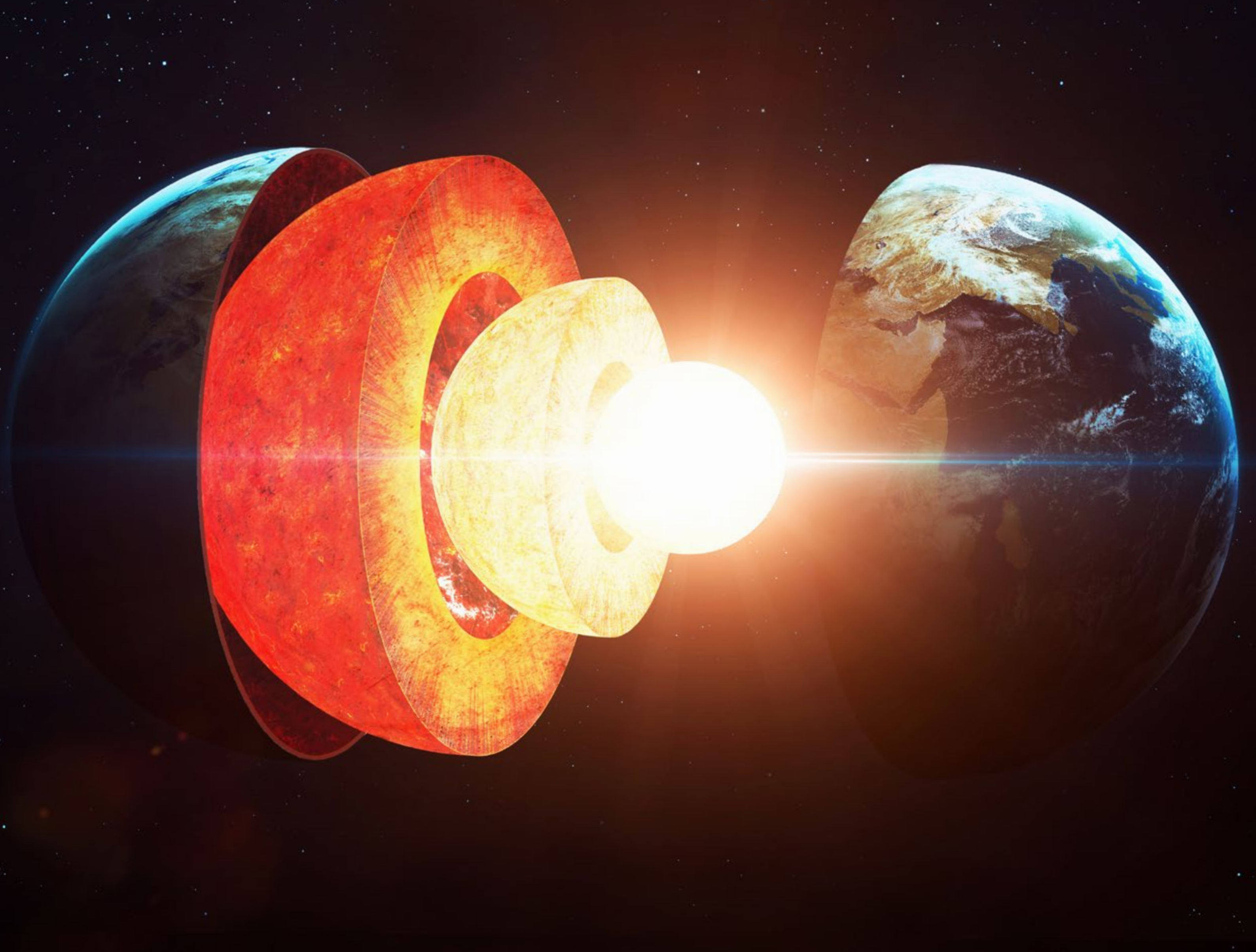

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GEOTHERMAL HEATING

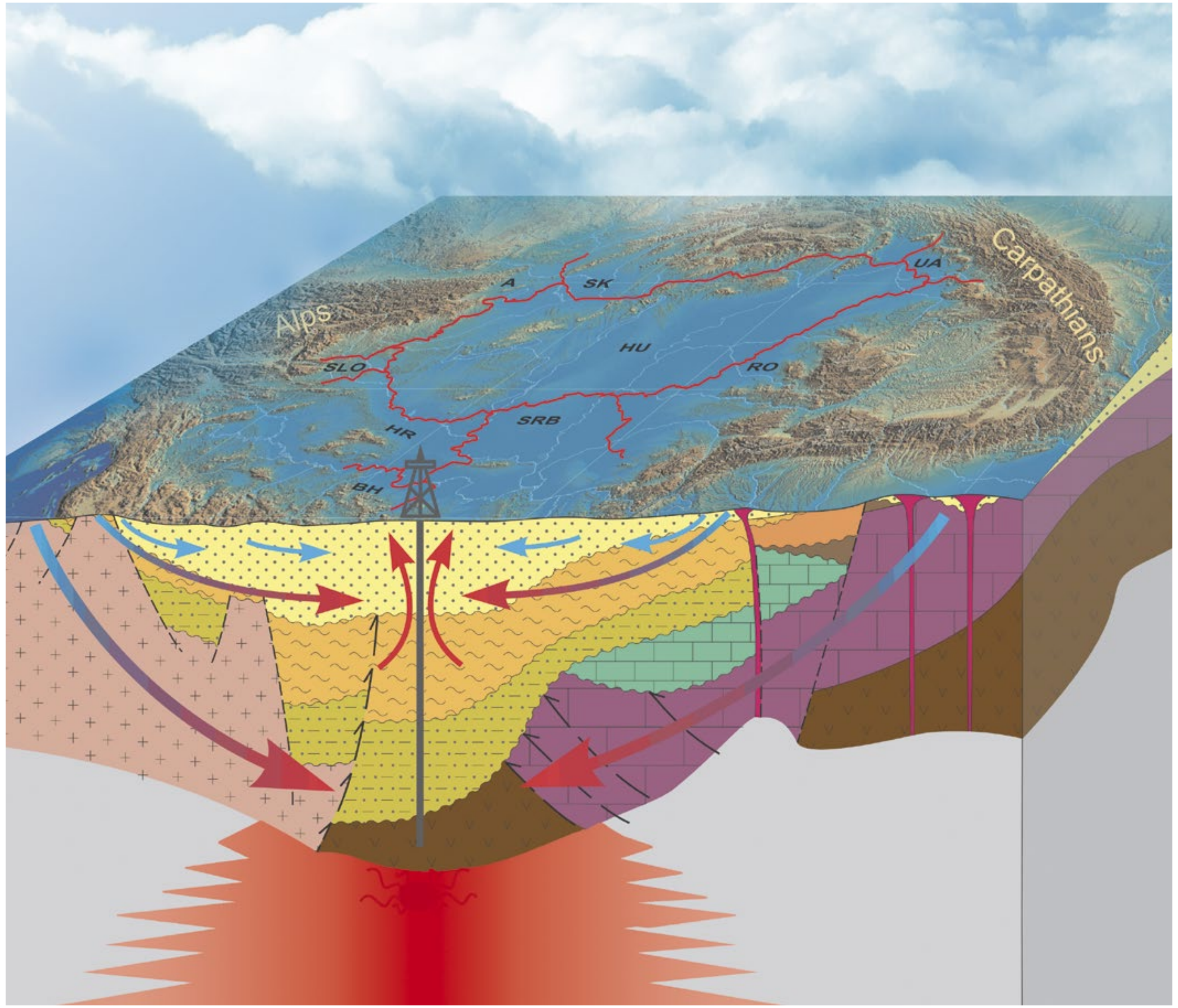
GEOTHERMAL ENERGY

Geothermal energy – by definition – is the energy stored in the form of heat in rocks and in vapours or liquids trapped in rock pores and fractures under the surface. The continuous renewal of geothermal energy is fed by the decay of radioactive isotopes found in the Earth's crust, and reaches the surface via constant terrestrial heat flow.

Geothermal energy has been a source of energy to humankind since the dawn of civilization. For centuries, hot springs have been used for bathing and therapeutic healing at numerous places all over Europe.

GEOTHERMAL ENERGY HAS MANY ADVANTAGES:

- it is a renewable energy source, which is local
- it is widely available, since underground heat is global
- it is a base-load energy source, it provides 24/7 delivery with predictable outputs irrespective of weather conditions
- it has huge untapped potential which can boost economic growth
- it has numerous applications: in addition to power generation from very high temperature fluids and vapours, geothermal heating can supply energy at different temperatures from low (15–20 °C) to high (100 °C or above). Furthermore multiple applications can be optimized by cascade-users of heat at progressively lower temperatures.
- its different loads (base load, or flexible adjusted to the actual demand) and capacities can be matched to different needs (from a few kW_{th} to tens of MW_{th}), thus providing flexibility for operators
- it can be combined with other energy sources (e.g. solar, biomass) to increase efficiency
- it has a low environmental footprint, as a resource it is invisible



Schematic diagram of the geothermal systems in the Pannonian basin

The Pannonian basin in Central Europe has a well-known positive geothermal anomaly, where the rich geothermal resources have been utilized mainly for direct use purposes for a long time. The overall high geothermal gradient of about 45 °C/km is related to the Early-Middle Miocene formation of the basin (about 10-12 million years ago), when due to extensional tectonic forces the Earth crust thinned and the hot astenospehere got closer to the surface providing a high heat-flux.

The DARLINGe project area is found at the southern part of the Pannoninan basin encompassing southern Hungary, north-eastern Slovenia, northern Croatia, northern Serbia, the northern parts of Bosnia and Herzegovina, and western Romania, altogether about 95,000 km^2. DARLINGe's ultimate goal is to improve energy security and efficiency in the Danube Region by promoting the sustainable utilization of the existing, however still largely untapped deep geothermal resources in the heating sector.

GEOTHERMAL HEATING – "THE HEAT UNDER YOUR FEET"

There are two ways of extracting geothermal energy from the ground for direct use (i.e. heating purposes):

- by heat recovery (closed loops at various depths, i.e. deep geoprobes)
- by extracting thermal water

The extraction of thermal water can happen in two different ways:

- During **direct thermal water utilization** the extracted fluid is used in the heat exchangers of the consumers (i.e. the extracted thermal water itself is circulated in the heating system). This can happen if the thermal water has favourable chemical properties, e.g. it has a low content of dissolved solids and thus does not cause scaling, it is not corrosive, or it has a low free gas content.
- During **indirect thermal water utilization**, the primary geothermal loop transfers the heat via heat exchangers to a secondary heating loop circulating "clean" water; it is the latter which provides the heat for consumers. This solution is preferable when the extracted thermal fluid cannot be fed directly into the heating system due its unfavourable chemical characteristics (e.g. it has a high content of dissolved solids, or an "aggressive" composition).

After utilization, the used and cooled thermal fluid can be discharged according to regulations in each country:

- into a sewage or rainwater system
- into an open surface channel (preferably through a cooling tank),
- into streams, or rivers
- returned back into the aquifer (reinjected)

The possible consequences of surface discharge can be:

- the salinisation and increased thermal load of natural surface waters, possibly along with methane and carbon-dioxide emissions from the associated gases of the thermal water
- a decrease of the thermal water resources and of the reservoir energy; these respective decreases may be reflected in a significant reduction of the water level and/ or a fall in pressure in the production wells

However, by using reinjection into the same geothermal aquifer these problems can be eliminated. Consequently, production becomes renewable and sustainable from the water-balance point of view; furthermore, it also becomes sustainable with respect to energy, since the reservoir is replenished and the reinjected cool water warms up again in the subsurface if the flow rates are not too large.

Geothermal heating of a greenhouse

In countries of the DARLINGe project, the typical outflow temperature of thermal water wells is 60–110 °C. This makes it possible to satisfy the heat demands of different consumers at different temperatures. It is always a customary process to match the energy source (geothermal fluid with a certain flow rate and temperature) and the local energy needs (heating/cooling with certain temperature levels and variance vs. time).

Typical cases of geothermal energy usage for heating purposes are the following:

a) **Geothermal district heating (geoDH):** this is frequently found in big cities with an existing district heating network and heating stations, originally fed by fossil fuels. In some cases these systems (or parts of them with certain heat loops) are supplied by thermal water.

b) **Thermal water town heating systems:** in these systems a few buildings (typically public buildings, such as the town hall, hospitals, schools, libraries, etc.) are heated by thermal water through a specially designed thermal water pipeline loop; the latter connects the production well, the buildings and – in most cases – a reinjection well. These systems are usually operated by municipalities, or municipally-owned companies, and there are no separate energy service companies (ESCO). Normally, such systems do not have capacities that are high enough to supply 100% of the heat demand, especially on the cold winter days, so the fossil fuel-based (typically gas, or coal) boilers of the individual buildings are necessary. In the DARLINGe area thermal water town heating systems are more prevalent than geoDH systems.

c) **Individual space heating:** this is common in spa complexes where the heat content of the produced thermal water for balneology is used to heat the associated buildings (most commonly through heat exchangers). These systems often lack reinjection wells, although the thermal water used solely for the heating could be reinjected (in contrast with the water used for bathing). Often, some of the water is also used for sanitary water heating, or as the sanitary water itself.

d) **Agricultural use:** in this particular area thermal water can be used for a great variety of purposes: heating of greenhouses, plastic tents/polythene tunnels, stables, hatcheries, soil heating, fish farming etc. In most of such cases there is only a single production well and the used water is discharged into surface recipients. Nevertheless, as only heat is extracted, these systems could reinject the thermally depleted water back into the aquifer.

CASCADE USE – EFFICIENT UTILIZATION OF GEOTHERMAL ENERGY

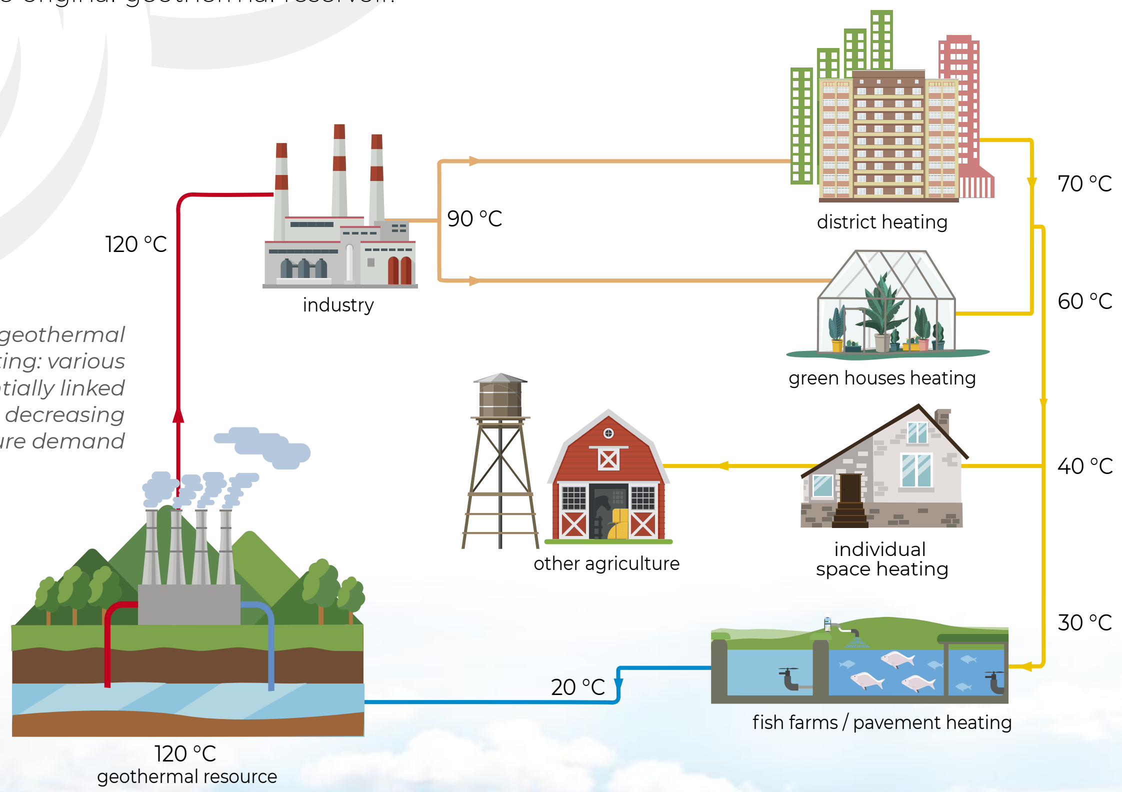
In older geothermal systems the facilities to be heated are able to use only a part of the thermal content of the medium and thus, on frequent occasions, the discharged fluid is still hot. One of the aims of the new systems is to try to order the consumer network into cascade systems, which multiplies the economics of a project. This means that heating circuits with various temperature differences are aligned in the system in order to maximize the specific heat capacity of the thermal water. The secondary medium of one district appears as the primary medium in another district, in line with the lowering of temperature demand. This cascade system guarantees the most efficient utilization of the heat content of the extracted thermal water.

For example, in the case of a 120 °C thermal fluid, the first consumer with the highest heat demand may be an industrial user. In the next stage, the fluid cooled to around 90 °C may be fed into a geothermal district heating system calibrated to a temperature range of 90/70 °C. Greenhouse heating can be also linked to the system, followed by individual space heating with modern floor, wall or hot-air heating; these can be made suitable for the complex utilization of a heating medium ranging between 45/35 °C. Other agriculture uses, such as heating of stables, hatcheries also fall in this temperature interval. After such installations, facilities with lower heat demand, e.g. sports halls or underground parking lots can be linked to the grid that can be heated through a temperature range of 35/25 °C. The "outgoing" fluid, with a temperature around 25 °C, can still be used for frost and snow removal, with warm pipes installed below the pavements of public areas, or in fish farming. Finally, the used fluid that had lost its heat content is reinjected into the original geothermal reservoir.

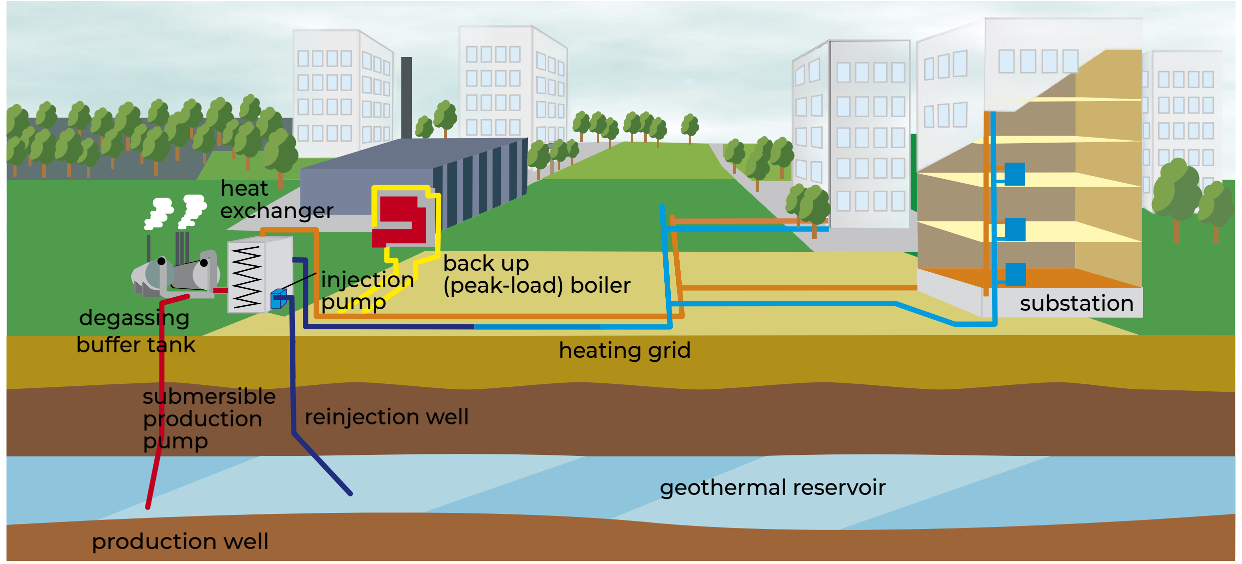
HOW DOES A HEATING SYSTEM OPERATE?

The **general operation** of existing (large scale) heating systems can be summarized as follows:

In a typical geothermal system a submersible pump installed in the production well and surface pumps installed near the well, pump the thermal water into a large insulated degassing buffer tank. In renovated or new systems, the programming of the yield of the



Cascaded use geothermal energy for heating: various users are sequentially linked according to decreasing temperature demand



Schematic diagram of the geothermal systems in the Pannonian basin

submersible pump – in accordance with the water level of the tank – guarantees the fluctuation-free operation of the well. With regard to several new thermal projects, the deaerated natural gas content is collected, cleaned and used in gas engines for cogeneration purposes.

Booster pumps in the engine room pump the degassed thermal water through pipelines to the consumer heating stations.

In some older systems the heating medium is directly transported through radiators without any kind of control. The motor valves in modern consumer heating stations are controlled by consumer heat demands (i.e. with local temperature-dependent control systems) and these valves transmit the heating medium to the heat exchangers at volumes that satisfy actual heat demand. An increase in heat demand in the consumer systems results in (a) the opening of the relevant motor control valve, (b) a drop in the supply pressure, (c) an increase in the speed of the booster pump in the well's engine room, and (d) the entering of more fresh thermal water into the system. In the opposite case a resetting of water production takes place.

After transmitting the hot water to the heating grid – preferably arranged in a cascaded system – the cooled thermal water from the last consumer reaches – in compliance with the given licences – either (a) an overground recipient (such as a cooling tank, wastewater or rainwater channel, river, natural or artificial lake, etc.) through the return pipeline with the help of installed booster pumps, or (b) a reinjection buffer tank through a reinjection pipeline. From the reinjection tank, adjacent reinjection pumps pump the cooled fluid through an overground filter system and a reinjection well, into the reservoir. The water level of the tank controls the operation of the reinjection pumps.

The operation of older, outdated systems is not monitored at all. In contrast to this, data recording systems have been installed in newer, or renovated systems for the control of operational parameters and the protection of the environment. The following parameters should be monitored and recorded during operation:

Production well and degassing buffer tank at the Makó cascaded system, Hungary

Heating station at Slobomir, Republic of Srpska, Bosnia and Herzegovina

- the water level of the production well, the main operating parameters of submersible pumps (operating hours, frequency), and the pressure, quantity and temperatures of outflowing water
- the water level of the buffer tank, and the main parameters of the forwarding pump (i.e. operating hours, frequency, quantity of transported water)
- the sectionalized pressure values of the pipeline network
- the pressure, temperature and quantity of the medium arriving at the consumers' heating stations, and the quantity of supplied heat
- the water level of the reinjection well, pressure values (at the wellhead) before and after the over-ground filter, the main operating parameters of the reinjection pump (operating hours, frequency, quantity of reinjected water), and the temperature of the reinjected water

Scaling of minerals from outflowing thermal water should be prevented by different measures

DARLINGe RECOMMENDATIONS FOR MORE EFFICIENT AND WIDESPREAD GEOTHERMAL HEATING SYSTEMS

The drilling costs of boreholes constitute the major element of a geothermal project. Therefore **reductions in drilling costs** can substantially impact the overall economics of a deep geothermal project. Research and development should focus both on novel drilling concepts and on improvements to current drilling technologies; including the careful planning of reinjection well. Furthermore, it should aim to optimize the economics related to drilling operations (horizontal, multidirectional, multi-well, etc).

Novel production technologies can improve the efficiency, reliability and cost of heat production (e.g. well-design and completion, definition of suitable materials). The primary targets are (a) to reduce operation and maintenance costs, (b) to improve system reliability and the energy efficiency of the operation (c) to increase the lifetime of boreholes and system components by monitoring, and to couple all this with (d) in-depth understanding of reservoir and thermal loop processes.

The **well and wellhead should be properly constructed;** this means it should be isolated from nearby buildings and constructions, protected from unfavourable weather conditions, free from the interference of unauthorized persons, and it should have enough fittings to install monitoring equipment to measure pressure, temperature and extraction rates.

There is wide range of potential **operational problems,** such as scaling, blowouts, clogging of screens, corrosion, sand abrasion of pump particles, etc.

These factors depend on the local geological and hydrogeological conditions. The risks of such problems should be examined carefully, and preferably on the basis of thorough analyses of samples taken downhole in the geothermal wells prior to site development. Based on these analyses, there is a considerable number of **preventive actions**, which should be chosen for each individual site, e.g.:

- Increasing the pressure in the surface installations in order to stay above the bubble point (i.e. to avoid degassing and scaling.)
- Filtering – both at reservoir level (screens and gravel packs) and at the surface (mechanical, bag and/or cartridge filters)
- Choosing the most suitable materials that are less prone to corrosion / scaling
- Injection of inhibitors to prevent scaling or corrosion, and perhaps even installing these downhole
- Regular treatments like the (soft) acidizing and cleaning of the wells (mechanical, back-washing)
- Adjustment of water flow rate

If free **gas** is also produced from the well, it is recommended that it is **utilized** (e.g. burning of methane for heat or electricity, bottling and selling CO_2, etc.).

Filtering system prior to reinjection, Lendava, Slovenia

During operation the energy demand for pumping can be a burden on overall efficiency. Therefore it is necessary **to improve pump efficiency and longevity** to secure reliable production.

Cascade systems should be **given greater priority** because these provide the efficient use of all temperature gradients.

Research, development and demonstration projects are essential to bring about a better understanding of the **technical constrains of reinjection;** they must be applied on a much wider scale than at present.

It is also necessary to develop innovative solutions for **refurbishing existing buildings** and optimizing the existing networks in order to be able to accommodate lower temperature fluids.

DARLINGe project is promoting the sustainable utilization of the existing, however still largely untapped deep geothermal resources in the heating sector at the southern part of the Pannonian basin.

For further information, please visit our website: http://www.interreg-danube.eu/approved-projects/darlinge or contact the project coordinator – nador.annamaria@mbfsz.gov.hu

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