Training Course on Geothermal District Heating

Manual

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Training Course on Geothermal District Heating

Manual

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For the *Training Course on Geothermal District Heating* in fourteen EU-countries held in June – November 2014 and organised in the framework of the GeoDH Project (www.geodh.eu).

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About GeoDH Project

"Promote geothermal district heating systems in Europe" (GeoDH) is a pan-European project on geothermal district heating technology. It is co-funded by the European Union through the *Intelligent Energy Europe Programme*.

The main objectives of GeoDH:

- Removing the regulatory barriers and the simplification of administrative procedures through the promotion of existing best practice,
- Developing innovative financial models in order to overcome the barriers hampering the financing of geothermal projects,
- Training technicians and regional and local decision-makers in order to provide the technical background necessary to approve and support geothermal district heating projects. One key element is to present to them the geothermal potential in Europe.

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1.1. Overview of geothermal energy (Annamaria Nador – MFGI)

1.1.1. Introduction

Worldwide there is a growing need for the enhanced use of renewable energies due to the increasing energy demand around the globe, to the restricted reserves of fossil fuels raising concerns on the security of energy supply, and to considerations related to anthropogenic emissions of carbon-dioxide affecting the Earth's climate. The current level of energy consumption is unsustainable, therefore action is urgently needed. This is addressed by several international and EU policies and strategies, such as, for example the Kyoto Protocol, or the European Union's 2020 headline targets of reducing greenhouse gas (GHG) emissions by 20%, to increase energy efficiency by 20%, and to increase the share of energy produced from renewable energy sources (RES) by 20% by 2020.

However, the increase of renewables would not only address the above mentioned challenges, but would also contribute significantly to economic development by introducing innovative and competitive technologies, triggering structural changes in industry and agriculture, creating new jobs, and contributing to rural development (Figure 1).

Climate and Energy Package 2020: **„20/20/20" by 2020:**	**Increase of renewables in the energy mix -** **integrated economic development:**
➢ **cut GHG emissions** ➢ **increase energy efficiency** ➢ **increase renewable energy sources (RES)**	✓ **innovative and competitive technologies** ✓ **structural changes in industry, services, residential and agriculture sectors** ✓ **new jobs** ✓ **smart cities and decentralised rural development**

Figure 1. Driving forces of enhanced use of renewables

1.1.2. Geothermal energy uses – an insight into the history

The presence of volcanoes, hot springs, and other thermal phenomena must have led even our ancestors to assume that parts of the interior of the Earth were hot. Geothermal energy has been known and utilised by humans for a very long time. Naturally discharging geothermal waters have been widely used even in the ancient roman times (Figure 2) and the middle ages mostly for balneo-therapeutical purposes, but the very first applications of using the heat content of geothermal waters also date back to pre-historical times, shown by numerous remnants across Europe and worldwide.

The use of hot steam/water systems for the generation of electric power is also more than a century old, with the first geothermal power station with a 10 kW generator having been developed in 1904 in Larderello, Italy, Tuscany (Figure 3).

Figure 2. Thermal bath of Caracalla, Thermae Antonianae

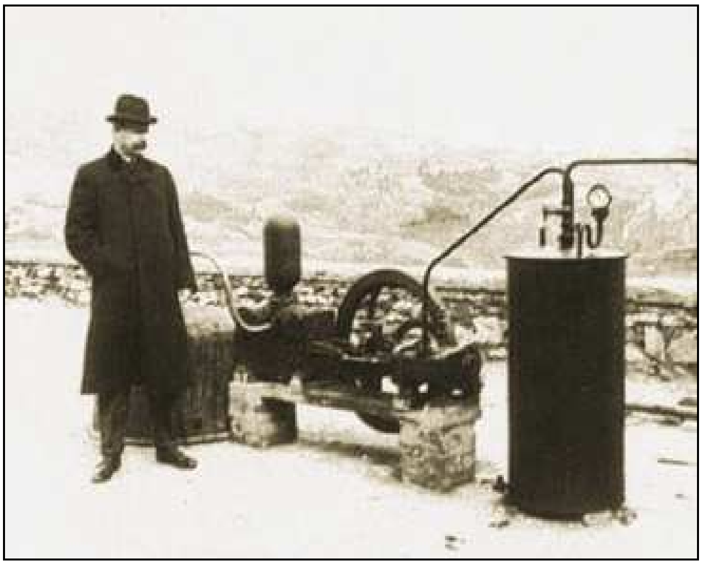


Figure 3. The world's first geothermal power station with a 10kW generator at the Larderello dry steam field, Italy, Tuscany (source: IGA material)

1.1.3. Geothermal energy: definition and basic concepts

Geothermal energy, by definition (Directive 2009/28/EC) is the energy stored in the form of heat beneath the surface of the solid Earth.

The heat content of the Earth is enormous: 99% of our planet's temperature is above 1000 °C. Altogether the estimated heat amount of the Earth is $12{,}6 \cdot 10^{24}$ MJ.

This immense heat has several origins:

- "Residual" heat of the Earth interior (mantle and core),
- Continuously producing heat from the decay of radioactive isotopes: U^{238}, U^{235}, Th^{232}, K^{40},
- Solar radiation (limited 5-25 m below the ground).

Although the solid crust represents only 2% of the total volume of the Earth, it is rich in radioactive isotopes, therefore mostly counts for the renewable heat generation.

The hot and viscous mantle represents the largest part (82%) of the total volume of the Earth, but due to the much smaller amount of radioactive isotopes, its role in average heat production is much less. The hottest core in the interior of the Earth accounts for 16% of the total volume, but contains no radioactive isotopes (Figure 4, Table 1).

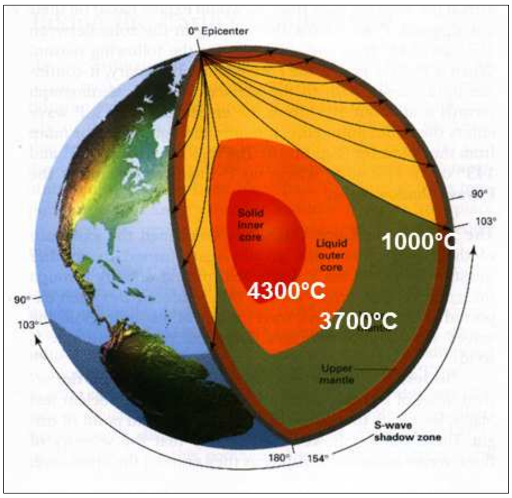


Figure 4. The inner structure of the Earth with temperature conditions (source: IGA material)

Table 1. Heat production and volume of the Earth's core, mantle and crust

Inner structure of the Earth	Total volume of the Earth	Average heat production, µW/m^2
Crust (rich in radioactive isotopes)	**2%**	**1 (continental crust)** **0.5 (oceanic crust)**
Mantle (radioactive isotopes)	**82%**	**0.02**
Core (no radioactive isotopes)	**16%**	**0**

1.1.4. Heat transfer, heat flow

There is a significant amount of heat that dissipates into the atmosphere via surface heat flow. This heat flow is composed of the radiogenic heat generated in the Earth's crust and the "residual" heat flow deriving from the mantle (and core) (Figures 5, 6).

Modern thermal models of the Earth demonstrated that there is no equilibrium between the radiogenic heat generated in the Earth's interior and the heat dissipated into the atmosphere, and that our planet is slowly cooling down. Even so, the cooling process is still very slow.

The heat content of the Earth would take over 10^9 years to exhaust via global terrestrial heat flow, so it is practically inexhaustible in human terms. The temperature of the mantle has decreased no more than 300 to 350 °C in three billion years, still remaining at about 4000°C at its base.

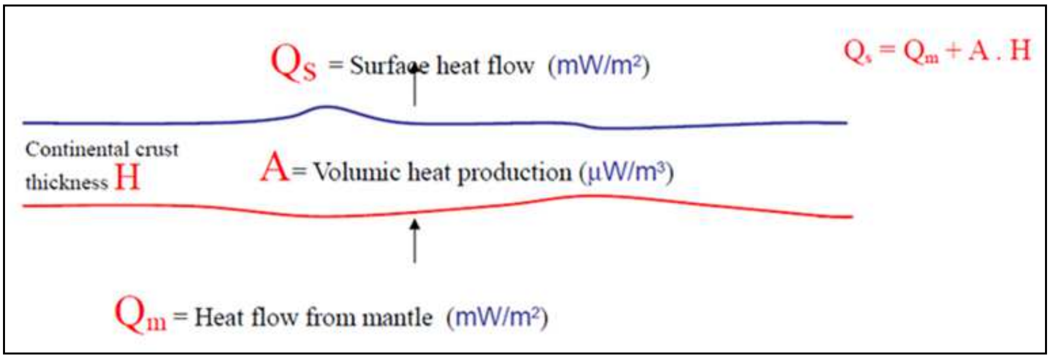


Figure 5. Components of surface heat flow

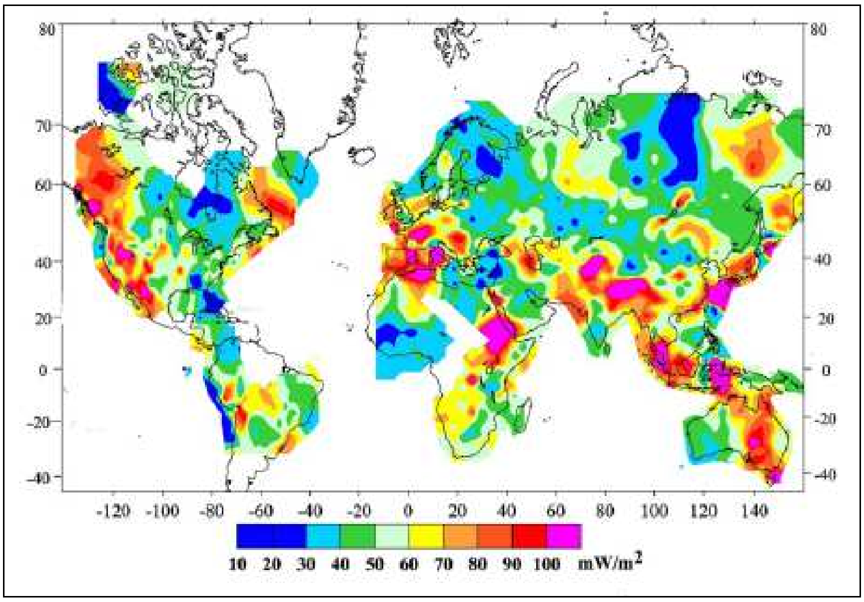


Figure 6. Surface heat flow map of the world

Heat transfer in the subsurface can happen in two ways: by conduction (heat transfer among rock particles), and by convection (heat is transferred by matter [typically fluid, i.e. groundwater] movement).

1.1.5. Geothermal gradient

The fact that the temperature increases towards with was discovered in the 16-17th centuries when the first mines were excavated a few hundred metres below ground level, and people had the simple physical sensation of the rising temperatures.

The geothermal gradient expresses the increase in temperature with depth in the Earth's crust (Figure 7). In continental areas the average geothermal gradient is 33 °C/km, while in tectonically active, or volcanic regions it can be as much as 500°C/km.

Due to the different thermal conductivity of the various rock types, the geothermal gradient is not linear (Figure 8), and from the changes of its dip one can conclude even which subsurface strata contain significant amount of water: this is possible because in such cases geothermal gradient is very low (while the dip of thermal profile is steep) resulting from the fact that heat transfer within geothermal reservoir is mostly driven by the convection mechanism.

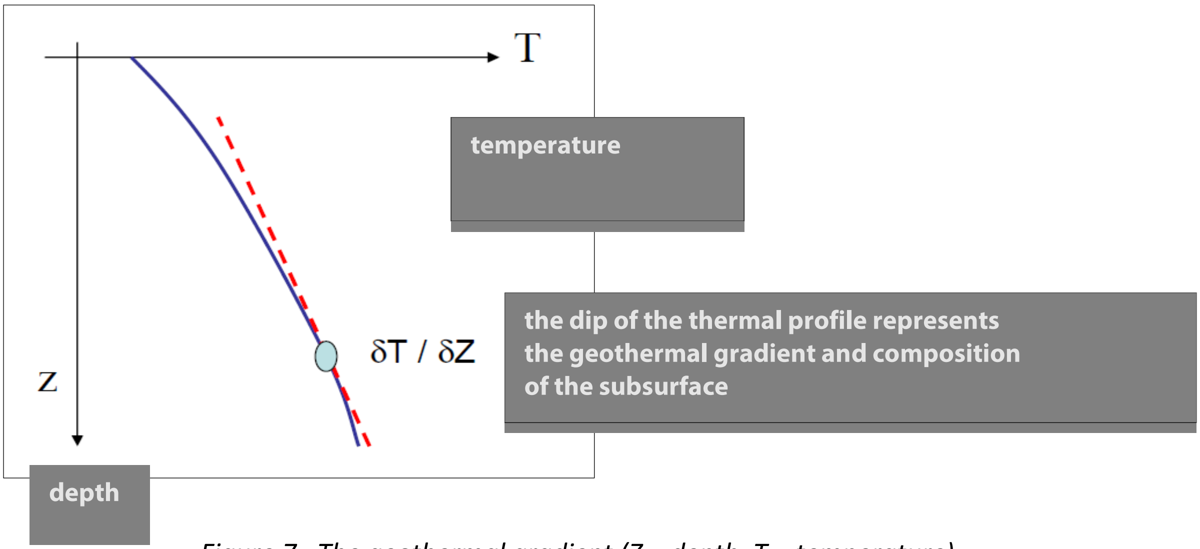


Figure 7. The geothermal gradient (Z – depth, T – temperature)

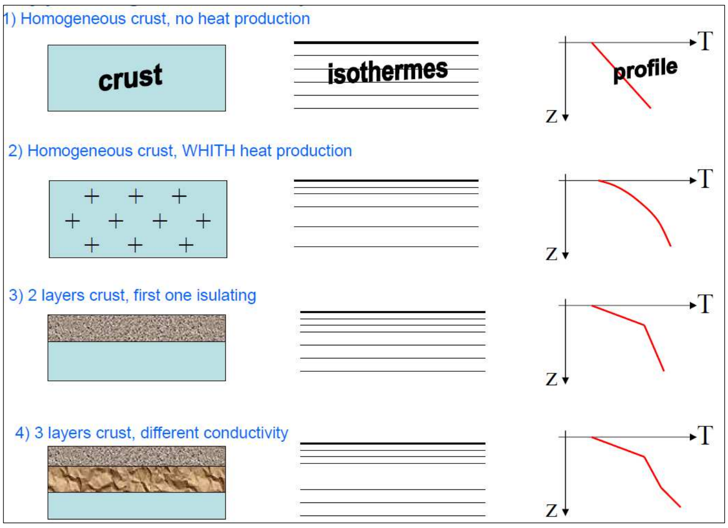


Figure 8. Changes in geothermal gradient refer to the subsurface lithology as a result of the different thermal conductivity of various rock types (Z – depth, T – temperature)

1.1.6. Geodynamics and geothermal

The planet Earth consists of a *crust*, which reaches a thickness of about 20-65 km in continental areas and about 5-6 km in oceanic areas, a *mantle*, which is roughly 2900km thick, and a *core*, about 3470 km in radius. The outermost rigid shell of the Earth, known as the *lithosphere*, is made up of the crust and the upper layer of the mantle, which has a thickness of less than 80 km in oceanic zones and of up to 200 km in continental areas. Below the lithosphere, the 200-300 km thick hot and plastic *asthenosphere* is found. Because of the difference in temperature between the different parts of the asthenosphere, extremely slow (a few centimetres per year) convective movements are present, which are maintained by the heat produced by the decay of the radioactive isotopes and the heat coming from the deepest parts of the Earth.

In oceanic areas, where the lithosphere is thinner, it is pushed upwards and broken by the very hot, partly molten material of the ascending asthenosphere. This mechanism creates the *spreading ridges* that extend for more than 60,000 km beneath the oceans, emerging in some places (Azores, Iceland) and even creeping between continents, as in the Red Sea.

The continuous formation of the new oceanic crust along the spreading ridges has caused these two branches to drift apart in opposite directions at a rate of a few centimetres per year. Since the Earth’s surface cannot expand, the newly forming oceanic lithosphere along the spreading ridges must be accompanied by a comparable shrinkage in other parts of the globe. This is happening in the *subduction zones*, which are indicated by huge ocean trenches, such as those extending along the western margin of the Pacific Ocean and the western coast of South America, where the oceanic lithosphere folds downwards and plunges under the adjacent cold continental lithosphere with higher density, and re-descends to the very hot deep zones, where it is “digested” by the mantle and the cycle begins all over again. Part of the digested lithospheric material returns to a molten state and may rise to the surface again through fractures in the crust forming *magmatic arcs* (volcanoes) parallel to the trenches (Figure 9).

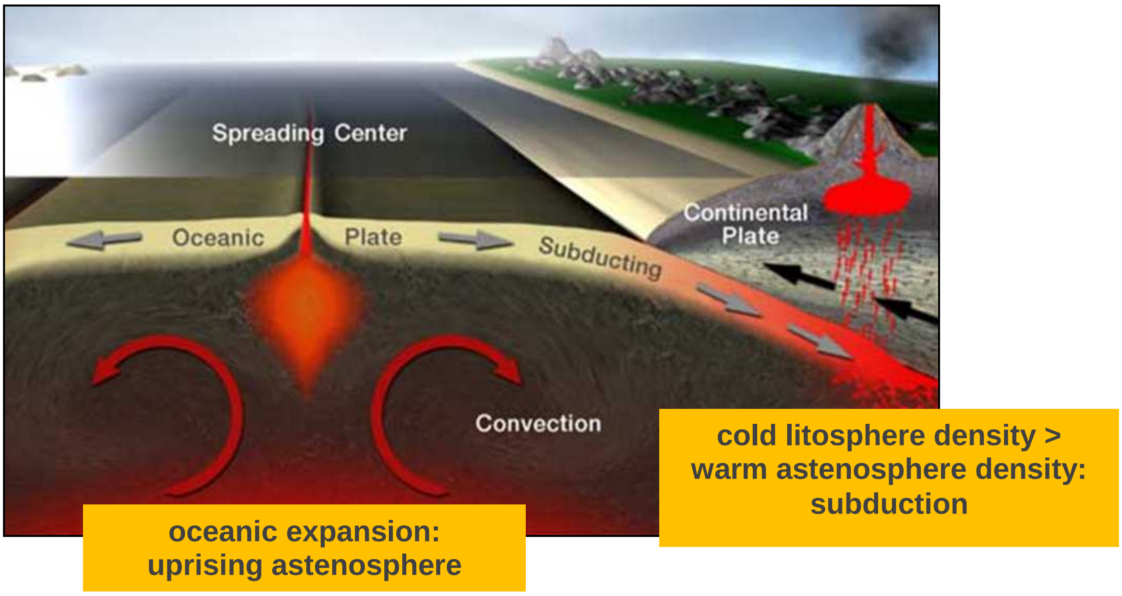


Figure 9. Sketch of plate tectonic processes

Spreading ridges and subduction zones form a vast network that divides our planet into six immense and several other smaller lithospheric plates, which – due to the above described mechanisms: spreading and subduction – are moving against each other very slowly, shifting positions continuously. The margins of the plates correspond to weak, densely fractured zones of the crust, characterised by an intense seismicity, by a large number of volcanoes and, because of the ascent of very hot materials towards the surface, by a high terrestrial heat flow. Therefore the most important geothermal areas are located around these plate margins (Figure 10).

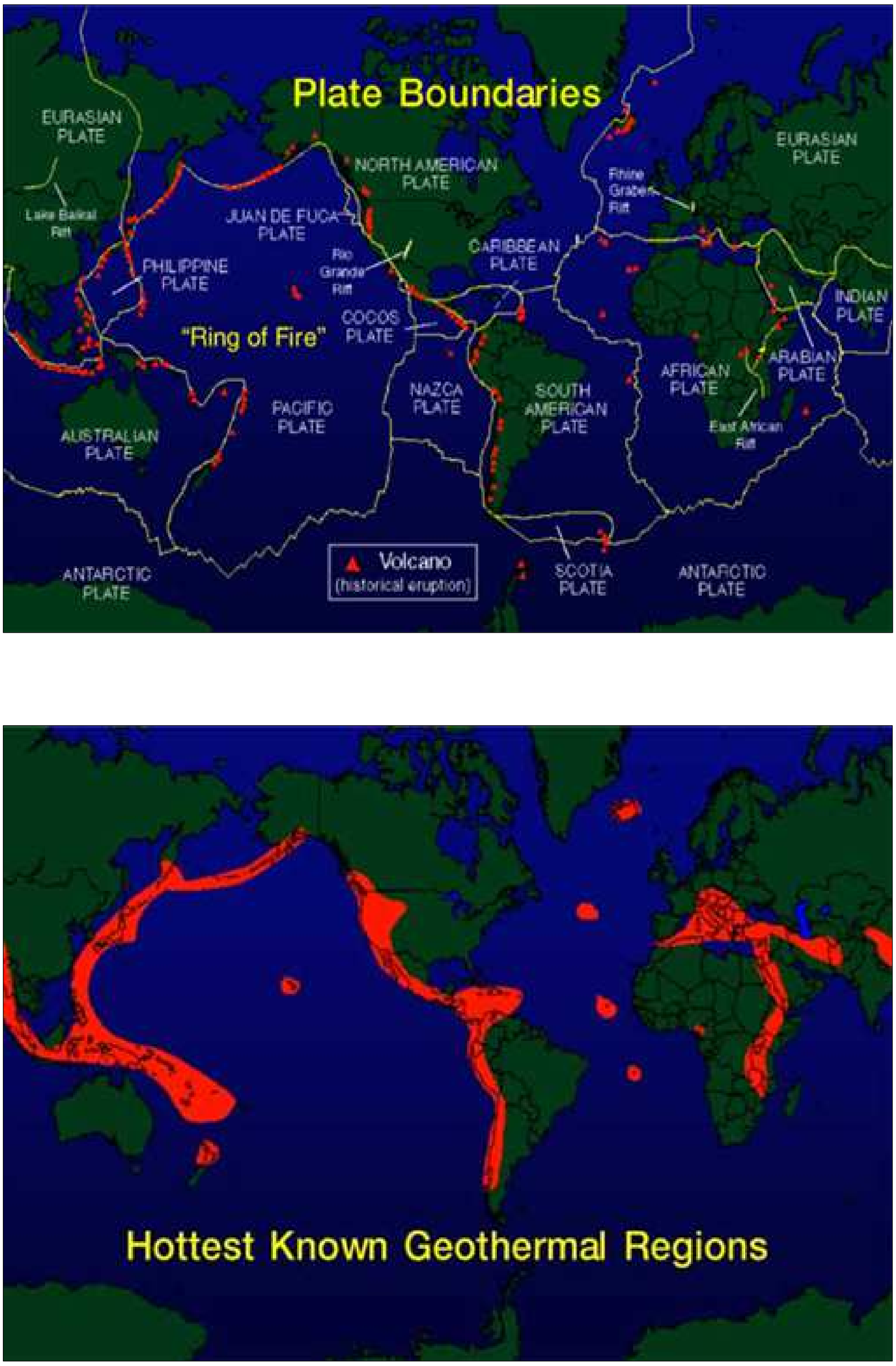


Figure 10. The hottest geothermal regions are related to plate boundaries

1.1.7. How to classify geothermal energy?

There are several ways to classify geothermal energy. One most obvious ways is according to the temperature of the geothermal reservoir. A geothermal reservoir can be defined as “a part of the geothermal field that is so hot and permeable that fluid or heat can be economically exploited. A rock that is hot, but impermeable is not part of the reservoir" (Grant and Bixley, 2011).

Different authors set up different temperature categories. According to Rowley (1982), we can differentiate between high- and low temperature reservoirs.

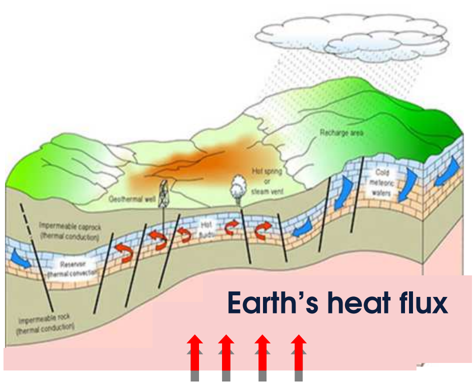
High-temperature (H-T): >150°C:

- Geothermal steam reservoirs (dry, wet steam),
- Heat source: mainly magma in magma chambers located at shallow depths (reaching the surface as lava during volcanic eruptions).

Low-temperature (L-T): < 150°C:

- Hydrogeothermal reservoirs,
- Heat source: mainly Earth’s heat flux,
- Low-temperature systems and related hydrogeothermal reservoirs occupy much larger areas.

It is also possible to classify geothermal energy according to the **type of the resource**. So far the most common method of the uses of geothermal resources has been limited to areas in which geological conditions provide a carrier (water in the liquid phase, or steam) to “transfer” the heat from deep hot zones to the near-surface. In these **hydrogeothermal systems** the large scale regional flows are governed by convection. Heating from the Earth interior causes thermal expansion of the subsurface fluids causing lower density, and therefore their rising along permeable pathways, e.g. faults. Usually cold water from precipitation with higher density and higher hydraulic potential recharges the systems (Figure 11).



Deep hydrothermal system

Elements:

heat source (Earth’s heat flow, magma chamber),
reservoir rocks,
isolating rocks,
heat carrying medium (fluid),
recharge area

Fluid convection:

heating → thermal expansion of groundwater → rising and replacement by recharging colder meteoric water

Figure 11. Sketch of low-temperature hydrogeothermal system (based on Barbier, 1997)

The temperature of the geothermal resources also determines their possible uses:

- Very low: <30°C – requires heat pumps,
- Low: 30–125°C – direct heat applications,
- Medium: 125–150°C – electricity generation with binary cycles, combined heat and power plants (CHP),
- High: >150°C – "efficient" electricity production.

Electricity generation mainly takes place in conventional steam turbines and binary plants, depending on the characteristics of the geothermal resource.

Conventional steam turbines require fluids at temperatures of at least 150°C. The steam is passed through a turbine in some cases may be released to the atmosphere (Figure 12).

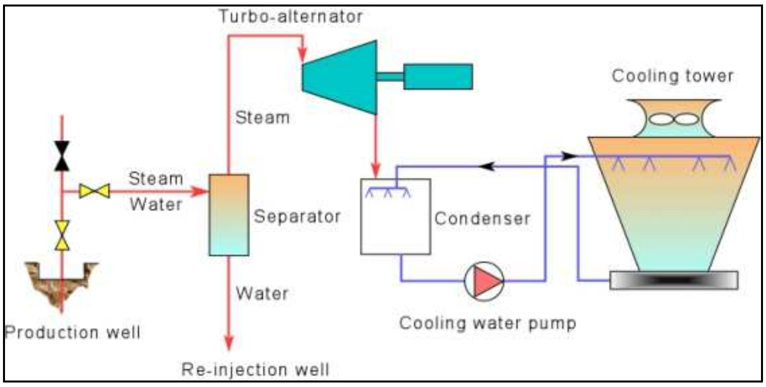


Figure 12. Sketch of a steam turbine with condenser

Binary plants use a secondary working fluid that has a low boiling point and high vapour pressure at low temperatures compared to steam. The secondary fluid is operated through a conventional Organic Rankine cycle (ORC, which usually applies an organic fluid) or a Kalina cycle (which applies a water–ammonia mixture): the geothermal fluid yields heat to the secondary fluid through heat exchangers, in which this fluid is heated and vaporises; the produced vapour drives a flow turbine, is then cooled and condensed, and the cycle begins again (Figure 13).

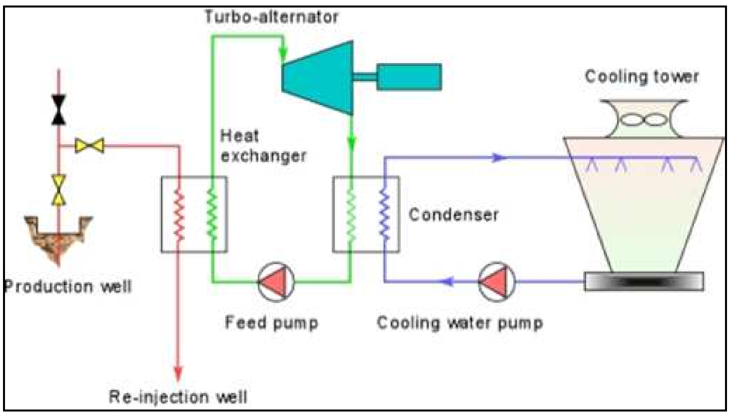


Figure 13. Sketch of a binary plant

Direct heat use is one of the oldest and most common form of uses of geothermal energy. Bathing, space and district heating, agricultural applications, aquaculture and some industrial uses are the best known forms (Figure 14).

Figure 14. Various direct heat applications are the most common way of using geothermal energy

Geothermal resources can be used in an efficient way in cascade systems, where the plants are connected in series, each using the waste water from the preceding one (e.g. electricity generation – industrial uses – district heating – animal husbandry) (Figure 15). The limits of temperature on possible uses are best represented on the Lindall diagram (Figure 16).

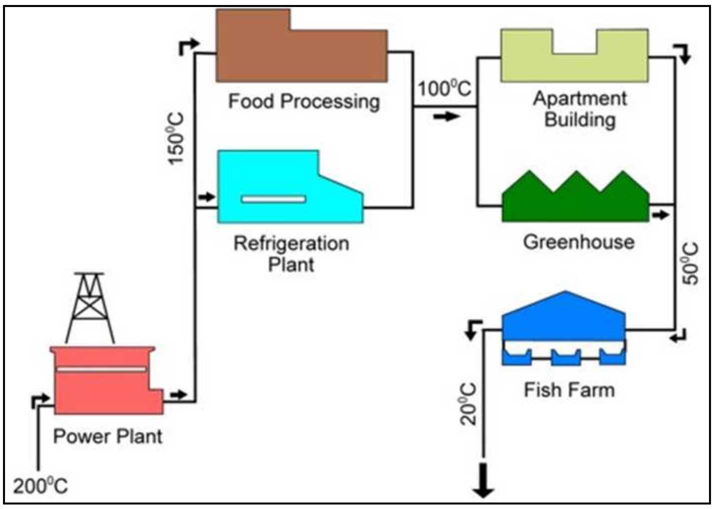


Figure 15. Cascaded systems – the most efficient way of using geothermal energy

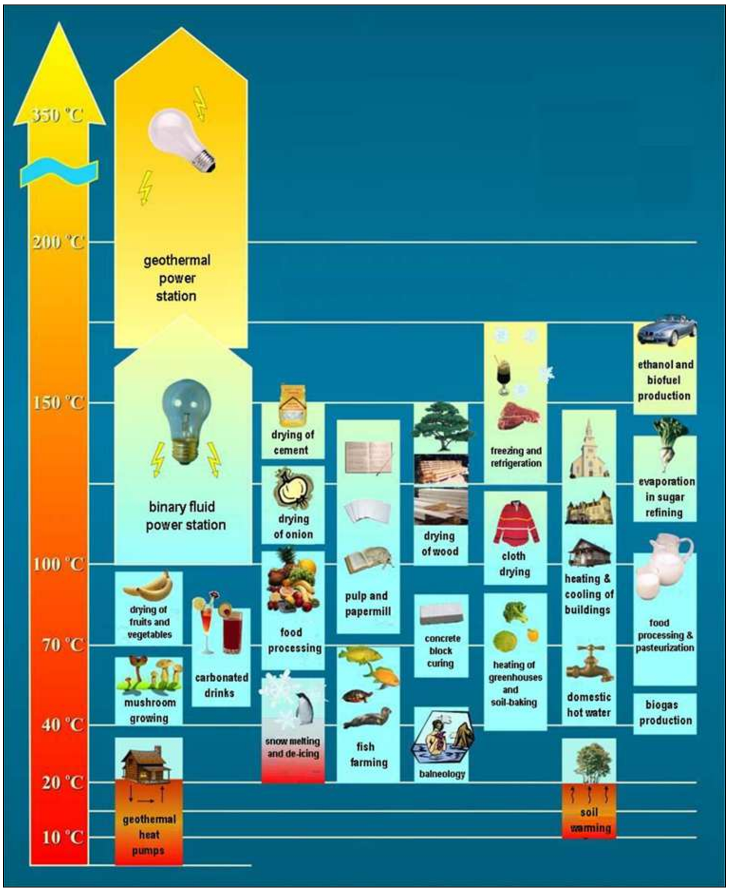


Figure 16. The Lindall diagram showing temperature ranges of various geothermal applications

Deep stimulated geothermal systems

A new emerging technology is represented by **Enhanced Geothermal Systems** (EGS), where the extraction of heat energy happens by circulating water via production and injection wells through artificially created fractures (by hydraulic fracturing) in massive hot rock volumes in the deep subsurface (Figure 17).

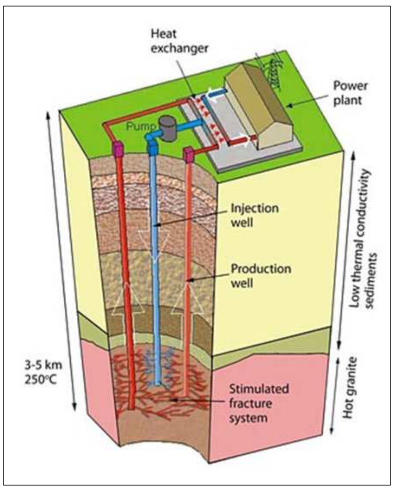


Figure 17. Sketch of an EGS system (based on Barbier, 1997)

1.2. Geothermal energy uses

(Annamaria Nador – MFGI)

1.2.1. Geothermal electricity production

The global total installed capacity for geothermal power production was 12,000 GWe in 2013 with the energy produced of ca 75,000 TWh. The "Top Five Countries" for capacity and produced energy were the USA, Philippines, Indonesia, Mexico and Italy. In 2013 the total installed capacity was around 1,85GWe in Europe producing some 11,70 TWh per year (EGEC 2013) (Figure 18).

In 2013 there were 68 geothermal power plants in Europe, with 51 in EU member states. The major players were Italy, Iceland and Turkey (Figure 19).

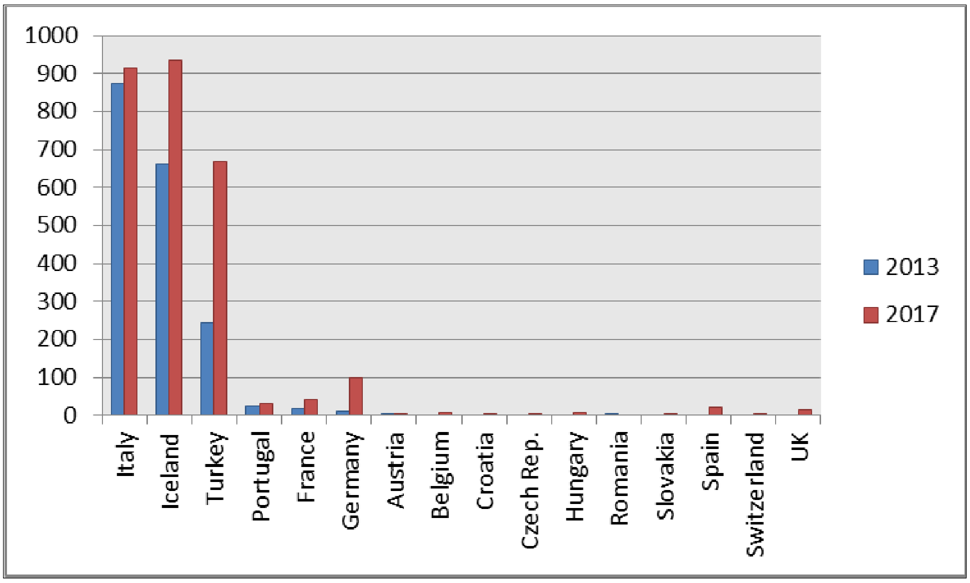


Figure 18. Geothermal power installed capacity per country in Europe, 2013-2017

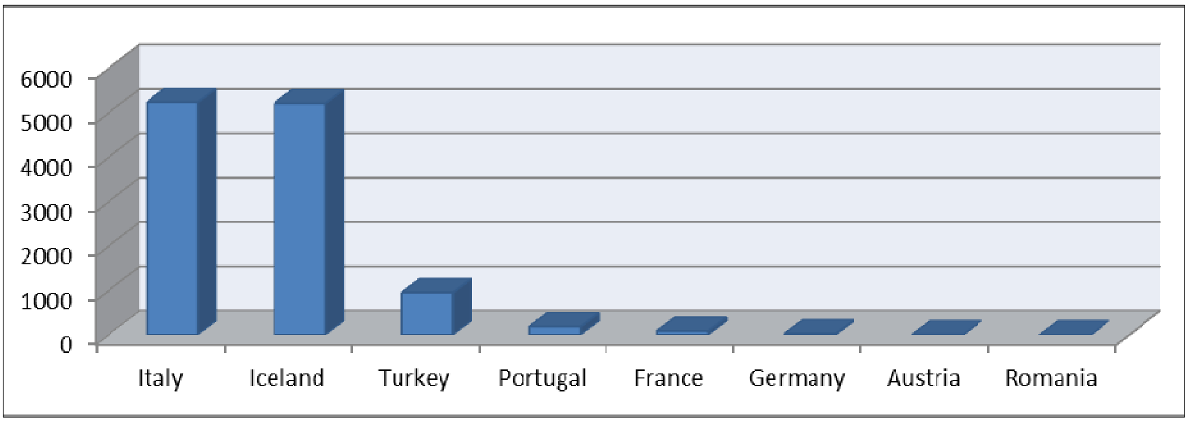


Figure 19. Geothermal electricity production (GWh) per country in Europe, 2013

1.2.2. Geothermal direct uses

The installed power for direct geothermal uses was 50,583 GWt worldwide with a thermal energy used of 438071 TJ/y in 2010. The share was ca. 49% for ground-source heat-pumps, 24.9 % for bathing and swimming (including balneotherapy), 14.4% for space heating (of which 85% was district heating), 5.5% for greenhouses and open ground heating, 2.7 % for industrial processes, 2,6% for aquaculture, 0.4 % for agricultural drying, 0.5% for snow melting and 0.2% for other uses (Lund et al. 2010) (Figure 20). In Europe geothermal district heating (geoDH) is one of the most important types of direct uses. In 2011, 237 geoDH systems (including cogeneration systems) were operational with a total capacity of ca. 4,300 MWth. The main geoDH markets are in France, Iceland, Germany, Hungary, and Denmark as an emerging country. However, almost all European states have some activity (EGEC 2013) (Figure 21).

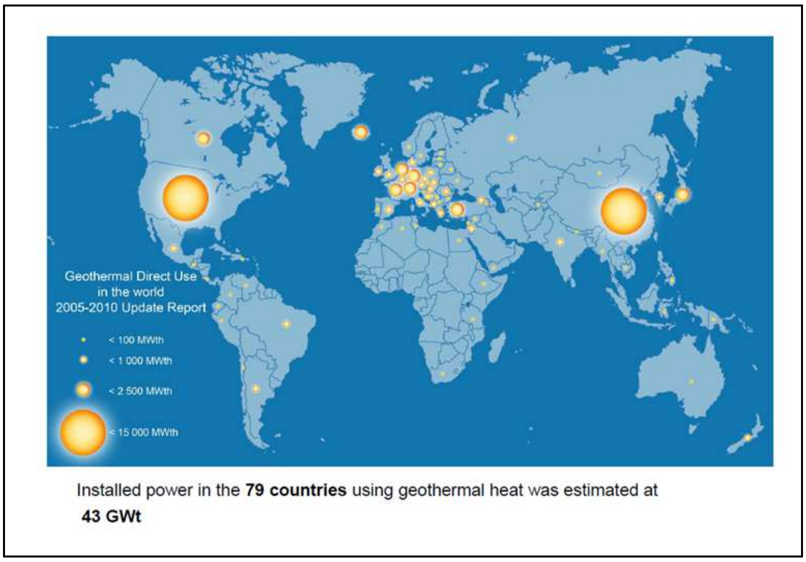


Figure 20. Worldwide geothermal heat production in 2010

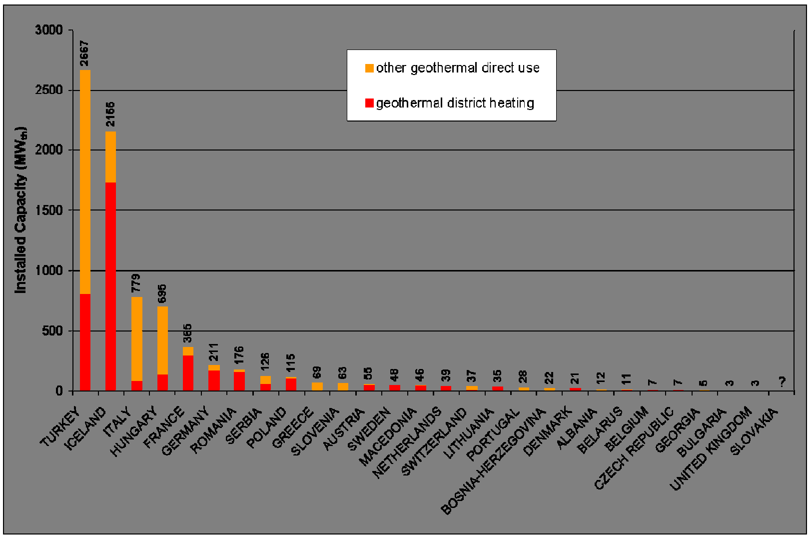


Figure 21. Installed capacity in geothermal direct uses in Europe, 2012, and share of geothermal district heating systems (Antics et al. 2013)

1.2.3. Main geothermal provinces of Europe

The main geothermal provinces of Europe reflect well the geological conditions. High enthalpy resources are associated with active volcanic areas (Iceland, Italy, Turkey), while medium enthalpy sedimentary basins are found in various geological settings: e.g. the Rhine graben, the Molasse basin in the Northern forefront of the Alps, the Paris basin, the Aquitanian basin, and the Pannonian basin, but also encompasses vast areas in Northern Europe (across Denmark, Germany, Poland) where various reservoirs rocks, forming the basement of the young sedimentary basins, store high-temperature geothermal ground waters (Figure 22).

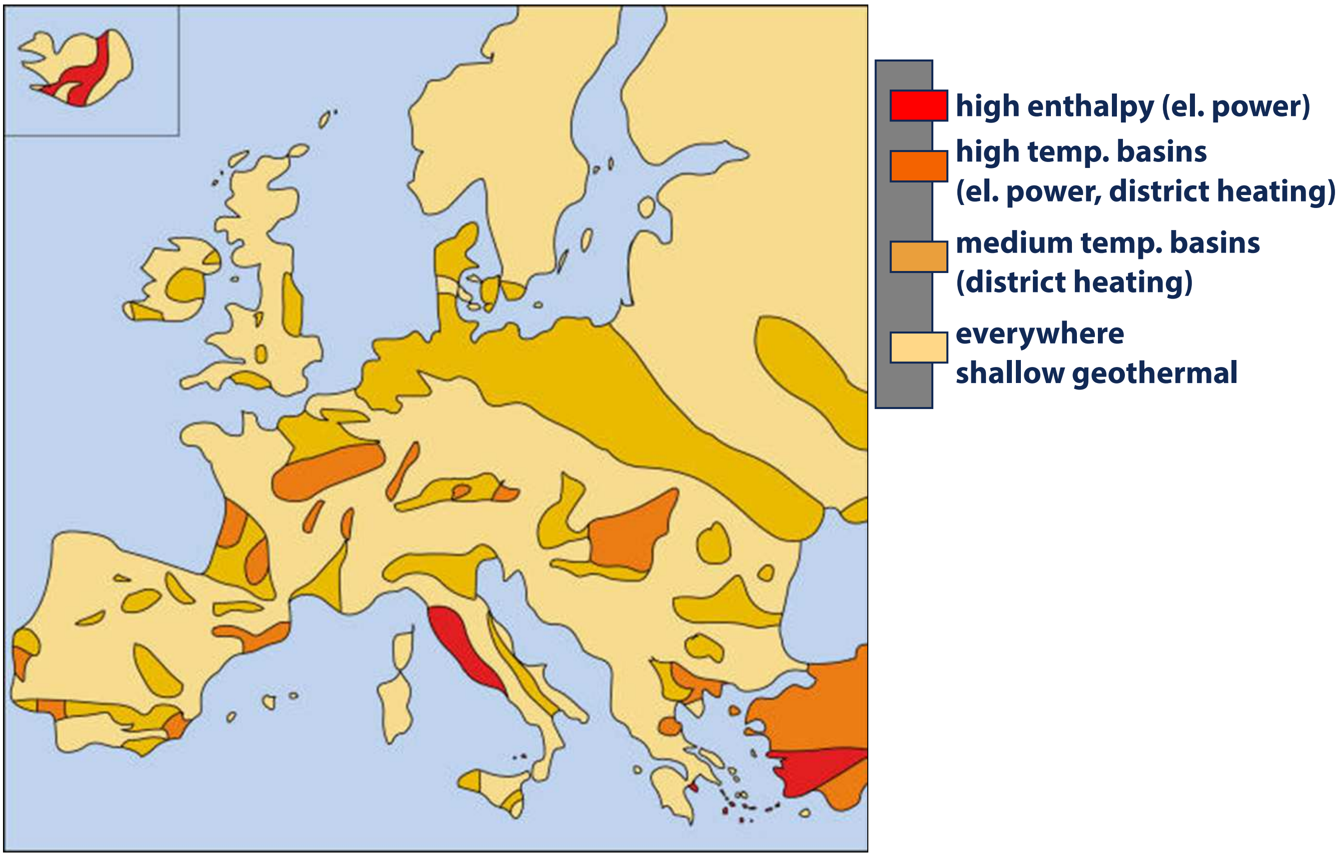


Figure 22. Main geothermal provinces of Europe (source: EGEC)
(Note: medium temperature basin stretching from NW to SE Europe is in its SE part covered by thick Carpathian formations (not marked) and situated at great depths)

1.3. Environmental aspects and sustainability
(Annamaria Nador – MFGI)

1.3.1. Sustainability of hydrogeothermal systems

As geothermal energy is usually described as *renewable* and *sustainable*, it is important to define these terms. *Renewable* describes a property of the energy source, whereas *sustainable d*escribes how the resource is used.

The most critical factor for the classification of geothermal energy as a renewable energy source is the rate of energy recharge. In the exploitation of natural geothermal systems, energy recharge takes place by advection of geothermal water on the same timescale as production from the resource.

The term *sustainable development* is used by the World Commission on Environment and Development to indicate development that "….meets the needs of the present generation without compromising the needs of future generations". In this context, the sustainable production of geothermal energy refers to a balanced fluid/heat production, i.e. not producing more than the natural recharge (Figure 23).

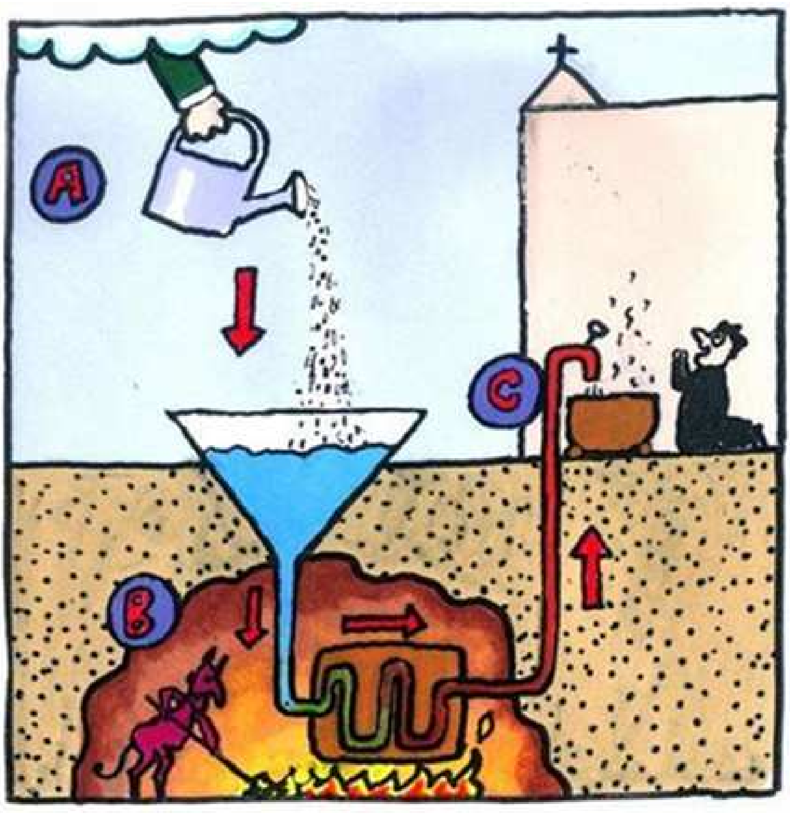


Figure 23. Sustainable use of natural resources is our responsibility

For each geothermal system and for each mode of production there exists a certain level of maximum energy production, below which it will be possible to maintain a constant energy production from the system for a very long time (100 - 300 years), which applies to total extractable energy (heat in the fluid and rock) (Axelsson et al., 2005). However, these rates are limited and often not economical for use.

1.3.2. Injection

As geothermal water reserves are limited (to an extent of their natural recharge from infiltrating meteoric waters), production can be increased/maintained without significant drop in the pressure only by re-injecting the cooled water back to the same reservoir, where it warms up at the depth, and thus makes possible the repeated exploitation of the enthalpy of the rock matrix (Figure 24). Consequently the utilisation of geothermal energy from hydrogeothermal systems can be considered as only “partly renewable” (the energy carrier medium, i.e. groundwater is not unlimited, while the heat content of the rock matrix is “unrestricted”, due to the immense heat content of the Earth). In addition to maintaining reservoir pressures, the other major aspect of re-injection is the protection of surface aquifers and ecosystems. The used geothermal waters of high temperature and organic matter content released into rivers or lakes are increasing the heat and pollution load of surface waters and the geological environment.

Injection of heat-depleted brines into clastic sedimentary reservoirs has been used for a long-time in the hydrocarbon industry (enhanced oil recovery). Re-injection is relatively simple into karstic carbonate aquifers, however it is a more complex procedure into sandstone reservoirs, as the necessary injection pressure can substantially increase within a relatively short time. The most common reasons are the plugging of screens (perforation) in the well and pore throats of the reservoir formation. The permeability may decrease due to clay swelling, pore-space blocking by fine particles, or precipitation of dissolved solids due to the mixing of injected and formation water. The advantages and disadvantages of reinjection are summarised on Figure 25.

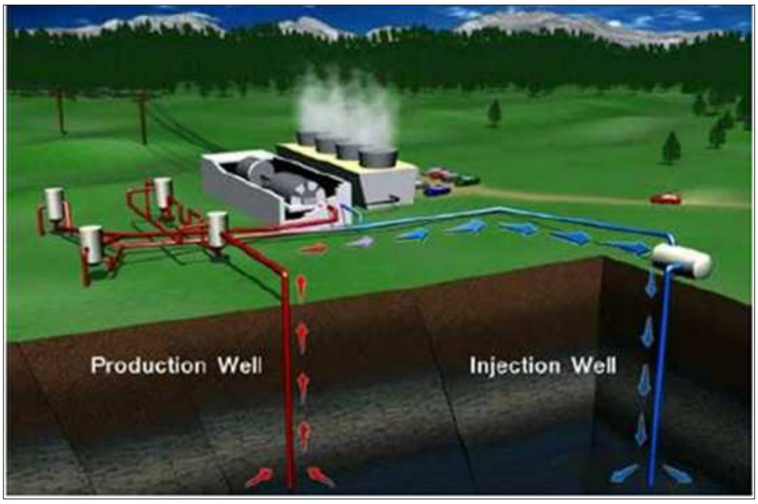


Figure 24. Production and re-injection well form a doublet, which makes possible the repeated use of the heat in the rocks in the deep subsurface

Benefits

- increased flow rates
- optimum heat recovery
- maintenance of pressure
- land subsidence control
- disposal of the cooled brine

Drawbacks

- ‘waste water’ contamination of the aquifer (e.g. bacteria, gas bubbles, precipitations of chemicals)
- premature cooling (thermal breakthrough) of production wells
- permeability impairment induced by particles

Figure 25. Pros and cons of reinjection

1.3.3. Geothermal energy and the environment

Although geothermal energy provides a stable and reliable heat supply 24 hours a day, 365 days a year in contrast with other RES, and generates no (or very limited) GHG emissions, it may have some environmental impacts which are presented on Figure 26 and Table 2.

Figure 26. Some environmental aspects of geothermal energy uses: well blow outs and landscape issues

Table 2. Possible environmental impacts of geothermal energy production

Impact	Probability of occuring	Severity of consequences
Air quality pollution	low	medium
Pollution of surface and ground waters (dissolved contents)	medium	medium to high
Thermal pollution (discharging waste water)	medium	medium
Land subsidence	low	low to medium
Earthquakes	low	low
High noise level	high	low to medium
Well blow-outs	low	low to medium
Social-economic problems	low	low

1.4. Geothermal energy resources for geothermal district heating – potential and national characteristics (webmap viewer)

(Annamaria Nador – MFGI)

The GeoDH Web GIS (developed as part of the GeoDH Project) presents the geothermal resource assessment carried out in the countries covered by this Project and highlights the areas where potential for geothermal district heating exists. Based on currently available information in terms of geological data, already operational district heating systems, and heat demand, it shows the respective potential in the 14 GeoDH Project countries: Bulgaria, Czech Republic, Denmark, France, Germany, Hungary, Ireland, Italy, the Netherlands, Poland, Romania, Slovakia, Slovenia, and the United Kingdom.

The geothermal potential is presented down to the depths of 2 km below ground level. In some countries prospective resources are located also at greater depths (e.g. Poland), in such cases relevant specific information is available by contacting GeoDH partners in the respective countries.

The viewer is available at www.loczy.mfgi.hu/flexviewer/geo_DH. For information on how the system works, please view the manual (available at geodh.eu). An example of GeoDH Web GIS screenshot in given on Figure 27.

Figure 27. An example of GeoDH Web GIS screen shot (www.geodh.eu)

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www.geothermal-energy.org (source of several figures in sub-chapters 1.1 – 1.4)

1.5. Geothermal project phases and concepts
(Christian Boissavy – AFPG)

1.5.1. Concepts and project phases

The economic success of a geothermal project is influenced by a variety of factors. Although each project should be considered unique, there are elements common to all.

"Geothermal district heating" is defined as the use of one or more production fields as sources of heat to supply thermal energy to a group of buildings. The main services available from a district heating system are space heating, sanitary hot water distribution, and space cooling. A district heating system is not limited to a particular type of heat source. Heat sources that could be used for a district heating system are not limited to geothermal; they include also co-generating power plants, conventional boilers, municipal incinerators, solar collectors, groundwater heat pumps, industrial waste heat sources, and geothermal sources (geothermal water in majority of cases). Depending on the temperature of geothermal water, it may be advantageous to develop a hybrid system including, in addition to geothermal, a heat pump and/or conventional boiler for peaking purposes.

A geothermal district heating system comprises three major components, as shown in Figure 28. The first part is heat production which includes the geothermal production, conventional fuelled peaking station and wellhead heat exchanger (elements marked 1-2-3-4-5 on Figure 28). The second part is the transmission/distribution system, which delivers the heated or cooled water to the consumers (element 7). The third part includes central pumping stations and in-building equipment. Geothermal fluids may be pumped to a central pumping station/heat exchanger or heat exchangers in each building. Thermal storage tanks may be used to meet variations in demand.

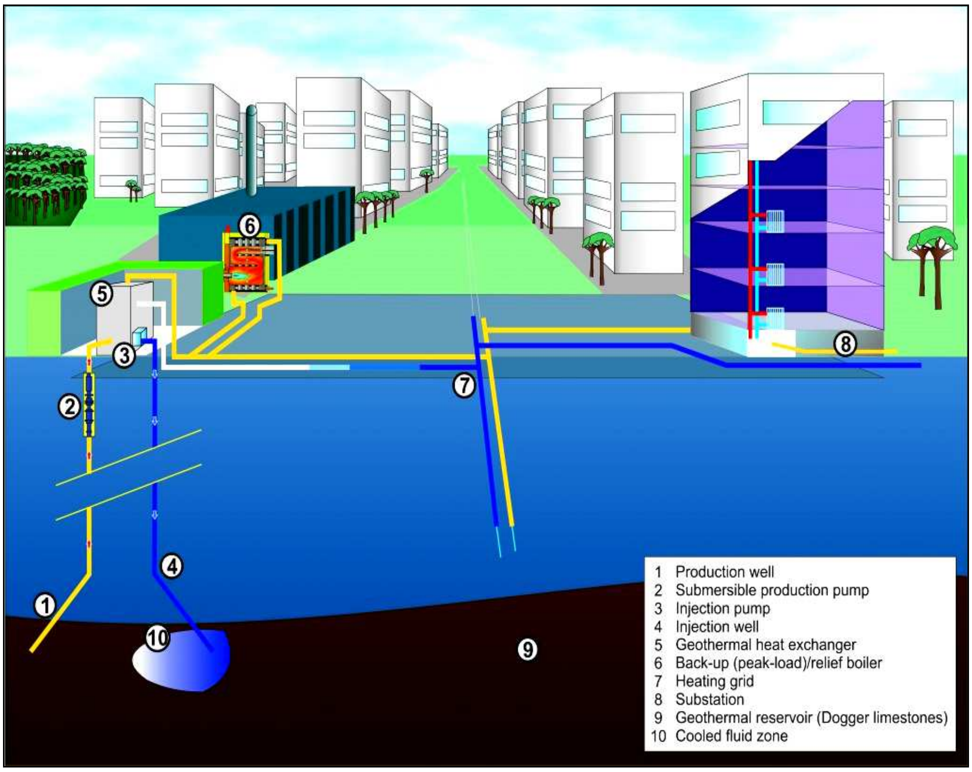


Figure 28. Main components of geothermal district heating system

1.5.2. Overview of the feasibility for a geothermal district heating system

A five step analysis is needed for an initial evaluation before launching the construction of a geothermal district heating:

1. **Analyse geothermal heat production** – this step uses information on the characteristics of an identified resource to estimate the heat production from deep geothermal resources;

2. **Identify district heating market areas** – this step provides procedures for identifying potential market areas for district heating service. Heating demands in the service area are estimated and several criteria such as the density of thermal loads and distance from production fields, are provided as guides in selecting market areas. If a district heating system (DH) already exists, this step will be limited to the adaptation of the heating loop;

3. **Preliminary design of the district network for selected zones inside the town** – this step considers engineering design options available for the geothermal district heating system, which is dependent on resource temperature, flow rate, geothermal water quality, and depth;

4. **Analyse the economic aspects** – this step provides a procedure to estimate capital expenditures, as well as annual operation and maintenance costs. These are then translated into costs per unit of energy for both district heating and conventional systems;

5. **Evaluate district heating feasibility** – this step explains how district heating and conventional costs are compared. Evaluation criteria are suggested to determine whether district heating is appropriate.

A limitation of this analysis is that thermal loads calculated, in general, are limited to space heating and domestic water heating. If industrial process loads are known, they can be included. Space cooling loads are also to be considered if office buildings are present. District heating is usually economically feasible in locations with a sufficiently long and cold winter season. It would be difficult to justify a DH system in a location with less than 2200 heating degree days. The area to be served by a DH system should have high hourly and annual demands for thermal energy per unit of land area. Typically, an area for which DH is being considered should be characterised by buildings that have several stories and are situated relatively close to each other.

1.5.3. Phases of a geothermal DH project at a glance

It is possible to divide a geothermal project into 4 key phases (Table 3): exploration, resource development, construction, and commissioning, operation and maintenance. The risks in the two last phases are just normal technical risks similar to those well known in the building sector.

If the project is located in a favourable zone already drilled and where the geological and hydrogeological conditions are known, the risk is considered as small and can be covered by a private insurance system (assuming that the third part expert doing due diligence for the insurance company does accept the conclusions of the specialised engineering company paid by the promoter or developer of the geothermal plant). If not, the developer has to drill the well at its own risk except in countries where a mutual insurance system is in place as in France, Germany, and the Netherlands. When the project is located in areas where no deep wells were drilled for water, mines or oil & gas exploration, the geological risk is at its maximum, and without the support of a national geological survey for an exploration well, the development of a geothermal plant is drastically limited.

Table 3. Key phases of a geothermal project

Phase/Quarter	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1a-Geothermal resources and DH prefeasibility study																
1b-Exploration permits																
1C-Detailed study on surface and subsurface equipments									Equity risk							
1d-Heat purchase agreement																
1e-Economics and financial																
2a-Risk insurance																
2b-Drilling first well										Maximum risk zone if no						
2c-Drilling second well										insurance coverage						
2d-Long term testing																
3a-Heating station																
3b-Network construction															Debt risk	
3c-Commissionning																
4a-Exploitation phase																

Based on experience, it takes about 3 to 5–7 years to bring a geoDH plant online (depending on the geological knowledge on particular area). The crucial first phase including all the studies and permits gathering is the longest and can last 15 months. The phase related to underground works including long term testing of the doublet is of 9 months. Full DH construction (incl. piping systems, heating station and commissioning) lasts up to 15 months and can be reduced to 5, if the DH already exists.

1.5.4. GO / NOGO pathway of a geothermal district heating plant construction

The following steps have to be taken:

- **Pre-feasibility study** which includes:
  - Pre-sales: Project pre-design, Memorandum of Understanding for heat purchase agreement with customers and financing research
  - Preliminary survey
  - Prefeasibility study (surface and sub-surface)

GO / NOGO

Expected geothermal potential confirmed and existing customers ready to buy heat at a fixed cost for a long duration which has to exceed the loan period

- **Exploration and feasibility study** which includes:
  - Detailed studies, including geophysics if possible, and permitting to obtain the right to drill a doublet system
  - Negotiation to get coverage for the first and second well + geothermal loop testing
  - Project economy review and financing strategy

GO / NOGO

Confirmation of geothermal potential (depth, temperature, flow-rate), insurance coverage secured, and financial details arranged

- **Drilling of wells** which includes:
  - Drilling of first well (preferably vertical)

GO / NOGO

The project is stopped if the result of the first well is under a temperature/flow-rate ratio under the limits of the success curve built and detailed in the insurance contract

  - Drilling of the second well and loop test

GO / NOGO

The project could be stopped at that time if the capacity of the second well is much lower or reinjection of the totality of the flow rate is not possible

- **District heating construction** which includes:
  - Equipment of geothermal loop (submersible pump, surface injection pumps, electric variators, heat exchanger installation, chemical treatment if any), monitoring of the loop and testing
  - Construction of the piping network or adaptation of the existing network
  - Construction of the heating station (the closest possible from the drilling pad) or adaptation of the existing one

- **Commissioning of the whole installation** which includes:
  - First year of operation with detailed measurements of the geothermal loop (levels in the wells, well-head pressure, water chemistry, pump electrical consumption, etc.)
  - First year of operation with detailed measurements on the DH network (temperature, flow rate, return temperature to the exchanger, follow up of back up boilers and calculations of energy balance with the coverage of geothermal)
  - Normal exploitation of the plant including well controls, repairs and heavy maintenance and equipment replacement.

1.5.5. Design of a geothermal doublet scheme

The geothermal doublet design is a requisite. Before many geothermal plants were fed with single geothermal well (e.g. Hungary, Romania, USA, Italy, France) and the geothermal water discharged into the environment after the heat exchange. This exploitation scheme is no longer acceptable. The re-injection of geothermal water is mandatory in order to avoid a pressure drop in the reservoir, the waste of water, and, if the fluid is mineralised and rich in minerals, the pollution of surface waters.

The ordinary proposed design, if the depth of the geothermal reservoir is sufficient, is to drill two wells- usually deviated from the same platform in order to reduce land occupation at the surface and minimise geothermal water transportation at the surface (Figure 29).

If the depth is not adequate two platforms are necessary in order to create a sufficient spacing between the production and injection well, which is of paramount importance to avoid the arrival of cold water at the hot production well. The traditional design of a modern doublet (based on Ile de France experience) is shown on Figure 30.

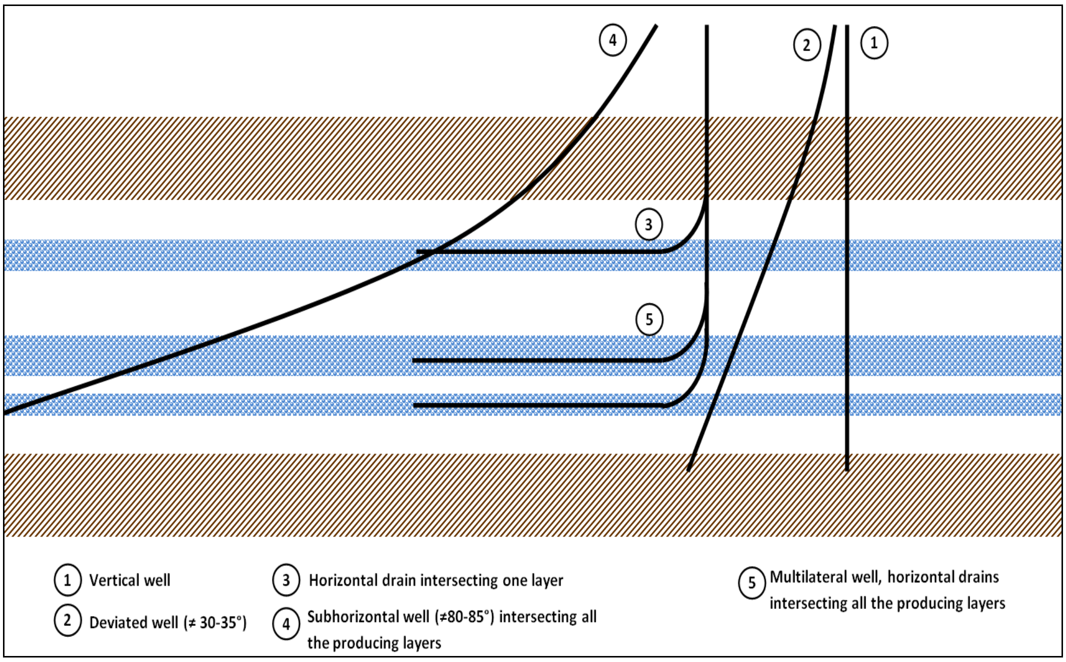


Figure 29. Various types of geothermal wells (source: GPC IP)

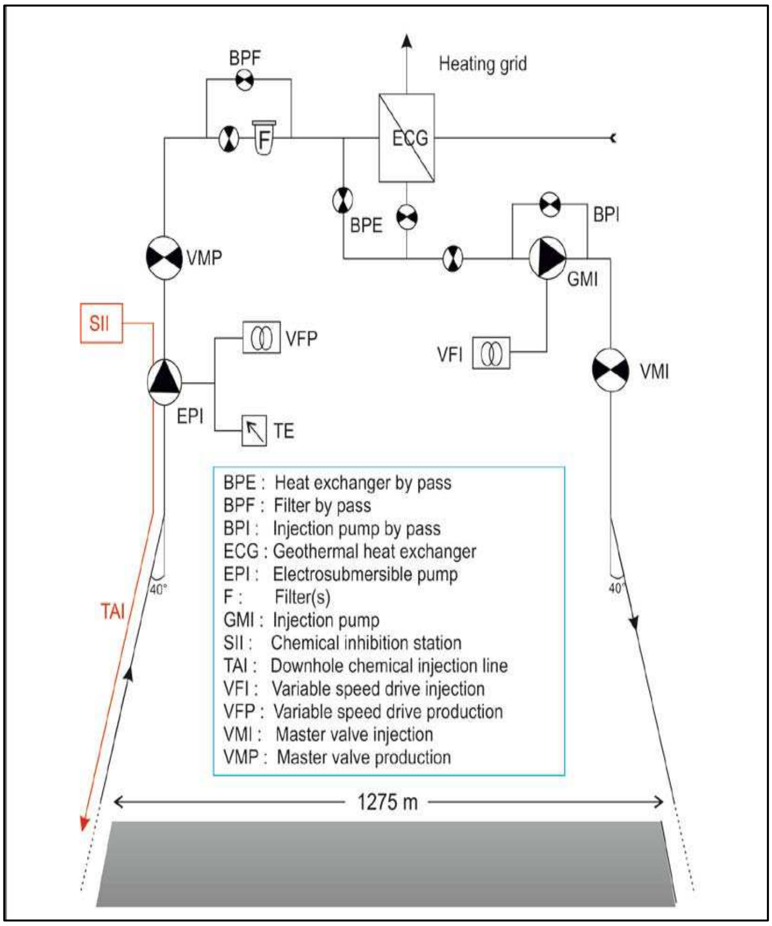


Figure 30. Traditional design of a modern geothermal doublet (based on Ile de France experience). Source: GPC IP

1.6. Drilling technologies

(Christian Boissavy – AFGP)

For geothermal deep drilling the technology used is that of rotary drilling, which began in the US at the end of the 19th century. The size of the rig is generally proportional to the depth of the reservoir target and the surface necessary to install the working site is usually rather big (5000 to 10000 m^2). Figure 31 gives an idea on drilling rig and its main elements. The technologies from oil and gas have been adapted and sized to the geothermal specificities. Table 4 shows the differences in between the two techniques.

Table 4. The specifics and differences between oil & gas and geothermal drillings

Characteristics	Oil and gas	Geothermal (Heat and CHP)
Depth of the reservoir	1000 to 7000 m	**500 to 4000 m**
Type of rocks	Sedimentary (carbonate, clastic, shale, various type source rocks)	Sedimentary (80% carbonate and 20% clastic)
Drilling site location	Remote, rural, off shore	**Urban, sub-urban, sometimes rural**
Pressure	Low to high	Low to near hydrostatic
Fluid types	Single, two or three phase	Single phase liquid, dissolved gas
Porosity type of rocks	Matrix, fractures non connected	Matrix and/or fractured
Fluid's flow rate	0.1 to 40 m^3/h	**100 to 400 m^3/h**
Temperature	30 to 250°C	30 to 150°C
Well design	Small to medium diameter	**Large to very large diameter**
Diameter	7''casing and 5" tubing and perforated 7"x 5" cemented	13"3/8 x 9"5/8, reservoir in 7" or 8"1/2 with screens 6"-7"
Completion types	Inner tubing, packer, safety valve completion	**Full-bore casing production, open hole, slotted liner or screens**
Production	Artificial lift gravity, self-flowing	Artificial lift, possible self-flowing

Figure 31. Drilling rig and its main elements (source: IGA material; www.geothermal-energy.org)

The first generation of geothermal plants drilled in the sixties are small diameter and usually vertical because deviation is modern technology. That is the case of the wells in Melun l'Almont (France) drilled in 1969. The wells drilled in the last 10 years are larger in diameter and normally deviated, sometimes even with big angles- up to 50°. A new generation is coming and horizontal wells have been already drilled, for example in Switzerland in 2013 (Figure 32).

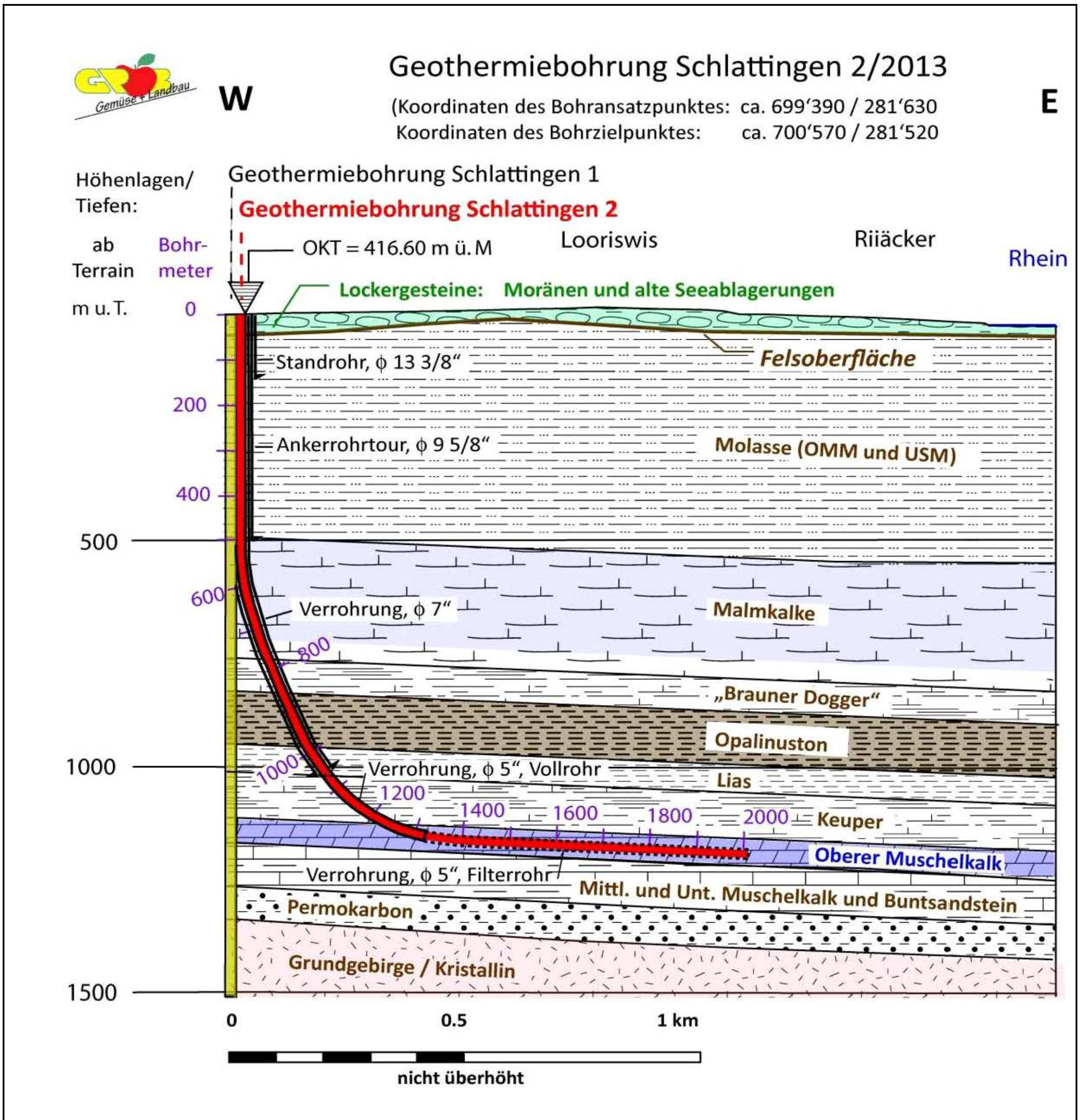


Figure 32. Sketch of new generation horizontal geothermal well – example from Switzerland, 2013

Deep well drilling is realised using the rotary technique with drilling fluids and bits adapted to the nature of the rocks to be drilled and the expected hydrogeological conditions. A typical drilling down to 2000 m and producing 300 m^3/h of water at 75-80°C is shown on Figure 33.

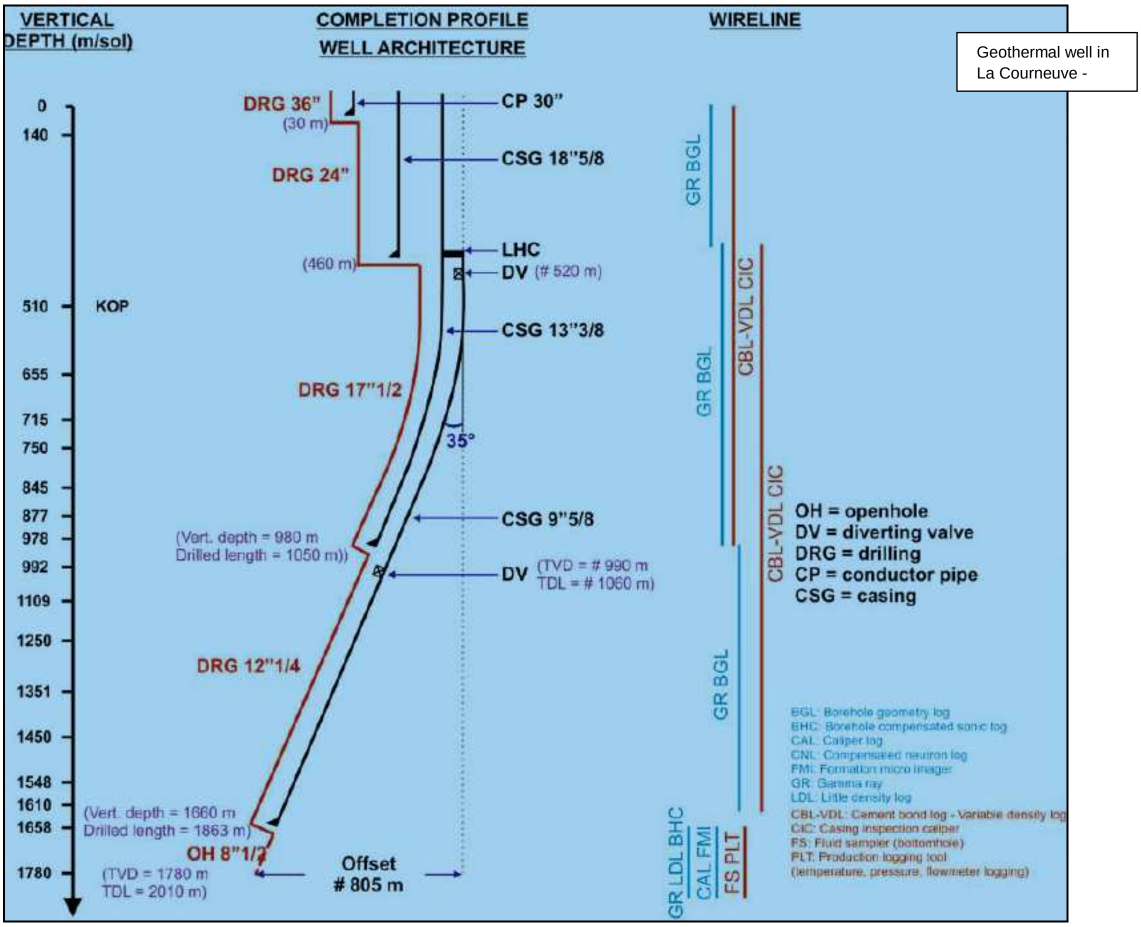


Figure 33. Example of a classical geothermal well drilling (total depth ca. 2000 m, production of 300 m^3/h of 75 – 80°C water)

The first step before starting to design a geothermal well is to select a suitable rig: the size of the engine and the mast has to be adapted to the depth and casing diameter to be set in the well, further several items need to be to be defined such as:

- **Site preparation and rig footprint**: the land needed is often 5000 – 10 000 m^2 and is usually inside towns. Special attention has to be paid to day and night works, noise, rotation trucks, etc.,
- **Drilling,**
- **Bits and adapted tools for fishing,**
- **Drilling fluids and mud treatment,**
- **Directional drilling** (special services companies to contract and precise target to attain),
- **Casing and liners,**
- **Cementing and products,**
- **Waste disposal and processing,**
- **Geological control and supervision.**

Several miscellaneous items such as water consumption and injection, mining risk insurance, sustainability, environmental aspects and administrative constraints, possible work-over in exploitation phases, screens in detrital reservoirs, mud solid control, drilling contract follow up, and rig management also need to be considered.

When the doublet has been successfully drilled and tested at the operational flow rate the engineering company in charge of the doublet construction has to design the surface equipment's which includes: geothermal well heads, electro-submersible pump and variable speed drive, electrical and piping equipment in the geothermal station, heat pump selection if any, anti-corrosion treatment if needed, filtering systems to avoid plugging in the geothermal loop, and heat exchanger with adapted metallurgy.

The geothermal doublet is built to be into operation during a minimum period of 30 to 35 years, to be extended to 50–60 years after necessary repairs and new casings with a smaller diameter. Therefore, a lot of attention has to be given to the usual annual maintenance and the heavy repairs which have to be anticipated, planned, and carried out during the life time of the plant. A contract has to be put in place from the beginning of the exploitation period to guarantee a full time operation of the plant.

Geothermal energy is available 24/24h all the year with energy content fixed and stable. It is of utmost importance to maintain this advantage constantly, which will lead to very cheap energy after the payback period.

An example: characteristics of the Dogger geothermal zone in the Paris basin

Geothermal development operations the Dogger aquifer use the "doublet" technology consisting of a closed loop with one production well and one injection well. The wells target productive layers at between 1500 and 2000 m deep. They are usually completed with an open hole through a reservoir thickness ranging from 100 to 150m of carbonate rocks. By the end of the 1970s, the routine acquisition of well logs, especially flow meter logs, revealed the high vertical and lateral variability in the hydrological characteristics of the aquifer. There can be from 3 to 20 individual productive layers in the formation with a net pay of only 10% of the total aquifer thickness. On average, this net total productive thickness is of the order of 20 m, with 10–15 high permeability (2–20 Darcy) layers. A single productive layer may represent as much as 80% of the total flow rate. Formation temperatures at the top of the productive layers are between 55°C and 80°C (Figure 34).

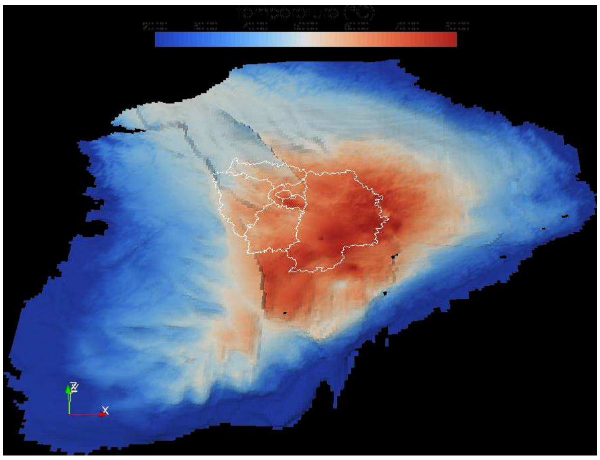


Figure 34. Presentation of temperature distribution of the Dogger reservoir, the Paris basin (source: BRGM)

The mean temperature gradient between the surface and the formation is 3.5°C/100 m. Minimum temperatures are found at 1650m below the surface, northeast of Paris, where average thermal gradients are as low as 2.75◦C/100m. This zone corresponds to a cold anomaly area that can be explained by regional cold water flows coming from the upper parts of the aquifer. Maximum gradients of 4.1°C/100 m are recorded southeast of Paris. The mineralisation of exploited waters ranges from 6.4 mg/dm^3 to 35 mg/dm^3. At basin scale, mineralisation increases from the southeast, where the reservoir outcrops (0.5 g/dm^3) to the deepest area where it reaches 35 g/dm^3. These variations of mineralisation influence the geothermal water density and viscosity and hence the aquifer-scale fluid flow, but these variations have a negligible effect at the scale of geothermal doublet exploitation. Facies and diagenetic porosity reduction patterns are complex. The original porosity and permeability properties are strongly influenced by contemporaneous dissolution events related to high frequency sea level fluctuations. Fracture porosity is often present. Investigations showed a direct relation between porosity and the sedimentary environment, particularly where sandy sediments with matrix porosity were deposited.

The doublet technology has several advantages:

- There are no environmental impacts as cooled geothermal water is fully injected back (reinjected) and prohibitive costs of its chemical processing for surface disposal are avoided,
- Production flow rate is maintained whereas a single well exploitation would have progressively reduced the reservoir pressure, eventually affecting pumping conditions,
- Thanks to the pressure interference the exploitation pressures are stabilized and the impact of pressure variation is limited: an exploitation domain can be legally defined by the authorities, thus allowing the setup of an efficient strategy for the optimal management of the aquifer.

1.7. Production, operation and management of geothermal energy resource (Christian Boissavy – AFPG)

The exploitation of a district heating/cooling network, as seen in Figure 35 has an Impact on many different elements of the energy infrastructure. Those elements highlighted in red are closely related to the geothermal resource, whilst the others relate to the surface network.

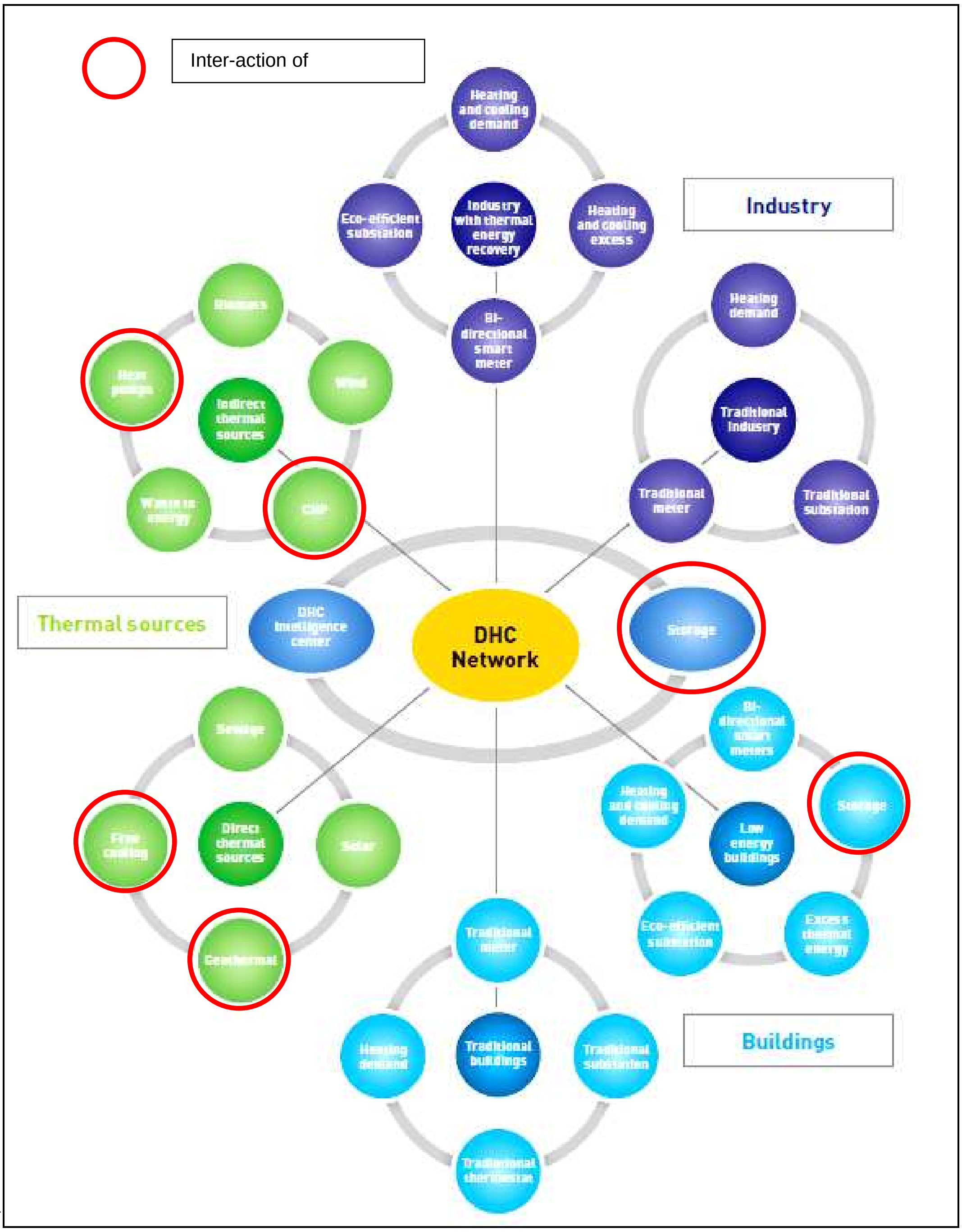


Figure 35. Graph showing groups of actions related with the exploitation of a district heating/cooling network (Euroheat and Power Annual Report 2012)

After the full completion of the geothermal doublet and the finalisation of the installations including the geothermal piping system and the main heat exchanger, the manager of the district heating system has to establish a contract with a company to provide the maintenance of the doublet and the control of the geothermal resource. These tasks are known as P2 and P3. P2 corresponds to the annual maintenance of the doublet including follow up of the pressure, temperature, and nature of the geothermal fluid. It includes also careful measurements of corrosion treatment if any, and the filtration system. The service company in charge must maintain the well heads, pumping equipment, and the frequency variations driving production and injection pumps. P3 corresponds to the heavy maintenance which can be planned during the summer to avoid the loss of too much geothermal energy during the heating season. These replacements concern mainly the pumping equipment and valves. When the submersible electrical pump is out from the production well, it could be wise to run some logging tools in the well to control the casing diameter and the performance of the well. A typical detailed cost analysis for a deep geothermal doublet is shown in Table 5. It can be seen that for an average investment cost for the doublet, maintenance and operating costs are divided into four sections for both systems: geothermal loop including the well to the main heat exchanger and surface and network installation downstream from the heat exchange with hot geothermal water. The operating and maintenance costs including electricity and gas consumption for back up, for a deep geothermal doublet (representing capital expenditures /CAPEX/ at 10 M€) are about 27%.

Table 5. A typical detailed cost for a deep geothermal doublet

Operating costs and maintenance		K Euros
Geothermal loop		
P1	Electricity	**240**
	Corrosion inhibitors	**70**
	Water	**5**
P2	Regular maintenance	**30**
	Electrical logging	**20**
P3	Heavy maintenance	**88**
	Equipment replacement	**40**
	Work force and 24/24h follow up	**15**
	Stock for repairs	**15**
P'3	Work over in the wells	**55**
	Insurance	**45**
District heating network surface installations		
P1	Electricity	**20**
	Natural gas	**1 100**
P2	Work force and 24/24h follow up	**420**
P3	Equipment replacement	**320**
P'3	Stocks for repair	**50**
	Insurance	**150**
Total		**2 683**

Explanations of symbols in Table 5: P1 – energy consumption (electricity and natural gas) for peak production and back up, P2 – regular maintenance, P3 – heavy maintenance and equipment replacement (if needed), P’3 – geothermal loop: work over provision for the two wells, P’3 – surface loop: stock for repair and insurance

References to sub-chapters 1.5 – 1.7

Euroheat and Power Annual Report 2012 (http://www.euroheat.org)

http://www.euroheat.org

www.geothermal-energy.org

2. District heating: technology and planning

2.1 Introduction

(Morten Hofmeister – Grøn Energy, Søren Berg Lorenzen – Danish Geothermal District Heating)

When considering any application of geothermal energy, the planning phase is crucial for identifying the available options and the feasibility. If the scope of the project is not only to introduce geothermal, but also to introduce district heating, the project is more comprehensive. When designing a geothermal district heating system, the technical parameters of both the existing network and the supply need to be considered. The following specific issues need to be addressed:

1) Planning
   a. Existing or new infrastructure
   b. Heat demand
   c. Other producers
   d. Interaction between geothermal and other producers to meet heat demand

2) DH network
   a. Transmission and/or distribution network
   b. Temperature level

3) Geothermal plant
   a. Principal sketch with elements
   b. Heat exchangers
   c. Heat pumps
   d. Design of plant size (revisit to interaction with other producers)
   e. Water chemistry

District heating is crucial element in energy efficiency. The Heat Roadmap Europe study (Aalborg University, Halmstad University, Ecofys Germany, Plan Energi, 2013) projects an increase of district heating from 12% in 2012 to 50% in 2050. Geothermal heat is projected to contribute to this with an increase from 2 TWh in 2012 to 100 TWh in 2050.

District heating can be categorised in four generations. With successive generations, lower temperature resources are used and efficiency increased (Figure 36). Greater utilisation of geothermal heat is well facilitated by 4th generation district heating. More than one generation of district heating may exist at the same time, even in the same city. A key point is that the development is towards lower forward temperature and that this facilitates more energy efficient district heating. In case the temperature of the geothermal water is high, simple application is possible and geothermal heat can be used without increasing the temperature level.

Geothermal can replace traditional energy sources in existing district heating systems, but the existence of a network is not a prerequisite. District heating requires a system which facilitates thermal energy supply; this is an infrastructure system like that for water or sewage.

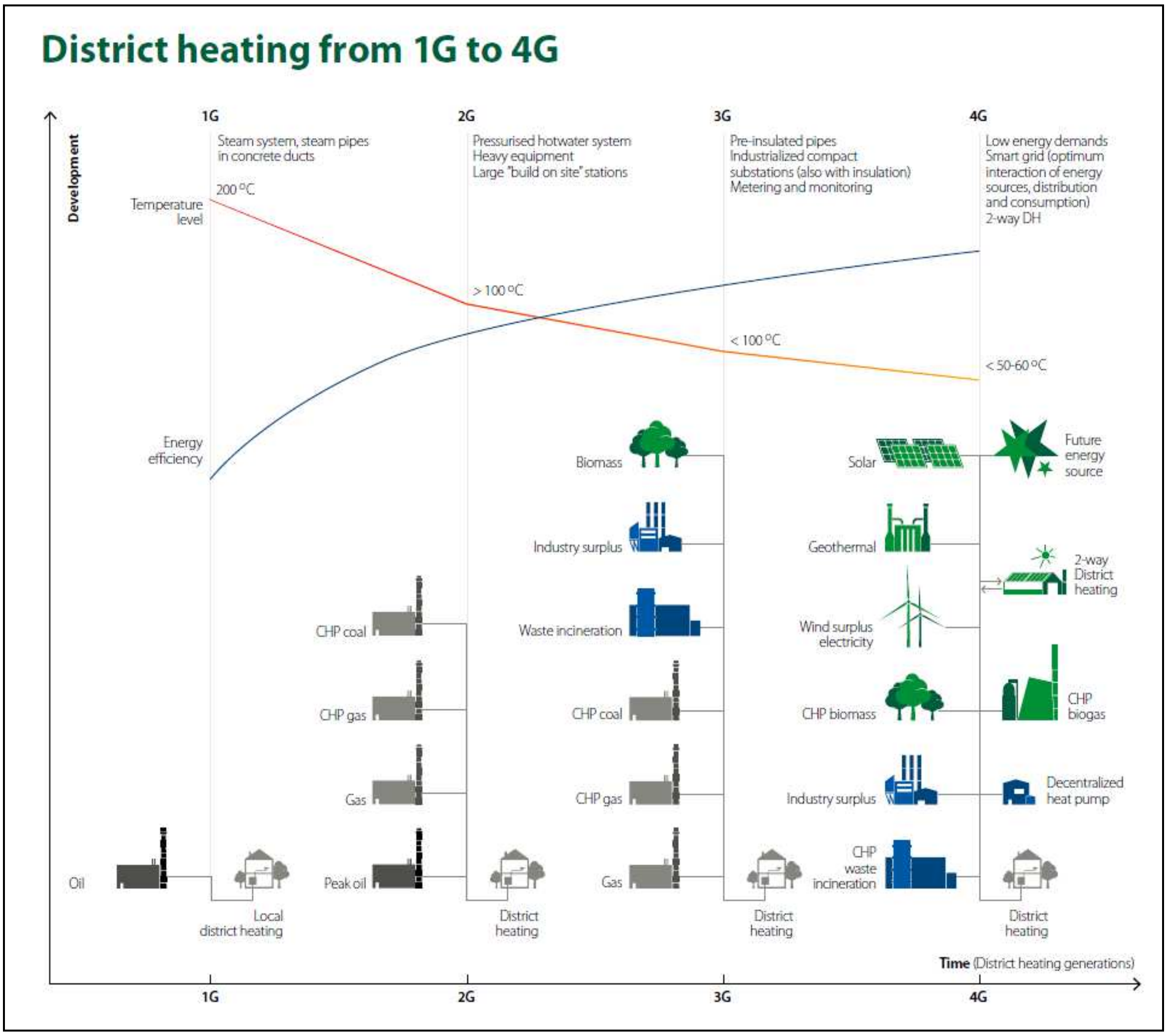


Figure 36. Four generations of district heating (1G – 4G)

The 1st generation (1G) is based on oil and uses steam as an energy carrier. The 2nd generation (2G) is more diversified in fuel usage, although still based on fossil fuels, and uses pressurised water as an energy carrier. The 3rd generation (3G) features further diversification of fuels and heat sources and applies hot water below 100 °C as an energy carrier. The 4th generation (4G) – currently being defined – is characterised by extensive diversification of heat sources and integration with the electricity sector – defining district heating as energy infrastructure facilitating energy efficiency and integration of renewable energy (both heat and electricity). The 4th generation is an ongoing research project (more information at www.4dh.dk).

Like other investments in societal infrastructure, a term view is relevant, necessary and requires appropriate organisation. A guiding principle is to apply regulation (of public or private utilities) which is based on a societal economy. A key characteristic for district heating is that it can facilitate the use of various types of heat sources at the same time. However, one should avoid over investing in too many sources. Given its high upfront costs, a geothermal plant requires a high level of use in order for the investment to pay off.

2.2. Planning

(Morten Hofmeister – Grøn Energy, Søren Berg Lorenzen – Danish Geothermal District Heating)

Geothermal energy has high investment costs compared to other heat sources which could supply a district heating system, whereas the operating costs are lower. The risk profile is important; the risk for investment is high, while for operation is low. This is illustrated in Table 6.

Table 6. Indicative size of investment, operation costs, and risk profiles for different district heating technologies (based on Danish figures). The figures for geothermal are based on 70°C reservoir water temperature and include an absorption chiller (Lorenzen et al., 2014)

District heating source	Investment		Operation incl. fuel, electricity and taxes	
	[MEURO/MW]	Risk	[EURO/kWh]	Risk
Geothermal	1.8	High	13	Low–medium
Gas boiler	0.1	Low	60	High
Biomass boiler	0.8	Low–medium	35	Medium–high

2.2.1. District heating infrastructure – new or existing

District heating constitutes a large investment in energy infrastructure. A distinction is made between areas which already have district heating and areas which do not.

Areas without existing district heating infrastructure

In areas without an existing district heating infrastructure, it is possible to design the district heating system (network and housing installations) according to the temperature level of the geothermal source. This could reduce or remove the investment required for auxiliary equipment, for example heat pumps and absorption chillers.

Areas with existing district heating infrastructure

Where an existing District Heating system is in place, a transmission pipeline may still be required to connect the resource. This investment can have a significant influence on the feasibility of the project. The temperature level, defined by the design of the housing installations and the network, will also have an impact. If the temperature level of the geothermal source is lower than the temperature in the district heating network, it is necessary to increase the temperature level for example with the use of heat pumps.

2.2.2. Heat demand

A crucial parameter when considering the heat source mix for a district heating network is the heat demand. Both its size and the profile influence the feasibility of the geothermal project.

Size of the heat demand

The size of the heat demand has an impact on the evaluation of which heating sources should be used in a district heating system. The potential and production capacity of the geothermal well should be determined, in order to identify how this fits with the heat demand.

The development of the heat demand in a 20-30, and even 50 year perspective should be identified. Since the investment costs of a geothermal project are relatively high, and the operation costs relatively low, a long-term perspective on the heat demand could be crucial in determining the full value of the investment in geothermal heat.

The heat demand may decrease due to energy savings, but may also increase due to the connection of more customers to the district heating network.

An increase in the heat demand may come from the connection of more consumers located in the same city, or to the connection of different district heating networks in different cities, located 10, 20 or even 50 km away.

When considering investments in geothermal heat and transmission pipeline, coordination of heat planning across several cities becomes relevant. Coordinated planning can be more cost effective than separate developments.

This strategic energy planning has implications not only for the heat supply, but also for the electricity supply, where for example large district heating networks and heat storage can enable the efficient use of electrically driven heat pumps, using power from renewable energy sources.

Profile of the heat demand

The base load – and the development of it – is important to identify. If the size of the base load fits the production capacity of the geothermal well, the number of production hours will be relatively high (Figure 37 overleaf). This is important in order to ensure the feasibility of the relatively large investment.

2.2.3. Other producers

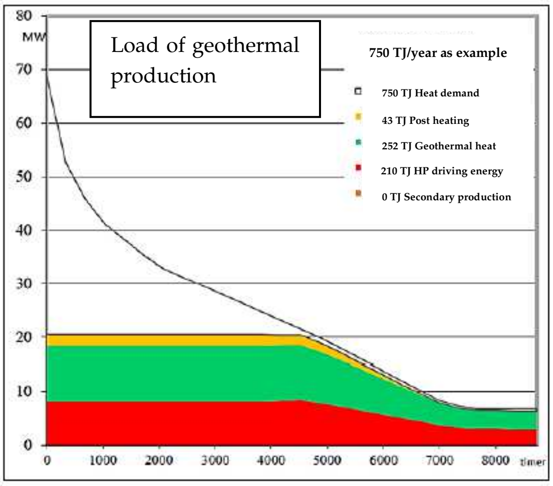
Other producers of heat – existing or potential – should also be identified to determine how the different sources could supplement each other. Some have good regulation capability, for example gas boilers. Geothermal production can also be regulated but due to the high investment costs, the number of production hours should be maximised.

Other heat sources such as waste incineration also have priority, i.e. should also be base load (Figure 38). The development of waste handling strategies should be observed.

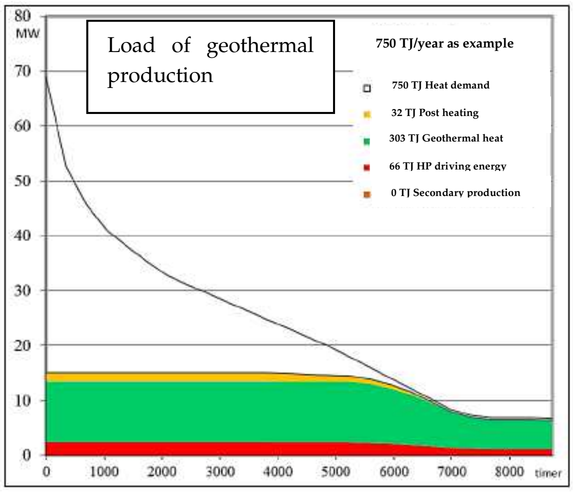
2.2.4. Interaction between geothermal and other producers to meet heat demand

The characteristics of the other producers should be identified, including:

- Production type, fuels etc.,
- Production capacity,
- Production costs (of heat),
- Operation and maintenance costs,
- Year of establishment,
- Expected remaining life time,
- Regulation of the production type (taxes etc.).



Example 1



Example 2

Figure 37. Examples of duration curves and how geothermal heat fits as base load. The green areas indicate the geothermal heat and the red areas indicate the driving energy in order to increase the temperature level from absorption chiller and electrical driven heat pump, respectively (Lorenzen et al., 2014)

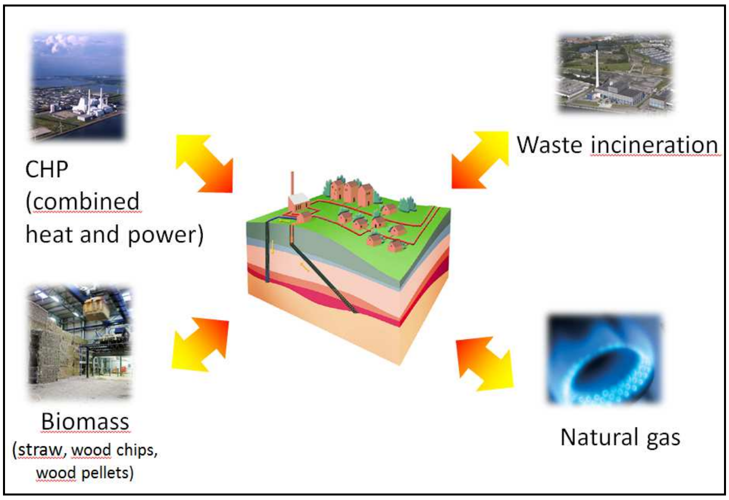


Figure 38. Geothermal can be a part of an energy system comprising different energy technologies. The optimal combination should be analysed for each location, in order to assess the feasibility of the different possibilities including geothermal

The purpose of this analysis is to establish whether geothermal is competitive, in the short, medium and long term. In this analysis, it will be important to note that geothermal district heating systems can take up to 5-7 years to be realised and that geothermal aquifers can serve as seasonal storage for heat produced by e.g. solar thermal or CHP.

2.3. District heating network

(Morten Hofmeister – Grøn Energy, Søren Berg Lorenzen – Danish Geothermal District Heating)

2.3.1. Transmission and/or distribution network

The characteristics of existing transmission and distribution networks should be identified. This includes both the current operating parameters such as temperature, pressure and capacity, as well as possible operating conditions, also taking into account the installations in individual buildings.

The location of the network is also important, in order to identify where the geothermal heat could be connected, as well as the size and capacity of the transmissions pipeline. This investigation would include analysis of the flow in the existing district heating network. Based on this analysis, the costs of connecting the geothermal heat source to the district heating network can be estimated, including the investment costs in a transmission pipeline and possible costs related to the adjusting the existing district heating network.

2.3.2. Temperature level

A general rule of thumb is to provide the lowest possible forward temperature in the district heating network. Low temperature district heating may entail relatively high pumping costs and, if the individual applications are designed for high temperature levels refurbishment may be required (and this may not be feasible in high heat density areas).

However, in low temperature district heating the geothermal resource may be integrated without altering the temperature, or the temperature may only need to be adjusted slightly, increasing the COP of the heat pump, and reducing heat losses in the system. The match between the temperature levels of the geothermal water and the district heating water is a crucial parameter for the feasibility of the geothermal project.

2.4. Geothermal plant

(Morten Hofmeister – Grøn Energy, Søren Berg Lorenzen – Danish Geothermal District Heating)

It may take up to 5-7 years for a geothermal district heating system to become operational. The main activities are shown in Table 7.

Table 7. Main phases, duration and time schedule in a geothermal project (Lorenzen et al., 2014)

Task	Duration Years	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Authorities	5	XX	XXXX	XXXX	XXXX	XXXX	XX	
Project development	2	XXXX	XXXX					
Seismic investigations	1.5			XXXX	XX			
Drilling	2				XX	XXXX	XX	
Surface	2						XXXX	XXXX

After analysis of the first drilling, the design of the surface plant can start. The purpose of the surface plant is to pump the geothermal water from the reservoir, transfer the heat to the district heating water in an efficient way, and then pump the cooled water back into the reservoir.

2.4.1. Principal sketch with elements

The geothermal plant consists of wells and heat exchangers. In case the temperature of the geothermal water is lower than the district heating forward temperature, a heat pump is installed. A principal sketch of district heating network and geothermal plant with absorption chiller (heat pump) is given in Figure 39: the return water from the district heating network (1) is heated by the geothermal water (2). In order to increase the flow temperature of the district heating water (3) the water is heated in a heat exchanger (4) by an absorption heat pump (5). Alternatively, the second increase of the temperature of the district heating water could be made by a heat pump driven by electricity, cf. the section above on profile of heat demand.

The design of the surface plant depends on the technical parameters of the geothermal reservoir and the district heating system. In particular the temperature level is important.

If the temperature of the geothermal water (the reservoir temperature) is significantly higher than the return temperature of the district heating water, the energy can be transferred directly in a heat exchanger. However, applying a heat pump can increase the utilisation of the geothermal heat source significantly.

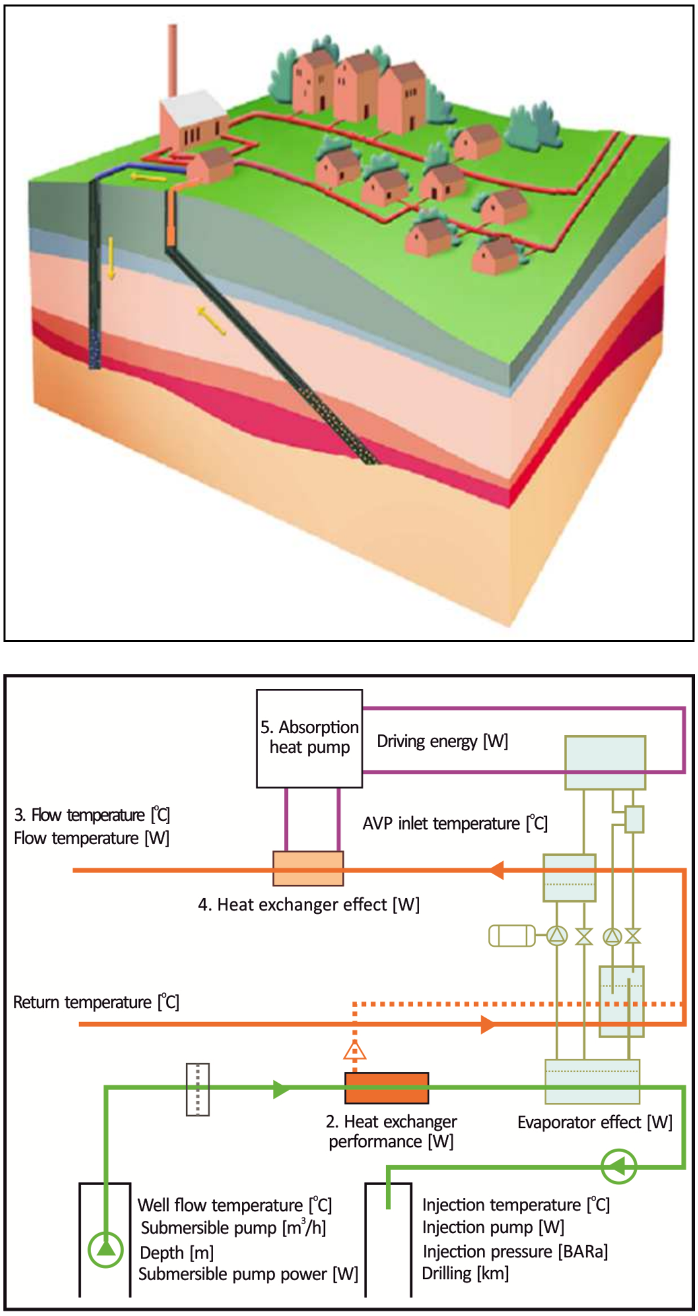


Figure 39. Principal sketch of district heating network and geothermal plant with absorption chiller in Denmark (Lorenzen et al., 2014)

2.4.2. Heat exchangers

The objective of the heat exchanger (illustrated in Figure 40) is to transfer the maximum amount of heat energy from the geothermal water to the district heating water. An efficient design is to place a heat exchanger early in the process, cf. the figure above, if the temperature of the geothermal water is higher than the temperature of the district heating water. The high content of salt (salinity) of the geothermal water makes it potentially highly corrosive, even more so if oxygen is present. Therefore the heat exchanger is typically made from titanium.

Figure 40. High plate heat exchangers in series ensure an efficient transfer of heat energy from the geothermal water to the district heating water (Lorenzen et al., 2014)

2.4.3. Heat pumps

The purpose of a heat pump is two-fold:

- To increase the temperature level of the geothermal water to the level of the district heating forward temperature,
- To extract as much heat energy as possible from geothermal water before it is injected back into the reservoir.

There are different types of heat pumps. The main types are absorption heat pumps, and heat pumps driven by electricity (compressor heat pumps). The choice may depend on taxes, the amount of heat energy to be transferred and costs of driving energy (e.g. biomass in a biomass boiler driving an absorption heat pump or electricity in a compressor heat pump).

A crucial parameter influencing the choice of heat pump is the efficiency- COP, coefficient of performance. It is defined as the amount of delivered heat energy, compared to the input driving energy.

The COP is generally lower for absorption heat pumps than for electrical heat pumps. The COP depends on temperature levels – the lower the difference between the geothermal water and the district heating water, the more efficient the heat pump, because less driving energy needs to be supplied.

The absorption heat pump requires boilers to supply the driving energy. These can be difficult to locate in city areas. Hence, the absorption heat pumps requires a more complex plant design; the operation of the boiler the supply of fuel (e.g. biomass). Therefore electrical heat pumps may be a more flexible solution. Large scale heat pumps have been used in some district heating systems, for example Sweden has many electrical heat pumps.

In order to achieve high temperature levels, electrical heat pumps are often installed in series. However, a third type of heat pumps – hybrid, combining the absorption heat pump and the electrical heat pump – can deliver high temperatures at lower pressure. Technical development is, however, needed.

2.4.4. Design of plant size

After investigations of the potential and the capacity of the geothermal heat source, as well as the other existing and potential heat sources, a feasible design including heat pumps etc. can now be developed. The design should in particular take into account the size and profile of the existing and projected heat demand.

2.4.5. Water chemistry

The chemistry of the geothermal water needs to be taken into account when designing the geothermal district heating plant. Operational problems could occur due to degassing, corrosion, precipitation/scaling, particle production, etc. The risks of such problems should be examined carefully, preferably on the basis of thorough analyses of samples taken downhole in the geothermal wells. Based on these analyses, preventive actions can be necessary, for example:

- Increasing the pressure at the surface installations in order to stay above the bubble point,
- Filtering, both at reservoir level (screens and gravel packs) and at surface (mechanical, bag and/or cartridge filters),
- Choosing more appropriate materials that are less prone to corrosion,
- Injection of inhibitors to prevent scaling or corrosion, perhaps even downhole.

Also regular treatments like (soft) acidizing and cleaning the wells through pump out can be necessary. More information and suggestions as to the methods for preventing or reducing problems caused by corrosion and secondary mineralisation (scaling) based on experience in a range of geothermal field, is widely available in publications such as Seibt et al., 2005; Seibt & Wolfgramm, 2008; Ungemach 2010a; Ungemach 2010 b).

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3. Regulations, financing and other non-technical issues

3.1. Regulations, standards and codes

(Luca Angelino – EGEC, Elianne Demollin-Schneiders – Gemeente Heerlen)

3.1.1. Introduction

Despite the significant potential of deep geothermal energy in several European countries geothermal DH systems have been poorly developed so far. This situation is notably due to the lack of adequate national and regional policies concerning district heating and geothermal district heating systems (geoDH) in particular. Developing a geothermal project requires several authorisations and the compliance with a number of national and local regulations; for project developers, regulatory barriers can result in additional costs. It is therefore crucial that a fair, transparent and not too burdensome regulatory framework for geothermal is in place.

This chapter provides an overview of regulatory barriers and some recommendations for their removal as well as some general information on standards and codes in force in Europe. Details on the national and local specificities will be given during the training courses.

3.1.2. Main areas of regulatory barriers

Barriers against geothermal district heating can result from:

- Poor national, regional, and local strategies and lack of support for renewable and efficient heating and cooling technologies,
- Lack of understanding, data and reliable information,
- Uncertainty over resource ownership, and for difficult procedures for obtaining exploration and development rights. In many countries, however, these issues have been solved in a satisfactory way,
- Very complex administrative procedures or, in certain cases, lack of a regulatory framework,
- Inappropriate environmental regulations. These regulations should both protect the environment and not hamper project development,
- Regulated prices for gas/other fossil fuels for heating purposes,
- Public acceptance problems, which must be taken seriously and solved, even if this is not legally required.

From the above listed issues, some such as the definition of geothermal energy, geothermal resource ownership and protection of the resource against other uses/users, licensing, and environmental regulations are presented below in more details.

Definition of geothermal energy

The lack of a common definition of geothermal energy, which was an EU-wide problem for many years, has been solved by the RES Directive (2009/28/EC), with a binding definition provided in Article 2:

”geothermal energy” means energy stored in the form of heat beneath the surface of the solid Earth.

Geothermal resource ownership and protection of the resource against other uses/users

A clear title for geothermal resource exploitation rights over a sufficient period is crucial. No licenses for other uses/users that would jeopardise the resource should be granted and a certain distance (or other protection) must be kept for other uses.

Who actually owns the geothermal resource? The options are the following:

- The state / the crown:
  - could be stipulated e.g. in mining law or in mineral resources law,
  - a good option if licensing is regulated properly,
  - more difficult if included in water legislation.
- The owner of the ground on surface:
  - may result in a problematic situation where for a larger project multiple owners are concerned,
  - for deep geothermal project this is very time consuming.
- Not regulated:
  - is considered as a worst case, because deep geothermal projects are almost impossible.

In case of the ownership being with the state, the following items are crucial for geothermal development:

- Who can apply for a license (non-discriminatory process),
- One- or two-step-process (exploration, development),
- Time period for which a license can be obtained, possible prolongations,
- Royalties (based upon what parameter? Fixed or as a percentage of production?),
- Time for obtaining a license.

Licensing

The main requirements / permits that may be required for a geothermal district heating project development are the following:

- Water, mineral, and mining rights,
- Exploration permits,
- Well construction permit,
- Development rights,
- Payment of royalties,
- Environmental impact assessment (EIA),
- Building permit for the plant/distribution network,
- Dismantling permit,
- Environmental permit.

It is worth highlighting that complex and very long administrative procedures can result in additional and superfluous costs, which can cause a loss of willingness to invest.

In line with Article 13 of Directive 2009/28/EC it is highly recommended that the permit/licensing procedures for exploration and development of geothermal energy should be streamlined:

- By transferring the licensing procedures to the competences of regional administrations,
- By introducing a single licensing system (one stop shop),

- The geothermal licensing procedures and the issuing of licences should be handled by a single dedicated regional authority. The sharing of responsibilities on these matters among various authorities should be avoided since this produces unfavourable effects on projects,
- The administrative process for the granting of licences for deep geothermal for DH should be reduced and the time scale should not exceed 6–12 months,
- The duration of a geothermal exploration permit/licence should not exceed 6 years,
- Deep geothermal energy/water exploitation permits/licences should be granted for a fixed duration of a minimum of 20–25 years with the possibility of extension to 50 years,
- For the district network, the local municipality should play a leading role as the planning authority carrying out the process of public procurement for (geo)DH systems on their territories and/or approving practical projects,
- The supply of energy to DH networks should be subject to an approval regime based on a socio–economic assessment comparing various alternative sources for heat supply, giving priority to locally accessible renewable energy sources.

3.1.3. Environmental regulations

The state has a duty to provide regulations protecting the environment or other public interests from possible negative consequences of geothermal energy production.

The following rules should be adhered to:

- A viable equilibrium has to be found between regulations that might have not the necessary protective effect, and those that might prevent geothermal development,
- Full Environmental Impact Assessment (EIA) procedures are required only for large projects with considerable risk potential,
- EIA screening, which is useful for a preliminary understanding about the possible impact of the project, is different to the EIA procedure and it has to entail a lower bureaucratic burden,
- Keep environmental regulations focussed on the protection of ground, groundwater, and surface from possible harm caused by the geothermal plant, and do not address unrelated issues!

Regarding the protection of water, Article 11 of Directive 2000/60/EC (Water Framework Directive) gives member states the option to authorise the reinjection into the same aquifer used for geothermal purposes. It is therefore within the competence of the national governments to decide as to whether reinjection of the geothermal fluids is required.

Negative example:
Drilling and safety regulations for hydrocarbon exploitation are imposed on geothermal drilling

The list of barriers resulting from environmental regulations can be rather long. There will, of course, be cases where environmental issues make a project impossible. However, this should be limited to as few cases as possible, and be known as early as possible.

3.1.4. Spatial Planning Regulation

Local authorities are obliged to draft plans for spatial planning in their region, based on a national Spatial Planning Act. According to this legislation member states may have the possibility to establish a requirement for connection to a DHC network, when new buildings are erected in an area.

There should be a clear policy at the level of the local authority dealing with DHC, in order to facilitate and safeguard investments. Aspects which need to be safeguarded are the tariffs for heating and cooling for customers and possible infringement procedures in case of non-compliance with energy market rules.

3.1.5. The GeoDH Regulatory Framework

In order to overcome the administrative barriers, the GeoDH Project has developed an ideal "Framework" including key recommendations to remove **regulatory barriers, promote the best practices, and simplify the procedures relating to geothermal district heating system for investors, operators and policy-makers.**

The Regulatory Framework is primarily addressed to regional public authorities in charge of regulations and local development, since they are deeply involved in licensing and other procedures related to geothermal energy exploration, development, use and management. Key stakeholders were consulted and endorsed this document. The full version of is available at www.geodh.eu.

These proposals should lead to regional and local regulations favourable to geothermal DH development in Europe. Key recommendations are provided overleaf. Their implementation will facilitate the introduction of complementary and cohesive legislation provisions essential to create a long term stable system for the development of geothermal district heating in Europe.

Key recommendations

- **National and local rules must include a definition of geothermal energy resources and related terms, in line with Directive 2009/28/EC.**
- **Ownership rights should be guaranteed.**
- **Administrative procedures for geothermal licensing have to be fit to purpose – they should be streamlined wherever possible and the burden on the applicant should reflect the complexity, cost and potential impacts of the proposed geothermal energy development.**
- **The rules concerning the authorisation and licensing procedures must be proportionate and simplified, and transferred to regional (or local if appropriate) administration level. The administrative process must be reduced.**
- **Rules for district heating (DH) should be as decentralised as possible in order to be adaptable to the local context, and stipulate a mandatory minimum level of energy from renewable sources, in line with Article 13 §3 of Directive 2009/28/EC.**
- **A unique geothermal licensing authority should be set up.**
- **Information on geothermal resources suitable for geothermal district heating systems (geoDH) should be available and easily accessible.**
- **geoDH should be included in national, regional and local energy planning and strategies.**
- **Policy-makers and civil servants should be well informed about geothermal.**
- **Technicians and Energy Service Companies should be trained in geothermal technologies.**
- **The public should be informed and consulted about geothermal DH project development in order to support public acceptance.**
- **Legislation should aim to protect the environment and set priorities for the use of underground: geothermal energy should be given priority over other uses such as for unconventional fossil fuels, CCS, and nuclear waste deposits.**

3.1.6. Standards and codes

As far as standards and codes for the development of geothermal district heating are concerned, four different parts of the system have to be distinguished. Table 8 shows the needs according to each of different areas.

Table 8. Overview of standardisation and certification needs for geothermal district heating systems

Area	Technical standards / regulations / guidelines needed for
1. **Geothermal side** e.g. drilling, pipe laying, well construction, etc.	Technical standards for environmental protection as e.g. for drilling, etc.
	Regulations and guidelines for licensing of geothermal systems (typically concerning groundwater protection), including legal regulations for the access to and ownership of the geothermal resources
2. **Distribution network**	Regulations and guidelines for substations and prefabricated district heating and district cooling
3. Spatial planning	Obligation for connection
4. Buildings	Standards on energy performance, thermal property, heating systems, AC, ventilation and cooling systems, lighting, building automation and control, inspection Regulations on Energy Performance of building (EPBD), energy efficiency (EED) and renewables (RES directive)
5. Classical heating and air conditioning installation e.g. plumbing, radiators, air ductwork, etc.	Rules are identical with any conventional heating and cooling installation

Standards for geothermal

For geothermal energy, EN-standards only exist for the safety of drill rigs (shallow geothermal), and from the petroleum industry (which has some relevance for deep geothermal, together with US API standards). Standards from the petroleum industry are only listed in the common EN form, and their national adaptation is only apparent in Germany and France.

The main administrative and licensing barriers applying to geothermal works are well covered by the overall EN standards. The European standards on drilling, which may be relevant to geothermal systems, are reported in Table 9.

Overall, no dedicated deep geothermal well construction standards are available, while in some cases technical standards for water wells apply also to geothermal energy. Indeed longer term implementation standards for large deep geothermal systems are required to facilitate the growth of the sector.

In the case a large heat pump is included, it is worth mentioning that for heat pumps a comprehensive and well harmonised set of technical standards exist. All member states have adopted the basic EN standards for testing and rating, safety, etc. into national standardisation.

Table 9 . The European standards on drilling which may be relevant to geothermal systems

EN 791:1996	Drill rigs safety
EN ISO 10405	Petroleum and natural gas industries - Care and use of casing and tubing
EN ISO 10407	Petroleum and natural gas industries - Rotary drilling equipment
EN ISO 10414	Petrol and natural gas industries - Field testing of drillings fluids
EN ISO 10423	Petroleum and natural gas industries - Drilling and production equipment
EN ISO 10424	Petroleum and natural gas industries - Rotary drilling equipment
EN ISO 10426	Petroleum and natural gas industries - Cements and materials for well cementing
EN ISO 10427	Petroleum and natural gas industries - Equipment for well cementing
EN ISO 10431	Petroleum and natural gas industries - Pumping units - Specification
EN ISO 10432	Petroleum and natural gas industries - Downhole equipment
EN ISO 11960	Petroleum and natural gas industries - Steel pipes for use as casing or tubing for wells
EN ISO 11961	Petroleum and natural gas industries - Steel pipes for use as drill pipe - Specification
EN ISO 13500	Petroleum and natural gas industries - Drilling fluid materials
EN ISO 13501	Petroleum and natural gas industries - Drilling fluids
EN ISO 13503	Petroleum and natural gas industries - Completion fluids and materials
EN ISO 13533	Petroleum and natural gas industries - Drilling and production equipment
EN ISO 13534	Petroleum and natural gas industries - Drilling and production equipment
EN ISO 13535	Petroleum and natural gas industries - Drilling and production equipment
EN ISO 13625	Petroleum and natural gas industries - Drilling and production equipment
EN ISO 13626	Petroleum and natural gas industries - Drilling and production equipment
EN ISO 13679	Petroleum and natural gas industries - Procedures for testing casing and tubing connections
EN ISO 13680	Petroleum and natural gas industries - Corrosion-resistant alloy seamless tubes for use as casing, tubing and coupling stock
EN ISO 14310	Petroleum and natural gas industries - Downhole equipment
EN ISO 14692	Petroleum and natural gas industries - Glass-reinforced plastics (GRP) piping
EN ISO 14693	Petroleum and natural gas industries - Drilling and well-servicing equipment

Standards for district heating

All district heating equipment and the system as a whole is to be approved in accordance with international, EU, and national laws, regulations, building codes and standards. Also, all rules from health and environmental authorities need to be taken into consideration.

A number of European standards exist for prefabricated insulated district heating and district cooling pipe systems, including pipes, joints, fittings, valves, expansion cushions and surveillance systems – as well as for the design and installation of prefabricated insulated pipe systems for district heating and cooling. They are published on the web page dedicated to CEN / TC 107[1]. Technical and certification guidelines for some of these standards have been developed by Euroheat & Power[2].

[1] Available here: http://standards.cen.eu/dyn/www/f?p=204:7:0::::FSP_ORG_ID:6089&cs=1B60849860D8D2FC54BD924FE64ECF44C

[2] See http://euroheat.org/Certifications-of-Pipes-61.aspx and http://euroheat.org/Technical-guidelines-28.aspx

Building codes

Building codes and regulations set minimum quality requirements to ensure that buildings are safe, healthy, energy-efficient, and accessible to everyone who lives and works in and around them. Legislation often includes requirements for construction works, procedures for design, building and operation of construction works, competences of national and local authorities, tasks and responsibilities of the workers involved, etc.

These codes differ widely from country to country and within national boundaries, for example central authorities set technical building regulations and regional and local authorities also set additional building regulations subordinate to national ones.

Information about the building codes and labels for several GeoDH Project countries is available on www.sustainablebuildingscentre.org and reported in table 10.

For the purpose of the GeoDH training courses it is worth highlighting that geothermal district heating can be a crucial technology in meeting the minimum requirements for the use of renewable energy in buildings and the minimum energy performance which all EU member states have to set in compliance with Directive 2009/28/EC on Renewable Energy Sources, and Directive 2010/31/EU on energy performance of buildings (EPBD) respectively.

The EPBD applies to new as well as existing buildings undergoing major renovation[3]. For new buildings, high-efficiency alternative systems, including district or block heating or cooling – particularly where it is based entirely or partially on energy from renewable sources), need to be considered. To this end, their technical, environmental, and economic feasibility should be assessed before construction starts.

In addition, the EPBD looks to the future and introduces, for the first time in EU law, the concept of "nearly zero-energy building", i.e. a building with a very high energy performance, from which the amount of required energy should be covered to a very significant extent from energy from renewable sources produced on-site or nearby. All new buildings owned or occupied by public authorities should become nearly zero-energy after 31st December 2018, while this provision is extended to all new private buildings by the year 2020. Table 10 contains building codes and labels in use in several countries.

[3] Member states may choose to apply one of the following definitions of 'major renovation': (a) the total cost of the renovation relating to the building envelope or the technical building systems is higher than 25 % of the value of the building, excluding the value of the land upon which the building is situated; or (b) more than 25 % of the surface of the building envelope undergoes renovation

Table 10. Building codes and labels from http://www.sustainablebuildingscentre.org/pages/beep

Country	Building codes (mandatory)		Labels (voluntary)	
Czech Republic	All buildings	Building code		
Denmark	All buildings	Building Regulations	New non-residential	DGNB Denmark
			Residential buildings	EBPD energy performance certificate
			Non-residential buildings	EBPD energy performance certificate
			New buildings	Passive House
			New buildings	Swan
France	Existing buildings	RT 2005	All buildings	BâtimentBasseConsommation (Low Consumption building) BBC
	New non-residential	RT 2012		
	New residential	RT 2012		
Germany	All buildings	Energy Conservation Regulations (EnEV)	New buildings	Passivhaus
			All buildings	ZukunftHaus: Energy performance cert...
Ireland	Non-residential buildings	Building Regulations: Part L Conservation of fuels and energy: Dwellings	Residential buildings	EBPD Building Energy Rating
	Residential buildings	Building Regulations: Part L Conservation of fuels and energy: Dwellings	Non-residential buildings	EPBD Building Energy Rating
			New buildings	Passive House
Italy	All buildings	National Code	Non-residential buildings	Energy Performance Building Certificate
			New residential	EPBD Energy Performance Certificate
			New residential	Passive House - ZEPHIR
Netherlands	All buildings	Bouwbesluit 2012: Chapter 5	All buildings	EPBD Energy Performance Certificate

References

http://www.sustainablebuildingscentre.org/pages/beep
www.geodh.eu

3.2. Environmental issues and social acceptance

(Virginie Schmidle-Bloch – AFPG, Dario Boncani, Loredana Torsello – CoSviG)

3.2.1. Introduction

Renewable energies are rightly associated with sustainability. But like all human activities, renewable energy projects, including geothermal, may also have an impact on nature; the realisation of a geothermal district heating project can even face resistance from the local population. Therefore, to ensure the sustainable development of a geothermal district heating (geoDH) project it is highly important to take into consideration these social aspects and possible pressures on the environment. These aspects have to be identified at every stage of the geoDH project and need to be addressed properly as a whole component of the project.

3.2.2. Environmental issues

The main geoDH's development phases that may have an environmental impact are:

- Explorative and production/injection well drilling,
- Access roads and pipe laying (both for the transport of geothermal water to heat exchanger and for the DH network),
- Construction of heat exchanger (including its building),
- Operation of the geoDH,
- Decommissioning of facilities.

The possible environmental impacts can be grouped into the following main categories:

1. Surface disturbances: as for any other construction activity, these impacts may occur during plant construction and may affect flora, fauna, soil and surface water (e.g. access roads, pipe laying, heat exchanger plant and associated land use). The construction of a DH network may also entail possible impacts on the historical and artistic heritage of a city center,
2. Physical effects: due, for instance to the extraction of the geothermal fluid,
3. Noise: such as equipment noise during drilling, construction (e.g. during DH network laying) and operation (e.g. noise produced by heat exchangers and pumps) activities,
4. Thermal pollution: for example due to hot liquid release on the surface;[4]
5. Chemical pollution: for example due to the disposal on the surface of exhausted geothermal water, accidental release of non-treated geothermal water or hazardous chemicals (e.g. chemical inhibitors, tracer materials, chemical reagents, etc.), degassing of fluids before the injection, solid waste disposal from drilling and digging activities (excavated earth and rocks), plant development activities and decommissioning,[5]
6. Nature conservation: concerns issues about the protection of flora and fauna.

[4] See also section 1.3 of this Manual
[5] See also section 1.3 of this Manual

Adopting mitigation measures and monitoring, along with proper environmental management procedures can minimise most of the impacts identified. For example, for each plant development phase it is important to select contractors with good environmental records, as well as expertise in adopting good architectural principles, both in the design and layout of geoDH facilities.

3.2.3. Social acceptance

Definitions

When it comes to “social acceptance”, one refers to the way people will accept the realisation of any important project in the area they are living in. The following definitions were established:

1. “Social acceptability is attained if the project activities do not result in drastic changes from the regular conditions of the area, and if the affected sectors can see some advantages issuing from the project” (De Jesus, 1995),

2. “Social acceptability of a profit – purported project is the condition upon which the technical and economic objectives of the project may be pursued in due time and with the consensus of local communities; consensus to be gained by acting in consonance with dynamic conditions of the environment, and in respect of the people’s health, welfare and culture” (Cataldi, 1997),

3. Public or social acceptance was also defined by Wüstenhagen et al. (2007) as “a combination of three categories: socio-political, market and community acceptance” (Figure 41).

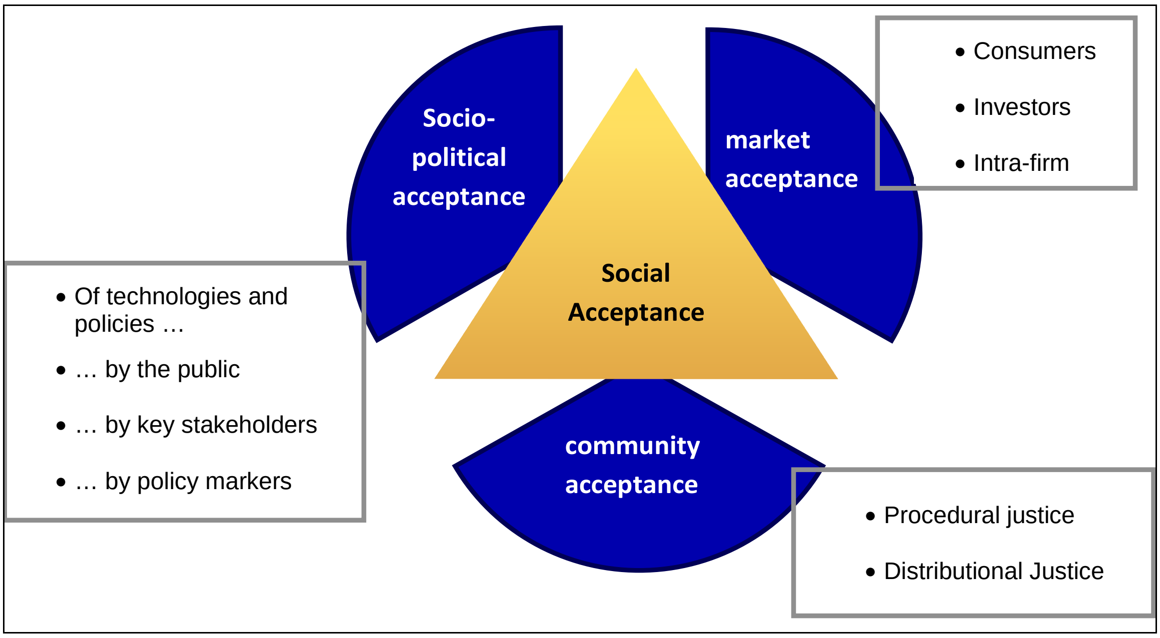

Figure 41.The triangle of social acceptance of renewable energy source innovation (Wüstenhagen et al., 2007)

Why do geothermal district heating projects face weak social acceptance?

Although geothermal energy has proven its various advantages (local, versatile, and secure renewable energy source), sometimes it still suffers from a lack of acceptance. At each phase of its implementation from the decision to use geothermal energy to the first “heating season” a geothermal DH project has to gain social acceptance from several groups.

Politicians, local authorities

Politicians and local authorities have to convince their citizens that a geothermal DH project represents an opportunity in terms of local energy management of their city but also regarding the cost of energy that will be more advantageous. They have to answer the following questions:

- Will the inhabitants of their city agree with the choice of a renewable energy to heat the local district heating network?
- Will they get enough interested in the environmental aspects to accept the disturbances linked to the works?

If the answer to both of these questions is a firm “no”, they will be in opposition to the implementation of a geothermal DH. They do not want to lose credibility, time and energy in convincing people of the “benefits” of this renewable solution. On the other hand, local authorities can also expect that investments in this field can have multiple positive effects on the local economy: revenues to their own budget (taxes and fees), support for local businesses, development in the job market, and benefits for the natural environment. It is obvious that without a strong political backing geoDH projects cannot be launched.

Neighbouring communities

This group is directly concerned by the implementation of a geothermal DH project. Their role is to defend their inhabitants from any kind of disturbance, such as that which is involved in the realisation/renovation of a geothermal DH. They represent “NIMBY” (Not In My Back Yard) acceptance issues. Their opposition can be hard to face; the group is concerned with protection of quality of life, but at the same time they can also rationally understand that using a renewable source of heating can contribute to an improvement of the general quality of life and that they will, in the medium term, benefit from an abundant and low cost energy supply. The problem comes from focusing only on the direct short-term aspects of the geoDH project related to the negative changes on their surroundings. Development of such a project lasts for a long time and disturbances can be identified at every stage of it.

The initial phase of a geoDH project includes well drilling and testing, sometimes close to residential property, using bulky and noisy equipment not familiar to local people. The traffic increases and leads to notable problems of noise.

Environmental pressure groups

This group is generally well informed about all the construction progresses and as a result anticipate eventual environmental consequences: waste treatments, disturbance of the underground water balance due to large artificial flow, etc.

Actions to win social acceptance

According to Cataldi (2001), “*to win social acceptance, geothermal and DH operators have to carry out a number of “external” actions such as communication actions, but also prevention and minimisation measures of adverse effects on environment and people and eventually indemnification measures. In the case of geothermal electric generation, we can also rely on the creation of local benefits. We will here mainly focus on the communication and information actions*”.

Public relations and information campaign

- During the planning stage of the intended project:
- Contact public administrators in the area concerned, not only to provide them with information on the project objectives, but also to begin to understand public attitude towards the new initiative,
- Preparation of public opinion through a clear and timely information campaign concerning the duration of the works, potential impacts of the construction, and benefits during the operating phase,
- Presentation to regional authorities, public administrators, and important entities of the area, of a brochure outlining the project objectives, the environmental measures in the program, and the social benefits that the project is expected to produce.

During the implementation stage of the project:

- Periodical dissemination of information on the activities already completed and in progress, through meetings with local administrators, and by means of media,
- Promotion of project related scientific meetings in the area,
- Guided visits to drilling sites and plants for local students and other interested people (Fig. 42),
- Help desk to inform citizens on possible weaknesses and disturbances that construction works will cause to the community,
- Creation of a “demonstration facility”, equipped with posters, models, photos, and leaflets about the project,
- Encouragement of the implementation of territorial development plans and new economic or social initiatives that might have positive impacts onto the project objectives.

ARGéO visitors centre, France
(Photo courtesy of COFELY)

Visit of ECOGI, second drilling
(Photo courtesy of AFPG)

Figure 42. Examples from a public relation (PR) and information campaign in France

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3.3. Risk insurance for geothermal district heating projects (Philippe Dumas – EGEC)

This contribution to the training course deals with the notion of geological risk and provides an insight into the different existing insurance concepts that cover such a risk in Europe. Last but not least, an overview of a proposed European Geothermal Risk Insurance Fund (EGRIF) promoted by the GEOELEC project, covering the geological risk in Europe is also discussed.

Any industrial project is exposed to risks, even if these risks do not ultimately materialise. Nevertheless, unlike any common project, a geothermal DH project has an additional and particular risk that lies in the geological characteristic of the geothermal resource. This risk, known as the geological risk, is an inherent part of any geothermal project (Fig. 43).

The geological risk covers:

- The short-term risk of not finding a sufficient geothermal resource (temperature and flow rate) during the drilling phase for an economically sustainable project to take place,
- The long-term risk of the geothermal resource depleting over time rendering the whole project economically unprofitable once operation of the geothermal plant has taken place.

Analyses of investment costs and risks underline that the financing of the exploration phase of a geothermal project is an important, even if not the most important barrier. During the exploration phase, the risk is high while the costs are already significant as e.g. seismic data has to be purchased or seismic investigations have to be conducted.

One of the largest obstacles for investment in deep geothermal systems is that the presence and quality of the resource is not proven until the first exploration well is drilled. On the other hand exploration wells have a relatively high success rate (80–90%) in developed regions and low success rate (20–60%) in not yet explored areas. To establish a comparison, in oil and gas exploration a success ratio of 20% is considered as rather good, taking into account the geophysical campaign carried out before (with associated huge cost) allows for a much better prognosis of geological conditions which is not the case in geothermal exploration. In consequence, only if the flow rate and temperature fulfil the expectations of the investor (e.g. profitability), it can be determined that the project achieves its objectives.

The reduction of the risk coming from limited geological information can be in some cases covered by government through geological exploration (drilling, seismic profiles, etc.) funded by the state. Unsuccessful drilling is an important risk that has to be taken and to be paid. Drilling costs are significant and can represent a non-negligible part of the overall project costs, however have to be financed somehow.

Regardless of the accuracy of the exploration phase that takes place, the short term geological risk can only be fully removed when drilling confirms the expected temperature and flow rate. In spite of the geothermal plant being operational, there is no guarantee that original conditions remain over time and that the original temperature and flow rate will not decline. When considering the geological risk, the whole financing of the geothermal DH project is at stake. Geothermal projects require high upfront investments that will never be available unless the geological risk is adequately handled. This can only be achieved by obtaining an insurance policy for the geological risk. Figure 44 illustrates risk management for a geothermal DH project and capital investment.

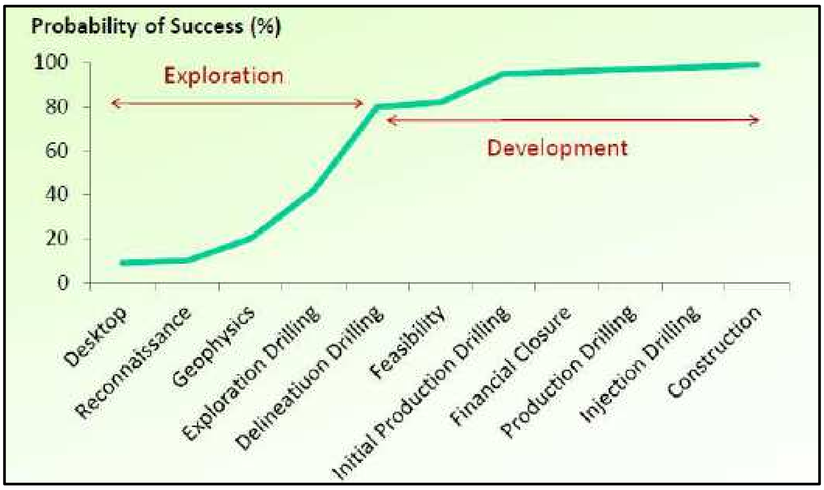

Figure 43. Variation of risks at different phase of a geothermal project (source: GEA 2008)

There are different insurance designs in existence in Europe to cover the geological risk. Apart from Germany, where the private insurance sector engaged in providing market-based insurance policies for geothermal projects, insurance is usually made available from national insurance funds that have been set up at the initiative of governments willing to support geothermal development. Some countries also propose repayable grants for drilling the first well.

In this respect, national funds may either offer a post-damage guarantee for the geological risk (for example in France, The Netherlands, Switzerland) or a guaranteed loan, which is forgiven in case the risk materialises (e.g. Germany, Iceland). Both insurance concepts offer pros and cons. However, they undoubtedly contribute to the strengthening of confidence in the geothermal sector.

In this context, insurance is of such significant importance for geothermal development that it is in the interest of all European policy makers and investors to give some consideration to the establishment of a European insurance fund to cover the geological risk at European level.

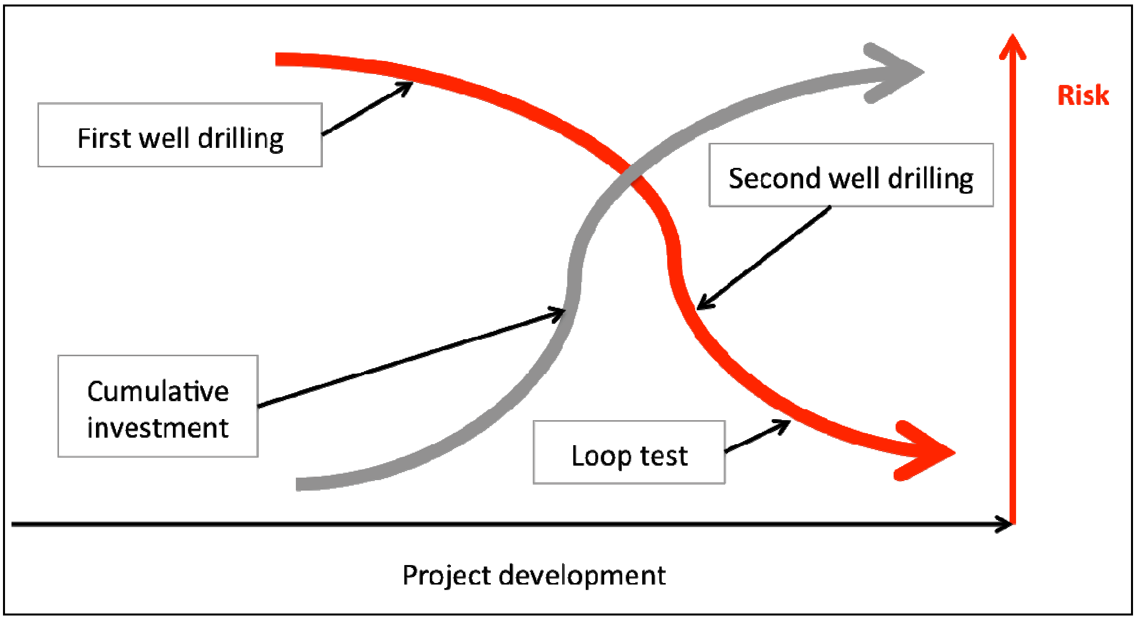

Figure 44. Risk management for a geothermal DH project and capital investment

3.4. Financing costs of geothermal district heating projects (Philippe Dumas – EGEC)

Geothermal heat may be competitive for district heating where a resource with sufficiently high temperatures is available and, preferably, an adaptable district heating system is in place. Geothermal heat may also be competitive for industrial and agriculture applications (foe example, greenhouses).

Geothermal space and district heating systems are capital (CAPEX) intensive. The main costs are generated by initial investments for production and injection wells, down-hole and surface feed pumps, pipelines and distribution grids, monitoring and control equipment, peaking stations, and storage tanks. Examples are given on Figure 45.Operating expenses (OPEX), nevertheless, are much lower than in conventional systems, consisting of pumping power, system maintenance, operation and control.

The financial performance of the system depends on the thermal load density, or the heat demand per unit area. The levelised costs of geothermal energy are presented in Table 11.

Table 11. Levelised costs (LCo) of geothermal energy (acc. to Update of Strategic Research Priorities for Geothermal Technology /2012, European Technology Platform on Renewable Heating and Cooling/, EGEC copyrights)

LCo of geothermal heat	Costs 2012		Costs 2030
	Range (€/kWh)	Average (€/kWh)	Average (€/kWh)
Geothermal DH	0.02 – 0.20	0.6	0.04
Geothermal direct uses*	0.04 – 0.10	0.05	0.04
LCo of geothermal electricity: combined heat and power	**Costs 2012**		**Costs 2030**
	Range (€/kWh)	**Average (€/kWh)**	**Average (€/kWh)**
Low-temperature and small high-temperature plants	0.10 – 0.20	0.15	0.07
Enhanced Geothermal Systems	0.20 – 0.30	0.25	0.07

* Direct uses are geothermal applications in balneology, greenhouses, agro-industrial processes etc.

Generating costs and selling prices are usually around 60 €/MWh thermal, within a range of 20 to 80€/MWh thermal. This depends on local geothermal settings (high/low heat flows, shallow/deep seated sources), socio-economic conditions and pricing policies (kWh thermal or m^3 of hot water) (Figure 46). In addition, district heating networks achieve an important share of the total costs for a geoDH system expenditure: around 1 Mio €/ km for the grid and the substations.

One considerable challenge in the current economic crisis concerns the financing and the development of new heat grid infrastructures. Retrofitting is an alternative for developing the geoDH market. Oradea, in Western Romania, is an example of the insertion of a geothermal heating system into the existing city: a coal fired/back pressure system typical of historical Central/Eastern Europe district heating practice was adapted for a combined heat and power (CHP) network.

In respect to financing, with levels of investment varying from 3 and 12 M € related to capacities from 2 and 10 MWth (1.2 to 1.5 Mio €/MWth installed), there are three frequently mobilised financing modes.

Firstly, public investment undertaken by the local or regional authority (usually at municipal level); secondly, private sector investment which in turn is granted the opportunity to sell the heat directly to grid connected subscribers over long duration (20 to 30 years contracts) and finally a "mixed" solution, which entails the creation of companies dedicated to the exploitation of the geothermal network with capital investment shared by both public and private entities (Figure 47). The first model (public scheme) was developed mainly in Austria, Germany, Denmark and others. The second (private DH utilities) is today used in France and the UK, among others. The third model (a public private partnership, PPP) applies elsewhere and is gaining popularity in several countries.

Figure 45. Investment and financial need for geothermal projects: typical project volume: 20 – 30 Mio. € depending on project type: electricity, district heating or combined project

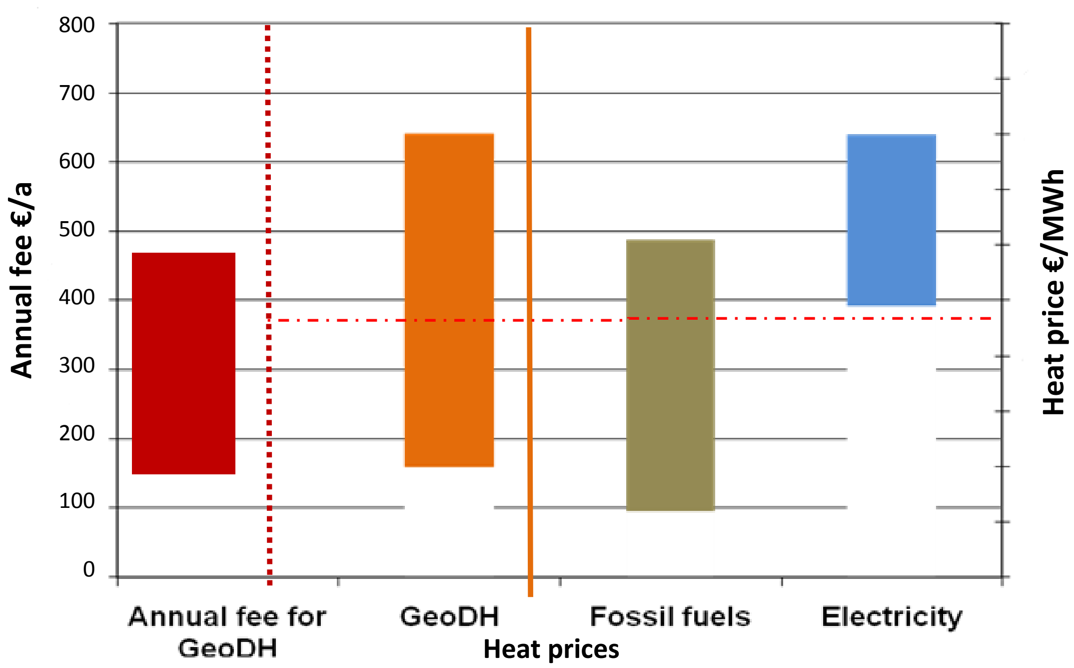

Figure 46. Typical fuel prices for heating and annual fee for geothermal DH, without integrating system costs (infrastructure and storage) and externalities. Comparative prices for delivered heat €/MWh thermal (source: EGEC figures 2012)

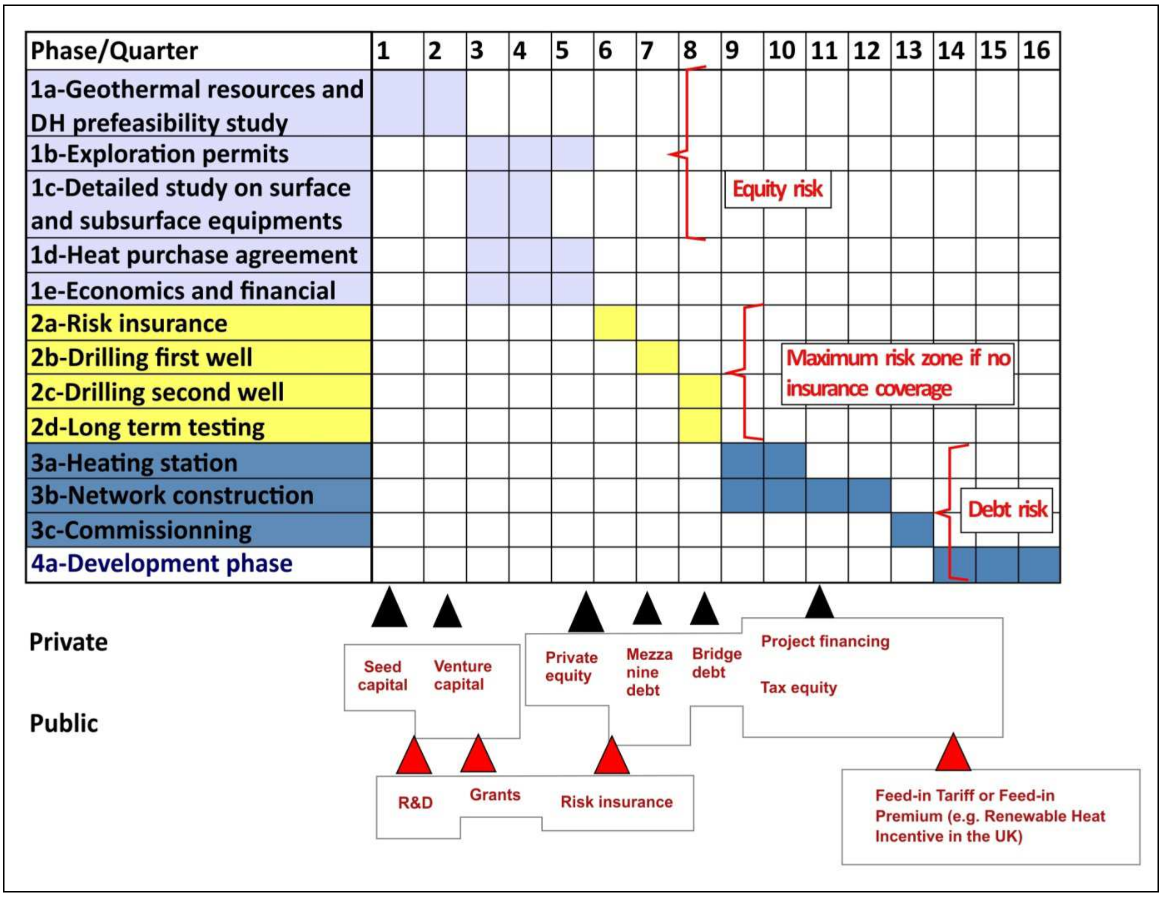

Figure 47. Possible funding mechanisms for geothermal projects (EGEC copyrights)

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List of abbreviations

CAPEX	–	capital expenditures / costs
CHP	–	combined heat & power
DH	–	district heating
EC	–	European Commission
EGS	–	Enhanced Geothermal System
EGRIF	–	European Geothermal Risk Insurance Fund
EIA	–	environmental impact assessment
EU	–	European Union
geoDH	–	geothermal district heating
GeoDH	–	acronym of IEE Project "Promote Geothermal District Heating Systems in Europe"
IEE	–	The Intelligent Energy Europe Programme of the European Union
NIMBY	–	"Not in my backyard" syndrome
OPEX	–	operating expenditures / costs
RES	–	renewable energy source

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