

## Technology Status of Direct Geothermal Utilisation

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### ABSTRACT

Geothermal energy has always been used, wherever natural resources were available. The technology developed slowly until the oil and gas prices increased significantly, and is developing fast at present due to environment protection concerns and requirements.

The paper presents an overview on the current status of the technology for the direct utilisation of geothermal energy, including some aspects of balneology, and excluding all aspects related to ground source (geothermal) heat pumps.

### 1. INTRODUCTION

Natural geothermal resources have been used by mankind since pre-historical times. There are even opinions that the natural hot springs were actually the places where *homo sapiens* evolved from primates, during a severe glaciation. Two of the main arguments are the vertical posture (most convenient in water, not on land) which left the hands free for work, the loss of fur except for head and eyes (as protection for direct and reflected solar radiation).

Recorded history has many examples of ancient use of natural geothermal resources all around the world, wherever available (Cataldi, Hodgson & Lund, 1999). Minerals from the mud in and around surface geothermal manifestations were used for dying and also for the treatment of different diseases. The hot water was used for bathing, washing, even cooking when the temperature was high enough.

The hot water was first used on location, where it naturally occurred. As the tools evolved, the "technology" developed from digging trenches and ponds to channel and store the water, to the sophisticated "Roman baths" built during the Roman Empire time (Cataldi, and Chiellini, 1995).

At present, geothermal energy is used for all kind of applications, wherever heat is needed. The purpose for which a geothermal resource can be used depends of the temperature of the available fluid, this being clearly shown in the well known "Lindal diagram" (Lindal, 1973).

The geothermal utilisations are usually divided in two main categories:

- **indirect utilisation**, meaning the conversion of geothermal energy in other forms of energy, at present electric energy only. The power plants are using either geothermal steam from high and medium enthalpy sources (working on the Rankine cycle), or geothermal liquid from medium and low enthalpy sources (working on the Rankine or Kalina cycle).
- **direct utilisation**, meaning the available geothermal energy is used for whatever process in which heat is

needed: space heating (including greenhouses and animal farms), drying (fruits, vegetables, grains, fish, wood, pottery, etc.), pasteurisation (e.g. milk), and probably the most important, district heating (also cooling being possible in certain cases).

There are two other particular cases included in the larger field of geothermal utilisation: ground source heat pumps and balneology.

In the first case, a (usually vapour compression) heat pump is extracting geothermal heat from underground (through horizontal or vertical heat exchangers, or from groundwater produced from shallow wells). This energy, together with the energy supplied to the compressor, is used for space and tap water heating. With reversible heat pumps, the heat extracted from rooms during the cooling season is used for tap water heating, the excess being sent back underground through the same system.

A similar, but much simpler way to extract geothermal energy is to use an underground heat exchanger and only circulate water through it using a pump, not a heat pump. When using existing wells (i.e. abandoned oil or gas wells), it is possible to obtain a significant heat flux at a reasonable temperature and at a rather low cost.

The utilisation of geothermal water for balneology has a long history and is still widely spread all over the world. It is, at present, included in the geothermal energy utilisations, as it saves additional energy otherwise needed to heat the water for health bathing to the proper temperature (37°C). Nevertheless, it must be mentioned that the temperature is only one of the curing factors, while probably more important are the chemicals dissolved in the geothermal fluid (different compositions from one reservoir to another, sometimes even from one well to another).

The paper presents an overview on the current status of the technology for the direct utilisation of geothermal energy, including some aspects of balneology, and excluding all aspects related to ground source (geothermal) heat pumps.

The way geothermal energy is used depends of two factors:

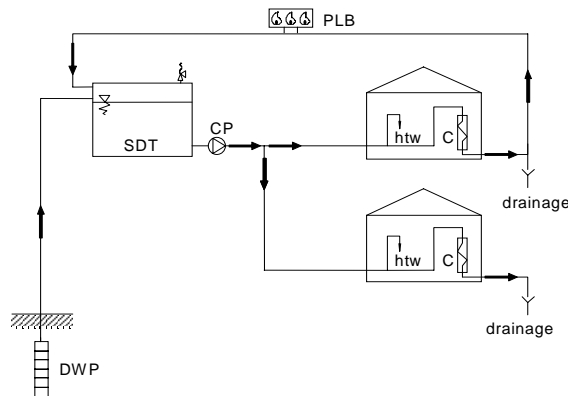
1. the resource: well head pressure and temperature, maximum flow rate that can be obtained in a sustainable exploitation, hydro-thermal parameters of aquifers for heat and/or cold storage;
2. consumers existing in the vicinity of the resource (except for power plants producing electric energy only, which can be transported long distances with low losses).

Where the well head temperature is high enough and there are a number of consumers in the area requiring different temperatures of the heat source, the utilisations can be cascaded, the final being usually health and recreational bathing, or fish farming.

## 2. DISTRICT ENERGY SYSTEMS

### 2.1 District Heating Using Directly Geothermal Water

In particular cases, when the geothermal fluid has no scaling, nor corrosion potential, or when these can be easily avoided at a low cost, it can be used directly as thermal agent in the system. In rare cases, the geothermal fluid complies to the legal specifications for drinking water, and can therefore be also used directly as hot tap water if the temperature is high enough. If the temperature is higher than the standard domestic hot water temperature (usually about 50°C), a three way valve is used to mix it with cold water.

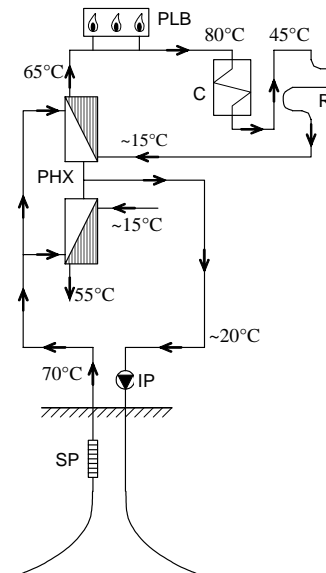


**Figure 1: Schematic layout of a district heating system using directly the geothermal water**

The layout of a very simple geothermal district heating system is given in Figure 1. This technical solution is common in Iceland, and can only be used when reinjection is not needed (for environmental reasons or to maintain the reservoir pressure) and the reservoir can produce a large enough flow rate of geothermal water with a well head temperature of 70-90°C of drinkable quality. The line-shaft or electric submersible deep well pump (DWP) feeds the geothermal water into the storage and degassing tank (SDT), from where it flows by gravity or is pumped to the users, where it is used both for space heating and as hot tap water. A peak load boiler (PLB) can be used to increase the supply water temperature, if it is not high enough for the nominal outdoor temperature. The heat depleted water is disposed of in the drainage or sewage system, and can be used before that for snow melting. Part of the outlet water can be returned to the STD, if the well head temperature is too high (above 80°C). The heat load is controlled by regulating the flow rate (control valves at the radiator inlet), as the supply temperature is constant. Another control valve limits the outlet temperature of the water from the heating system. The consumer is invoiced for the quantity of water used.

### 2.2 “Doublet” Type District Heating Systems

The geothermal doublet concept has been developed in the Paris basin and is currently used in many other places in different designs. Basically, a doublet is made of one production and one injection well, in some cases drilled from the same platform (requires less space in urban areas), both deviated but to different directions to increase the distance between the production and the injection place in the reservoir. The re-injection is required in many places, for maintaining reservoir pressure, or for environment reasons, but the re-injection issues will not be addressed further in this paper.



**Figure 2: Schematic layout of a geothermal doublet for district heating**

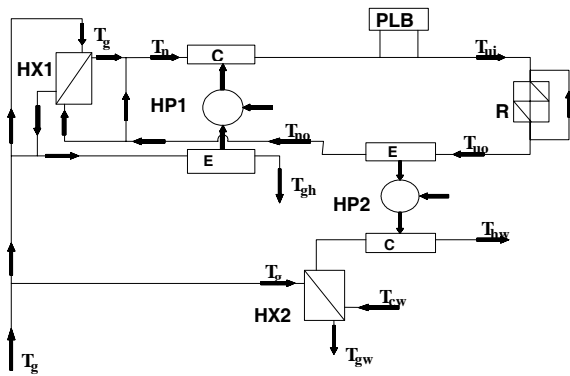
A simplified layout of a geothermal doublet is presented in Figure 2. In order to use as much as possible of the exergy content of the geothermal fluid already extracted from the reservoir, it is possible to cascade the heating agent from users with convection (C) space heaters (requiring higher inlet temperature) to users with radiation (R) space heaters (with lower inlet temperature). The final return temperature in the secondary network is therefore lowered even at high loads, more heat is extracted from the available geothermal fluid, which is reinjected at a lower temperature. This option is usually viable in new housing developments, or when part of the consumers have anyhow to be fully renovated.

In systems of this type (Figure 2) the heat load is usually controlled by modifying the geothermal fluid flow rate in the primary plate heat exchanger (PHX) and consequently the supply temperature in the secondary network. The deep well pump (DWP), the injection pump (IP), and the circulation pumps (CP1 and CP2) have usually frequency converters for variable speed drives (for variable flow rate). The storage and degassing tank (SDT) and all the storage tanks (ST) needed are sized to compensate the daily variations in demand.

A peak load boiler (PLB) is used when the temperature of the geothermal water is not high enough, or when there are more consumers in the area. Geothermal energy supplies only the base load for space heating (usually 60-80% of the nominal load), the additional heat need during peak loads being supplied by the boiler.

### 2.3 Heat Pump Assisted Heating Systems

In some cases, the temperature of the geothermal water is too low to cover even a significant part of the nominal load. Even if expensive, in certain economic environments it is still economic to assist the geothermal district heating by heat pumps, either directly (extracting residual heat from the outflow geothermal water), or indirectly (extracting heat from the return pipe of the secondary network). In Figure 3 is given a possible layout for space and tap water heating using a source of geothermal water with a temperature of about 50°C, the consumer being equipped with cast iron radiators for space heating.

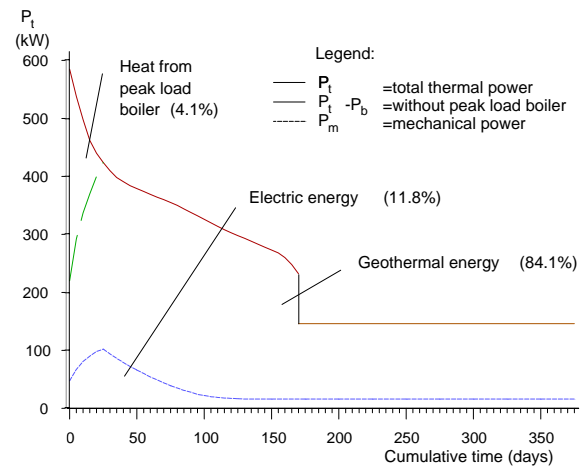


**Figure 3: Schematic layout of an indirect heat pump assisted geothermal heating system**

The system is basically a heat pump assisted with direct evaporator type. At low partial loads, as long as the radiator water inlet temperature is below 45°C, the heat demand is supplied through direct heat exchange from the geothermal water by the primary heat exchanger (HX1). The condenser of the heat pump (HP1) is by-passed in this case. As the required radiator water inlet temperature increases above 45°C, the primary heat exchanger can no longer supply the total heat demand and HP1 is turned on. The radiator water outlet temperature is increasing at the same time, causing an increase in the geothermal water outlet temperature from the primary heat exchanger. The latter is therefore passed through the evaporator of the HP1 in order to lower the temperature of the waste geothermal water as much as possible. When the network return temperature ( $T_{no}$ ) reaches 40°C the direct heat exchange through HX1 is no longer efficient and it is consequently by-passed. The evaporator of the HP1 is then fed with geothermal water at well head temperature ( $T_g$ ). During the periods of time when the heat pump is working at partial loads, it is not desirable to regulate its speed continuously in order to ensure all the time the required inlet temperature for the radiator water. It was considered more energy efficient to have the possibility to mix a part of the outlet radiator water with the inlet radiator water. In this way the inlet temperature can be regulated continuously by regulating the mass flow rates of the two streams, while running the heat pump at a certain constant speed. When the required inlet temperature of the radiator water increases above the maximum outlet temperature from the condenser of the HP1, the heat supply is supplemented by the peak load boiler (PLB).

The fresh water is first heated by direct heat exchange up to the intermediate temperature  $T_{iw}$  in the heat exchanger HX2. Subsequently it is heated up to the standard temperature  $T_{hw} = 65^\circ\text{C}$  in the condenser of the second heat pump (HP2). This arrangement insures a decrease of the radiator water outlet temperature, improving the heat exchange in the HX1. During the time the space heating system is turned off (out of the heating season), geothermal water at the well head temperature  $T_g$  can be fed to the evaporator of the HP2.

For a consumer with a total thermal power demand of about 600 kW (for both space and tap water heating), the power demand intensity duration curve is shown in figure 4. The lower part represents the energy needed for heating the tap water (constant all year long), and the upper part represents the energy for space heating. Almost 85% of the total annual heat demand is supplied by geothermal energy, less than 5% by the boiler, and about 11% is the electric energy used by the two heat pumps.



**Figure 4: Power demand intensity duration curve for a heat pump assisted geothermal heating system with peak load boiler**

#### 2.4 Integration of Geothermal Energy in a Large District Heating System

There are cases where a geothermal resource is located in the immediate vicinity of a town that already has a district heating system. A good example is the City of Oradea, Romania, located in the western part of the country, with a population of about 239,000. The district heating system is supplied by a co-generation power plant with five units and which also has three hot water boilers used for district heating only. The boilers are fired by solid fuel (low grade coal and, at present, mainly biomass), except for two steam boilers which are fired by natural gas (a distribution network being developed in the last 5 years). The power plant and the district heating are a single company, which belongs to the Municipality of Oradea.

The City of Oradea is placed on a very geothermal reservoir located in fractured calcite and dolomite at a depth between 2 and 3 kilometers. The reservoir has a natural recharge of more than 300 l/s. There are 12 wells already drilled in Oradea, and one more is drilled at present. Artesian production is possible up to a certain flow rate from each well, and when a higher flow rate is needed, the wells are produced by line shaft pumps with variable speed drives. The wellhead temperatures decrease from 105°C in the western part of the city to about 70°C in the east.

The company having the exploitation license for the Oradea geothermal reservoir created a joint venture with the Municipality to supply primary heating agent to some sub-stations located in districts with high heat load density, i.e. districts with blocks of flats. The systems are also doublet or triplet type, with one or two production wells and one re-injection well. The geothermal heat plants have stainless steel plate heat exchangers, circulation pumps, storage tanks, and natural gas fired peak load boilers. Part of the heat depleted geothermal water is used in swimming pools near the geothermal heat plant, the rest being reinjected.

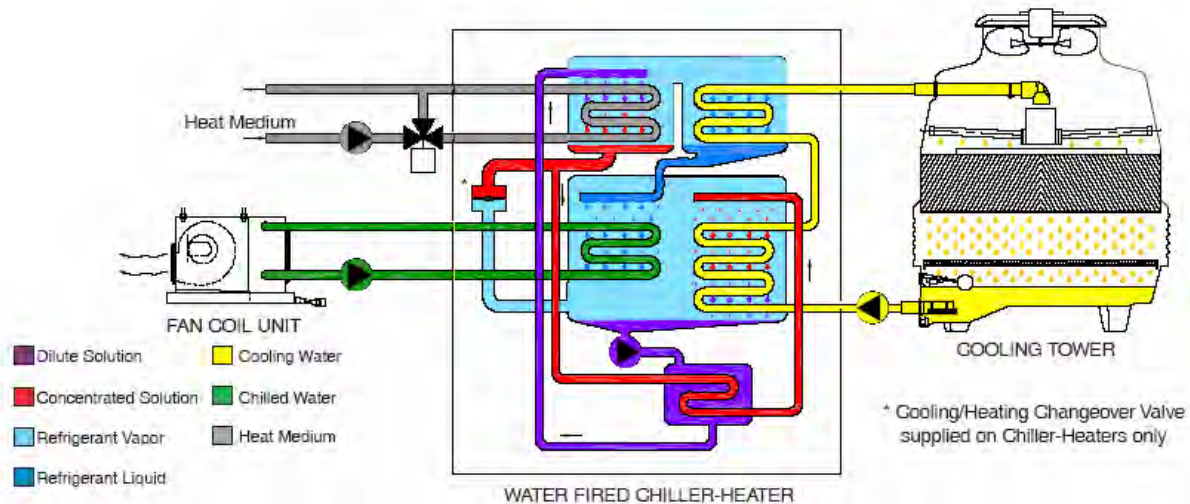
The modifications required in the sub-station for using primary heating agent from the geothermal heat plant have been minimal. As the co-generation power plant supplied 120°C heating agent at peak loads, and the geothermal heat plant supplies only 90°C primary agent, the heat exchangers had to be re-designed and changed, but the sub-stations had anyhow have to be completely renovated, due to their age.

## 2.5 District Heating and Cooling Systems

The geothermal district heating systems in the Paris Basin usually have a central geothermal heat plant which supplies the primary fluid (in a closed loop, supply and return pipes) to substations. The thermal energy demand for sanitary hot water and for the base load for space heating is supplied by geothermal energy. In most cases, during the cold system, a cogeneration plant is also operated in the close vicinity of the geothermal heat plant, the recovered heat being used to increase the inlet temperature of the primary fluid supplied

to the substations. Some substations might also be equipped with peaking / back-up boilers fired by fuel oil or natural gas. The supply temperature of the primary fluid is about 70°C in the warm season, and up to 95°C at the nominal space heating design temperature of -7°C.

In this situation, one or more chillers, as needed, can be placed in the substations (Figure 5). The heat medium will be the primary fluid supplied by the geothermal heat plant. Each absorption chiller unit will be equipped with a cooling tower (for the cooling water).



**Figure 5: Absorption reversible heat pump for geothermal district heating and cooling systems.**

The chilled water will be piped to the consumers through the same network used for space heating. It can then be used by the consumers in the existing room heaters (cast iron radiators or floor heaters), but a better option would be to install new fan coil units or, even better, ceiling coolers (with false ceiling tiles).

There are now available on the market absorption heat pumps which can use down to 70°C water as heat medium. These can be very well used in geothermal district heating systems, increasing the production of geothermal energy during the warm season (and therefore the business for the company operating the system), and providing a better thermal comfort to the consumers by decreasing the indoor temperature a few degrees below the outdoor temperature.

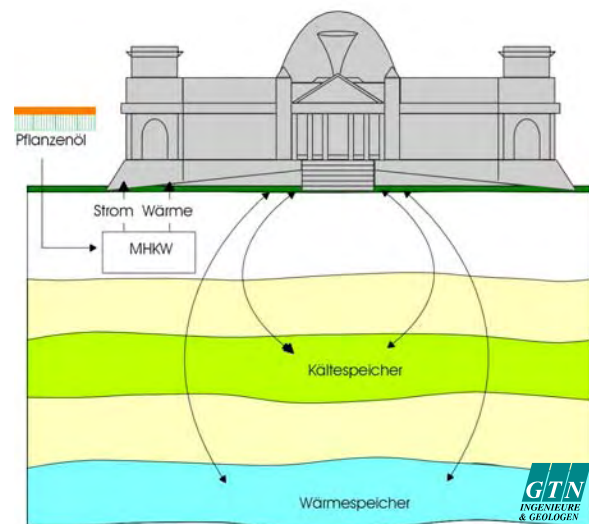
## 2.6 District Energy Systems with Heat and Cold Aquifer Storage

The system in Figure 6 supplies electric energy, space heating and cooling (by air ventilation), and hot tap water to the German Federal Parliament and some other office buildings in the area (Kabus and Seibt, 2000). The power generation units have Diesel engines fired by biofuel. All the heat (from water and oil coolers, as well as from exhaust gases) is recovered and used for space and water heating, the surplus being stored underground in a deeper aquifer. A shallower aquifer is used for cold storage.

The system is automatically controlled and can maintain a constant temperature in each room, cooling certain rooms while heating others, as needed due to their orientation and utilisation (offices, meeting rooms, television studios, etc.)

It is not a typical geothermal district heating system, but the storage of heat and cold in underground aquifers is used in

other places too, and is considered as being one type of geothermal energy utilisation.

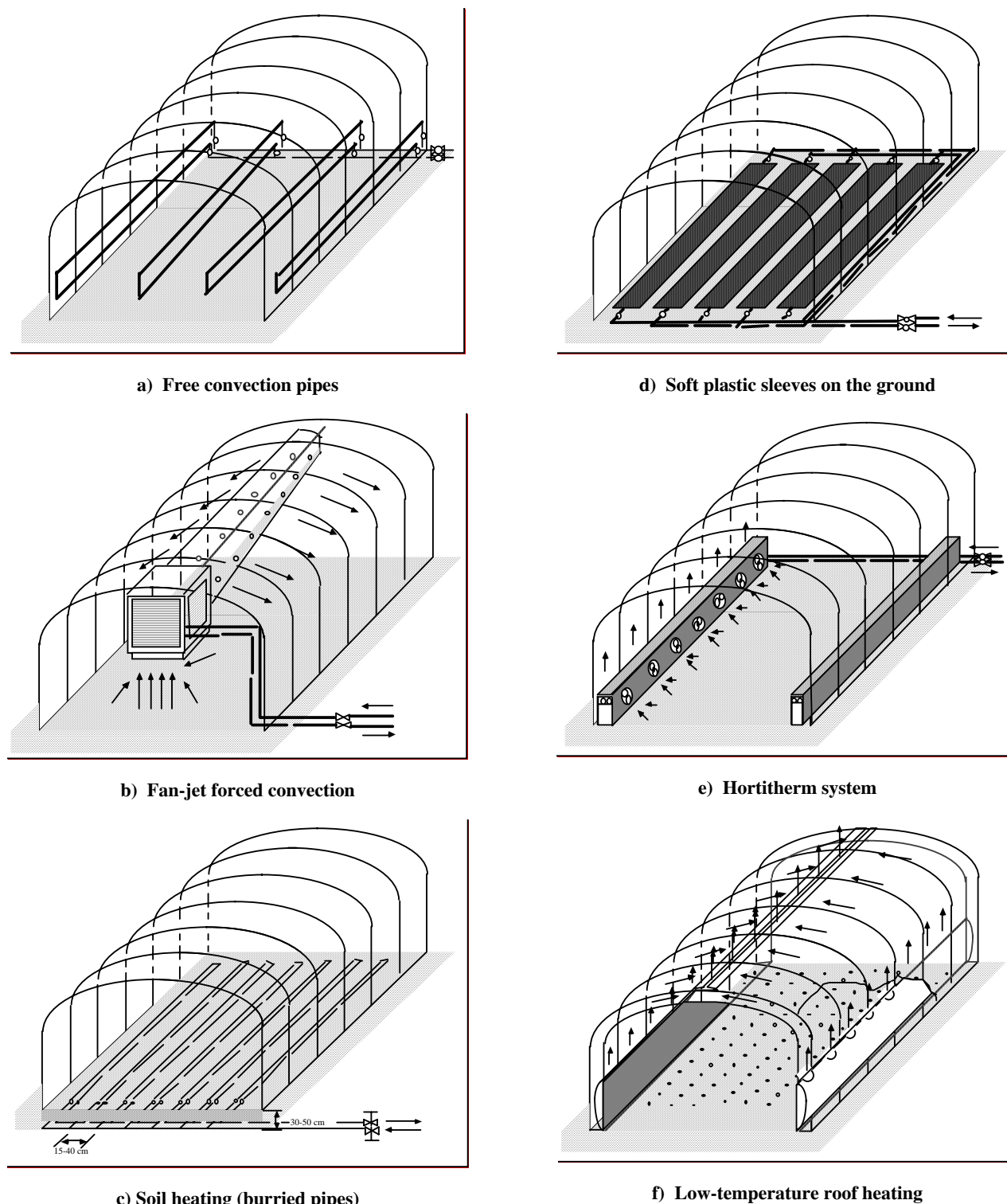


**Figure 6: District energy system with underground heat and cold storage for the Reichstag complex (Poppei et al., 1998).**

## 3. INDUSTRIAL AND OTHER UTILISATIONS

### 3.1 Greenhouse Heating

Greenhouse heating is one of the most common direct uses of geothermal energy. The completion of greenhouses can vary significantly in shapes and materials, some being made of plastic foil, other of glass, in one or more layers, with quite different surface areas.



**Figure 7: Greenhouse heating technical solutions** (after Popovski, 2001)

The main types of technical solutions for greenhouse heating are shown in Figure 7 (after Popovski, 2001). The technical solution for heating a greenhouse is selected as function of the climatic conditions and mainly of the type of plants cultivated in the greenhouse.

An much more simple technology can be used in areas with milder climates. Plastic pipes are laid on the ground and covered with soil on which vegetables (e.g. asparagus) are growing outdoors. When the air temperature is too low, geothermal water is flown through the buried pipe, heating the roots. The plant grows faster and can be on the market earlier, at a price that covers the additional cost.

### 3.2 Drying

Geothermal energy is used to dehydrate or dry different materials such as wood, vegetables, fruits, grains, pottery, etc. The water-to-air heat exchanger can be supplied with geothermal water (when it has no scaling, nor corrosion potential which can not easily be avoided), or by treated water heated with geothermal energy.

The temperature, humidity and velocity of the hot air used for drying, as well as the time needed for drying, depend of the type and size of the materials that are dyed, in order to insure a good quality of the final product.



The dryers are basically of two types: chambers and tunnels. The drying chambers are filled with the material to be dried arranged in piles or on tray placed on racks, leaving room for air circulation. After the required time, the dried charge is replaced, and a new drying process starts. In drying channels, the material to be dried moves from one end to the other, in the hot air current, either on conveyor belts, or on racks with wheels.

The complexity of drying installations varies in a wide range. For high quality timber, the wood has to be dried to a very low humidity, actually to remove part of the water in the cells, and humidified again after that, in order to avoid cracking during further processing. Timber driers have to be automatically controlled (air temperature, humidity and velocity, and time needed for drying and humidification), as function of the wood essence and timber dimensions.

Probably the simplest drier is presented in Figure 8, used for tomato drying (Andritsos et al., 2002). The trays with sliced tomatoes are placed on wheeled racks, which are pushed manually inside the drying tunnel, at the far end from the fans and heat exchangers, where the air temperature is lower and humidity higher. The racks with the dried tomatoes are evacuated at the other end of the tunnel. In this way, the dried tomatoes are of a very good quality, not too dry outside and too wet inside.

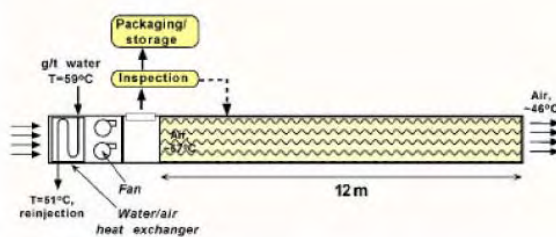


Figure 8: Tomato drying tunnel (Andritsos et al., 2002)

### 3.3 Pasteurisation

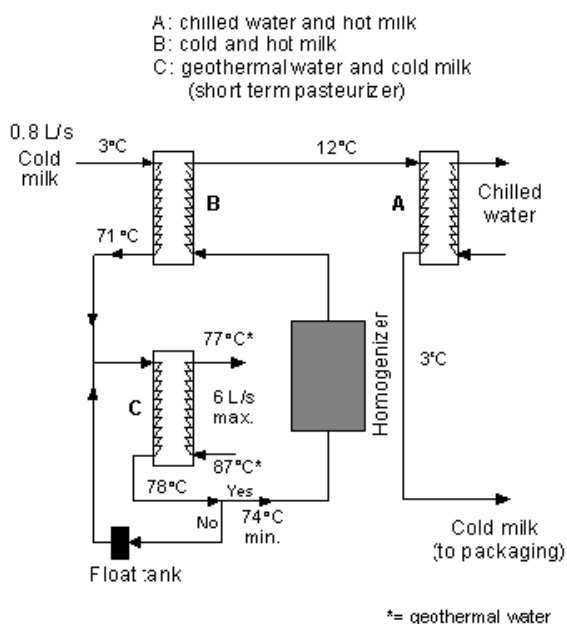


Figure 9: Milk pasteurisation using geothermal energy (Lund, 1997)

Many drinks need to be pasteurized before packing, to prevent alteration during long storage time.

A simple milk pasteurization system is presented in Figure 9. The required temperature for short term pasteurization of milk is 75-85°C for 30-20 seconds (in plate heat exchanger C). After pasteurization, the milk is cooled to 12-14°C by the incoming cold milk (in plate heat exchanger B), and finally chilled down to 3-4°C by cold water (in plate heat exchanger A). Similar systems, with different temperatures and times, can be used for any other liquids.

### 3.4 Other Direct Utilisations

#### 3.4.1 Aquaculture

Many species of fish are grown in fish farms for food (carp, catfish, pike, eel, trout, salmon, etc.) or just for their aesthetic value (for aquariums). Some aquatic plants, mainly algae, are also grown on industrial scale in special ponds. The most well known microscopic algae is probably *Spirulina platensis*, which contains 70-75% proteins of the best quality, plus many other compounds with a beneficial effect on the human body, the reason why it is currently grown in more than 60 countries world wide.

In order to increase the growing rate of any cultivated aquatic specie, it is important to provide a constant water temperature around the year. The heat loss by evaporation, convection, conduction and radiation has to be supplied by a constant inflow of warm water. Geothermal fluids with low temperatures can be used, where available, provided their chemical composition is acceptable for this purpose.

It is obvious that heat depleted geothermal fluids discharged in ponds or pools (for aquaculture or for bathing) can no longer be reinjected into the reservoir. This might be a disadvantage in confined reservoirs or with a relatively small natural recharge, but where the reinjection is not necessary for maintaining the reservoir pressure, this type of end uses have the advantage of providing a good reason to reduce the investment costs (for drilling injection wells) and the exploitation costs (for running the injection pumps).

#### 3.4.2 Snow melting

Low temperature geothermal water is used in some cases to melt the snow and ice on city streets and sidewalks, airport runways, bridges, etc. Simple, inexpensive and efficient snow melting systems are used in Iceland. The geothermal water used for space heating flows through small size pipes laid under the pavement in front of the house and garage entrance, and even under the sidewalk, before going into the draining or sewage system. As the consumer pays the water consumption, there is no additional running cost.

Another simple and efficient technology is used to melt the ice on bridges. Water heated in borehole heat exchangers is pumped through pipes under the pavement of the bridge in winter time. During summer, the water is cooling the road, preventing the softening of the asphalt layer, and stores the heat underground. No heat pump is needed, just circulation pumps.

In order to optimise the energy consumption, snow melting systems can be automatically controlled. Temperature and light sensors detect the snow or ice, and the process computer opens the control valves and starts the circulation pumps.

#### 3.4.3 Flax and hemp retting

For retting, the flax and hemp straw is soaked in ponds, canals, tanks, etc., to allow bacteria to soften the woody tissue so that the textile fibers can subsequently be

separated by scutching (beating) and hackling (combing). By using geothermal water from a well with very low temperature or the outflow from another utilization in a cascaded scheme, the retting time is reduced to half the natural process time of 14-16 days in surface water at atmospheric temperature (16-18°C in September-October). It has also been noticed that the fiber quality is improved due to the chemical composition of the geothermal water.

Geothermal water with temperatures of 35-45°C can be first used as a heat source for a rapid and controlled drying of the flax and hemp fibers, and then, at 25-30°C, it is used in retting ponds or tanks. The reduced retting time and improved fiber quality encouraged the development of this type of low temperature geothermal water utilization in many areas where flax and hemp are cultivated on large surfaces and low enthalpy geothermal resources are available (Plavita and Cohut, 1992).

#### 3.4.4 Sludge digester

Sludge digester heating at the waste water treatment plant of Arad city, Romania, uses 42°C geothermal water which is directly pumped through steel pipes placed in the lower part of the two digesters (150 m<sup>3</sup> capacity each). The geothermal heat decreases the processing time (that uses living anaerobic microorganisms). The biogas produced from the digested sludge is collected, cleaned and sold to other users.

#### 3.4.5 Sea water desalination

In islands with insufficient or no fresh water sources but with geothermal resources, the geothermal energy can be

used for the desalination of sea water. The most widely used desalination process, in terms of capacity, is the multiple stage distillation process. When only low enthalpy geothermal resources are available, with temperatures of 70-90°C, the multiple effect distillation process is more efficient (Karytsas et al., 2002).

#### 4. CASCADED USES

A schematic flow chart of cascaded geothermal energy uses is given in Figure 10. This can be used when the available geothermal water has relatively high temperatures (about 100-120°C). The geothermal water is first used for power generation in the vapour generator of a binary cycle power plant (ORC in Figure 10, Kalina unit also possible to use).

After the power generation unit, the geothermal water can be used in an absorption cycle refrigerator which can be used in storage rooms for fruits or vegetables (in areas with agricultural production), or for district cooling. For freezers working on the absorption cycle, if higher temperatures are needed, primary geothermal water (from the production well, can be used in the vapour generator.

The geothermal water can then be used for a district heating system, for drying vegetables or fruits produced in the area, for greenhouse heating, or for any other purpose.

The heat depleted geothermal water can further be used for recreational and even health bathing (when the chemical composition of the geothermal water has known properties). When the chemical composition of the geothermal water is adequate, it can also be used for fish farming and/or for aquaculture, or even for flex and hemp processing.

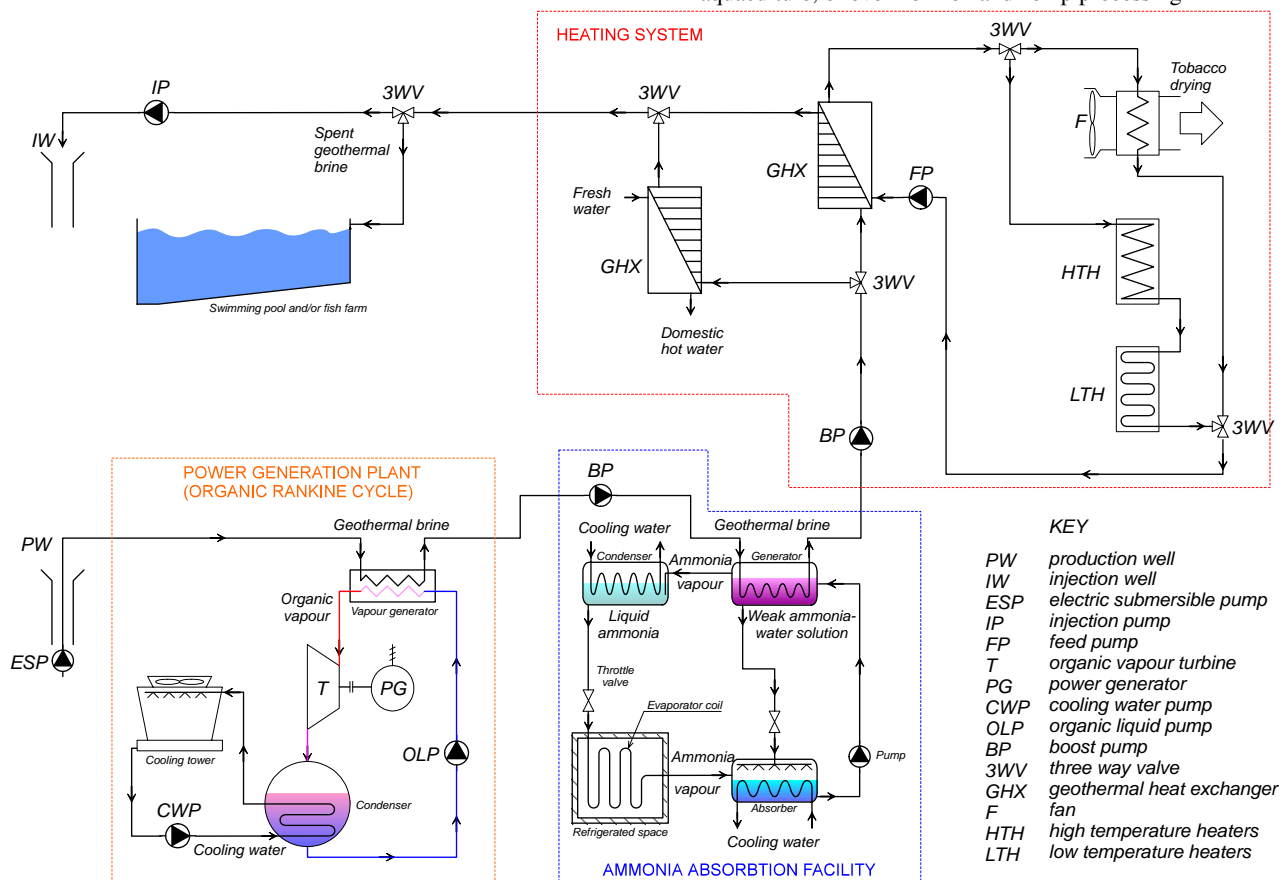


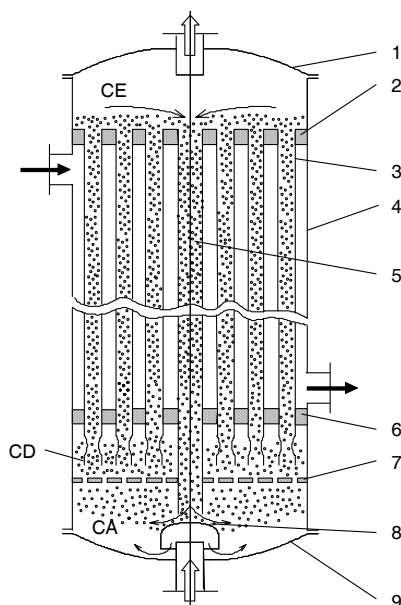
Figure 10: Example of cascaded utilisations of geothermal energy

## 5. EQUIPMENT

### 5.1 Heat Exchangers

The plate heat exchangers are probably the most used in geothermal system. These have high heat exchange areas in relatively small volumes, and also high overall heat transfer coefficients. The plates are usually made of stainless steel, but when the geothermal water is highly corrosive, titanium plates have to be used, although more expensive. When the geothermal water has no scaling potential, the plates can be welded. In case the geothermal water has scaling potential, the heat exchanger has gaskets between the plates, and it can be disassembled for cleaning, which is done quite easy with high pressure cold water when the plates are still hot and, when contracting, brake the scale.

Shell-and-tube heat exchangers with straight tubes are used when the geothermal water has a relatively high scaling potential, mainly when the scale is amorphous (mud), being even easier to clean than the plate heat exchangers. A similar heat exchanger is the fluidized bed heat exchanger (Figure 11), used when the geothermal water has a very high scaling potential.



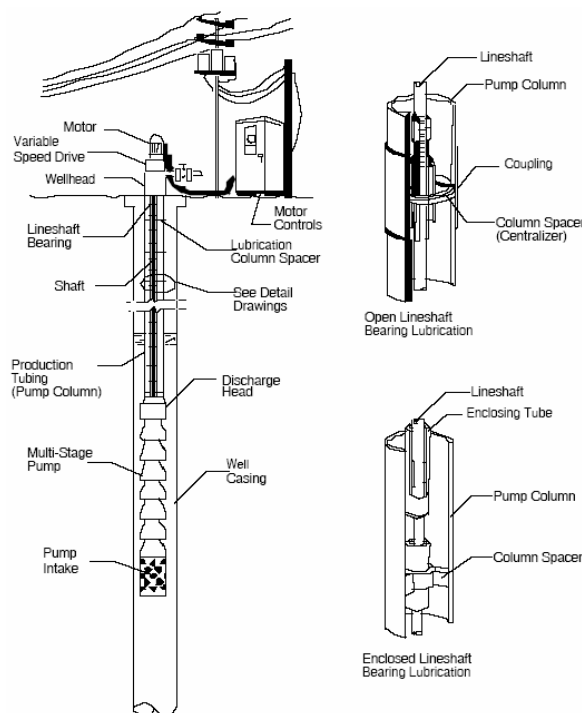
**Figure 11: Schematic representation of a fluidized bed (shell-and-tube) heat exchanger**

A large number of small solid particles (5) are maintained in a quasi-fluidized state by the dirty water flowing upwards in the tubes (3). These particles have an abrasive effect on the inside wall of the tubes, removing the scale continuously. The tubes are fixed in the upper (2) and lower (6) plates, which separate the space inside the shell, where the clean water flows, from the distribution (CD) and evacuation (CE) chambers. The geothermal fluid is fed at the bottom end to the admission chamber (CA), through the valve 8 (bell shape, working on its own weight). The distribution plate 7 has a large number of orifices, providing a relatively uniform distribution of the solid particles. To avoid the plugging of the lower part of the tubes by agglomeration of particles, two opposite holes are made in tube walls, at about half their length in the CD. In the CE the flow velocity decreases below the immersion velocity of the particles, so they drop on the upper plate 2 and further down to the CA. The upper (1) and lower (9) lids can be removed for periodical cleaning and particle replacement.

### 5.2 Down hole pumps

Two types of down hole pumps are commonly used for production from geothermal wells: line shaft and electric submersible pumps. Turbo-pumps are only used in very special conditions.

The line shaft pump is schematically presented in Figure 12 (Lund, 2002). The electric motor with variable speed drive is placed at the surface and is coupled to the pump by a long shaft (cased or open) inside the production column. The bearings are usually lubricated with the produced water (after filtering at the surface), and in some cases with oil. The main advantage is that the electric motor is at the surface, so it works at relatively low temperature, with no cooling problems, and therefore the mean time between failures is very long. The main disadvantages are: the cost of line shaft and its casing, difficult assembling, strict requirements for the linearity to avoid early damaging of the bearings, careful design to compensate the differences in the length of the shaft, its casing, and the production tubing when the pump operates and not, as the clearance between the rotors and bowls is limited.

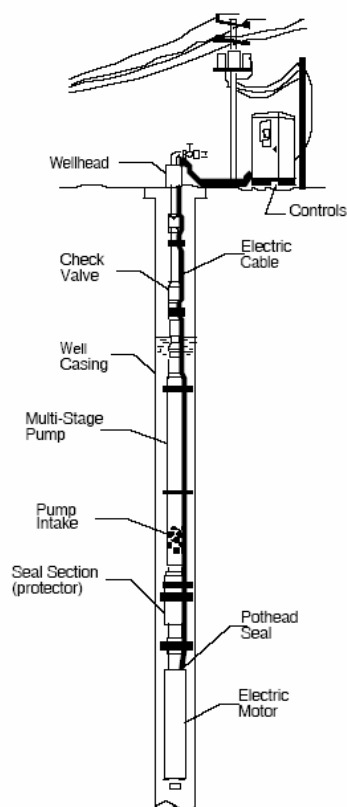


**Figure 12: Line shaft pump assembly (Lund, 2002)**

The electric submersible pumps have the motor inside the well, below the pump (Figure 13, Lund, 2002). The main advantages of this pumps are: simpler and less expensive assembling, as there is only the production tubing, with no special requirements for linearity, can also be installed in deviated wells. The main disadvantage is that the motor is inside the well, working in hot water, so it has to be specially designed to work at high temperatures. The water is many times even corrosive, and it may damage the electric cable insulation, in most cases at its entrance point in the motor's outer casing. For these reasons, the mean time between failures is usually shorter than for line shaft pumps. The electric submersible pumps are also more expensive. Regular cold water pumps can be used to produce up to about 60°C geothermal water without any significant problems for the motor. Electric submersible pumps for higher temperatures are available on the market,



at present of quite good quality, with longer mean times between failures, but at a much higher price than those for cold water.



**Figure 13: Electric submersible pump** (Lund, 2002)

As a rule of thumb, line shaft pumps are generally a better option when the deep well pump has to be set at a depth of no more than 200 m, if the well is straight enough.

### 5.3 Other Equipment

#### 5.3.1 Pumps

Common circulation or booster (when high pressures are needed) pumps are usually used in geothermal direct utilisation systems. When used for geothermal brines, the pumps have to be even more carefully supervised and maintained in order to avoid any leakages. Wherever the geothermal water is leaking, it evaporates fast, the solids dissolved in it deposit on that spot, and under these deposits the steel corrodes very fast.

#### 5.3.2 Valves

For valves used in networks for geothermal water it is recommended to select the ones that create the lowest turbulences and have hardened edges (mainly emergency shut off valves). The scale, and even the very fine sand carried in suspension by the geothermal water is accumulating in places of high turbulence. The edges have to be hardened and the actuators (i.e. electric motors) of higher power, to be able to break a potential scale without being damaged. The stuffing box is usually longer, for more efficient sealing, in order to avoid leakages.

#### 5.3.3 Pipes

Different types of pipes available on the market can be used in geothermal systems, made of steel, different plastics, or

reinforced fibre glass. For a certain system, with a specific chemical composition of the geothermal brine, the material for the pipe is selected so that it will not be damaged by the dissolved chemicals. The most important thing is to use materials that do not allow the oxygen from air to pass through the pipe walls, or at least not to use this kind of materials in parts of the system after which the geothermal fluid flows again through steel pipes. The geothermal fluid usually has no dissolved oxygen, the contact with the oxygen from the air should therefore be avoided as much as possible, to reduce additional costs for oxygen abatement..

#### 5.3.4 Control Systems

Systems working at variable loads or conditions are usually automatically controlled. The technology is the same as for similar systems using other energy sources. For geothermal systems, it is very important to have also an automatic data acquisition system (usually a Supervisory Control and Automatic Data Acquisition – SCADA – system), in order to continually monitor the geothermal production data. The information is needed to refine the geothermal reservoir model and to estimate the future behaviour of the resource.

There are already available on the market software that work together with SCADA systems and optimise the operation of district heating systems (to counterbalance the thermal inertia of the system), controlling the system in advance based on estimations of weather conditions for the following 2-3 days, using statistical weather databases or forecast algorithms. This type of software is also fully compatible with software used for the design of district heating systems.

## 6. CONCLUSIONS

Geothermal energy has always been used, wherever natural resources were available. The technology developed slowly until the oil and gas prices increased significantly, and is developing fast at present due to environment protection concerns and requirements.

The direct utilisation of geothermal energy means that the available geothermal energy is used for whatever process in which heat is needed: space heating (including greenhouses and animal farms), drying (fruits, vegetables, grains, wood, tobacco, fish, pottery, etc.), pasteurisation (e.g. milk), sea water desalination, flax and hemp processing, sludge digesters, and probably the most important, district heating (also cooling being possible in certain cases). Ground source heat pumps, thermal energy storage in aquifers, aquaculture, and health and/or recreational bathing are also included in the direct uses of geothermal energy.

For any particular process needing heat, the technology that can be used is basically similar, if not the same when using geothermal energy as when using other energy source. The differences are caused by the specific characteristics of the geothermal resource, such as well heat temperature and pressure, maximum flow rate that can be produced from the well, maximum annual average flow rate available from the reservoir for a sustainable production and, maybe the most important, the chemical composition of the geothermal fluid which, in many cases, can be corrosive or have a scaling potential. Some particularities of the equipment to be used in geothermal utilisation systems are mentioned above.

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