Amica is a completely new approach to environmental policy designed to combine long-term climate protection with short- and midterm adaptation measures on the local level as a means to improve coherence of decisions and allocation of financial means.

The world’s climate system has such long response times that experts now agree that, to some extent, climate change can no longer be halted completely. The impacts of climate change are already being felt around the world. In Europe, recent experiences with climatic extremes are a clear signal of the severe impacts of climate change, making it only too apparent that there is a substantial need for mitigation and adaptation measures.

AMICA is an integrated climate policy approach which combines the measures necessary to protect the environment by working to halt further climate change while promoting adaptation to the changes already occurring.

About Remining-lowex

Remining-lowex is a FP6 CONCERTOII project concerning the redevelopment of European Mining Areas into Sustainable Communities by Integrating Supply and Demand, based on Low Exergy Principles. The participating communities are Heerlen, the Netherlands and Zagorje ob Savi, Slovenia. Associated communities are Czeladź Poland and Bourgas Bulgaria.

The project concerning the redevelopment of European Mining Areas into sustainable communities by integrating supply and demand, based on low-exergy principles. It intends to use locally available, low-valued energy sources for heating and cooling of buildings. The source for thermal supply is water from abandoned mines—minewater. The Remining-lowex supply system is based on low exergy principles that are implemented by an integrated design of buildings and energy concepts.

To show the applicability of minewater use and the low-exergy principles, the project focuses on pilot implementation projects, which are supported by research, training and dissemination.

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Water from abandoned mines

Introduction
Abandoned and flooded mines have a high geothermal energy potential. The huge amounts of water in the cavities are great heat and cold storages. The inflowing water that slowly fills mined galleries and panels as soon as pumping is stopped heats up by the geothermal potential of the earth. The temperature gradient is approximately 3° Kelvin per hundred meters. Depending on the depth of the shafts the water reaches temperatures between 15 and 40°C in a depth of 800 to 1.000 meters. This geothermal water is a great energy source for heating and cooling if the right technologies are applied. To use the geothermal potential directly the heat and cold demands of the buildings must be low. If higher or lower temperature levels are needed additional technology, such as heat pumps, have to be used (Fig. 1).

What is LowExergy?
In our everyday live we rarely care about where energy comes from or where it goes to. Energy efficiency, saving of fossil fuels and the reduction of CO₂-emissions are nevertheless important issues in political discussions and the media. We have to ensure a better management of our energy consumption if we want to limit the effects of climate change and our dependencies of fossil fuel imports. In a first step this is about consuming less energy. The LowExergy concept goes one step further and asks what type of energy we need for our demands, i.e. heat or cold or electricity. On a second glance we notice that energy is not equal to energy:

- Would you use a 350 bhp V8 motor to power your bicycle?
- Would you enter a hypersonic aircraft to get to your workplace which is 1.5 kilometres away?
- Would you heat up your oven to 250 °C to boil your egg for breakfast?

Probably the answer to all these questions is “no”. But this is more or less what we are currently doing when we heat or cool our buildings. We burn fossil fuels like oil and natural gas at temperatures over 1000°C to heat our houses. To do better than this is what the Exergy Principle is about.

![Diagram](source: Cauberg-Huygen / Remining-lowex)
The LowExergy Concept

Introduction
The building sector is responsible for about one third of the overall European energy consumption. The heating demand dominates the energy balance of most residential and non-residential buildings. In the last decades the energy demand for cooling and electrical appliances has constantly increased while the energy demand for heating was reduced for new buildings.

Energy in buildings is mainly used for heating and cooling rooms, to keep the indoor air temperature at about 20 °C. For heating and cooling system temperatures close to the desired air temperatures are used. This means that they have a low exergy content. By common definition exergy is the part of an energy flow that is capable of performing work. In the case of a highly efficient natural gas boiler used to supply low temperature heat, the potential to produce work (exergy) of the fuel is very high, because the exergy content of the natural gas is near 100% because of its chemical exergy content. On the other hand the exergy content of the water in the heating system is very low. The high potential of the gas is almost completely lost in the combustion and mixture processes.

The aim of the exergy concept is to achieve a better match between low-exergy demand and supply and to save high-exergy potential by this. Energy savings and efficiency measures lead to reduced overall demand, the search and application of low temperature supply sources lead to a high exergy efficiency. Good low temperature energy sources are: solar energy, geothermal and waste heat from industrial processes.

Different levels of temperatures are needed for different appliances within a building. The production of domestic hot water needs temperatures of about 55 °C, the exergy needed is slightly higher than that of heating a room to 20 °C. For energy applications such as cooking or heating a sauna, a slightly higher exergy level is needed. For the operation of electrical household appliances and lighting only electricity with the highest exergy content of 100% can be used. Today’s energy supply structure does not match well today’s energy demands. Usually all energy is supplied as electricity or as fossil fuels. An increase in CO₂ emissions and shortages of fossil fuels are side effects. The exergy level of the supply today is unnecessarily high (Fig. 2).

Figure 2: Energy supply by fossil fuels for a typical building [source: Fraunofer IBP].

 REMINING LOWEX
The LowExergy Concept

Consequently the matching of the exergy levels of supply and demand could be improved by covering, for example, the heating demand with low temperature energy sources like minewater. In the case of the MineWater Project in Heerlen the warm and cold water in abandoned coal mines is used for heating and cooling buildings on the surface. The available temperatures range between 16 and over 30°C at different levels underground. In well insulated buildings with energy efficient ventilation systems and low temperature emission systems these temperatures are sufficient for heating and cooling over large periods of the year. Higher or lower temperature demands can be supplied by additional heat pumps. To transport the energy to the buildings, the minewater has to be pumped from the underground mind galleries if there is no more active pumping for de-watering the mines. Then it is transported in a grid to the buildings. Additional heat pumps, storages or backup boiler systems can be placed in the buildings or in central energy stations. Other appropriate low exergy sources, such as industrial waste heat or solar energy can also be fed into the grid if available. By using low temperature sources, the exergy levels of supply and demand are matched (Fig. 3).

The LowEx concept applied in buildings and communities bases on a modular approach. The whole energy supply chain of a building is divided into several subsystems. As figure 4 shows, the energy chain for space heating in a building starts with the primary energy demand, undergoes various systems, and ends at the building envelope. All conversion steps in the energy supply chain are directly related to each other. The performance of each step depends on the performance of the others. For example, in the first component “generation” heat losses accrue. In the next component (storage) less energy can be stored. An overall optimisation of the whole building energy system can be accomplished with respect to the single components.

Figure 3: Matching demand and supply using minewater [source: Fraunhofer IBP].
The LowExergy Concept

The advantage of the modular approach in exergy analysis is the option of analysing the subsystems while keeping the total performance in view. The modular approach supports better understanding of single processes in every subsystem. It simplifies the comparison of different alternative solutions. At the same time the overall performance indicates how well the system solution is designed from an exergy and energy perspective. The next chapters present typical technical subsystems for low-exergy building design and minewater use. Starting with the building envelope the logic of presentation follows the energy efficiency principles but exergy optimisation goes along with it.

Figure 4: Energy supply chain for space heating in buildings, from primary energy transformation to final energy, including all intermediate steps.

Remining-lowex- what does it mean?
Remining-lowex is a CONCERTO II project of the European Union and co-funded by the European Commission within the Sixth Framework Programme. The project concerning the redevelopment of European Mining Areas into sustainable communities by integrating supply and demand, based on low-exergy principles. It intends to use locally available, low-valued energy sources for heating and cooling of buildings. The source for thermal supply is water from abandoned mines- minewater. The Remining-lowex supply system is based on low exergy principles that are implemented by an integrated design of buildings and energy concepts.

To show the applicability of minewater use and the low-exergy principles, the project focuses on pilot implementation projects, which are supported by research, training and dissemination. The pilot sites are located in Heerlen (NL), Czeladz (PL), Zargorje op savi...
The LowExergy Concept

LowExergy Design Principles
To come to holistic concepts of LowExergy supply systems, a number of design principles and technologies have to be considered. In general, the concept of the ‘TriasEnergetica’ (Fig. 5) applies to LowExergy design as well. The first step for any energy system based on a large portion of renewable energy sources is the necessary reduction of the overall energy demand. To reduce the energy consumption of buildings the heat losses through the building envelope have to be reduced by better insulation and air-tightness. At this step of maximizing efficiency the exergy demand decreases proportionally to the energy demand. The improved efficiency comes along with a number of good side-effects:

- improved thermal comfort due to higher internal surface temperatures
- avoidance of draughts and heat loss due to better air-tightness
- reduction of mould risks and better hygienic conditions by improved insulation
- lower supply temperatures and heat loads for the heating system
- higher supply temperatures and cooling loads for the cooling system

Alongside with the reduction of overall heating costs these are the preconditions to use low temperature minewater as a renewable geothermal energy source for heating and cooling. For the design of buildings for a LowExergy supply system the rules for energy efficient building design apply:

- Compact building structures
- Good thermal insulation of the envelope
- Reduction of thermal bridges
- Air-tight building envelope

For new buildings a significant reduction of exergy demand can be achieved by choosing a good building shape. The “envelope-to-volume” ratio indicates the size of the heat-losing building envelope (compared) to the heated building volume. The larger the ratio the more insulation is required to avoid exergy losses (Fig. 6). Vice versa compact buildings need less insulation and have a better energy performance.

Figure 5: The principle of TriasEnergetica applies also to the LowExergy concepts.

Figure 6: “Envelope-to-volume” ratio of different objects of the same volume starting with a hemisphere with a radius of 4.5 [source: dena 2007].
LowExergy Buildings

The Building Envelope

All exergy supplied to the rooms for heating or cooling is eventually lost through the facade. The amount of exergy lost through the different external building elements depends on the building structure and of course the quality of the building envelope and the building age (Fig. 7).

![Figure 7: Typical heat losses in a single-family house [source: dena 2007].](image)

Depending on the facade materials the insulation effect of the construction is very different. Figure 8 shows the equivalent thickness of different building materials leading to the heat transfer coefficients of $U=0.24\ \text{W/(m}^2\text{K)}$.

![Figure 8: Layers of building materials leading to an equal level of insulation [source: dena 2007].](image)
LowExergy Buildings

The facade ensures comfortable indoor conditions and is the main building element to apply efficiency measures to. In existing buildings an external insulation layer is sometimes impossible to apply because of protected historic facades (monument conservation) or design requirements. In this case it is to some extent possible to apply insulation to the internal surface of the walls, but precaution has to be taken to avoid moisture and damage to the construction by condensation (Fig. 9). The reason for this are the lower temperatures within the construction layer. If internal insulation is used it has to be ensured that moisture can dry from the construction over the warmer period towards the outside.

Special attention has to be laid on the location of airtight and diffusion tight layers. External insulation is always the preferrable solution wherever possible, because the risk of damage to the construction is reduced, thicker insulation layers can be realised and the risk of constructional cold bridges is smaller. External insulation is also preferable because of the fact that the thermal mass is within the insulation layer and can thus be used for heat or cold accumulation. This increases the comfort and suits the low-temperatur (LT) heating and high-temperature (HT) cooling emission systems.

Figure 9: The position of the insulation layer has large effects on the temperatures within the structure [source: Anton Maas, Uni Kassel].
LowExergy Buildings

Thermal Insulation
Thermal insulation is a cost effective way to improve the exergy efficiency of buildings. Thermal insulation is usually associated with the thermal conditions during the heating period but it is almost equally important under summer conditions. The level of thermal insulation of buildings is characterised by the overall heat transfer coefficient (u-value) which indicates the heat transfer rate through a building element under standardized conditions over a given area. Small u-values indicate very good insulation quality while high u-values indicate large heat losses.
The insulation effectiveness increases with the thickness of insulation layers. The proportion is hyperbolic though. This means that with the first few centimetres of insulation already large saving effects can be achieved whereas very high insulation levels demand much thicker insulation layers (Fig. 10).
The insulation layers generally can be placed on the external or the internal surface of walls. In cavity walls the insulation is usually placed between the two layers of brickwork.

The external insulation is the most common measure for new buildings and refurbishments without any specific requirements for the facades.
Compared to the internal or core insulation the external insulation has some significant advantages:
- retrofiting can be done without great disturbance of users
- thermal bridges can be reduced more easily
- less risk of building damages due to condensation
- the load-bearing construction is weather protected
- thermal mass within the the insulation layer can be used for heat and cold accumulation.

As a rule of thumb the vapour permeability of the building materials has to increase from the inside to the outside to allow condensation to dry during the summer period. This is of great importance for all internal or core insulation concepts, because in existing buildings the vapour permeability of materials is sometimes unknown. To avoid damage, a professional planning of insulation measures is required.
To roofs or attics insulation layers can easily be applied. Usually the insulation material is put between the rafters or on the top most floor, if the attic is unused space. Similar to the insulation of cellar roofs these measures are very energy efficient and cost-effective. In the case of retrofitting existing buildings roofs are often the first elements to be insulated.
In case of a new building the insulation layers have to be carefully planned to avoid cold bridges and damages.

Figure 10: The first few centimetres of Insulation save the most energy.
LowExergy Buildings

Insulation materials

Insulation can be characterised by the material it is made of, by its structure and/or the way it is applied to the building elements. Additionally, the function of the insulation as thermal or sound insulation is an important criterion. Most insulation materials for buildings are either made of polystyrene (EPS), extruded polystyrene (XPS) or polyurethane (PUR) foams or of (glass) wool batts (either rock and slag wool or fibreglass). There are also insulation materials based on natural fibres such as wood fibres, cellulose or cotton. These materials perceive a growing popularity because of their renewable origin but still cover only a very small market segment (Table 1).

Table 1: Thermal conductivities of different insulation materials.

<table>
<thead>
<tr>
<th>Material</th>
<th>Thermal Conductivity [W/(mK)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Silica Aerogel</td>
<td>0.017 - 0.021</td>
</tr>
<tr>
<td>Mineral and Fibreglass wools</td>
<td>0.035 - 0.045</td>
</tr>
<tr>
<td>Polystyrene and polyurethane foams</td>
<td>0.032 - 0.050</td>
</tr>
<tr>
<td>Wood fibres</td>
<td>0.037 - 0.042</td>
</tr>
<tr>
<td>Cellulose</td>
<td>0.040</td>
</tr>
</tbody>
</table>

The most common application of insulation material in buildings is as panels or batts. For cavity walls, attics, cavity floors or hard-to-reach corners, loose-fill fibre materials are used. These materials are blown into the cavities filling up all the holes and nooks. In floors, extruded perlite is also often used to achieve better sound insulation behaviour. Insulation materials are characterised by their thermal conductivity which is measured in Watts per meter and Kelvin [W/(mK)]. Table 1 shows typical thermal conductivity values of different insulation materials. The smaller the values, the better the thermal insulation ability of the material is.

Innovative insulation materials such as vacuum insulation panels (VIP) are a fairly new development trying to achieve best conductivity values within slim constructions. The VIP consists of a nearly gas-tight enclosure foil over a core panel element made of foamed silica, aerogel, glass fibres or foams from which the air has been almost fully excavated. Due to the vacuum, convection is nearly completely eliminated leading to very good insulation values. VIP panels have to be installed carefully avoiding any damage to the foils. For this they are sometimes coated with conventional insulation materials for protection.

Driven by the requirements of the „European Performance of Buildings Directive“ (EPBD) the insulation levels required by national regulations has constantly increased over the past years in most European countries. The national requirements take into account local climatic conditions and building traditions, therefore the national requirements for thermal insulation of buildings show some differences throughout Europe. Nevertheless, highly efficient thermal insulation for all new buildings is a European trend.

For minewater applications a good insulation level is necessary to comply with the low supply temperatures. Taking the energy performance regulations of the Netherlands as an example, a LowExergy building concept would result in values slightly above the common practiced level (Table 2) but below the passive house standard.

Table 2: LowEx insulation levels for minewater application in Heerlen.

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Envelope</td>
<td>0.37</td>
<td>0.30</td>
<td>&lt;0.25</td>
<td>0.10-0.15</td>
</tr>
<tr>
<td>Windows</td>
<td>3.00</td>
<td>1.50</td>
<td>&lt;1.20</td>
<td>&lt;0.80</td>
</tr>
</tbody>
</table>
LowExergy Buildings

Thermal bridges
Thermal bridges are areas of the building envelope where more heat is conducted from the inside to the outside than in undisturbed areas. Thermal bridges can have several causes:

- change of material within the construction (e.g. wood post to stone filling)
- building geometry (e.g. in building corners)
- building elements on the outside surface (e.g. overhangs)
- gaps and leakages caused by unprofessional construction.

Thermal bridges are not only spots of unnecessary exergy loss but can also cause building damages or hygienic problems by supporting mould formation. Since the local heat loss is higher at the thermal bridge, the internal surface temperature drops (Fig. 11). These spots of low interior temperatures can cause condensation, sometimes followed by mould formation and poor indoor air-qualities. In the worst case constructions vulnerable to moisture may get irrecoverably damaged. To avoid thermal bridges, external insulation layers should cover the entire outer surface of the building in an undisturbed manner. Corners cannot be avoided but their number can be reduced by compact building shapes. The connection between different building elements such as walls to roofs or walls to basement ceilings should be implemented carefully to ensure that the insulation covers all gaps in the connection. In the building process all insulation work has to be supervised and closely monitored to

![Figure 11: Typical thermal bridges in a building.](image-url)
LowExergy Buildings

To detect thermal bridges a thermography camera can be used during a cold winter day. Thermography cameras record the intensity of thermal infrared radiation emitted by the facade. The colours of the picture corresponds to the transmission losses through the building envelope. Figure 12 shows a typical infrared picture of a building envelope of an old timber-frame building in Germany. While the type of construction may not be visible from the outside because of plastering, it clearly shows on the infrared picture. The red areas around the windows show high heat losses from inside the building, which result from the lower insulation level of the windows. The blue-green areas represent the areas where little thermal losses appear.

Another important aspect of quality control in lowexergy buildings is the testing of air-tightness. The Blower Door test (Fig. 13) is done after the main construction and insulation work is completed, but before the airtight-layer is covered by internal plastering or cladding. The Blower Door is a powerful fan which creates a slight pressure difference between the interior and exterior of the building. If the house by blowing air into or out of the building. This pressure gradient forces air through all holes or leakages and breaches in the building envelope. Blower Door tests are performed at a pressure difference of 50Pa. The Blower Door system measures the air-tightness of the entire building envelope by simultaneously measuring the air flow through the fan and the fan’s effect on the air pressure inside the building. The better the air-tightness of the building is, the less power the Blower Door fan needs to maintain the pressure difference.

Figure 12: Typical thermography recording (source: ZUB).

Figure 13: (left): Typical leakages in the building envelope (source: TÜV Nord), (right) Blower Door fan in a back door (source: ZUB).
LowExergy Emission Systems

This section describes emission systems, which are most suitable to be used in the context of lowexergy heating and cooling systems, to use low temperature energy sources like minewater. This includes floor and wall heating and cooling systems, concrete core activation and ventilation systems.

The emission of heat respectively cold in is very exergy efficient if the temperature of the heat or cold carrying medium is close to the room temperature. Furthermore, the heat transmitting surfaces should be large and the volume flow small. In addition, these emission systems as well increase the room comfort.

LowEx Emission systems in buildings - Centre for Sustainable Building - ZUB in Kassel, Germany

The ZUB can be described as a link between theory and practice. It is a research building and a demonstrator for innovative building systems. It contains offices and labs, a flexible facade and a rather flexible HVAC system, that can be operated in various modes. The building was constructed in 2001, designed for energy efficiency and located on a former industrial site, it has a close connection to the adjacent University buildings.

The building is close to PassiveHouse Standard reaching an overall heating demand of less than 25 kWh/m² per year. The technical systems include a concrete core activation and floor heating system, a ventilation system and a efficient facade for good natural ventilation, illumination and passive solar energy use. All floor slabs have conventional underfloor heating. In addition, pipes are laid on the lower reinforcements for concrete core activation. For cooling in summer, it is possible to use either overnight ventilation, or alternatively the thermo-active ceilings and the heat exchanger within the foundation slab. A chiller is not installed.

The ventilation system with heat recovery is designed for a maximum volume flow of 4,000 m³/h and is regulated according to air quality sensors (VOCs). It encompasses two separate ventilation areas (lecture hall and office areas) which can either be operated in parallel or one at a time. If the volume flow is insufficient for the office area, additional ventilation via the windows is necessary. Indeed, throughout summer, window ventilation is the method of choice for the offices.

The building is connected to the city’s district heating grid, therefore the systems for low supply temperatures would not have been absolutely necessary. Since the building can be operated with supply temperatures of maximum 28°C throughout the heating season it would as well be 100% minewater-proof.

Figure 14: Institute building of ZUB
[source: ZUB].
LowExergy Emission Systems

Floor and wall heating
Floor and wall heating systems supply heat over radiation and at a low temperature level. They consist of waterpipes in the floor screed. Large heat transfer surfaces ensure the necessary transmission power. The large portion of radiation increases the user comfort. To avoid cold air drop at the facades the distance of the transmission pipes can be reduced near the facades. Floor heating systems react slowly to temperature changes and different heating demands. For this reason room temperatures cannot be adjusted quickly. If the energy quality of the building is good the reaction time is sufficient because the entire building reacts more inertially and stable.

Figure 15 shows a floor heating system under construction. In this case the pipes are placed between pre-fabricated grid-elements that are covered with concrete or a well transmitting floor covering. Because of the comfortable temperatures floor and wall heating systems can also be used for cooling in summer. Figure 16 shows different possibilities of floor heating constructions for residential buildings.

The water pipes for floor heating can be located inside the levelling screed (Construction C), they can be installed under the screed in the heat insulating layer (Construction B), but also in the floor screed itself (Construction A).

Figure 15: Floor heating system.

Floor heating can be arranged in a relatively thick screed, to use the mass as „heat storage“. Floor and wall heating systems can also be applies in retrofitting while concrete core activation systems can only be realised in new buildings. In connection to a floor heating system it is also possible to use a carpet, assumed it has a „Certificate of Quality“, indicated by a red „t“, of the European Community Association (ETG). The advantage of such kind of carpet is, that it gives off heat from the floor heating system to the room air in an effective manner and prevents the cooling in the non-heating periods in the soil. This effect increases the comfort in the building and decreases the demanded heat energy.

Figure 16: Floor heating constructions for residential buildings [source: Bundesverband Flächenheizungen e.V. (BVF)].
LowExergy Emission Systems

For wall heating (Fig. 17) the heating pipes or space heating elements are put directly on an insulation panel or system panel on the wall and fixed there. The room-facing wall construction serves as heat transmission area. Figure 18 shows different possibilities of wall heating constructions for residential buildings. Some attention has to be laid upon securing and indicating the position of the water-bearing pipes to avoid later damages (nailing) due to improper use. An advantage of wall-heating systems is the fact that walls are usually easier to access than ceilings or floors, which makes the system attractive for retrofitting.

Figure 18: Wall heating constructions in residential buildings [source: Bundesverband Flächenheizungen e.V. (BVF)].
LowExergy Emission Systems

Concrete Core Activation (CCA)

In the case of concrete core activation the building structure is used as a thermal buffer. Like floor heating systems, thermo-active ceilings offer a good thermal room climate. In new constructions they are fairly simple and cost-effective to install and they can be operated with low supply temperatures. In contrast to chilled ceilings or floor heating, thermo-active ceilings temper the entire ceiling construction. The concrete acts as a thermal storage mass and enables a thermal phase shift to be exploited without great expense. Thermo-active ceilings in effect allow cold night air to be used for cooling during the day. This decreases the load peaks of the building so that reduced cooling capacities are required.

The large energy transfer surface of the thermo-active ceiling permits very small temperature differences between the room temperature and the heating/cooling water temperature. This means that minewater can be used effectively. If the necessary supply temperatures are very low the concrete core activation allows a direct use of the minewater temperature levels without additional heat pumps throughout the year.

The pipelines for this system are located in the area of the neutral axis of the ceiling construction or in the monolithic screed. Locating the pipes in the monolithic screed is advantageous because it simplifies the construction process and allows repairing damaged pipes more easily.

The ceiling temperature is kept at a constant temperature of approximately 23 °C. If the room temperature rises above this temperature, the ceiling cools the room by transmitting surplus energy from the room air; if the room temperature drops, the ceiling heats by the same principle. The transition between heating and cooling processes is smooth. In practice there will be a set-point for heating and cooling of course, but in principle the building could be operated by a constant supply temperature.

The thermal inertia of the system implies that a quick adjustment of the room temperature is not possible. For testing reasons in the case of the ZUB two pipe systems were installed, one in the screed and one in the ceiling slab. It has shown that heating is more effective via the floor system, while cooling is better via the ceiling system.

Figure 19: Installation of concrete core activation [source: ZUB].

Figure 20: Concrete core activation. Location of the pipes in the thermoactive ceiling [source: Bundesverband Flächenheizungen e.V. (BVF)].
Accoustic effects on CCA
Uncovered concrete slabs are acoustically „hard“, that’s why sound absorbent constructions are usually necessary, to allow a good acoustic performance in buildings. Traditional acoustic solutions, like for example sound absorbent constructions, cannot be used in combination with CCA, because the cooling effect from the concrete ceiling is screened off. Also this traditional solutions usually have a thermally insulating and radiation inhibiting effect, with negative effect for the CCA. Alternatively, free-hanging units can be used, which improve the acoustics as well as allowing the cooling effect to pass through.

Chilled ceilings, chilled beams
A typical cooling system are chilled ceiling panels. Chilled ceiling panels can be placed into the plaster on the soffit or as larger chilled panel “sails” into a suspended ceiling. Depending on the type of construction (Fig. 21), suspended systems can interact with the surrounding room air to achieve a considerable convective effect; however, the cold is mainly released through radiation which provides a higher level of comfort. Chilled ceiling panels can also be used with higher feed temperatures which allows for regenerative sources of cooling energy to be exploited. Therefore, they are particularly suitable for heat supply with minewater, which provides cool water at a temperature level of about 16 °C.

Figure 21: Different types of chilled ceiling systems [source: Integrale Climasysteme GmbH (ICS)].
LowExergy Emission Systems

Ventilation
Because of the high insulation level and to maintain a comfortable indoor climate a ventilation system should be used. Especially in airtight buildings ventilation systems play an important role. The ventilation system ensures the necessary air-change rate for high indoor air-quality without loosing unnecessary amounts of energy. Mechanical ventilation systems allow to recover heat from the exhaust air-flow and transfer it to the inflowing air. Usually hybrid ventilation systems are installed for residential buildings with a mechanical ventilation system for the heating season and natural ventilation for the summer. In non-residential buildings ventilation in summer can also be very effective to directly cool the room air. In this case warm outside air can be passively cooled by underground airducts or the rooms are cooled down by free or forced night-ventilation.

Natural ventilation systems rely on natural driving forces, such as wind and temperature differences between the room and its environment. Good natural ventilation can be achieved by:

- Cross ventilation: ventilation openings on opposite facades.
- Wind and rain protected and security window openings to allow night ventilation
- Adjustable window-openings to avoid draughts and high flow velocities.

Demand controlled ventilation allows the users to pre-define the ventilation demand, that does not result in constant air floor, but varies to the level of use and pollution in the building. Some window producers already offer these kinds of adjustable window-openings. Commonly this will be realised by a mechanical ventilation system.

Mechanical ventilation systems force fresh air into the rooms using ducts and fans. They are commonly used in office buildings, and buildings with high air-quality requirements. But also for residential buildings compact mechanical ventilation systems are highly recommendable. They offer:

- Better indoor air quality
- More control
- Improved comfort
- Reduced energy consumption

Ventilation systems can be realised as mere exhaust ventilation systems, with fans extracting moist used air from rooms like kitchens and bathrooms. Fresh air flows freely from adjacent rooms. No heat recovery is possible. Central exhaust and supply ventilation systems also supply fresh air to living and bed rooms via ducts. With these systems a heat recovery is possible. The energy loss via ventilation is significantly reduced. In Passive Houses, the ventilation is sometimes the only installed heating system. The small remaining heat demand of the rooms is provided via the air-flow. To avoid using electricity for pre-conditioning of the air, a water-based heat-exchanger using minewater energy could be used.

Hybrid ventilation can realise a bridge between natural ventilation and air-conditioning. The concept makes it possible to neutralise the limiting effects of natural ventilation and to avoid the negative aspects of being always dependent on a mechanical HVAC-system. The applied mode of operation may vary depending on the season and within each day. This means that the active mode of operation is dependent on the external climate conditions. As long as the outside temperatures allow natural ventilation it is used, if not the rooms are mechanically ventilated. The main advantage of these systems is the reduction of electricity use of the fans by natural ventilation as much as possible.
LowExergy Sources: Minewater Use

Outside the buildings that are supplied with low temperature energy, the essential questions of a matching and sustainable exergy source and supply has to be solved. In the case of geothermal minewater use this includes aspects of the geothermal potential analysis, access to the reservoirs, drilling, pumping, the distribution of the mine water and the installation of appropriate back-up and re-heating systems.

The Minewater Reservoir
The minewater reservoir is of course the backbone of the minewater system. The size and capacity of low temperature water depends on the geological conditions in the abandoned mine shafts and galleries. A detailed analysis of the available flow rates and temperatures is the essential precondition for the configuration of the minewater system. Some mines, like in Heerlen, have been closed a long time ago. Detailed geological research has to precede the planning in such a case. Historic mining maps are sources of analysis. These maps are digitalised to obtain a detailed 3-D model of the underground conditions. According to the modelled geological conditions, flow rates and directions of the underground water, the most promising spots for accessing the reservoirs have to be detected.

In cases were there is still active mining, like in Czeladz, the planning parameters are much easier to obtain, because water flows from active pumping can be used and directly measured.

Next to the definition of drilling spots on the surface, the expectable temperature levels and maximum flow rates have to be determined to model the minewater potential. This can be achieved by pumping tests that give information on the temperature developments from the reservoirs over a period of time under defined pumping conditions. The question what flow rates lead to a stable recovering of reservoir temperatures is important for the planning. Also a detailed chemical analysis of the produced minewater can be done during the pumping tests to get information on the necessary pipeline and technical equipment materials.

Figure 22: Shafts and galleries were digitalised from old mining maps in Heerlen.

Figure 23: The temperatures in the reservoirs are modelled.
LowExergy Sources: Minewater Use

Drilling
Drilling is necessary when the shafts of the closed mines have been filled in. In a first step the best position for drilling has to be located. For this the relationship between pressure differences and minewater volume of the reservoir and surface infrastructure has to be determined. After that many tests have to be done to determine the reservoir structure:

- flow tests
- chemical tests
- Measurements of temperature, water-levels, pressures, flowrates, PH and conductivity
- and porosity tests

The results of the drilling can be used to inform the decision of whether it would be practically possible for the minewater to be used for supplying useful energy to the local community.

To minimize the circulation it is important to drill in the mined galleries and not into the shafts of the mines. Furthermore, also questions about stability of the extraction zone especially the worst-case scenario, when the tunnels collapses, have to be discussed and it has to be clarified the question whether in this case there is enough flowing minewater to supply the settlement.

Figure 24 and 25 show the HH-2 well-site in Heerlen, which was located within a tiny park between houses, roads and apartments. HH-2 is the “warm water-buffer” well. Originally meant to inject heated water obtained through cooling buildings during summertime. In this way creating an extra amount of warm water in the deeper parts of the mine. This water “naturally” flows to, and adds to the warm water in the HH-1 (Heerlerheide #1) well reservoir-area. In this way enlarging the warm water amount(s) available. (VITO).

Figure 24 and 25: HH-2 in Heerlerheide [source: VITO].

Pumping
Pumping is needed to transport the minewater from the shaft to the heat pump or heat exchanger. The heat exchanger separates the aggressive minewater from the district heating. To ensure the efficiency of minewater supply, the chemical composition of the reservoir water has to be investigated. A bad chemical composition of mine water can cause scaling and corrosion of the pump and thus reduce its efficiency. Also the material selection for the pump and pipes has to be adjusted to the chemical composition of reservoir water.

Minewater is not completely free of solid particles and chemical compounds, so, as a good standard pump adopts a normal speed of about 1450 l/min with high-grade austenitic stainless steel as the material.

Pumping must be ensured to secure the supply when the pumps has to be serviced or replaced. For servicing the pumps a high regulate and intensive effort is required and specialist staff needed.
LowExergy Sources: Minewater Use

**Distribution grids**
A central element of the low-exergy minewater system is the distribution grid between the mine and the buildings. While in some mining locations there is still active pumping or only short distances between the mines and the buildings, in some cases long distances have to be overcome with the distribution grid.

Because of the chemical content of the minewater, which promotes scaling of pipes and corrosion of surfaces at technical installations, the primary grid transports the minewater to a central heat exchanger of very high quality. The secondary grid does not contain minewater any more but only distributes the geothermal energy to the buildings. In the secondary grid the energy stations are located which re-heat the supply flows if necessary (Fig. 26). If the temperature level from the minewater is sufficient, like in the case of direct cooling (Fig. 27) the energy stations are bypassed. The heat exchange to the tertiary grid, which are the buildings' energy grid are basically standard district heating technologies.

**Figure 26:** Schematic principle of heating with mine water [source: Cauberg-Huygen / Remining-lowex].

**Figure 27:** Schematic principle of direct cooling with mine water [source: Cauberg-Huygen / Remining-lowex].
LowExergy Distribution

An alternative to the central energy stations are decentral energy stations at every customer (Fig.28). This is a favourable solution if there are very diverse demands regarding the heating and cooling temperatures. Also this solution could be a good idea if there are existing re-heating systems in the buildings that can be used with the mine water. If the minewater is not problematic in its chemical content the secondary distribution grid could be saved and the heat exchangers can be placed directly into the buildings' energy stations (Fig.29). Because of the direct connection between building system and minewater system it is possible to store surplus heat from decentral producers into the mine reservoir. This demands a sophisticated heat management to avoid unnecessary pumping and unwanted mixture processes.

Figure 28: Decentral heat generation with central mine water heat exchanger (winter season) [source: Cauberg-Huygen / Remining-lowex].

Figure 29: Decentral heat generation with decentral mine water heat exchanger (winter season) [source: Cauberg-Huygen / Remining-lowex].
LowExergy Re-heating

Heat-pumps
The temperature levels exploited from the mines might be too cold or too warm for some periods of the year. To raise or lower the temperatures to the required levels, heat pumps offer very effective lowex possibilities. In heating mode heat pumps raise the temperature of the water from a lower temperature level to a higher temperature level, using the thermodynamic Carnot principles of refrigeration cycles. The performance of heat pump is indicated by their „Coefficient of Performance“ (COP). The COP depends on the necessary temperature-hub the heat pump has to deliver. A small temperature hubs lead to a high performance of the heat pump. In the case of minewater systems the source temperatures are quite high and the required supply temperatures for the low-energy buildings are low - very favourable conditions for using heat pumps.

In energy stations the heat pump is usually designed to cover about 90% of the heating or cooling demand. Because of the decreasing COP with rising temperature hubs it is usually better to combine a heat pump with an additional boiler for peak loads rather than using only the heat pump as a stand-alone back-up system. The boiler back-up system is high-exergy without question, but the operating hours are reduced to a minimum and to reduce the environmental impacts bio-oil or biomass can be used. Furthermore, the conventional boiler is a back-up in the case of a failure of the mine water or heat pump system.

Domestic hot water production
The demand for domestic hot water cannot be provided directly with mine water because of the high temperatures of 55 to 65 °C for hygienic reasons. In minewater systems the domestic hot water can be pre-heated by minewater and then heated to the hygienic temperature by highly efficient boilers. This way, the mine water heat pumps preheat about 30 % of the annual demand for domestic hot water. Figure 30 shows such a configuration for a residential complex.

Figure 30: Domestic hot water cannot be prepared by minewater alone [source: Cauberg-Huygen / Remining-lowex].
The REMINING locations

Heerlen/ Netherlands
In the Mine Water Project in Heerlen water from abandoned and flooded mines is used for heating and cooling of buildings. The temperatures that have been found (16...30°C) are used in very well insulated buildings, with energy efficient ventilation systems and low temperature emission systems; the thermal comfort is excellent during 365 days/year. At the same time there will be a CO$_2$ reduction of 50% in comparison to a traditional solution.

The project started in Heerlerheide by drilling the warm wells in February 2006. In October 2007 the last cold well was drilled. This project is situated on the concession of the Mine ON III pit in a relatively deep mined area with warm water wells (30...35°C) and cool water wells (appr. 15°C). At the energy station Heerlerheide are served:

- apartments (ca. 170)
- a cultural centre
- some commercial shops
- a school with kindergarten and gym
- a supermarket (only cooling demand)
- and the solitary energy station near the city centre of Heerlen.

The energy supply includes the building of an energy station and a small scale distribution grid from this 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 building the main investor 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 mine water. In Heerlen different solutions for distribution systems have been supplied. Thereby, mine water is extracted from four different wells with different temperature levels.

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 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 warm wells. Next to it, the planned building functions require heating as well as cooling.
The REMINING locations

Heerlerheide Centre
In the Case of Heerlerheide Centre a central solution with district heating is supplied. One central energy station is located in the neighbourhood and is the hydraulic separation of the mine water and the building services. The primary energy grid transports the extracted mine water from the warm wells (~30°C) to local energy stations. In these energy stations heat exchange takes place to the secondary services. The primary energy grid transports the extracted mine water from the warm wells (~30°C) to local energy stations.

In these energy stations heat exchange takes place to the secondary energy grid (from the energy station to the buildings).

This secondary energy grid provides low temperature heating (35…45°C) and high temperature cooling (16…18°C) supply and one combined return (20…25°C) to an intermediate well. In the building complexes the heat and the cold of the secondary grid is transferred to a tertiary grid that serves the individual apartments and other end-users. The different temperature levels of the wells considered can be seen schematically in Figure 32.

In Heerlen Centre 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.

![Figure 31: Schematic cross section of the underground conditions of the ON I and ON III mines](source: Municipality of Heerlen).
The REMINING locations

Zagorje ob Savi/Slovenia
In the frame of Remining-lowex activities in municipality Zagorje ob Savi, Slovenia, in 2011 the work concentrated on completing minewater use demo research unit OLEA. Other objectives were to:

- set the first charging stations for electric vehicles in this region
- complete community energy monitoring and management system
- connect the first solar photo voltaik power plant to the public grid
- expand biomas district heating grid
- and to complete project documentation for further expasion of biomass district heating.

Research unit OLEA
Research unit OLEA is a low-energy self sufficient mobile unit for demonstration of new concepts of low-exergy technologies on the basic of renewable sources. Unit serves to carry out regular events related to minewater use for heating and cooling buildings, renewable energy exploration and energy efficiency measures in build environment.

Technological innovations presented in it are associated with the culture of mining thus transcending it to show and promote sustainable energy systems. In the technology field, minewater is exploited from abandoned mines for low-exergy heating of the building. Interior and as well the surrounding structures of the unit mimics a mine shaft and with this keeps the heritage of mining that look palse there for 250 years alive. Exterior of the building is adapted to mining architecture. With research uni OLEA transition between black, carbon based history and green sustainable future in this municipality and wider region is shown.

The unit shwos and demonstrated the following technologies:

- Low-exergy direct surface heating with minewater
- building envelope in the standard of passive buildings
- phase change materials for heat and cold storage
- solar thermal collectors for sanitary hot water preparation and support of heating
- ventilation system with waste air heat racovery with highly efficient regenerators
- cooling of building with the use of ground air heat exchanger
- energy efficient LED electrical light
- solar photo voltaic cells and direct methanol fuel cell for electrical self-sufficiency
- advanced control systems on the basic of weather forecast and responsive system management
- rain water storage
- dry compost toilet with waste water treatment in constructed wetland
The REMINING locations

Energy management system
In 2011 the installation of energy monitoring via telemetry in three public buildings was completed. Facilities were selected based on the heating system (gas, oil and district heating on biomass). This allows to be able to compare, manage and analyse three different heating systems and with this decrease energy use. In addition internal environment parameters (air temperature and humidity, CO₂ concentration) are monitored in order to ensure healthy indoor environment. Main purposes of system are to:

- measure and control energy flows
- analyse data and define actions with the purpose to optimize energy consumption
- to replace out-of-data energy accountancy
- and also for educational propose to responsible and environment friendly energy management

Charging stations for electric vehicles
In August 2011 official opened the first charging station for electric vehicles (Fig. 34). The project was realized in cooperation with the largest distributor of electricity in Slovenia (Electro Ljubljana) and with a local company ETI, which makes among other, also charging stations for electric vehicles.

Figure 33: Opening of the charging station for electric vehicles in the municipality of Zagorje [source: University of Ljubljana].

The co-operation with companies should become a model layout of the entire network for charging electric vehicles in Slovenia. Charging of electric vehicles is free for users, with the aim, to encourage the use of electric vehicles.

Solar power plant
The first municipality’s solar power plant had been connected to the national grid in March 2011. Its capacity is 13,88 kW, for an annual predicted production of 15,000 kWh of green electricity for the Slovenien grid. Using this facility equates to a reduction of 8 tons of CO₂ emissions per year.

Reference: Jure Vetršek, University of Ljubljana
The REMINING locations

First must be pointed out that Czeladz and Bourgas are (non-investing) feasibility studies whereas Heerlen and Zargorje are demonstration sites.

Czeladz/ Poland
Czeladz is a neighbouring city and a suburb of Katowice and is part of the Silesia Agglomeration. It has a relatively high standard of living, lacks big block real estate, has a lot of green areas and is known as local centre of services and logistics. The Czeladz development strategy specifically targets entrepreneurship, road and traffic system, park & ride, Old Town revival and mine property use (Saturn mine). Municipal policies focus on infrastructure (sewage system, roads), the real estate market, leisure and sports, education and culture, environment surrounding and safety. Specific policies on energy include regulations, the municipality as a regulator in case of market failure, liquidation of CO₂ emission, saving the energy (RUE) as a pre.

General must be pointed out that Czeladz and Bourgas are (non-investing) feasibility studies whereas Heerlen and Zargorje are demonstration sites.

Research & Networking
The project team in Poland worked on the following tasks:

- Preparation of the “Czeladź community heat, electricity and gas fuels supply plan guidelines”
- Completion of three feasibility studies concerning minewater energy application in Czeladź:
  - Renovation of residential dwellings
  - Modernisation of the CZOK office building
  - Real estate development in the Piaski District

Project partner SRK (Coal Mine restructuring Company) CZOK’s head office will be retrofitted and connected to minewater, pumped by the „Pawel“ shaft, Saturn Area, to heat using heat pumps. The outline of the drainage of the Saturn Area, the project of the pumping station in „Pawel“ shaft and the concept of the deep-water heat from the „SATURN“ area have all been worked out in detail.

Also the economic conditions have been investigated. The simple pay back time is about 10 years. The total heat demand will be reduced from 201 kW to 96 kW and the energy saving is estimated at 841 GJ/year. Also energy audits for the CZOK building have been carried out by local experts. One of the major results was that there are 6 new probable projects in which pumping mine water can be used:

1. The Industrial Park Nowa Ruda
2. The area of the abandoned mine „Jan Kanty“ in Jaworzno
3. The area of the abandoned mine „Kleofas“ in Katowice

Figure 34: Coal Mine in Czeladz
[source: www.remining-lowex.org].
The REMINING locations

4. The Mine and Metalurgy Heritage Park in Siemianowice Slaskie
5. The area of the abandoned mine „Debiensko“ in Czerwionka-Leszczyno
6. The area of the abandoned mine „Niwka-Modrzejow“ in Sosnowiec
7. The area of the abandoned mine „Szombierki“ in Bytom

SRK is willing to encourage potential partners by promoting these 6 projects to developers interested in implementation of modern heating and cooling technology, local authorities implementing RUE plans in energy policy and R&D institutions from the mining areas.

The Development of the new housing estate Piaski District will be situated in south eastern part of Czeladz. At the moment this is a potential project and the owner of this area is the city of Czeladz. The estimated population is about 980 persons, who will live in 260 flats with an average area of the flats of 78 m². Concerning the initial technical analysis, the minewater temperature is 12,2-14,4 °C and is suitable for indirect heating (heat pumps) and free cooling. As a pilot project two existing houses in the Piaski district have been selected, which are houses that are 100 % municipal property. In this project it is possible to implement the installation with using minewater or other sustainable and renewable sources of energy. Heat pumps are planned to heat the residential area and to provide domestic hot water. The idea is to apply separate heat pumps and heat exchangers to all buildings, that are close to the mine-shaft „Pawel“.

Research activities for Czeladz
The research activities for Czeladz are concentrated on:

- The Study of application of heat pumps for retrofitted buildings
- The Study of legal aspects concerning the use of minewater in Silesia
- The Study of georectifying mining excavation maps of the Saturn coal mine
- Energy audit and feasibility study for the use of heat pumps for water pumped from the Pawel shaft, Saturn mine.
- Energy audit retrofitting the CZOK building.

Figure 35: Coal Mine in Czeladz [source: www.remining-lowex.org].
The REMINING locations

**Bourgas/ Bulgaria**

Bourgas coal basin is located in the south-eastern part of Bulgaria. Cherno More and Rudnik are villages situated in the vicinity of the coalmines and are declared as mining sites. They expanded in time and at the moment are almost merged. The major activity in the two villages is agriculture.

Both villages are the possible minewater consumers. Water temperature of the mineral springs in Rudnik is about 23°C. The potential public and private consumers in Cherno More mining village are subject to the project.

**Research**

The three mines - Brigadir mine, Blagoev mine and 9.IX. mine are interconnected and form one reservoir. These mines were abandoned in the period 1970-1988. Currently only „Cherno More-2“ is producing brown coal. The only access to the minewater is a vertical shaft 1 located in 9.IX. mine.

Geological and hydrogeological investigations have been done. The expected minimum flow rate from the vertical shaft 1 is 17-19 l/s. Temperature level of the minewater pumped from the vertical shaft 1 is about 15-16 °C. The composition and quality of minewater is analysed - water is neutral with TDS varying in the range of (1,3-1,7) g/l.

The applied hydrodynamic model reasonably describes the regional hydraulic conductivity and heads distribution and provides initial and boundary conditions for the local hydrothermal model. The water movement in the region of the abandoned mines and disturbed temperature distribution during exploitation are simulated.

**Energy and assessment of exploitation**

In Bourgas, it is planned to use energy from minewater for the heating and cooling 8 selected buildings with a heat load of about 434 kW (assumed indoor air temperature in winter = 18-20 °C) and a cooling load of about 378,2 kW (assumed indoor air temperature in summer = 25 °C). Potential selected buildings are the Culture centre, School, Kindergarten, Bakery (private),

Figure 36: Bourgas coal basin and the shaft of the 9.IX. mine [source: Geological Institute, Bulgarian Academy of Sciences].
The REMINING locations

Post office, Municipality and the private Furniture company - ABV &Son. This system could be realized only after renovation and insulation of the buildings (except for the Furniture factory).

The furniture factory is located at about 250 m east of the vertical 9.IX shaft. The building is insulated according to the requirements for low-exergy-heating. The existing internal installation could also be used after doubling the number of the available heating units. Currently the conventional fossil fuel boiler (on wooden debris) is used to supply a heat load of about 70-80 kW. Following preparations have already taken place:

- Preliminary schemes of the connection and grid of the ABV furniture factory to the minewater of the 9.IX shaft;
- Elaboration of the measures to prepare the building for the use of minewater;
- Preliminary exploitation calculations.

In a first step the energy performance and profiles of the selected buildings and the potential users of the minewater have been analysed. The energy assessment for using minewater for heating and cooling the furniture company is made together with the Dutch partner.

Technical schemes for heating and cooling the selected buildings in Cherno More mining village and the furniture company have been proposed. Also the preliminary assessment of the total cost of the system for the furniture company has been made.

Extended research
An extensive survey of abandoned coal mines in Bulgaria has been initiated to evaluate the opportunities for implementing the Remining-lowex expertise in more coal fields. The present state of abandoned coal mines (totally or partially liquidated) is analyzed by collecting information on the:

- geological conditions,
- mine water temperature and quantities,
- available access to the mines,
- surface conditions,
- preserved shafts and existing consumers.

The expected outcome of the study is to define the most prospective coal mines, which meet the complex criteria for a future exploitation.

Reference: Klara Bojadgieva, Geological Institute, Bulgarian Academy of Sciences

Figure 37: Furniture Company ABV&Son [source: Geological Institute, Bulgarian Academy of Sciences].