netherlands - low exergy in practice

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SUMMARY

In Heerlen, the Netherlands, warm and cold water volumes from abandoned mines is used for heating and cooling of buildings, based on a low exergy energy infrastructure. The combination of low temperature heating and cooling emission systems, advanced ventilation technologies and integrated design of buildings and building services provide an excellent thermal comfort and improved indoor air quality during 365 days/year, combined with a CO2 reduction of 50% in comparison with a traditional solution.

INTRODUCTION

Abandoned and flooded mines have a high potential for geothermal utilization as well as heat cold storage of water volumes in remaining underground spaces. The use of heat and cold from mine water is one of the important aspects of rational and sustainable utilization of post mining infrastructure and may bring positive socio-economic results, social rehabilitation and improved health for communities living in European areas with (former) mining activity. In Heerlen, the Netherlands, the redevelopment of a former mining area, including a large scale new building plan, is being realised with a low exergy infrastructure for heating and cooling of buildings, using mine water of different temperature levels as sustainable source. Mines have large water volumes with different temperature levels. In Heerlen the deeper layers (700 – 800 m) have temperatures of 30 – 35^0 C; shallow layers (200 m) of 15- 20^0 C. These water volumes can be considered as heat/cold storage as well as geothermal sources. Most crucial however is that these sources provide low valued energy (low exergy). As on the demand side heating and cooling for buildings also require low valued energy the intended design strategy is to realise the climatisation of the buildings in this pilot directly by mine water. The combination of low temperature emission systems with advanced ventilation technologies and integrated design of buildings and building services provide an excellent thermal comfort for 365 days a year, including sustainable heating and cooling and improved indoor air quality. This sustainable energy concept gives a reduction of primary energy and CO_2 of 50% in comparison with a traditional concept (level 2005).The project is funded by EC Interreg IIIb, the UKR program of the Dutch ministry of Economic Affairs and the EC FP6.

THE ENERGY CONCEPT

The mine water energy concept in Heerlen is in principle as follows. Mine water is extracted from different wells with different temperature levels. In the concession of the former ON III mine (location 1 Heerlerheide) mining took place to a level of 800m. In this concession the warm wells (30^{0}C) can be found. In the former ON I mine (location 2 Heerlen SON) mining took place to a level of 400m and here the cold wells are situated. The extracted mine water is transported by a primary energy grid to local energy stations. In these energy stations heat exchange takes place between the primary grid (wells to energy station) and the secondary grid (energy station to buildings). The secondary energy grid provides low temperature heating (~ $35^0 – 40^0$ C) and high temperature cooling ($16^0 - 18^0$ C) supply and one combined return (20^0 - 23^0 C).

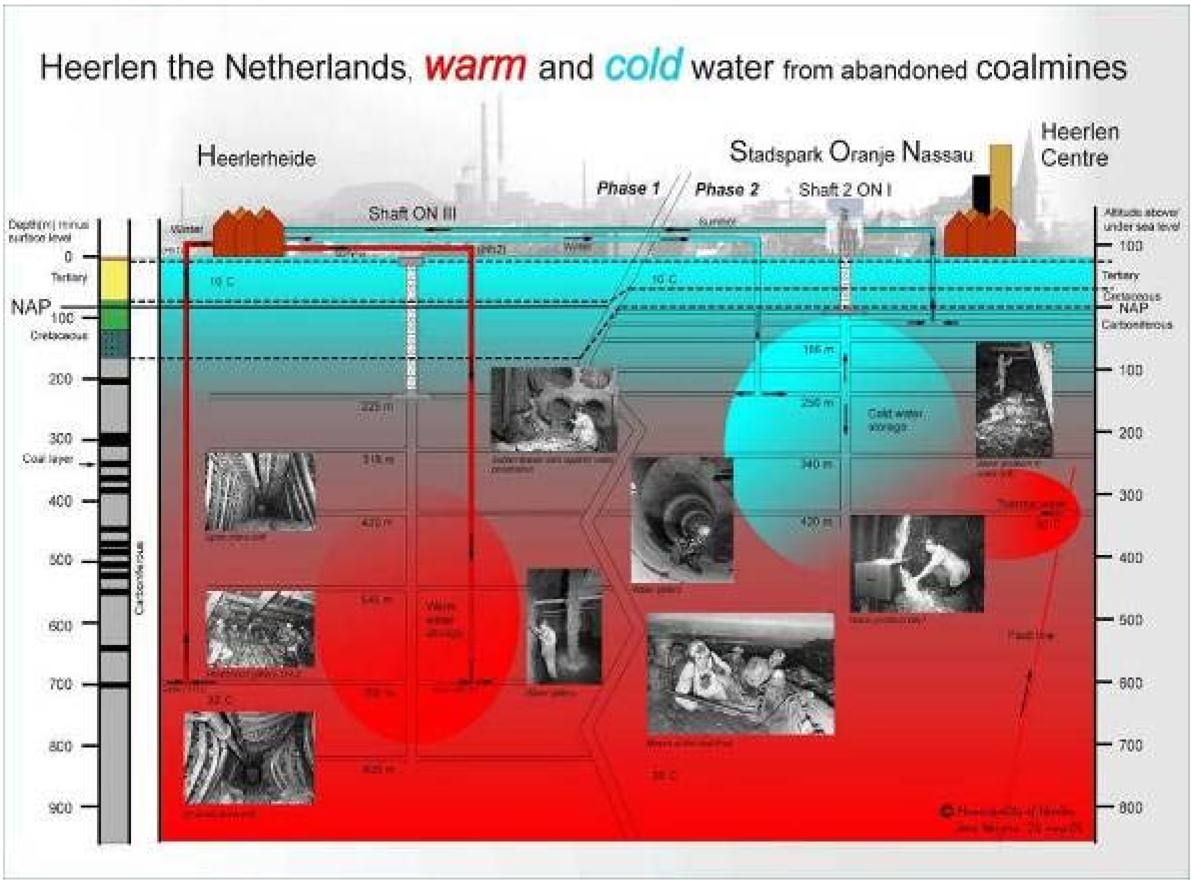


Figure 1. Schematic cross section of the underground conditions of the ON I and ON III mines

The two locations 1 and 2 are connected by a pipeline. Warm water is partly transported from location 1 to 2 and, visa versa, cold water is partly transported from location 2 to 1. Return water of 22 to 23^0C is transported to an intermediate well (400m). The temperature levels of the heating and cooling supply are "guarded" in the local energy stations by a polygeneration concept existing of heat pumps in combination with gas fired boilers and CHP on (preferably) on biomass in combination with local storage tanks. The (biomass fired) CHP provides the electricity to power the heat pumps but also the higher temperature levels (65 – 70^0C) for domestic hot water and peaks during extreme conditions. As, by this integral approach, the demand profile of DHW is almost equal to electricity, the CHP can be designed in the most economic and energy efficient way. The surplus of heat in buildings (for example, in summer, cooling, process heat) which can not used directly in the local energy stations can be lead back to the mine water volumes for storage. If necessary local sub-energy stations in buildings for preparation of DHW by heat pumps, small scale CHP or condensing gas boiler, depending on type of building and specific energy profile. The total system will be controlled by an Intelligent Energy Management System including telemetering of the energy uses/flows at the end-users. A scheme of the total concept is given in figure 2.

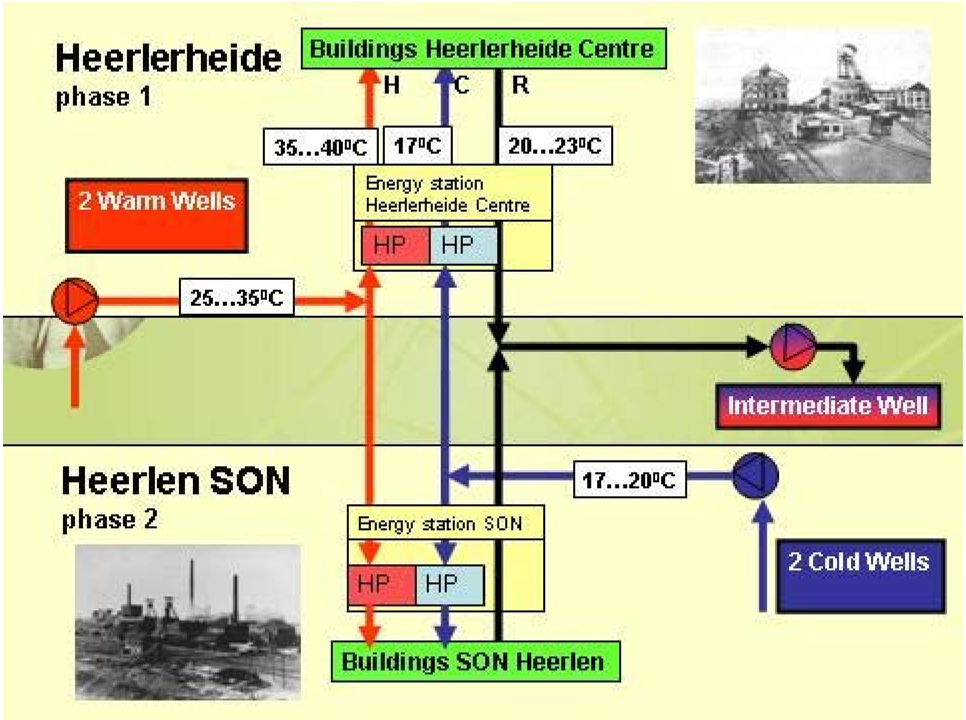


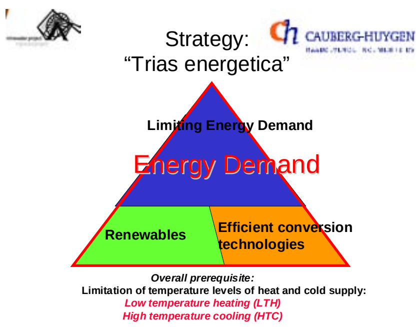
Figure 2. Schematic view of the energy concept in Heerlen, connection of the wells and energy stations

INTEGRATED DESIGN APPROACH VERSUS TRADITIONAL APPROACH

The present development of energy efficient buildings in an increasing way requires an integral design approach. A couple of decades ago energy efficient design and building mostly focussed on improving a certain technique or apparatus. Nowadays an energy efficient building, supported by an energy efficient installation, has to be combined into one integrated energy efficient concept with an optimal performance in terms of indoor climate, thermal comfort, user’s satisfaction etc. This asks for an integral design approach in which well balanced choices are being made. This means that in sustainable building projects it is crucial to consider the design and realization of the sources, the heat generation (especially with non-traditional solutions such as heat pumps, cogeneration, heat/cold storage) distribution and emission together including all possible interactions with the building, building properties and building users. Only this approach can lead to a set of well defined performance criteria concerning energy performance, sustainability, indoor air quality, thermal comfort (365 days/year, winter and summer conditions), and health. Next to it is necessary to have specific emphasis on investments and energy exploitation, as well as communication to the end-users. A traditional approach is often based on partial optimization of the different disciplines. An integrated approach will achieve a total optimization, taken into account all disciplines and their interaction. Basis is a set of unambiguous well defined performance criteria. The design strategy applied in this approach is the so called Trias Energetica. It is a three step approach that gives a strategy to establish priorities for realising an optimal sustainable energy solution. The approach is introduced in 1996 by Novem the Netherlands and has been further worked out by the Technical University of Delft the Netherlands, containing the following steps:

Step 1: Limitation of energy demand
Step 2: Maximising share of renewables
Step 3: Maximising efficiency of using fossil fuels for remaining energy demand

With as overall prerequisite: limit the temperature levels of heat and cold supply (conform 2nd law of thermo dynamics)



In general the heating and cooling of buildings can be realized with very low valued energy, with medium temperatures close to required room temperatures. The better the building properties (extreme high thermal insulation, suitable emission systems) the closer the temperatures of heat an cold supply can be to room temperatures. In order to utilise these extreme moderated temperatures for heating and cooling the buildings must comply to a number of boundary conditions such as:

- Limitation of heat losses ($U_{envelope} < 0.25$, $U_{windows} < 1.5$)
- Limitation of ventilation losses and peaks by air tight building (n50 < 1.0), mechanical ventilation with heat recovery or state of art demand controlled hybrid ventilation systems
- Limitation of solar and interal gains to limit cooling loads, integrating shading and sun blinds in architectural design
- Application of combined low temperature heating and high temperature cooling emission systems, (thermally activated building components, floor and wall heating).

Technologies for low temperature heating and high temperature cooling are available on the market an are described for example in the IEA Annex 37 Guidebook (www.lowex.net)
For some functions higher temperatures will be necessary such as domestic hot water. Also lower temperatures can be necessary for certain functions (high cooling loads for some types of buildings, some processes, etc.). Another aspect to be taken into account is that the use of geothermal energy and heat/cold storage as such does not cover electricity use/sustainable electricity generation. Therefore additional sustainable solutions have to be taken into account. Sustainable electricity generation can be realized by cogeneration (such as biomass CHP). This combination can also deliver higher temperatures for DHW.

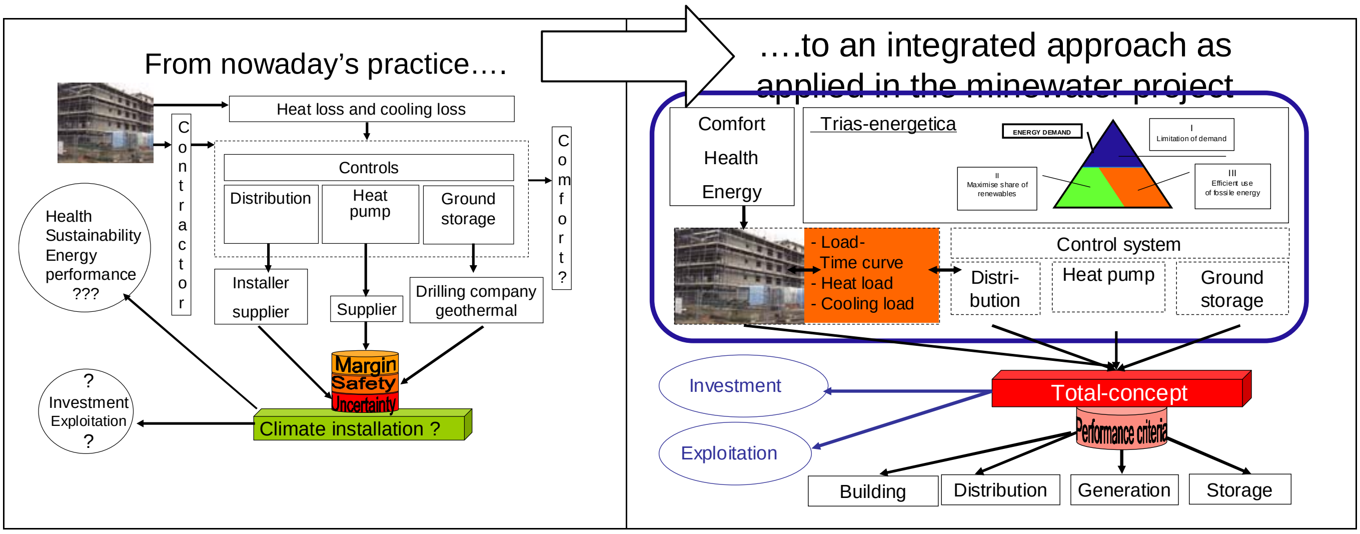


Figure 3. From a traditional to an integrated design approach

THE DEMONSTRATION LOCATIONS

1 Location Heerlerheide Centre:

This plan is situated on the concession of the ON III pit in a relatively deep mined area with warm wells ($30 – 35^0$). The plans include the following activities for ***new buildings:***

- 33.000 m^2 (330) dwellings (single family dwellings and residential buildings)
- 3800 m^2 commercial buildings
- 2500 m^2 public and cultural buildings
- 11500 m^2 health care buildings
- 2200 m^2 educational buildings

The first new building and construction activities in Heerlerheide Centre have started in 2006. The total plan will be realised between 2006 and 2008. All planned buildings will be connected to the energy supply (heating and cooling) from mine water. All these buildings are planned in a very compact area which is very favourable for energy distribution. The building location is situated between two potential wells. This means that the length of the transport lines between the wells and the energy station is limited. Next to it, the planned building functions require heating as well as cooling. The location of the wells has been determined as a result of geological research. The drilling of the wells took place from February to June 2006. The two warm wells and the primary net (i.e. the connection between the two wells) was completed in June 2006, followed by a successful testing in July. The energy supply includes the building of an energy station and a small scale distribution grid from this station to the buildings. In the energy station the mine water is brought to the necessary heating and cooling levels by heat pumps. In order to facilitate the process and to guarantee all real estate developers, involved in this building plan, the delivery of energy to the buildings the main investor, Housing Corporation Weller, is realising the exploitation of the energy supply, including the building and construction of the energy station and distribution grid. The liberalised energy market in the European Union makes it possible for housing corporations to exploit the energy supply for their buildings. It is important to realise, that with minor modifications this energy supply can also be functional and operational without the application of mine water. In that case the heat pumps will be connected to closed loop ground heat exchangers (separate bore holes). Although this option is less energy efficient in comparison with the use of mine water as source this will be still much more energy efficient then the traditional option with condensing gas-fired boilers and electrical cooling devices for air-conditioning.

	
Old situation Heerlen, location Heerlerheide	New situation

Figure 3. Impression of location 1 Heerlerheide

2 Location SON (Stadspark Oranje Nassau)

This area is situated on the concessions of the ON I pit. This is a relatively shallow mined area (200 – 400 m) with cold and intermediate wells. There for this area is connected with a master connection to the warmer wells in the ON III area (Location Heerlerheide). Cold form the ON I area is transported to Location Heerlerheide Centre. The development of Stadspark Oranje Nassau has a strategic significance for the social and economical rehabilitation of Heerlen. This plan will offer an opportunity to improve the image of Heerlen, to develop new economical opportunities and to enhance and stimulate the existing (but poorly functioning) activities inner city of Heerlen. This plan will be realized in combination with sustainable mobility and accessibility. The total programme contains the realisation of approximately 100.000 m^2 of new buildings (offices, shops, residential, school and a hotel) and the renovation of a large existing office building (43.500 m^2) of the Dutch Central Office of Statistics.

3. Location Heerlen centre ABP head office

This location concerns the retrofitting of the ABP head office of 41.000 m^2. ABP is the pension fund for employers and employees in service of the Dutch government and the educational sector. The total building envelope is retrofitted to a level better then the current Dutch Building Decree values for new buildings. The minewater is used for comfort heating and cooling (i.e. low temperature heating and high temperature cooling in all offices). The ABP building will have a direct connection to the minewater wells and will have its own energy station to provide the required temperature levels for the distribution net. The energy station will have heat pumps. The emission systems in the offices are climate ceilings. Special glazing will be used to limit solar radiation in summer; this makes it possible to use high temperature cooling (in most of the time direct from minewater).

Maankwartier (Moon Quarter)

Renovation of the CBS office

Figure 4. Impressions of location 2 Stadspark Oranje Nassau (SON)

BALANCING SUPPLY AND DEMAND SIDE

For the elaboration of the final energy concepts following questions should be answered:

- total heating and cooling demand, how to control and limit this demand
- the target values for percentage of renewables in total energy demand
- what is the available amount of renewable energy form mine water (i.e. how much water can be extracted) and other renewables
- what is the most efficient conversion technology for the (not sustainable) back-up system.

This input is necessary for the integrated design process including building, sources and energy systems, distribution and emission systems. An important tool for the assessment of this process and balancing demand and supply side is the so called energy profile of a building, expressed in a so called load-duration curve, based on dynamic calculations (using TRNSYS) of the energy demands of the buildings. This curve is a profile representing the energy demand over a total year, including heating and cooling. This curve also provides a good indication of the maximal capacities for heating and cooling as well as the balance between heating and cooling demand. Important for balancing the supply and the demand side is the tuning and balancing between the cold and heat sources, in this case, the deep (warm) and shallow (cold) wells. This assessment takes place in relation to the required temperature levels, the yearly extracted volumes and the energy demands of buildings; this in relation to the available water volumes in the reservoirs. The load duration curves give important information about:

- the balance between cold and heat demands,
- the effect of optimisation (for example limiting heat losses by thermal insulation or heat recovery, etc.)
- the way how to limit the installed capacity of heat pumps, CHP and other heat generation, and , on the other hand, how to increase the number of operation hours, in combination with storage, to increase the efficiency and to decrease investment costs. Also thermal impact on the ground is made visible and can be assessed.

In order to establish a balance between the rational use of energy needs on the building side and the renewable energy supply a total annual heat-load duration curve of the total building plans in Heerlerheide Centre and SON is calculated by dynamic simulations with TRNSYS. In figure 5 the heat-load duration curve for Heerlerheide (location 1) is shown.

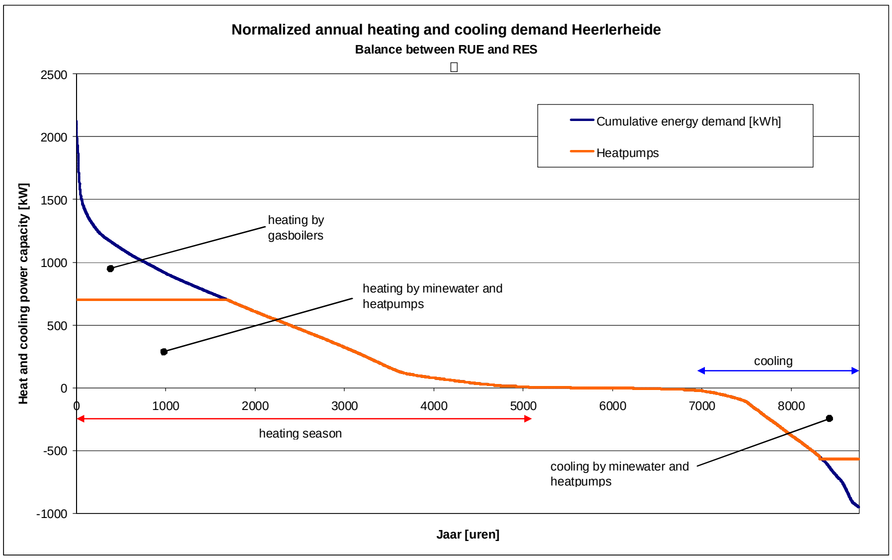


Figure 5. Load-Duration Curve for location 1 Heerlerheide

FEASIBILITY BY PRIVATE ORGANIZED ENERGY EXPLOITATION

Despite the rather high level of investments for the energy installations and buildings measures this concepts is economically feasible by private organized energy exploitation. In this case, the main investors will also organise the energy exploitation, i.e., in separate private owned Energy Exploitation constructions). These private organized companies can use lower internal interest rates, 6 to 8% instead of the usual 15% of utilities and district heating companies. The main reason is that profits from selling energy is not considered as core business. By establishing connection fees for heating and cooling and avoiding a gas infrastructure on building/dwelling level, as well as avoiding extra cooling installations, these constructions offer possibilities for economical sound energy exploitation. Economical benefits will also occur because of the integrated design and especially combining heating and cooling in the same emission system (i.e. floor heating and cooling, thermally activated building components etc.). Using these combined emission systems avoids the investment costs for a separate cooling system

CONCLUSIONS

Abandoned and flooded mines can be reutilized for a new sustainable energy supply for heating and cooling of buildings. The minewater project in Heerlen shows that temperatures of 28 – 30 ^{0}C can be found at 700 m and 16 -17 ^{0}C at 200 m. These temperatures can be used for heating and cooling of buildings if these buildings are very well insulated, have energy efficient ventilation systems and have emission systems suitable to operate with moderated temperatures like floor heating or concrete core activation. Despite the rather high investment costs such projects can be economical profitable avoiding additional cooling systems and by integrated design and if energy exploitation is organised by the investors.

ACKNOWLEDGEMENTS

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