The Minewaterproject Heerlen - low exergy heating and cooling in practice

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SUMMARY

In Heerlen, the Netherlands, warm and cold water volumes from abandoned mines will be 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 CO_2 reduction of 50% in comparison with a traditional solution.

1. 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 minewater 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 minewater 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°C; shallow layers (250 m) of 15..20 °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 preferably directly by minewater. 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.

2. THE ENERGY CONCEPT

The minewater energy concept in Heerlen is in principle as follows. Minewater is extracted from four 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 800 m. In this concession the warm wells (~ 30 °C) can be found. In the former ON I mine (location 2 Heerlen SON) mining took place to a level of 400 m and here the relatively cold wells are situated. The extracted minewater 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 °C – 45 °C) and high temperature cooling (16 ..18 °C) supply and one combined return (20..25 °C) to an intermediate well.

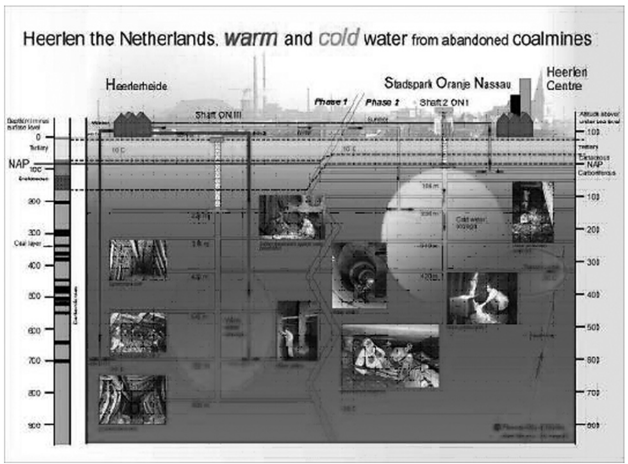

Figure 1. Schematic cross section of the underground conditions of the ON I and ON III mines

The five well locations and energy stations will be connected by a three pipelines of 7 km each. Warm water is transported from the warm wells at the north and cold water is transported from the shallow wells at the southern region to the energy stations. Return water of 20..25 °C is transported to an intermediate well (450 m). The temperature levels of the heating and cooling supply are "guarded" in the local energy stations by a polygeneration concept existing of electric heat pumps in combination with gas fired high-efficiency boilers. The surplus of heat in buildings (for example, in summer, cooling, process heat) which can not be used directly in the local energy stations can be lead back to the minewater volumes for storage. DHW is prepared in local sub-energy stations in the buildings 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.

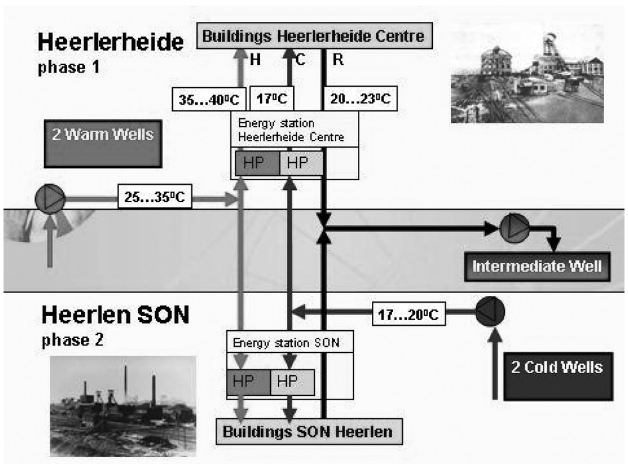

Figure 2. Schematic view of the energy concept in Heerlen, connection of the wells and energy stations

3. 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, containing the following steps (figure 3):

Step 1: Limitation of energy demand

Step 2: Maximizing share of renewables

Step 3: Maximizing 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).

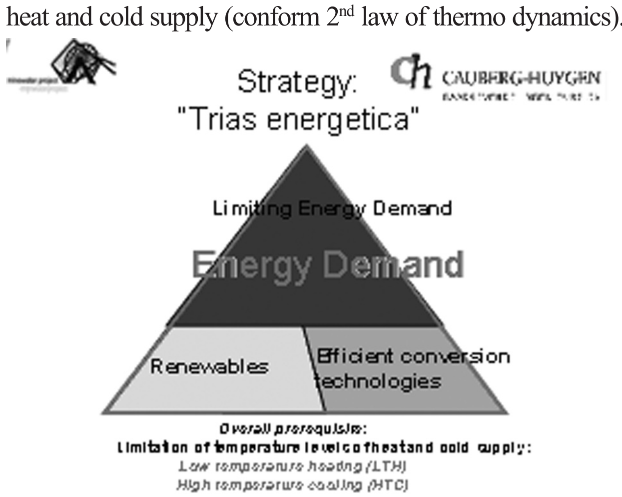

Figure 3. Trias energetica

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, high air tightness and a 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 ($U_{envelope} < 0.25$ W/m^2.K, U_{win-}

$_{dows}$ < 1.5 W/m^2.K)
- Limitation of ventilation losses and peaks by air tight building (n50 < 1.0), mechanical ventilation with high efficiency heat recovery or state of art demand controlled hybrid ventilation systems
- Limitation of solar and internal 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). 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, dehumidification of supply air 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.

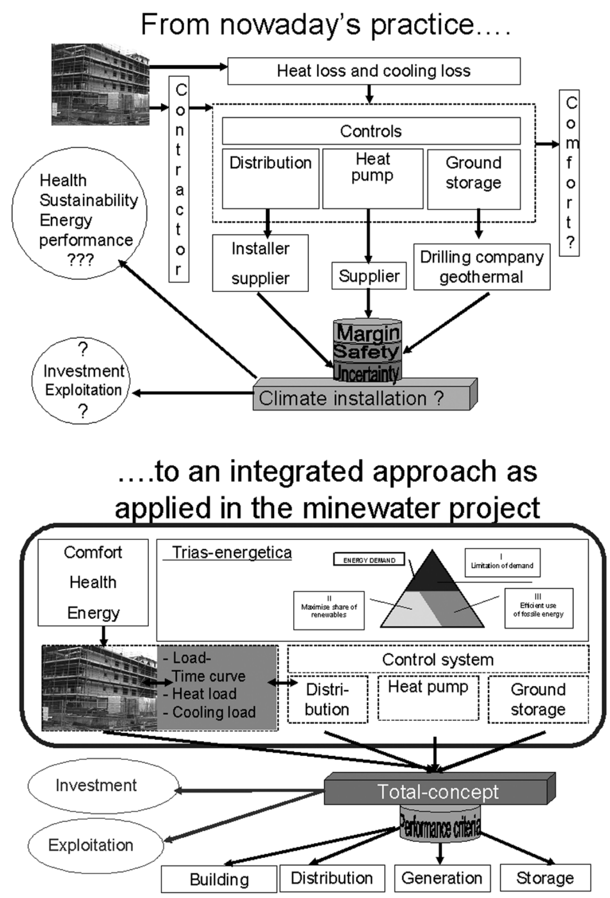

Figure 4. From a traditional to an integrated design approach

4. THE DEMONSTRATION LOCATIONS

There are three main demonstration locations:
- Heerlen Heerlerheide Centre
- Heerlen centre SON (Stadspark Oranje Nassau)
- Heerlen centre ABP head office

The locations at the centre of Heerlen are assumed to participate in the Minewaterproject, while Heerlerheide Centre is already "minewaterproof" at this moment.

4.1 Location SON

The development of Stadspark Oranje Nassau has a strategic significance for the social and economical rehabilitation 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.

4.2 Location ABP head office

This location concerns the *retrofitting* of the ABP head office of 41.000 m^2. The total building envelope is retrofitted to a level better then the current Dutch Building Decree values for new buildings. The minewater will be 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).

4.3 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 °C). The plans include the following activities for *new buildings:*
- 33.000 m^2 (330) dwellings (single family dwellings and residential buildings)
- 3.800 m^2 commercial buildings
- 2.500 m^2 public and cultural buildings
- 11.500 m^2 health care buildings
- 2.200 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 2011. Most of the planned buildings will be connected to the energy supply (heating and cooling) from minewater. All these buildings are planned in a very compact area which is very favourable for energy distribution. The building location is situated between two warm wells. Next to it, the planned building functions require heating as well as cooling and warm water supply. The location of the wells has been determined as a result of geological research. The drilling of the warm wells took place from February to June 2006. The two warm wells and the first primary net (i.e. the connection between the two warm wells) was completed in June 2006, followed by a successful testing in July (Laenen, Amann – Hildenbrand, Van Tongeren, 2007; Swart, 2006). The cold wells in the southern region are drilled from August to October 2007 (Van Tongeren, Amann – Hildenbrand, Daneels, 2007). 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 minewater 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. It is important to realise, that with minor modifications this energy supply can also be functional and operational without the application of minewater.

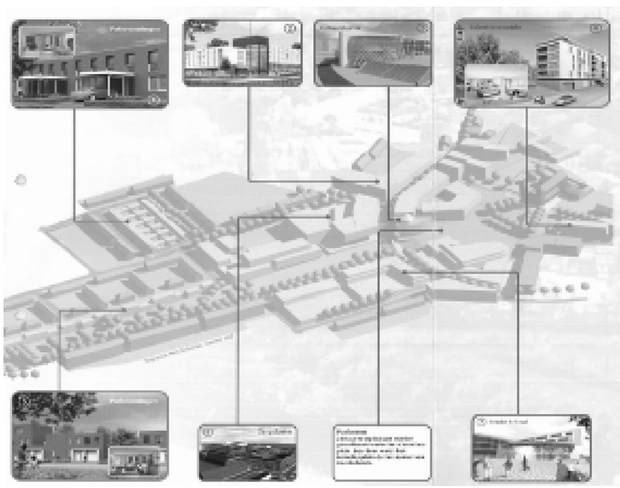

Figure 5. Impression of location Heerlerheide

5. 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 from minewater (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 buildings, 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.

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 6 the combined heat-load duration curve for Heerlerheide is shown.

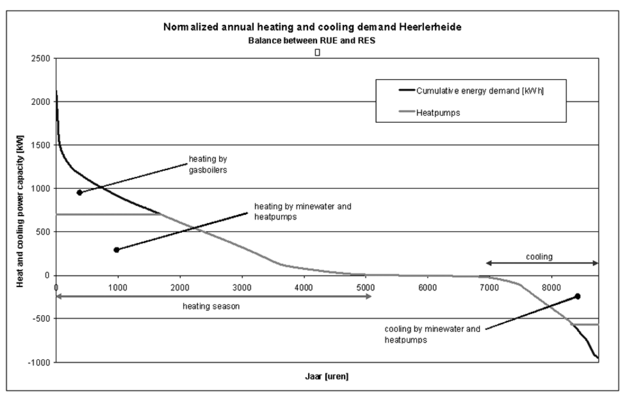

Figure 6. Annual load-duration curve Heerlerheide

The peak heating power is about 2.2 MW; this is about 20 % lower than calculated with traditional heat loss calculations and can be explained by the internal gains and heat accumulation as taken into account only in the TRNSYS calculations. The four heat pumps in the Heerlerheide energy station will have a combined peak capacity of 700 kW_{th} and thus covering up to 80 % of the annual heat demand. Due to the small temperature step, the average COP of the heat pumps is ~ 5.6, but can raise up to 8 under favourable circumstances. A total heating capacity of 2.7 MW gas-fired condensing boilers will be installed as back-up and for peak moments (20 % annual). The heat-load curve also shows a period of ~ 2000 hours/year without any heating or cooling demand. The maximum cooling demand is ~ 1 MW and can be mainly covered by the minewater and inversed heat pumps. The heat and cold of the energy station are supplied tot the individual buildings by district heating. The supply temperature for the floorheating depends on the outdoor temperature and will be maximum 45°C at -10°C outside. The calculated seasonal average supply temperature will be 35°C and thus fit perfectly into the principle of 'very low heating". DHW is prepared by preheating the cold water with the supply for central heating and afterheated to 70°C with condensing high-efficiency boilers. In this way, the minewater heat pumps preheat about 30 % of annual demand for DHW (figure 7).

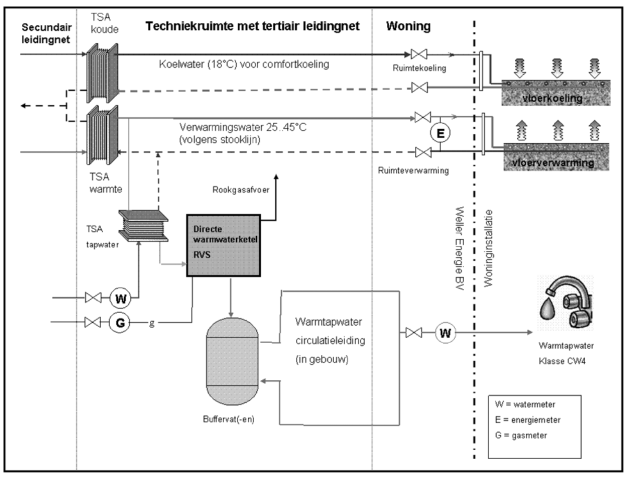

Figure 7: Energy concept Heerlerheide

All the dwellings at Heerlerheide will have floor heating and cooling. This requires good information to the habitants about the typical thermal behaviour of floorheating and –cooling, which means relatively slow response to temperature settings and including the restrictions on tapestry. The ventilation of all dwellings consists of mechanical supply and exhaust with high-efficiency heat-recovery (η = 90 %). Commissioning of these systems is important to get properly functioning HVAC-systems under all circumstances. The lack of a infrastructure for natural gas forces the habitants to electric cooking, a non-traditional solution in the Netherlands.

6. ECONOMIC FEASIBILITY BY PRIVATE ORGANIZED ENERGY EXPLOITATION

Despite the rather high level of investments for the energy installations and buildings measures this concept can be economically feasible by private organized energy exploitation. In this case, the main investors will also organize 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 12 to 15% of utilities and district heating companies. The main reason is that profits from selling energy for these investors is not considered as a 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. The economic value of the heat and cold out of the minewater is expressed in a GJ-price en is determined by three factors:
- the running costs of the minewater company, including electricity for the well pumps and transportation, maintenance, replacements and administration
- the costs of the upgrading of the low valued heat and cold by the heat pumps and gas fired boilers
- the reference energy bill of the end-user as a limit, according to the NMDA-principle (NMDA = maximised price level for end-users, referred to common heating and cooling)

The first en second costs are estimated from the load-duration curves, but can still be influenced by the positive effect of the siphon-principle if any between the wells (this reduces the pump energy of the wells significantly). At the other hand, the end-user will probably compare his energy bill to that of a similar dwelling with conventional heating. The calculations of the reference energy-costs are subject to many discussions and points of view, due to different interests. In basic, for the Minewaterproject 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 to a fixed rate. In this way, the metering costs are avoided, habitants start cooling as early as possible to get a maximum effect out of the limited capacity of the floor cooling and as much as possible heat is returned into the mines (heat storage). In fact, a standard or general tariff for low-exergy cooling is not yet available in the Netherlands. Essential for the economic study is the distinction between the variable and fixed costs. This ratio should be roughly equal for supplier and buyer.

7 .CONCLUSIONS

Abandoned and flooded mines can be reutilized for a new sustainable energy supply for heating and cooling of buildings. The Minewaterproject in Heerlen shows that temperatures of ~30 °C can be found at 700 m; the temperature of the shallow wells is to be expected 16..18 °C at 250 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. Although the pilot has not ended yet and three wells are being drilled at this moment, the project is scaled up to extra buildings and commercial profitable. This requires a reliable and efficient distribution system that lasts for at least 30 years and therefore extra measures have to be taken to prevent scaling and corrosion in the piping. Because of the chemical composition of the minewater HDPE-pipes are selected, which normally last 50 to 80 years. For the not yet fully defined post-pilot period extra measures will be taken like oversized, insulated transportation pipes with leakage detection and a junction of the transportation pipes for warm, cold and return minewater including valves and pumps for flow management. A important recommendation is to locate the wells and end-users as close a possible, thus avoiding necessary permits (archaeological, flora and fauna, civil infrastructure) and costs for the transport pipes. Another main recommendation is to integrate the Low-ex concept already at the first drafts of the building design and keep on convincing the building parties about the concept, of course with regard to the actual building design. A strict separation should be made between the distinct temperature levels for heating, cooling and DHW on the one hand and the seasonal influences at the other hand.

ACKNOWLEDGEMENTS

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