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Geothermal Development of Low Temperature Resources in European Coal Mining Fields, the EC REMINING-Lowex Project

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ABSTRACT

For the last ten years numerous research and commercial initiatives have been undertaken in Europe in relation to development of the low temperature resources in coal mining fields. The most successful of them was the MineWater project in Heerlen, the Netherlands, where low-temperature geothermal district heating system was launched in October 2008. Other projects are carried on in Germany, Scotland and in some other European countries. Continuation of research on utilization of geothermal energy from abandoned mines is a goal of the 6th Framework Program project EC REMINING LOWEX Redevelopment of European Mining Areas into Sustainable Communities by Integrating Supply and Demand Side based on Low Exergy Principles. Four local communities from the Netherlands, Slovenia Poland and Bulgaria participate in the project. The project aims to demonstrate the use of locally available low valued renewable energy sources, specifically water from abandoned mines, for heating and cooling of buildings. The system is based on low energy principles, and is facilitated by an integrated design of buildings and energy concepts. Duration of the project is 5 years (2007-2012).

1. INTRODUCTION

Abandoned and flooded mines have a high potential for geothermal energy utilization as well as heat and 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 energy source. Abandoned mines have large water volumes with different temperature levels. In Heerlen the deeper layers (700 – 800 m) have temperatures of ~30°C; shallow layers (200 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 content). As on the demand side, heating and cooling of buildings also requires 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 (CONCERTOII REMINING-lowex).

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.

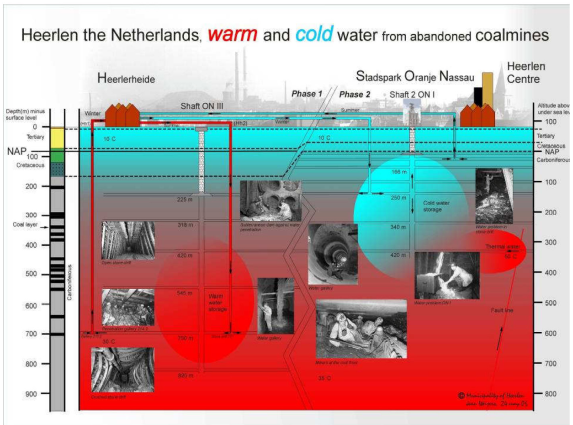

Figure 1: Schematic cross section of the underground conditions of the ON I and ON III mines

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 used directly in the local energy stations can be lead back to the minewater volumes for storage. Domestic hot water (DHW) is prepared in local sub-energy stations in the buildings by heat pumps, small scale combined heat and power (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.

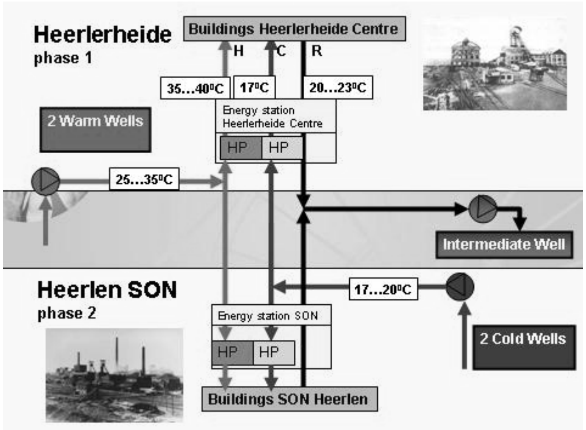

Figure 2: Schematic view of the energy concept in Heerlen, connection of the wells and energy stations

The location of the wells has been determined as a result of geological research. The final determination of the location took place in narrow collaboration with former miners, using their knowledge about the underground circumstances at the time the mines were abandoned. 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) were 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).

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 focused on improving a certain technique or apparatus. Nowadays an energy efficient building, supported by an energy efficient installations, 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:

Step 1: Limitation of energy demand
Step 2: Maximizing share of renewables
Step3: 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).

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 and cold supply can be to room temperatures. In order to utilise these extreme moderated temperatures for heating and cooling the buildings must comply with a number of boundary conditions such as:

- Limitation of heat losses ($U_{envelope} < 0.25$ W/m^2.K, $U_{windows} < 1.5$ W/m^2.K)
- Limitation of ventilation losses and peaks by air tight building ($n_{50} < 1.0$), 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.

4. THE DEMONSTRATION LOCATIONS

There are three main demonstration locations:

1. Heerlen Heerlerheide Centre
2. Heerlen centre SON (Stadspark Oranje Nassau)
3. Heerlen centre ABP head office

4.1 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 °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. All planned buildings will be connected to the energy supply (heating and cooling) from minewater. All 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. 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.

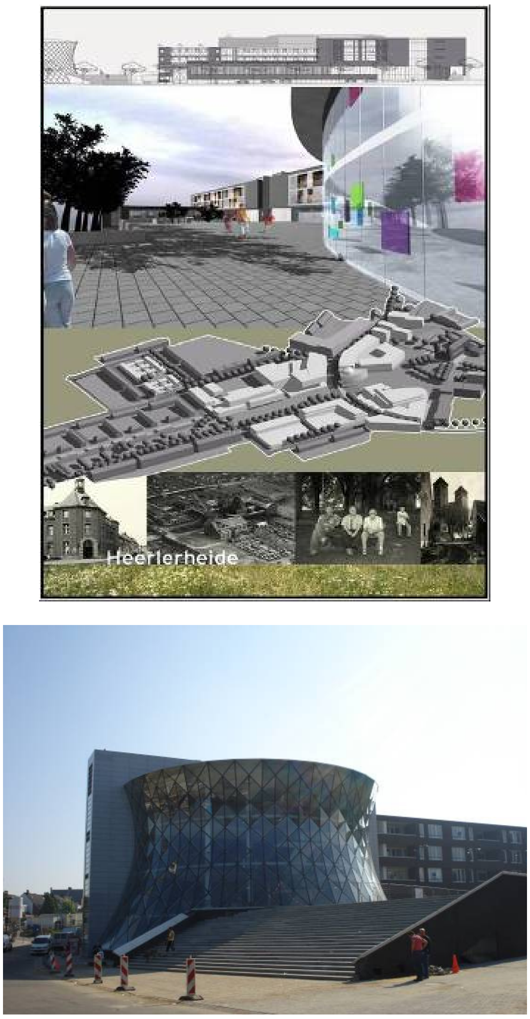

Figure 3: Impression Heerlerheide centre with the completed mine water energy station

4.2 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 new buildings (110 apartments, 14000 m^2 commercial buildings, 4000 m^2 hotel, 19000 m^2 offices), the renovation of a large existing office building (43.500 m^2) of the Dutch Central Office of Statistics (CBS) and the realisation of the new office building of CBS (21.000m^2). The new CBS office is completed in June 2009 and is connected to the minewater grid.

Figure 4: Impression of location Maankwartier

Figure 5: Existing CBS office

Figure 6: New CBS office, completed in June 2009

4.3 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 gains in summer; this makes it possible to use high temperature cooling.

Figure 7: ABP building

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

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 rise 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 floor heating 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 temperature heating”. DHW is prepared by preheating the cold water with the supply for central heating and after heated to 70°C with condensing high-efficiency boilers. In this way, the minewater heat pumps preheat about 30 % of annual demand for DHW (figure 9).

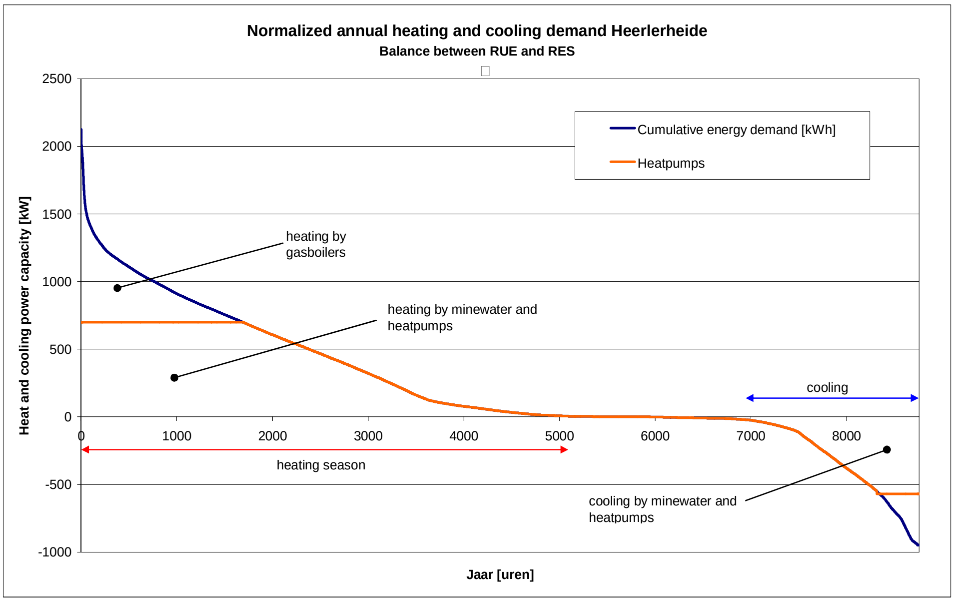

Figure 8: Annual load-duration curve Heerlerheide

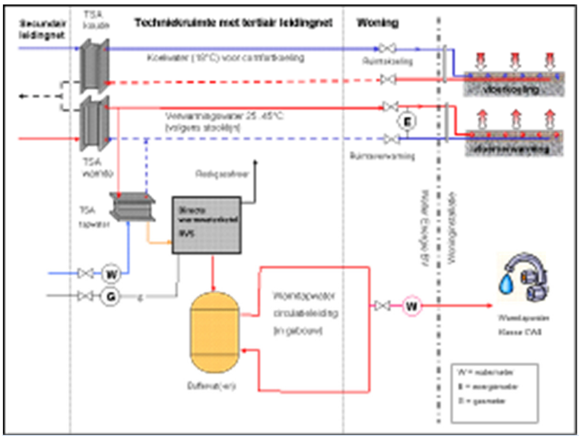

Figure 9: Energy concept buildings Heerlerheide

All the dwellings at Heerlerheide will have floor heating and cooling. This requires good information to the habitants about the typical thermal behaviour of floor heating and –cooling, 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. LOW EXERGY DISTRIBUTION SYSTEMS

In Heerlen different solutions for distribution systems have been applied. In Heerlerheide Centre a central solution is applied with one central energy station where mine water is exchanged and post processed and a secondary distribution grid to the buildings. In the buildings there is a tertiary grid for example to the apartment. A special feature in Heerlerheide is that apartments (social housing segment) have cooling.

In Heerlen Center decentralised solutions are applied. In this part there are larger office buildings with their own energy stations where the mine water is exchanged and post processed, specifically to the building needs (which can differ to a large extent).

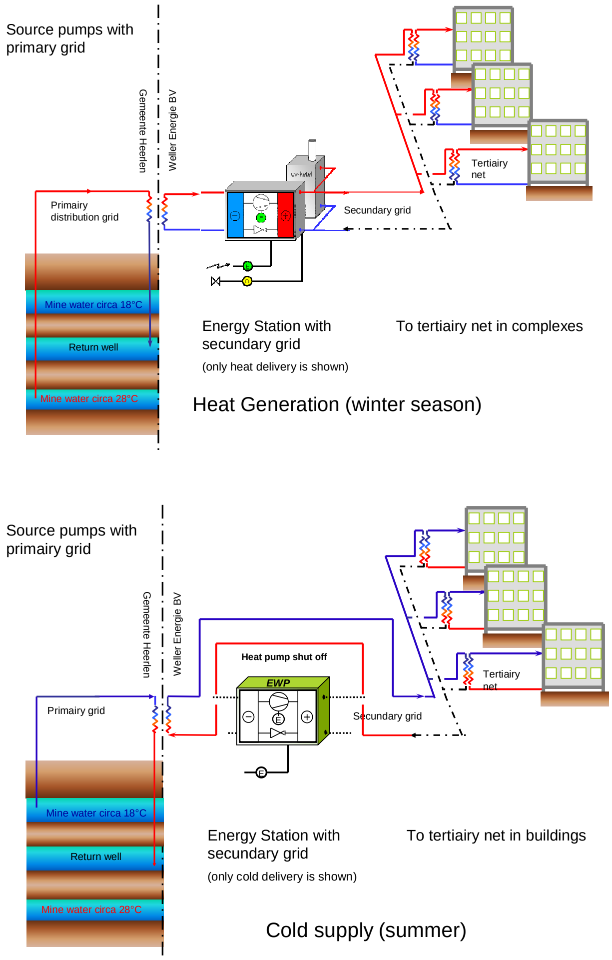

Figure 10: Distribution concepts Heerlerheide

7. LOW EXERGY BUILDING DESIGN CONCEPTS IN PRACTICE TO USE LOW TEMPERATURE GEOTHERMAL SOURCES

In general the building design should be adapted to the use of the moderate supply temperatures for heating and cooling. This means limitation of transmission and ventilation losses and avoiding excessive peak loads. The latter is a special attention point for the ventilation and infiltration losses. This means the application of (advanced) controlled ventilation systems like balanced mechanical ventilation with heat recovery or advanced actively controlled natural ventilation systems. To avoid infiltration losses buildings should have a very high air tightness. Considering transmission losses the level of thermal insulation should be (in the Netherlands) better then the levels required by the building regulations (Dutch Building Decree) however, not on passive house level. In table 1 a summarised overview is given of the measures to make a building ‘mine water proof’ (i.e. lowex) for a moderate climate. It is crucial to design the buildings as ‘lowex’ as possible in order to be able to use direct heating and cooling. In that case it is theoretically possible to heat and cool buildings without the intervention of heat pumps. However, a back up systems is still favourable. In most cases however indirect heating and cooling is applicable where the final supply temperatures are post processed by heat pumps. Heat load duration curves give information about the hours in the year that this post processing is necessary.

Indirect heating and cooling is always the case if other emission systems then floor heating/cooling or concrete core activation are applied, for example low temperature enlarged radiators or low temperature forced air systems (like the new CBS office).

Table 1. Generic overview of measures to make buildings suitable for low temperature geothermal sources in comparison with current practice.

	Building Reg’s NL	Practice 2008 NL	Mine water (Lowex)
Thermal insulation	Envelope U = 0.37 Glazing U = 3.0	Envelope U = 0.30 Glazing U = 1.5	Envelope U < 0.25 Glazing U < 1.2
Ventilation	No system requirements	No system requirements In practice 50% ME and 50% MVHR	MVHR with η = 95% Or demand controlled natural ventilation
Air tightness	$n_{50} = 3$	$n_{50} < 2$	$n_{50} < 1$
Emission system	No requirements	Radiators	Floor heating and cooling (residential) Concrete core activation (non residential)
HVAC system/efficiency	No requirements (but in EPR)	Condensing boilers η = 95% No cooling	Mine water with heat pumps (boiler back up) Sustainable cooling
Energy Performance (EPC) dwellings	0.8	0,8	0,5

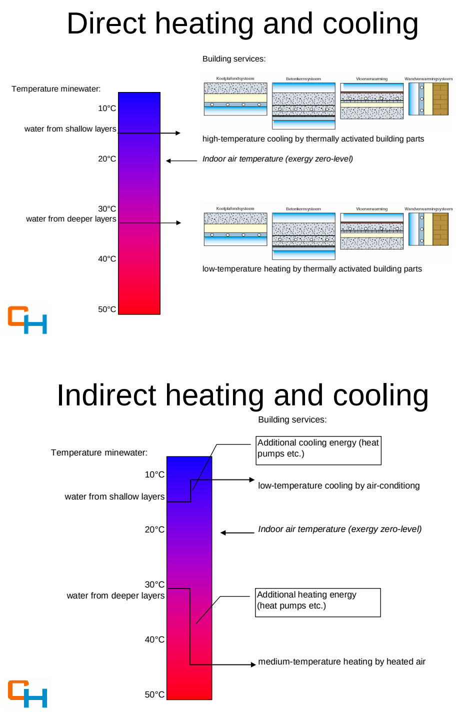

Figure 11: Direct and indirect heating and cooling

8. EXERGY RATING BY THE PER-EXERGY DIAGRAM

Techniques for sustainable energy or renewables are often judged by their energy savings. A more sophisticated approach is a ranking on the savings of fossil fuels (and thus reducing greenhouse gases) and the exergetic efficiency as a index for the use of low valued energy sources. Both aspects can be presented in a combined diagram as shown in figure 12.

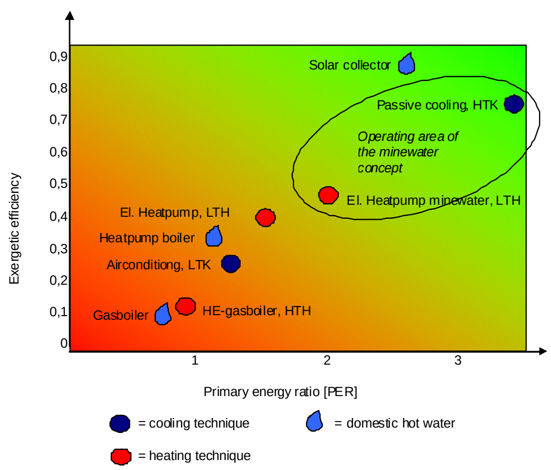

Figure 12: PER-EXERGY diagram

The horizontal axis indicates for each system the so called primary energy ratio (PER). The primary energy ratio is the ratio of the useful energy output to the primary energy input i.e. the energy contained in the fossil fuel. For electrically driven heat pumps a PER can also be defined, by multiplying the COP with the power generation efficiency. The PER can be calculated for nearly every energy system or device when the conversion efficiencies are known. PER values above 1 are only possible at the energy systems which use renewables, like a solar collector. The vertical axis is het exergetic value of the system, more especially the total exergy score which is subject to the Annex 49 programme. It is calculated as:

$$Exergetic\ efficiency = \frac{usefull\ energy\ output * quality\ \ factor}{energy\ input * quality\ \ factor}$$

Different symbols are used in the diagram for heating (red bullet), cooling (blue bullet) and DHW (light blue water drop). The size of the symbol can be used to indicate the accuracy (or spreading in the results) of the calculations. This is useful to cover up the sometimes exaggerated expectations of the accuracy of such calculations. In practice, the external influences on the actual savings like losses and suboptimal control are much bigger than the accuracy of the calculations.

In general, a high PER means that only a small part of the useful energy is extracted from fossil fuels; a high exergetic efficiency indicates a good match between the quality (temperature level) of the used and delivered energy.

9. ECONOMIC FEASIBILITY OF LOW TEMPERATURE GEOTHERMAL PROJECTS 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 a profit from selling energy 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 and
- the reference energy bill of the end-user as a limit, (according to the Dutch so called NMDA-principle (= costs are not more then usual)).

The first and second costs are estimated from the load-duration curves, but can still be influenced by the positive effect of the siphon-principle 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 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 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.

The energetic and financial performance of minewater as an energy source depends on a variety of parameters. A basic calculation model which compares a minewater solution to a conventional solution at a unit level of 1 GJ is used to identify them. Important parameters are:

- Direct or indirect heating and cooling by minewater (practice: mix of systems),
- effectiveness of pumping and distributing the minewater,
- type of ownership of the wells and/or the buildings,
- cost of capital for the investments and
- cost of fossil energy (natural gas versus electricity) and their future price development.

Direct heating and cooling is strongly preferred because of the high energy savings, the clear structure of costs, low investments and less dependency on fossil fuel prices. A disadvantage of direct heating and cooling with the minewater is the sensitivity for fluctuations of the minewater temperature (if any). If the minewater temperature and the buildings services temperature don't match, post processing by heat pumps is an option. In this case, an optimization of the temperature difference (ΔT) for heat extraction is necessary.

A special point of attention is the electricity use for the pumps, which are considerably high. One of the factors is the length of the grid and the fact that a certain velocity (and pressure) is necessary to avoid scaling in the pipes. The overall performance of the pumping and distribution of minewater can be improved by creating a closed loop between the wells (reduces hydrostatic pressure difference) or by a turbine in the injection well. Both techniques need more study.

It may be undesirable to have minewater in the building services and is a hydraulic separation necessary, mostly at an energy station with district heating or services to large commercial buildings. District heating schemes require a long term approach. It is therefore highly recommended to use a life cycle costing approach. Generally, smaller schemes are easier to initiate but larger schemes will deliver the better long-term savings. The cost effectiveness will depend on a range of factors including size of scheme, whether new-build or refurbishment, sectoral mix and available and applicable energy supply alternatives (e.g. on or off gas grid). Special attention should be paid to the domestic hot water, which becomes dominant in low-exergy houses and can't be provided with minewater.

Making business models and financial forecasts for minewater as a commercial energy source is of particular importance. Preferably, all activities for the use of minewater for climatisation of buildings are in one hand. In practice, the pumping and distribution can be done by a different entity than the energy consumer. This requires clear appointments between the supply and demand side of minewater. For example, the pricing of the minewater can be put in the volume consumption (m^3 of minewater) or, as an alternative, in extracted energy (GJ) from the minewater. The first option allows relatively simple contracts between supplier and demander and stimulates the demander for maximum energy extraction. In the second case, the GJ-price for a half fabricate of energy should be defined at clear conditions like the temperature level and the minimum temperature difference for energy-extraction. Furthermore, the allocation of the cost for optional extra investments like back-up systems and low-exergy climatisation system requires negotiations between the supply- and demand side of minewater energy. A basic rule for the supplier of minewater energy is that the capital costs of the investments should be roughly covered up by the fixed costs like the standing right and that the variable costs like the electricity for the pumps should be covered of by the energy price per unit sold. The supplier of minewater energy can state a fixed standing right to cover up his capital costs and a variable price (€ per GJ or m^3) to cover up the pump- and distribution costs.

General recommendations are:

- A small as possible distance between the minewater source and energy demander(-s);
- matching temperatures for minewater versus building services (in general, only the latter can be influenced by low-ex emission systems);
- a clear business model and financial forecast appoints the economic and energetic return of the system.

In fact, the optimum between reducing the energy demands to allow low-ex solutions and the possibility of earning back the (extra) investments done for allowing low-ex energy sources by “selling” enough energy is fragile. Figure 13 gives an illustration:

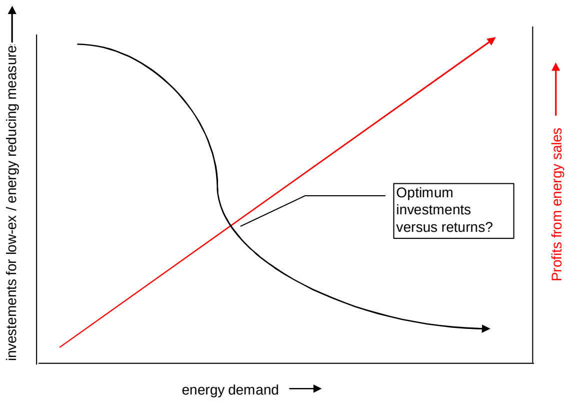

Figure 13: Energy demand versus profits from energy sales

The case studies indicate a reduction in energy costs and CO_2-emissions of 20 to 40 % in comparison to conventional, fossil based heat and/or cold generation. The difference between the reference energy costs and the scenario’s with minewater is in fact the available financial space for the minewater production costs and possible extra investments for low-ex buildings.

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 ~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 project is more or less an experiment, the project is already scaled up to extra buildings to make it 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. For the post-pilot period also extra measures will be taken, like oversized, insulated transportation pipes with leakage detection.

An important recommendation is to locate the wells and end-users as close as 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. Use of electricity for the transport pumps should not be neglected.

ACKNOWLEDGEMENTS

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