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Potential of geothermal energy in the Upper-Rhine-Valley

A Master Thesis submitted for the degree of
"Master of Science"

supervised by
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Vienna, November 2008

Affidavit

I, **Mag. Martin-Manoel Dominik Diermeier**, hereby declare

1. that I am the sole author of the present Master Thesis, "Potential of geothermal energy in the Upper-Rhine-Valley", 51 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master Thesis as an examination paper in any form in Austria or abroad.

Vienna, December 5th, 2008

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Manoel Diermeier

Abstract

The potential of geothermal energy in the Upper-Rhine-Valley and the question how it is possible to use the enormous energy reservoir beneath the earth's surface in a sustainable and an economical way for power generation and heat production are the core objectives of this thesis.

The purpose of this thesis is to give the reader an insight into the field of geothermics. Beside general aspects of geothermics and geological conditions in other regions the thesis concentrates especially on the conditions in the Upper-Rhine-Valley. The aim is to follow the diverse considerations and steps of development which are necessary if you want to set-up a geothermal power station.

The thesis includes information's about the fundamentals of technique, various steps for the development of the location and about a project development process. Because of the different uncertainties concerning geothermal projects the thesis introduces into the field of risk management.

The calculation for a geothermal power station (4 years construction phase and 20 years of operation) shows that because of the guaranteed feed into the grid tariff it should be possible to set-up a geothermal power station under economical conditions. Especially the duration of 20 years for the feed into the grid tariff of 20 €cent and the additional bonus for power plants which start operation before January 1st, 2016 of 4 €cent are responsible for the positive calculation. Of course it is clear that the realisation of a geothermal project in the Upper-Rhine-Valley poses a large amount of entrepreneurial risks.

It seams that because of the overall conditions the next steps in progress can be achieved within the next years.

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1 Introduction

Geothermal energy is available on our planet independent of climate and weather, by day and by night and every hour of the day.

Geothermal energy is energy stored within the earth's surface. It is possible to use a part of this energy for heating, cooling or the generation of electric power. Nevertheless this renewable energy source has not had thorough success so far. There are several significant factors for this. For instance, the risks for investors aren't spread profitably – the greatest risks lie in exploration, the first phase in which the success of the project can't yet be correctly assessed. Another point is that the prices for drilling and the needed materials have risen drastically in recent years. This price rise can be traced to the high global demand for oil and the resulting direct competition between geothermal and oil drilling.

Even though geothermal energy does not currently play a major part in the field of renewable energy in most countries, it is worth looking at this kind of energy because geothermal energy can be used as base load energy. This makes the technique quite interesting to develop, because this fact represents a big advantage compared with other sources of renewable energy.

Due to the introduction of the Renewable Energy Act (REA) in Germany the interest in utilization has risen significantly. Especially the Upper-Rhine-Valley seems to offer good geological conditions for using geothermal energy in Germany.

1.1 Core objective of work

The core objective of this thesis is *the potential of geothermal energy in the Upper-Rhine-Valley*. The thesis tries to answer the main questions in this context. Some of them are: *How can we use this enormous energy reservoir beneath the earth's surface in a sustainable and an economical way for power generation and heat production in the Upper-Rhine-Valley?* Is a sustainable utilisation of geothermal energy in the Upper-Rhine-Valley possible? What are the risks of such a project? Is it possible to reduce some of the risks by additional research (e.g. seismic exploration)? How does a possible structure of a project development look like? Is it possible to set up an economical successful geothermal power station in the Upper-Rhine-Valley? How do the economical calculations look like?

The thesis is structured to give the reader a broad insight into the field of geothermics. Therefore it is necessary that the thesis does not only concentrate on one single project in the Upper-Rhine-Valley, but also gives an overview over general aspects in this context. Step for step this process is explored.

1.2 Structure of work

The work covers the current status of utilisation of geothermal energy *(Utilisation of geothermal energy)*, interesting fields connected to geothermics and the Upper-Rhine-Valley *(Regions with geothermal potential)*. After narrowing the scope to the fields of geological interest *(Geological conditions in the Upper-Rhine-Valley)*, the technical principles will be discussed *(Fundamentals of technique)*. In addition to an intense study of individual stations, which are especially important for the success of geothermal projects *(Exploration, Seismic Exploration, Drill planning, Location for a geothermal power station)*, the individual milestones for project development will be detailed *(Project development)*. Further emphasis is put on the risk management *(Risk management)* and the economical assessment of geothermal projects *(Economic consideration)*. Because the realisation of infrastructural projects is impossible without negative impact on the surroundings, such considerations are included with a view on defusing the potential for conflicts *(Social consideration)*.

Furthermore, digressions will try to give an insight into examples of practical experience. This practical description is complemented with the principal legal elements *(Renewable Energy Act (REA) in Germany and Federal Mining Act)*.

2 Utilisation of geothermal energy

The development of geothermal resources and the subsequent exploitation through **hydrothermal** or **Hot-Dry-Rock-techniques** appear useful from separate points of view:

- Geothermics could be an important component in the composition of the future energy mix;
- In this relation, the sustainability of geothermal energy utilisation has to be highlighted: the individual locations can be used for decades and therefore make an important contribution to the reduction of carbon emissions;
- The utilisation of geothermics for power and heat generation leads to a lower dependency on other energy sources. Because geothermal resources are used locally, this also means a lower political dependency on the nations exporting fossil fuels and at the same time a lower dependency on the international commodity markets.

Forecasted Energy Mix of Renewable Energies – up to the Year 2050 (Scenario for Germany)

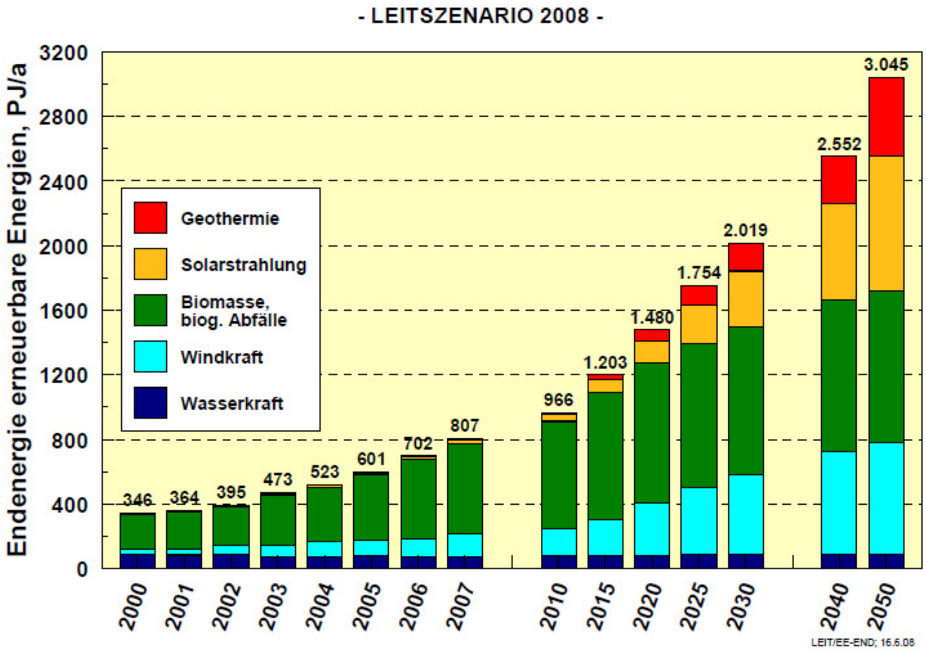

Figure 1: Forecasted Energy Mix of Renewable Energies[1]

[1] Nitsch, Dr. Joachim; Leitstudie 2008; Weiterentwicklung der "Ausbaustrategie Erneuerbare Energien" vor dem Hintergrund der aktuellen Klimaschutzziele Deutschlands und Europas; Bundesminesterium für Umwelt, Naturschutz und Reaktorsicherheit (BMU); October 2008

Throughout the realisation of projects that aim at the utilisation of geothermics for power or heat generation, an ecologically and economically balanced concept must be observed. Due to the fact that the utilisation of geothermal reservoirs provides a relatively high amount of heat, a corresponding utilisation of this heat is desirable. It is important that the needed infrastructure for this is available or is constructed. But this requires that an adequate number of heat consumers is present or is being established. Those must be willing to take advantage of a connection to the heat supply. An already established infrastructure which can be used from the beginning (maybe an opportunity exists to utilise existing district heating networks through conversion from conventional heat supply to sustainable heat supply) is clearly the ideal case, but will be found on very few locations. Furthermore, a significant amount of the costs is related to the distribution of the heat between producer and consumer, which is not directly connected to the individual geothermal project. It should also be considered that the availability of a sustainable „heat source“ can attract heat consumers at a later date. This can be the chance for, or the beginning of, an interesting homogenous development which must not necessarily be present at the start of planning

If a combined utilisation of power and heat CHP (Power-Heat-Coupling) is assumed as an unalterable condition, the potential locations for the utilisation of geothermics are greatly reduced.

2.1 Utilisation worldwide

The utilisation of geothermal resources has already reached considerable extent in individual regions and nations. That is especially true for regions where the conditions for such utilisation are present. But it has to be noted that geothermics – apart from very few exceptions – so far covers only a very small portion of the energy mix.

Table 1: National and Regional Geothermal Power Contributions[2]		
Country	**% of National or regional Capacity (MWe)**	**% of National or regional Energy (GWh/yr)**
Tibet	30	30
San Miguel Island, Azores	25	--
Tuscany, Italy	25	25
El Salvador	14	24
Iceland	13,7	16,6
Philippines	12,7	19,1
Nicaragua	11,2	9,8
Kenya	11,2	19,2
Lihir Island, Papua New Guinea	10,9	--
Guadeloupe, Caribbean	9	9
Costa Rica	8,4	15
New Zealand	5,5	7,1

2.2 Utilisation in Europe

Utilisation of geothermics in Europe has developed rather slowly in the past. In recent years however, this development has gained momentum and there have been a few successes. Even so, there is a couple of reasons which complicate the realisation of geothermal projects – in comparison with other projects in the field of renewable energy. Listed below are a few of these factors, which only represent a selection.

- For an economical utilisation of geothermics, only some (few) regions in Europe seem suitable.
- The realisation of geothermal projects requires a considerate project management because the circumstances are very different at each location. The use of standardised units is hardly possible.
- Drilling represents a significant factor for cost and risk in every project. But a successful prospection cannot be guaranteed prior to drilling. That means

[2] Lund, John W.; Geothermal, Renewables and Global Warming; Source: Bertani, R., 2005; World Geothermal Power Generation in the Period 2001-2005; Geothermics, Vol. 34, No. 6 (Dec.) Elsevier, Amsterdam, Netherlands, pp. 651-690

that until drilling has been completed, the success of the geothermal project is still in doubt.

- The realisation of a geothermal project requires several years; therefore investors with a vision and adequate endurance are needed.
- The possible profits do not constitute normal (adequate) risk compensation. That means that usually investors expect higher profits if they accept the risks inherent with a geothermal power plant.

Despite the mentioned obstacles, the development has gained momentum in recent years. Every realized project increases the standard of knowledge and helps with the planning and realisation of future projects.

Geothermal direct use in Europe GWh/a

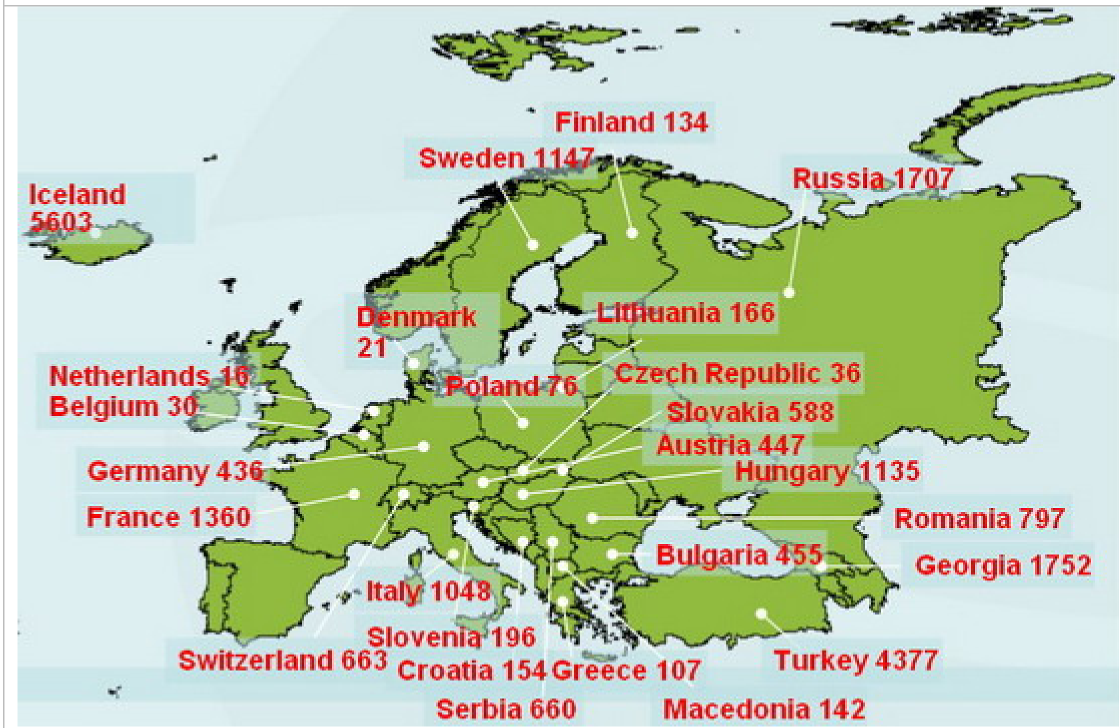

Figure 2: Geothermal direct use in Europe (Map)[3]

[3] Milics, Gábor; Module 4: Geothermal Energy, Wind Power and Small Hydro Power; Renewable Energy in Central and Eastern Europe, April 20th, 2007; source: http://www.europeanenergyforum.eu/graphs/DV20050528-21.jpg

2.3 Utilisation in Germany

The geothermal market in Germany so far shows only few successful power-producing geothermal projects (Neustadt-Glewe, Unterhaching, Landau), despite promotion since 2000 by the Renewable Energy Act (REA). The increase of the feed-in compensation from 2009, the geologically successful project in Unterhaching and the surprisingly high temperatures at the projects in Dürrnhaar and Sauerlach have now led to an increase in the activity in the realisation of geothermal projects. In addition to the geothermal projects for power generation, several geothermal heat projects have been successfully realized in the molasse basin since 1999, from geological and partly also from economical point of view (Erding, Unterschleißheim, Pullach, Riem, Braunau-Simbach). Currently several drillings are being made in the molasse basin and in the Upper-Rhine-Valley.

2.4 Advantages of geothermal energy

The utilisation of geothermics for power generation greatly increases the regional supply security. That is in direct correlation with a decreased dependency on energy imports and therefore an increase in the local net product.

3 Regions with geothermal potential

Regions where geothermics are used for power generation are globally concentrated in those regions which have high-enthalpy-deposits close to the surface. In regions that do not have high-enthalpy-deposits close to the surface, the trend in recent years has been to utilise geothermal resources from low-enthalpy-deposits (temperatures between 100-150℃) as well.

The most interesting regions for energy generation from geothermal resources – geologically – are located on sites where continental plates meet. These are the locations where the heat from the interior of the earth is in shortest distance to the surface of the earth.

A good overview is provided by the following world maps. In Figure 3: Plate Tectonics the continental plates can be clearly seen, as well as the fault zones where two continental plates meet.

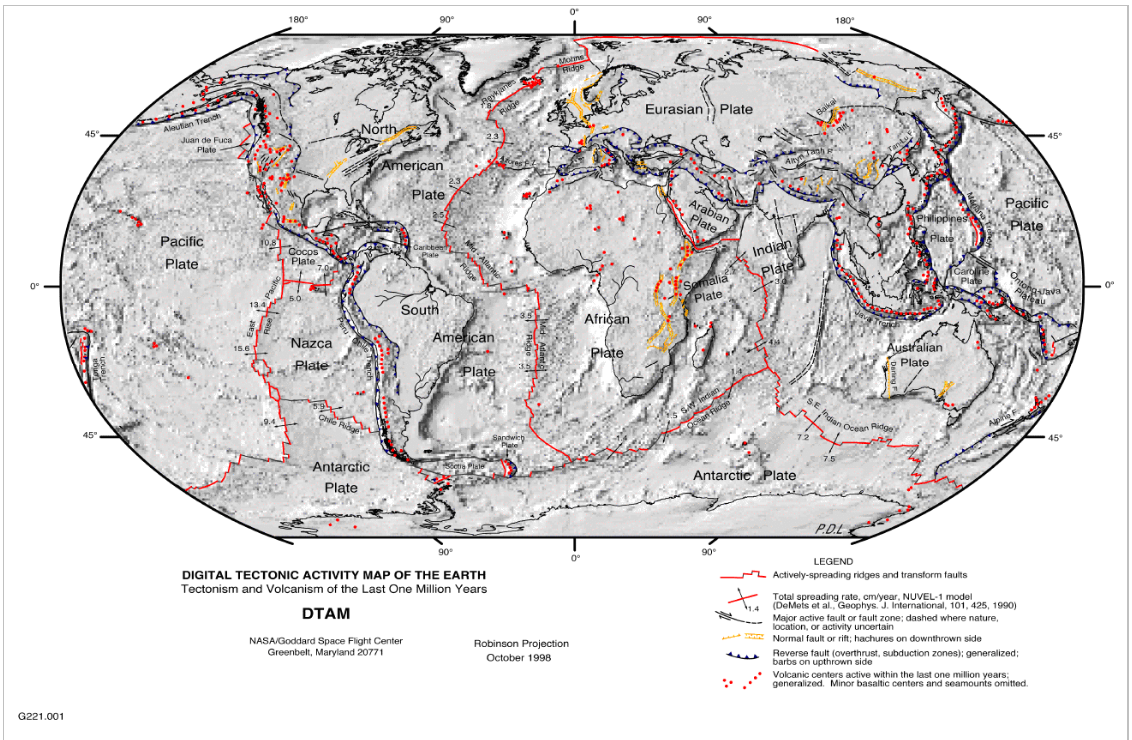

Figure 3: Plate Tectonics[4]

[4] http://epod.usra.edu/archive/epodviewer.php3?oid=39392; Query from October 5th, 2008

In Figure 4: Geothermal Regions – Worldwide those regions are marked that are most suitable for geothermal projects. These are in effect the disturbance zones which are located on land.

Hottest Known Geothermal Regions

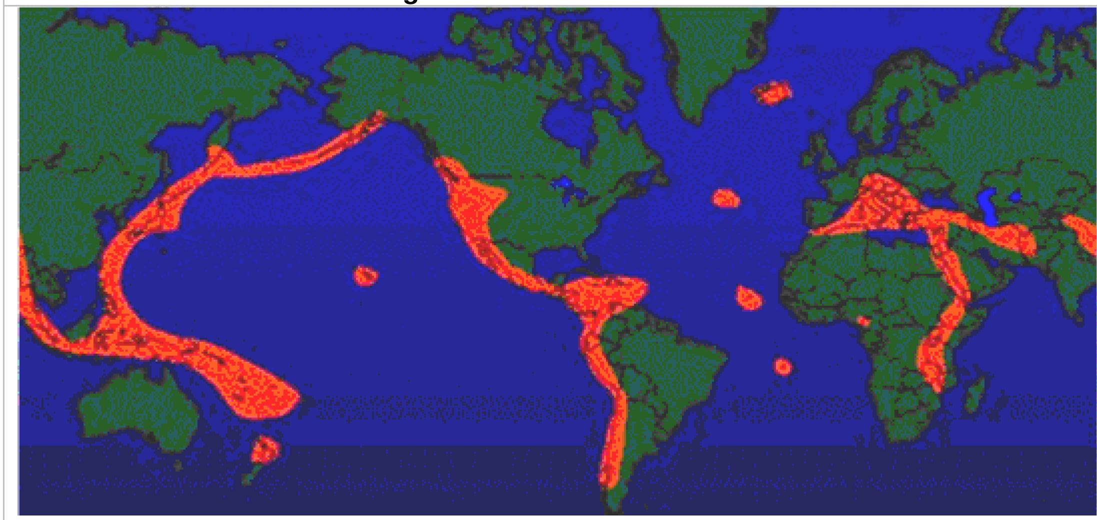

Figure 4: Geothermal Regions – Worldwide[5]

[5] M+W Zander FE GmbH; www.mw-zander.com; Query from October 20th, 2008

4 Geological conditions in the Upper-Rhine-Valley

In Germany, the Upper-Rhine-Valley offers the most favourable conditions for geothermal power generation. Within the Upper-Rhine-Valley, the section between Strasbourg and Darmstadt is most suitable for the utilisation of terrestrial heat.

The Upper-Rhine-Valley is a striking segment of a rift system that stretches from the Mediterranean Sea to the North Sea. The valley has a width of approximately 30 – 40 kilometres and stretches over a length of about 300 kilometres.

In large parts of the Upper-Rhine-Valley, temperature gradients of more than 5°C per 100 m depth can be observed, so that the temperatures needed for power generation of more than 120°C can already be found at comparatively low drilling depths. These above average temperature gradients can be explained by the much shallower border between crust and mantle of the earth in the Upper-Rhine-Valley which is only 25 km compared to about 30 km at other locations. This leads to higher temperature gradients. Local heat anomalies like those in Landau are created by the circulation of hot waters.

The Upper-Rhine-Valley is located in an area of tension that is still active today and is amongst other things characterised by local extension processes. Together with those extension processes, rift- and fractured formations exist, which create water pathways. This system of rifts and chasms offers a high, water-filled chasm volume. Thereby, a sufficient amount of water is present to operate geothermal power plants.

The geology in this region is characterized by the sediment filling of the Upper-Rhine-Valley. In the west, the valley is terminated by the coloured sandstone layers of the Palatinate Forest. In the northeast the Forest of Odes is located and in the southeast the Black Forest. The Forest of Odes as well as the Black Forest are made up by units of coloured sandstone, rotliegend sandstone and bedrock.

The in-depth geological survey of the Upper-Rhine-Valley that was initiated with the introduction of the REA in 2001 has so far revealed that the temperature gradients, which were so far assumed to be only spotty, probably exist more widespread.

5 Fundamentals of technique

When we talk about the technical fundamentals of geothermal power production, we first have to differ between **hydrothermal** and **petrothermal** (or **Hot-Dry-Rock**) **systems**.

5.1 Hydrothermal systems

The characteristic of the hydrothermal system is the existence of natural, underground water reservoirs. When such a reservoir has been explored and its temperature has been above 100°C, the issue then is to gain access to that water and through the extraction of heat use it to generate power and provide long-distance heating. Because the cooled water is returned to the same layer where it has been extracted from, it is described as a circulatory system.

> *Hydrothermal geothermics use natural hot-water sources in deep depths which can exist in water-bearing layers. The hydrothermal energy can be extracted through utilisation of the heat or through conversion into electricity, depending on the temperature.*

Geothermal Reservoir – Hydrothermal Systems

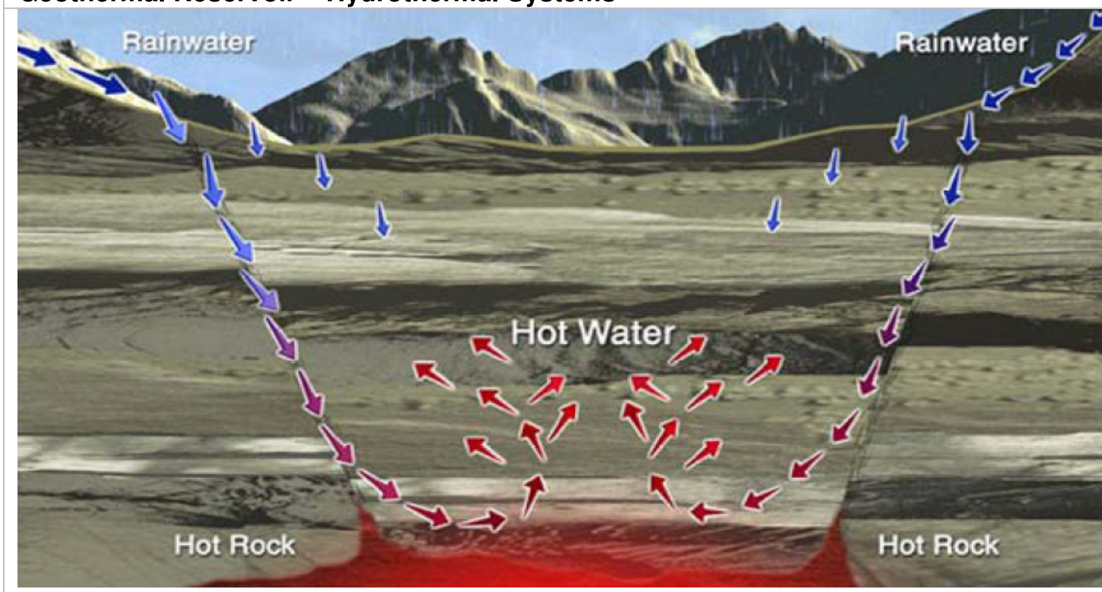

Figure 5: Geothermal Reservoir[6]

[6] Valdimarsson, Prof. Dr. Pàll; Module 4: Geothermal Energy, Wind Power and Small Hydro Power; Renewable Energy in Central and Eastern Europe, April 20th, 2007

5.2 Digression: The hydrothermal geothermal project in Landau

In Landau, the first industrial geothermal power plant in Germany was opened in 2007. The preparations for this project began in 2003. The location was selected based on a geological survey. This project shows that it is possible to use hot-water sources from deep layers of the earth's crust in the Upper-Rhine-Valley for power generation and heat supply.

The utilisation of the extracted water is handled in two steps in Landau: first, heat is extracted from the water and used to generate power. Then the residual heat is used for district heating. The electrical power of the power plant is 3 MW, the thermal output is between 6 and 8 MW.[7]

Figure 6: Geothermal Power Plant in Landau shows a model of the power plant in Landau. Both the surface parts and subsurface wells of the plant can be seen. In the case of the geothermal project in Landau a so-called doublet has been drilled, that means one extraction- and one injection well.

[7] cf. www.geox-gmbh.de; Query from October 20th, 2008

Schematic of the Geothermal Power Plant in Landau

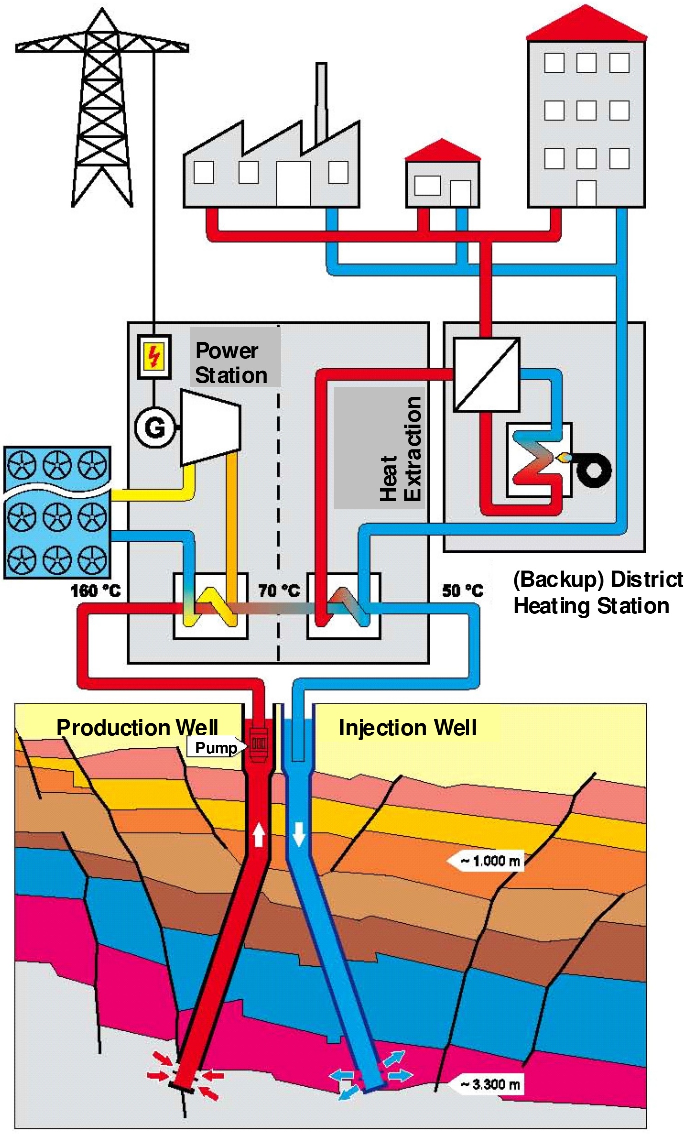

Figure 6: Geothermal Power Plant in Landau[8]

5.3 *Petrothermal systems*

These systems are also called **Hot-Dry-Rock systems**. Such systems are suitable for regions where it is possible to find the required temperature in the earth, but no or an insufficient amount of water is available to transport and exploit this heat. In such a case water is pumped into the earth and circulated in a system of artificial rifts.

“Steam and hot water reservoirs are just a small part of the geothermal resource. The Earth’s magma and hot dry rock will provide cheap, clean, and almost unlimited energy as soon as we develop the technology to use them. In the meantime, because they’re so abundant, moderate-temperature sites running binary-cycle power plants will be the most common electricity producers”[9].

Hydraulic Stimulation

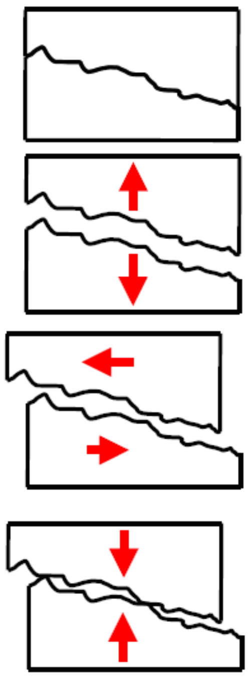

Figure 7: Hydraulic Stimulation – Schematic[10]

The technical development of the Hot-Dry-Rock system is not fully mature today. Despite years of development (for instance in Soultz-sous-Forêts), the technique is not yet controllable enough as to be used everywhere without problems. This experience has been made by a large-scale geothermal project in Switzerland, which circulated through the media at the turn of year 2006/2007. In that case, earth shocks were triggered by the preparatory operations during which the rock is broken up to make it permeable for water (fracturing).

[8] http://www.geox-gmbh.de/de/Schema.htm; Query from October 19th, 2008; own lettering
[9] www.eere.energy.gov; U.S. department of Energy – Energy Efficiency and Renewable Energy; Geothermal Technologies Program; October 20th, 2007
[10] Sass, Prof. Dr. Ingo; Seismizität und mögliche Probleme; Darmstadt; September 2007; own lettering

Magnitude of the Earthquake in Basle

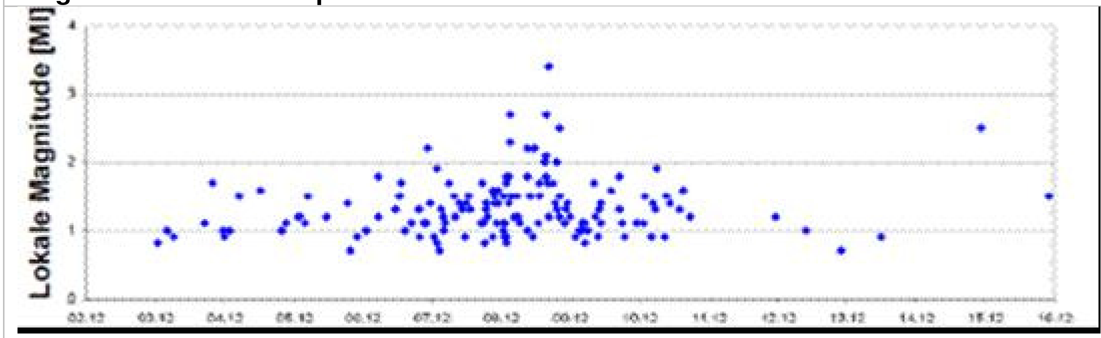

Figure 8: Illustration of the Earthquake in Basle[11]

Earthquake on December 8th, 2006

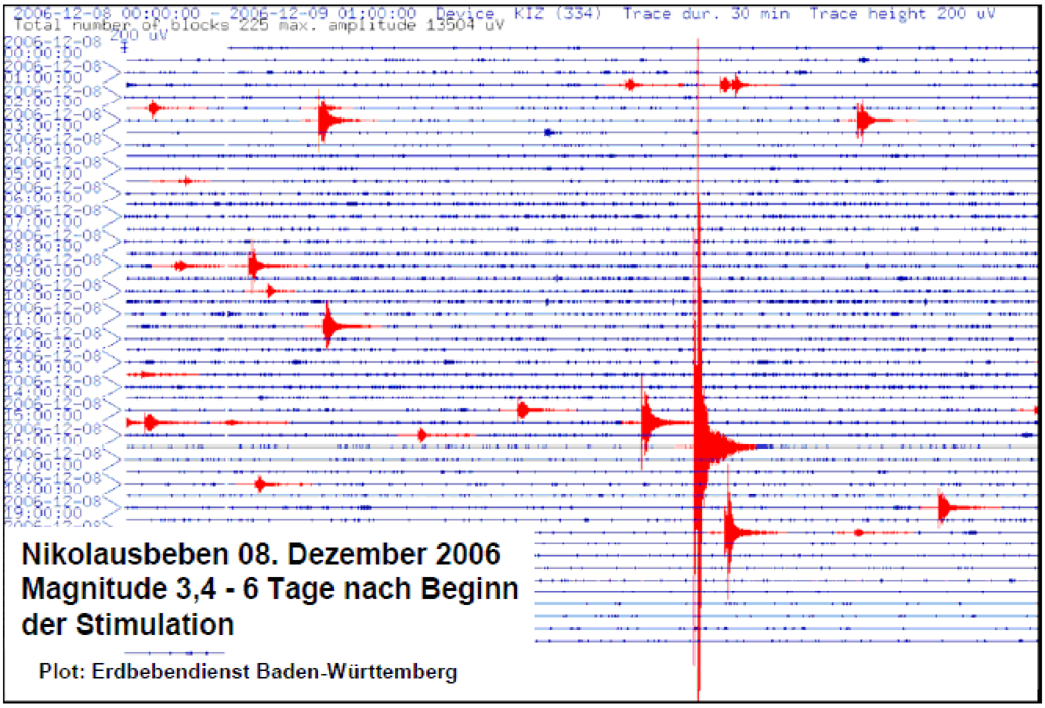

Figure 9: Earthquake in the Region Basle[12]

5.4 Digression: The HDR project in Soultz-sous-Forêts

The Hot Dry Rock (HDR) project in Soultz-sous-Forêts is a European research project. After years of work the first Hot-Dry-Rock power plant in the world started trial operations in June 2008. The installation built in Soultz-sous-Forêts has an output of 1,5 MW. The energy source of the installation is located in a depth of 4.000 – 4.500 m within a artificially created heat exchanger.

[11] Sass, Prof. Dr. Ingo; Seismizität und mögliche Probleme; Darmstadt; September 2007
[12] Sass, Prof. Dr. Ingo; Seismizität und mögliche Probleme; Darmstadt; September 2007

The Surface System – Power Generation
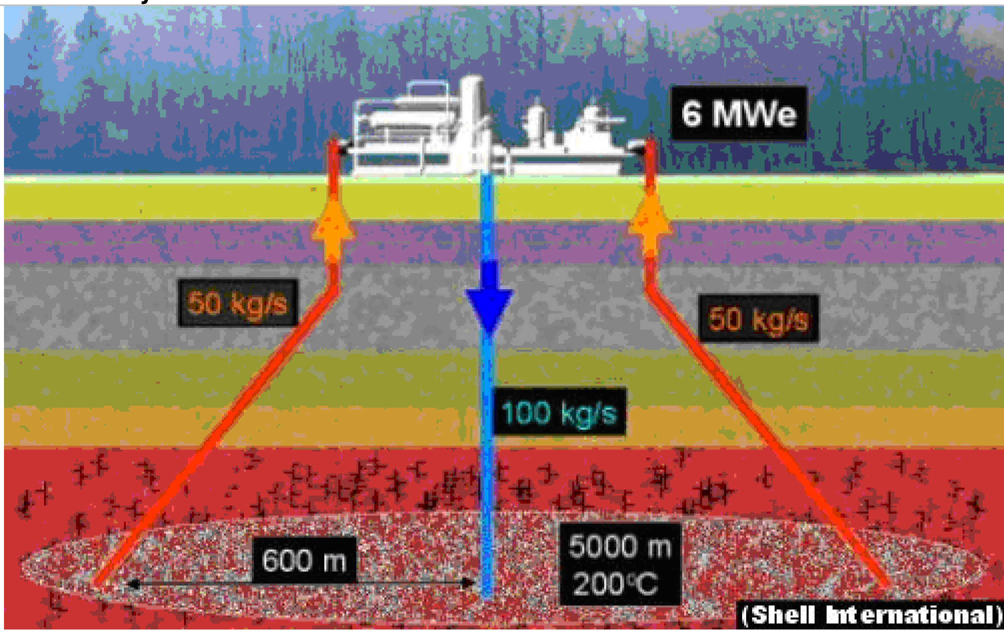
Figure 10: The Hot Dry Rock Base Module[13]

Since 1987 the technique for the production of electricity from dry plutonic rocks is developed in Soultz sous Forêts of Alsace. The location (which is situated 50 kilometres north of Strasbourg) is one of the largest heat anomalies of Central Europe. In 5.000 meters of depth there are already temperatures of 200°C. The geological conditions in Soultz are exemplary also for German locations in the Upper-Rhine-Valley. An international team of researchers, engineers and energy specialists from all of Europe worked longer than one decade hand in hand. The aim of this research project is to gain information's about the long-term behaviour of a heat exchanger in the deep underground.[14]

[13] http://www.soultz.net/version-en.htm; Query from October 19th, 2008
[14] cf.: http://www.geothermie.de/kurzmeldungen/08-06-23-ssf.htm; Query from October 19th, 2008

The underground system

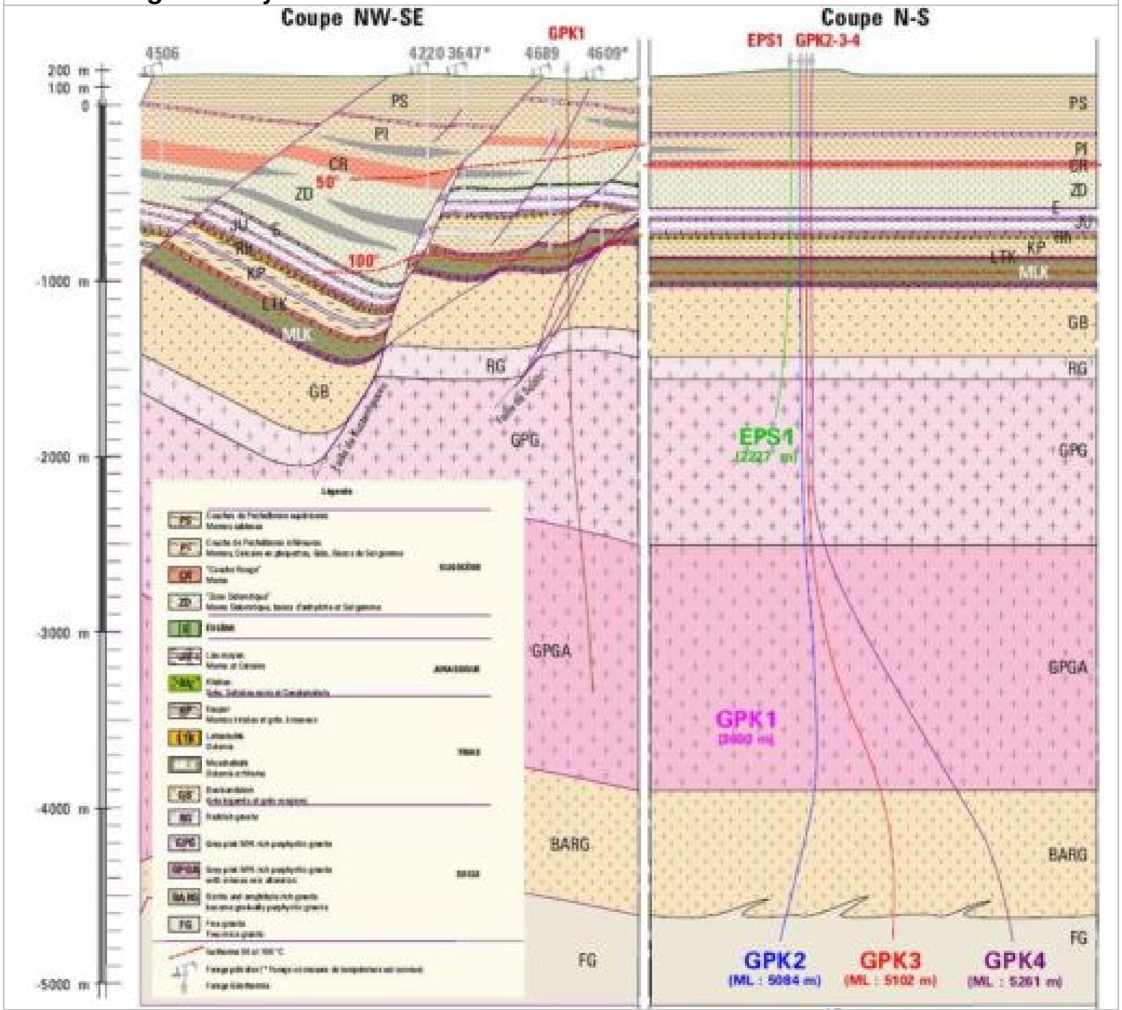

Figure 11: Enhanced Geothermal System (EGS) heat exchanger[15]

5.5 Summary

The main difference between the hydrothermal and the petrothermal (or Hot-Dry-Rock) systems is that in a Hot-Dry-Rock system, a subsurface network of rifts and fracs needs to be created artificially, while in hydrothermal geothermics the existing and hot-water filled network of rifts and fracs is explored by drilling and the heat is exploited. Because of this, in hydrothermal geothermics it is not necessarily required to fracture the rock with high pressure, which can lead to earth shocks that can be noticed aboveground. Nevertheless sometimes there are stimulations in a hydrothermal system required (e.g. acidizing or fracs).

[15] http://www.soultz.net/version-en.htm; Query from October 19th, 2008

6 Exploration

The main risk in a geothermal project lies in the exploration phase. The reason for this is that an unsuccessful drilling not only costs a lot of money, but it can also mean the loss of some of the investment made during project development before. The highest priority in the exploration phase is therefore to minimize the probability of failure.

The search for raw materials is divided into two phases:

- In a first phase, „rich“[16] regions are being looked for. This phase is called *prospection phase*;
- When the target regions are identified, the *exploration phase* follows. During this phase, the target region is surveyed for the assumed deposits with the help of geophysical measurements (and possibly also drillings).

The goal of the entire exploration is to find the raw materials to utilise them afterwards (for instance through extraction).

Knowledge of the target region is being gained throughout the exploration using all available methods, so that the perception is as accurate as possible in regard to the actual deposits. The final confirmation of the presence of the expected hot water reservoirs and the estimation of the volume of such can be achieved and verified by drilling of the exploration wells only.

[16] Meaning: rich deposit of a specific raw material (mining vocabulary)

7 Seismic exploration

To gain extensive knowledge of the target region during the exploration phase and to locate possible reservoirs of hot water, seismic examinations of the subsurface are often used during geothermal projects.

With the help of seismic investigations, the anticipated layers and their depths can be mapped quite clearly. But it is not possible to locate water reservoirs on seismic profiles or to predict extraction volumes from them.

The goals of seismic investigations are:

- The examination or stratification and tectonics down to a depth of 4.000 meters.
- The search of suitable structures for the exploration wells.

Benefit of a seismic campaign: Is it worth the large effort in labour, money and time? A seismic campaign means that a perception is gained as to the location of water-leading disruptions and chasms. A modern seismic analysis visualises the different structures down to a depth of about 3.000 meters.

Differences between 2D-seismics and 3D-seismics: During a seismic investigation, 2D-seismics as well as the 3D-seismics are used. Like the names suggest, a 2D-seismic is two-dimensional and a 3D-seismic three-dimensional.

Due to the complex geological structure of the Upper-Rhine-Valley, the choice of a location for a geothermal project can only be made after the completion and analysis of a location-specific 3D-seismic examination. Only if the exact direction and structure of the fracs can be determined with the help of the 3D-seismic, a drilling of explorations wells should be performed.

In other words:

- The 2D-seismic examination provides a cross-section of the geological structure of the target area. The 2D-seismic can be performed along a pre-set line. With the help of the resulting data, an image of the consistency of the underground can be processed;
- The 3D-seismic provides a spatial view of the examined target region. The 3D-seismic is made for a specific area. Because of the resulting data, faults and even the flow direction of formations can be mapped.

8 Planning of drilling concept

Usually, the resource (e.g. hydro carbons) is extracted from a reservoir during production and the reservoir is successive filled with water to maintain reservoir pressure and stability of the formation. Therefore, during the utilisation of geothermal energy for energy generation, the hot water is extracted but has to be returned into the earth afterwards. Geothermics therefore intervene in the natural water cycle (to extract the heat) while trying to preserve the overall system.

Schematic of Drilling

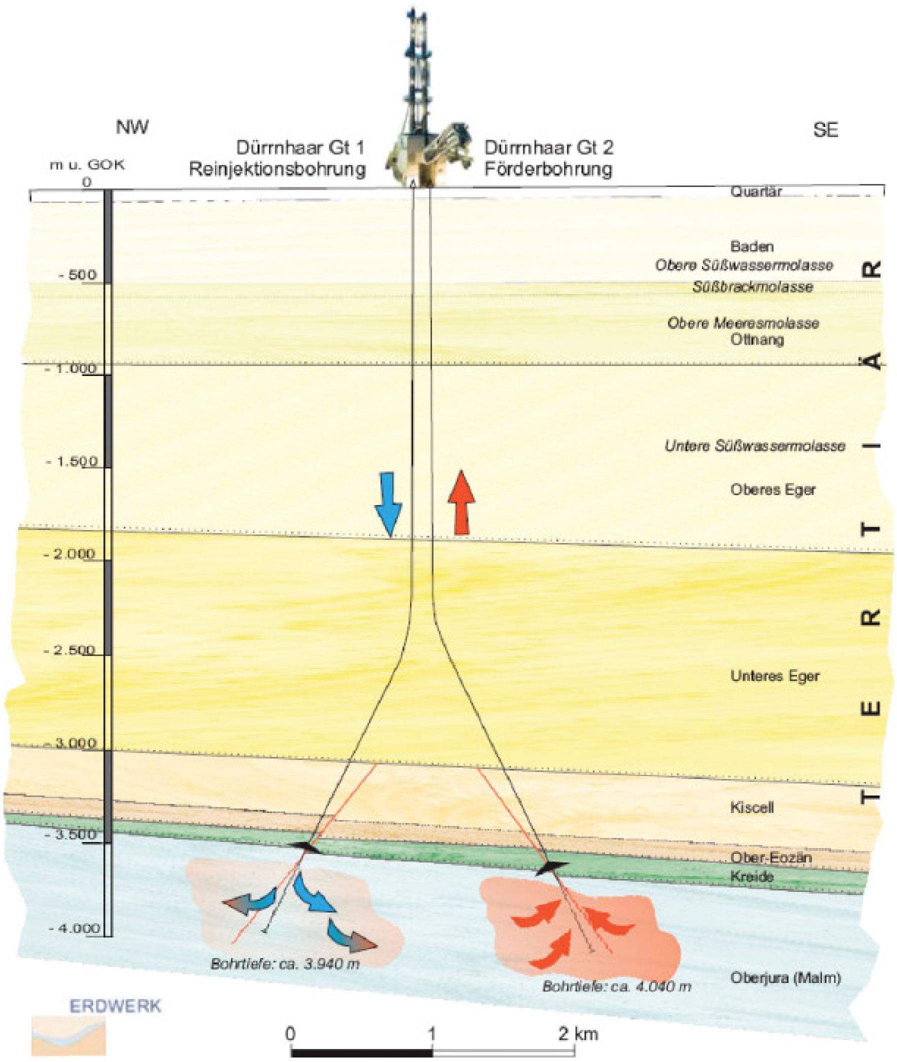

Figure 12: Project Dürrnhaar[17]

[17] Wächter; Dipl.-Ing. Dipl.-Wirt.-Ing. Tilo; Renerco AG; Geothermieprojekt Dürrnhaar; Geothermiekongress Bochum; October 2007

Planning of drilling concept deals with drawing up a drilling concept. This includes the determination of the estimated required drilling capacity, as well as the preparation of a technical and economical drilling concept. Furthermore, focus is on the definition of the demands on the drilling rig and the selection and determination of the required components.

Figure 12: Project Dürrnhaar shows a schematic illustration of the extraction- respectively the injection drilling in the course of a geothermal project. The drilling depth of both drillings is around 4.000 meters.

For the exploitation of the geothermal reservoir a drilling site is built. At surface the drilling is designed in a way so that the two drill holes are close together. Thereby, the advantage is that the drilling equipment does not have to be disassembled, but can be moved „easily". This saves time and money. Belowground, especially in the layers where the water is extracted, the two termination points of the drillings are comparatively wide apart (in the case of Dürrnhaar approximately 2km). This is required to allow that the „cold" water injected after usage does not directly mix with the „hot" water still present in the reservoir, which would lower the overall temperature. The expected temperature is between 125 and 140 °C.

9 Location for a geothermal power station

The most suitable drilling location has to be determined carefully before the property for the future geothermal power plant is acquired. For the future location of the power plant, the required drilling and construction permissions have to be achieved.

Already while choosing the location, surface infrastructure (for instance: connection to a power grid, possibilities to cool the installation, possible heat consumers, ...) has to be taken into account. However, it has to be noted that the belowground conditions should have much higher priority. The reason for this is relatively simple: the conditions belowground are unchangeable, and the highest risk lies in the exploitation of the hot water reservoir as heat carrier. The conditions aboveground can, if needed, be improved.

The following points, among others, have to be taken into account when choosing the location for the future geothermal power plant:

- Available infrastructure
  - Transport connection
  - Connection point to power grid
  - Potential heat consumers
- Natural habitats
- Noise protection
- Power plant cooling technique
- Cooling water preparation

10 Digression: Renewable Energy Act in Germany

The Renewable Energy Act (REA) promotes geothermally generated power through a price and sales guarantee for 20 years from the construction of the production plant (promotion period). Thereby, the producer of REA-power is protected from all sale- and price risks within that promotion period. The REA, through the price guarantee, creates the necessary economical foundation for the power generation on a geothermal basis in Germany.

In Germany, renewable energies gain increasing importance since the introduction of the power feed-in act (1990). The power act was replaced by the REA (2000) and amended in 2004 and 2008.

§ 28

Geothermie

(1) Für Strom aus Geothermie beträgt die Vergütung

1. bis einschließlich einer Anlagenleistung von 10 Megawatt 16,0 Cent pro Kilowattstunde und
2. ab einer Anlagenleistung von 10 Megawatt 10,5 Cent pro Kilowattstunde.

(1a) Die Vergütungen erhöhen sich für Strom nach Absatz 1 aus Anlagen, die vor dem 1. Januar 2016 in Betrieb genommen worden sind, um jeweils 4,0 Cent pro Kilowattstunde.

(2) Die Vergütungen erhöhen sich für Strom nach Absatz 1 Nr. 1, der in Kombination mit einer Wärmenutzung nach Anlage 4 erzeugt wird, um jeweils 3,0 Cent pro Kilowattstunde (Wärmenutzungs-Bonus).

(3) Die Vergütungen erhöhen sich für Strom nach Absatz 1 Nr. 1, der auch durch Nutzung petrothermaler Techniken erzeugt wird, um jeweils 4,0 Cent pro Kilowattstunde.

Figure 13: Renewable Energy Act (REA)[18]

Since the introduction of the REA, geo-power is among the promotable renewable energies. At each amendment of the REA, the feed-in compensation for geo-power was raised, specifically the top rates for installations up to 5 MW from originally €cent 8,95/kWh in 2000 to €cent 16/kWh in 2008 for installations up to 10 MW.

[18] Renewable Energy Act (EEG), Germany, § 28

With the amendment in 2008, the following premiums are added:

- For installations that start operation before 01. January 2016, €cent 4,0/kWh respectively
- For installations that produce power in combination with a heat utilisation according to attachment 4 of the REA 2009, €cent 3,0/kWh respectively
- For installations that produce through means of petrothermal techniques, €cent 4,0/kWh respectively

In spite of the rise of the feed-in compensation, geothermal power plants are at best marginally profitable in Germany. The reason for this is mainly the large rise in drilling costs, but also the rising costs for other material (for instance: piping). These large rises in costs can not be fully compensated by the rise of the feed-in compensation.

11 Digression: Federal Mining Act

In Germany the searching, extracting and processing of resources is regulated by the Federal Mining act (Bundesberggesetz; BBergG).

Terrestrial heat is, as a mineable resources (§ 3, Abs. 3, lit. 2b BBergG) not the property of the land owner, but the property of the community (the state). It's utilisation is covered by mining law.

§ 3 Bergfreie und grundeigene Bodenschätze

Als bergfreie Bodenschätze gelten:
1. alle Bodenschätze im Bereich des Festlandsockels und,
2. soweit sich aus aufrechterhaltenen alten Rechten (§§ 149 bis 159) nichts anderes ergibt,
   a) alle Bodenschätze im Bereich der Küstengewässer sowie
   b) Erdwärme und die im Zusammenhang mit ihrer Gewinnung auftretenden anderen Energien (Erdwärme).

Figure 14: Federal Mining Act

If somebody wishes to explore non-mountainbound terrestrial heat, he is required to obtain a concession according to the mining law; if somebody wants to use terrestrial heat, he needs permission according to the mining law or – and this will most likely not happen in practical terms – the mine ownership.

The preparatory actions for a geothermal project, including the drilling of the exploration and development well(s) are typical actions of a prospection and require a concession according to the mining law.

The owner of a concession owns, according to § 7 BBergG, the exclusive right to prospect for the specific resource within the time span of the concession; the concession owner therefore has an absolute legal position to develop a geothermal project – in accordance with the overall legal regulations. In the case of a successful prospection action the concession owner has a direct legal claim on the issuance of permission or on the issuance of the mine ownership. With receipt of the prospection concession, the concession owner is therefore in the legal position, according to the mining law, to make the necessary investments for a geothermal project.

12 Project development

The development of a geothermal project passes through several stages. For a successful realisation I think it is very important that adequate attention is given to working out a milestone based development plan.

The individual stages are principally the same for every project. The milestone based development plan can therefore be used as an overall guideline for the execution of a geothermal project, which then has to be adapted to the specific requirements of the individual projects. This chapter attempts to give an overview of the fundamental development stages (milestones) during this process.

12.1 Project concept

At the beginning of a geothermal project stands, as with any other project, an idea. The first steps are the development of a rough concept and the determination of the region where the application for a prospection concession should be made.

12.2 Prospection concession

The prospection concession is issued on request by the mining authority in charge. Prospection concessions are issued for a certain limited time period. To receive a prospection concession, the defined work program has to be fulfilled. If there are serious deviations from this work program until the prospection concession is over, an extension can be denied.

The prospection concession owner is exclusively authorised to search for the authorised raw materials. The prospection concession does not, however, allow the extraction of the explored resources. For that, permission must be obtained.

12.3 Prospection

To explore the resources, a series of operations is necessary. First a suitable region has to be located within the prospection concession, which appears promising for further development. This search is called prospection. In the prospection phase the – available – information (for instance geology, tectonics and geophysics) on the target area is collected and analyzed.

12.4 Exploration

If the prospection has succeeded in identifying a suitable target area, the exploration phase begins. During the exploration phase the available seismic and borehole data are analysed. If necessary, the area is investigated for the expected reservoir by using geophysical measurements (for instance seismic measurements and their analysis). Furthermore, the exploration can be supported or secured by test wells.

12.5 Identification of location

If the activities mentioned above show promising results, a target area that shows suitable geological conditions is determined with the help of detailed analysis of the available data. For this target area, the geological data are then refined – preferably using a 3D-seismic analysis.

After examination and analysis of the data collected on the target area, a suitable location for the drilling and the future geothermal power plant is being selected. Because of economical considerations, an assembly drilling point is preferable. This means that all the drillings necessary for the geothermal power plan start from one location. The drilling equipment therefore does not need to be disassembled and reassembled at a new location, but can be moved as a unit.

12.6 Development of location

Already during the selection of the location the surface infrastructure (for instance: access to a power grid, possibilities to cool the installation, possible heat consumers) has to be taken into account. But the highest priority must be given to the subsurface conditions. The reason is relative simple: the subsurface conditions belowground cannot be altered, and the extraction of the resources bears the greatest risk. The conditions aboveground can, if necessary, be improved.

After the selection of the location and its purchase or lease, the required permissions for the construction and operation of a geothermal power plant have to be obtained. Once these permissions have been granted, the drilling phase begins.

12.7 Drilling phase

The drilling phase represents the biggest individual risk for a geothermal project. Once the first well has been successfully drilled, the second well follows. Since a geothermal project is designed as a circular system – hot water is extracted, heat is extracted from this water to generate energy, the cooled water is re-injected into the ground – the second well is necessary. Every modern geothermal power plant includes at least one extraction well and one re-injection well. At a good location, several extraction wells can be present.

Once the wells have been drilled, the circulatory tests start. A circulatory test is required to determine the flow rate of the circular system.

12.8 Power plant construction

The size of the geothermal power plant depends mainly on two factors: firstly on the water flow rate – that is the amount of water that is regularly available within a determined time frame (for instance: litre per second) – and secondly on the temperature of the extracted water. Once these parameters are known, planning of the power plant can begin. Because – especially with geothermal projects – every location is highly specific in regard to the different conditions, planning can only begin once the data mentioned above is known.

After construction of the power plant and connection to the power grid, the operation phase of the geothermal power plant begins.

12.9 Operation phase

The operation phase of a geothermal power plant should normally be noted by the base load capacity of the technique. On top of that, a fairly long operational period can be counted on for a geothermal power plant. In Germany, the situation can be described roughly like this: the owner of the power plant has to maintain a relatively continuous operation of the plant and reduce shutdown times to a minimum. The sales side is regulated by the Renewable Energy Act (REA). For geothermal power, the compensation is a fixed amount and provided for twenty years of operations.

12.10 Decommissioning

After conclusion of the operation phase the power plant is decommissioned and disassembled. The distinctiveness of geothermal power plants is that the wells have to be liquidated. Decommissioning of a successful geothermal project should only happen after several decades of operation at a point where the water in the underground reservoir is slowly cooling off. Then the water temperature does not support a profitable operation any longer.

13 Risk management

Risk management helps in dealing with the project risks that exist, and the measures that can be adopted to minimize them. In this, a distinction between preventive and correctional measures can be made.

- **Preventive measures**: the risk should already be neutralized beforehand.
- **Correctional measures**: the damage of risk events that have already occurred should be minimized by adopting these measures consequently

13.1 Risk assessment

With geothermal projects, a big part of the risk lies subsurface. Including all operations and activities that take place below the earth's surface. This exploration risk is not exclusive to geothermal projects, but inherent in all activities that deal with exploration.

During exploration for raw materials, only the actual finding can bring the evidence for their presence. For geothermal project this means that only drilling can bring final assurance. The exploration is therefore connected to the highest risk at the end of the exploration phase. Attempts are made to minimize this exploration risk as much as possible through geological and geophysical measures.

All related measures and preliminary examinations that reduce the exploration risk are used as a decision basis for the realisation of the drilling project. Such a decision is made according to economic aspects and takes into account the probabilities with which drilling can discover a reservoir that can be exploited profitably.

Attempts are made to maximize the probability of a successful exploration through analysis of borehole data from former drillings for geothermal- or hydro carbon exploration, which have been made in a geologically and regionally defined area.

13.2 Insecurity as a constant companion

To be able to take adequate risk preparations, the underlying insecurities have to be identified first:

For geothermal projects, the geological risks and the quality of the geological data which have been collected, together with the technical risks in drilling and the human factor are essential. As already discussed, the main part of this is located subsurface. At surface, risks and resulting mistakes, while unpleasant – using up resources, time and money – can usually be managed.

13.3 Geological risks

The geological risks include all risks that can arise due to geological conditions which cannot precisely be predicted (for instance: the quality of the geological data, the quantity of the geological data).

During the identification of possible locations for a geothermal power plant, existing geological data are often used because it is the cheapest way to make the necessary evaluations. This data could, for example, already have been collected by the hydrocarbon industry. If such data's are available and the quality is suitable, then it is necessary to obtain the rights for this data from their owner, if possible.

If inadequate or no data are available for the target area, this means that additional exploration efforts have to be made.

At the primary assessment, existing data usually have to be used – published material, maps or similar material. This data carries the risk that they are based on outdated or incorrect geological concepts and exploration strategies. A great risk in this connection is posed by incorrect data which are not identified as such, and the unquestioned adoption of such data. When such insecurities accumulate, they can negatively influence the geothermal project at a later date.

13.4 Geological data

Detailed knowledge of the geological data concerning the *stratification* is of high importance for a successful geothermal project. The exact knowledge of the *stratification and formations* is required for the determination of the exploration target and the drilling depths. Inadequate knowledge of the rock composition and properties leads to insecurities during planning of drilling concept. Among other things, drill chisels are selected according to the expected density and hardness of the formation.

Knowledge of the direction of *faults* and *stratification* – this means the tectonics – represents another risk in the area of geological data. The location and direction of faults represents the basis for the localisation of possible reservoirs. Fault zones can, for example, act as a hydraulic seal and locally limit a reservoir. This knowledge is required in order to define securities regarding the determination of drilling depths during the planning of the drilling concept.

The *temperature* of the reservoirs is a major factor for the profitability of a project. The exact prediction is therefore a key question during exploration. Exact predictions of the temperatures in the target reservoir can only be made by drilling of exploration wells and the necessary tests.

In addition to the reservoir temperature, the *water flow rate* is a deciding factor for the geothermal energy exploitation. If a sufficient temperature is found in a reservoir, but the water flow rate (= the amount of water that can be extracted within a defined time) is to low for economical exploitation, attempts can be made to improve the flow. This means that the rock formations within the reservoirs are fractured to form an artificial network of fracs. The effectiveness of these attempts is different for each individual case. Of course, such influence in the rock layers bears additional risks. These must be weighed in each individual case.

13.5 Technical risks during drilling

The technical risks during drilling are in close connection with the exploration, because the drilling target and the rock layers which have to be crossed are determined by the geological data pool. The task of the technical planning of drilling is the identification of potential problem zones. Planning of drilling is location-specific based on the collected data.

Finally, the risk based on the human factor has to be discussed in this connection. In the end, every decision is made by a human – the one in charge of the specific project. In this, wrong decisions can be made, and their consequences differ from case to case. This risk cannot be calculated. Therefore it is especially important to process the issues and data, which have been mentioned before, with greatest care to ensure a good and well-founded decision basis.

14 Economic consideration

In many countries it is quite difficult to use the geothermal potential profitable. It’s use is limited by several economic factors. These are – among others – high drilling costs, drilling risks, uncertain drilling success. For a suitable district heating system there is a certain minimum consumption of heat required, which requires an investment in a district heating network. Another fact is that for profitable power generation, temperatures above 100 °C are required.

14.1 Basis concept of a geothermal power station in the Upper-Rhine-Valley (presumptions)

The geothermal power plant consists of two circulation systems, one geothermal and subsurface, and a surface power-plant circulation, the secondary circulation.

The geothermal primary circulation consists of a closed and therefore ecologically harmless circulation. The hot water rises autonomously (over-hydrostatic conditions) or is pumped to the surface using the production wells from thermal water layers, located in a depth of about 2.500 to 4.000 m. Then, heat is extracted from the water using a heat exchanger, after which the water is pumped down to the thermal water layers through a re-injection well. Currently it can be assumed that through two extraction drillings, 110 l/sec of water can be extracted and returned into the ground through a re-injection drilling. The closed primary circulation not only ensures that the thermal water has no negative ecological effects, but also that the reservoir stays pressurised throughout the entire operation period.

The volume of rock within the influence of the wells and the water exchange is cooled by the circulating thermal water only very slowly during the operation period of the power plant. At the end of the calculated operation period of 20 years, the starting temperature can still be reached at the extraction wells.

At surface, the heat energy of the extracted thermal water is transferred into the secondary circulation through a heat exchanger. The secondary circulation also represents a closed system, so that this circulation, like the primary, has no risk of negatively influencing the environment – apart from influence through the cooling of the power plant.

The power plant itself will be a low-temperature-plant.

The economic success of a geothermal power plant is generally subject to two preconditions: highest possible temperature of the thermal water as possible and a high rate of volume (water flow rate).

14.2 Heat utilisation versus power generation

In the newest edition of the Renewable Energy Act, the utilisation of heat has received special attention. The additional, prioritised utilisation of heat is compensated with additional 3 €cent per kWh for the electrical power generated afterwards.

As can be seen from this, authorities place increasing importance on the overall utilisation ratio of geothermal power plants. Partly, the individual federal state authorities try to make the utilisation of heat a condition for the authorisation of a geothermal project. This is a strong intervention in the entrepreneurial freedom and synonymous to non-feasibility on many locations. The mining right owner is therefore told in advance how he may later use the extracted energy. So far, such restrictions are not common in regard to the utilisation of raw materials (for instance in the extraction of hydro carbons).

Heat utilisation in a geothermal project in the Upper-Rhine-Valley is desirable. From the beginning, it should be attempted to include this into the overall concept of the geothermal project.

In my opinion a business plan of a geothermal power plant in the Upper-Rhine-Valley should be calculated – because of the principles of commercial caution – without earnings from the sale of heat.

14.3 Economical particularities/specifics of the REA

In Germany, the Renewable Energy Act guarantees the compensation of geothermics for duration of 20 years. Also, under certain conditions, additions to the standard level of compensation, amounting to 16 eurocent per kilowatt hour, are paid (please refer to chapter 10: Digression: Renewable Energy Act in Germany).

Table 2: Fed into the grid tariff (REA)[19]

		Operation Hours p.a.				
		100%	90%	80%	70%	60%
MW	KW	8.760	7.884	7.008	6.132	5.256
1	1.000	1.401.600	1.261.440	1.121.280	981.120	840.960
2	2.000	2.803.200	2.522.880	2.242.560	1.962.240	1.681.920
3	3.000	4.204.800	3.784.320	3.363.840	2.943.360	2.522.880
4	4.000	5.606.400	5.045.760	4.485.120	3.924.480	3.363.840
5	5.000	7.008.000	6.307.200	5.606.400	4.905.600	4.204.800
6	6.000	8.409.600	7.568.640	6.727.680	5.886.720	5.045.760
7	7.000	9.811.200	8.830.080	7.848.960	6.867.840	5.886.720
8	8.000	11.212.800	10.091.520	8.970.240	7.848.960	6.727.680
9	9.000	12.614.400	11.352.960	10.091.520	8.830.080	7.568.640
10	10.000	14.016.000	12.614.400	11.212.800	9.811.200	8.409.600

		Operation Hours p.a.				
		50%	40%	30%	20%	10%
MW	KW	4.380	3.504	2.628	1.752	876
1	1.000	700.800	560.640	420.480	280.320	140.160
2	2.000	1.401.600	1.121.280	840.960	560.640	280.320
3	3.000	2.102.400	1.681.920	1.261.440	840.960	420.480
4	4.000	2.803.200	2.242.560	1.681.920	1.121.280	560.640
5	5.000	3.504.000	2.803.200	2.102.400	1.401.600	700.800
6	6.000	4.204.800	3.363.840	2.522.880	1.681.920	840.960
7	7.000	4.905.600	3.924.480	2.943.360	1.962.240	981.120
8	8.000	5.606.400	4.485.120	3.363.840	2.242.560	1.121.280
9	9.000	6.307.200	5.045.760	3.784.320	2.522.880	1.261.440
10	10.000	7.008.000	5.606.400	4.204.800	2.803.200	1.401.600

Base Tariff according to REA	€ 0,16

[19] Own illustration

Table 3: Fed into the grid tariff (REA)[20]

Fed into the grid tariff (REA) including the bonus for Installations that start before January 1st, 2016

		Operation Hours p.a.				
		100%	90%	80%	70%	60%
MW	KW	8.760	7.884	7.008	6.132	5.256
1	1.000	1.752.000	1.576.800	1.401.600	1.226.400	1.051.200
2	2.000	3.504.000	3.153.600	2.803.200	2.452.800	2.102.400
3	3.000	5.256.000	4.730.400	4.204.800	3.679.200	3.153.600
4	4.000	7.008.000	6.307.200	5.606.400	4.905.600	4.204.800
5	5.000	8.760.000	7.884.000	7.008.000	6.132.000	5.256.000
6	6.000	10.512.000	9.460.800	8.409.600	7.358.400	6.307.200
7	7.000	12.264.000	11.037.600	9.811.200	8.584.800	7.358.400
8	8.000	14.016.000	12.614.400	11.212.800	9.811.200	8.409.600
9	9.000	15.768.000	14.191.200	12.614.400	11.037.600	9.460.800
10	10.000	17.520.000	15.768.000	14.016.000	12.264.000	10.512.000

		Operation Hours p.a.				
		50%	40%	30%	20%	10%
MW	KW	4.380	3.504	2.628	1.752	876
1	1.000	876.000	700.800	525.600	350.400	175.200
2	2.000	1.752.000	1.401.600	1.051.200	700.800	350.400
3	3.000	2.628.000	2.102.400	1.576.800	1.051.200	525.600
4	4.000	3.504.000	2.803.200	2.102.400	1.401.600	700.800
5	5.000	4.380.000	3.504.000	2.628.000	1.752.000	876.000
6	6.000	5.256.000	4.204.800	3.153.600	2.102.400	1.051.200
7	7.000	6.132.000	4.905.600	3.679.200	2.452.800	1.226.400
8	8.000	7.008.000	5.606.400	4.204.800	2.803.200	1.401.600
9	9.000	7.884.000	6.307.200	4.730.400	3.153.600	1.576.800
10	10.000	8.760.000	7.008.000	5.256.000	3.504.000	1.752.000

Base Tariff according to REA	€ 0,16
Bonus for Installations that start before January 1st, 2016	€ 0,04

[20] Own illustration

Table 4: Fed into the grid tariff (REA)[21]

Fed into the grid tariff (REA) including the bonus for Installations that start before January 1st, 2016 and the bonus for preferred heat utilisation

		Operation Hours p.a.				
		100%	90%	80%	70%	60%
MW	KW	8.760	7.884	7.008	6.132	5.256
1	1.000	2.014.800	1.813.320	1.611.840	1.410.360	1.208.880
2	2.000	4.029.600	3.626.640	3.223.680	2.820.720	2.417.760
3	3.000	6.044.400	5.439.960	4.835.520	4.231.080	3.626.640
4	4.000	8.059.200	7.253.280	6.447.360	5.641.440	4.835.520
5	5.000	10.074.000	9.066.600	8.059.200	7.051.800	6.044.400
6	6.000	12.088.800	10.879.920	9.671.040	8.462.160	7.253.280
7	7.000	14.103.600	12.693.240	11.282.880	9.872.520	8.462.160
8	8.000	16.118.400	14.506.560	12.894.720	11.282.880	9.671.040
9	9.000	18.133.200	16.319.880	14.506.560	12.693.240	10.879.920
10	10.000	20.148.000	18.133.200	16.118.400	14.103.600	12.088.800

		Operation Hours p.a.				
		50%	40%	30%	20%	10%
MW	KW	4.380	3.504	2.628	1.752	876
1	1.000	1.007.400	805.920	604.440	402.960	201.480
2	2.000	2.014.800	1.611.840	1.208.880	805.920	402.960
3	3.000	3.022.200	2.417.760	1.813.320	1.208.880	604.440
4	4.000	4.029.600	3.223.680	2.417.760	1.611.840	805.920
5	5.000	5.037.000	4.029.600	3.022.200	2.014.800	1.007.400
6	6.000	6.044.400	4.835.520	3.626.640	2.417.760	1.208.880
7	7.000	7.051.800	5.641.440	4.231.080	2.820.720	1.410.360
8	8.000	8.059.200	6.447.360	4.835.520	3.223.680	1.611.840
9	9.000	9.066.600	7.253.280	5.439.960	3.626.640	1.813.320
10	10.000	10.074.000	8.059.200	6.044.400	4.029.600	2.014.800

Base Tariff according to REA	€ 0,16
Bonus for Installations that start before January 1st, 2016	€ 0,04
Bonus for preferred Heat Utilisation	€ 0,03

[21] Own illustration

Table 5: Fed into the grid tariff (REA)[22]

Fed into the grid tariff (REA) including the bonus for Installations that start before January 1st, 2016, the bonus for preferred heat utilisation and the production with petrothermal techniques

		Operation Hours p.a.				
		100%	90%	80%	70%	60%
MW	KW	8.760	7.884	7.008	6.132	5.256
1	1.000	2.365.200	2.128.680	1.892.160	1.655.640	1.419.120
2	2.000	4.730.400	4.257.360	3.784.320	3.311.280	2.838.240
3	3.000	7.095.600	6.386.040	5.676.480	4.966.920	4.257.360
4	4.000	9.460.800	8.514.720	7.568.640	6.622.560	5.676.480
5	5.000	11.826.000	10.643.400	9.460.800	8.278.200	7.095.600
6	6.000	14.191.200	12.772.080	11.352.960	9.933.840	8.514.720
7	7.000	16.556.400	14.900.760	13.245.120	11.589.480	9.933.840
8	8.000	18.921.600	17.029.440	15.137.280	13.245.120	11.352.960
9	9.000	21.286.800	19.158.120	17.029.440	14.900.760	12.772.080
10	10.000	23.652.000	21.286.800	18.921.600	16.556.400	14.191.200

		Operation Hours p.a.				
		50%	40%	30%	20%	10%
MW	KW	4.380	3.504	2.628	1.752	876
1	1.000	1.182.600	946.080	709.560	473.040	236.520
2	2.000	2.365.200	1.892.160	1.419.120	946.080	473.040
3	3.000	3.547.800	2.838.240	2.128.680	1.419.120	709.560
4	4.000	4.730.400	3.784.320	2.838.240	1.892.160	946.080
5	5.000	5.913.000	4.730.400	3.547.800	2.365.200	1.182.600
6	6.000	7.095.600	5.676.480	4.257.360	2.838.240	1.419.120
7	7.000	8.278.200	6.622.560	4.966.920	3.311.280	1.655.640
8	8.000	9.460.800	7.568.640	5.676.480	3.784.320	1.892.160
9	9.000	10.643.400	8.514.720	6.386.040	4.257.360	2.128.680
10	10.000	11.826.000	9.460.800	7.095.600	4.730.400	2.365.200

Base Tariff according to REA	€ 0,16
Bonus for Installations that start before January 1st, 2016	€ 0,04
Bonus for preferred Heat Utilisation	€ 0,03
Bonus for Production with Petrothermal Techniques	€ 0,04

The tables provide a clear overview on the yearly turnover of geothermal power plants in Germany, which are compensated according to the Renewable Energy Act.

For example, at a plant capacity of 4 MW and an availability of 80 %, a yearly turnover of € 4.485.120 is reached. If the power plant is operational before 01.01.2016, the produced power is compensated with € 5.606.400. If, in addition, the heat is utilised prior to power generation, the generated power is compensated with € 6.447.36. If furthermore petrothermal techniques are employed, the compensation amounts to € 7.568.640.

[22] Own illustration

As can be seen from the tables above, the economic characteristic is that the future turnover could be predicted accurately, if the factors required for a calculation are known. The operator of a geothermal power plant is exempted from the search for consumers for the next 20 years.

14.4 Implementation plan

The implementation plan offers an overview over the expected implementation periods of the individual phases within the project development.

Table 6: Implementation Plan

Milestone	**Action**	**Lead time**
Conception of Project	- Basis concept - Application of permission for exploration	6 months
Definition of target areas	- Geophysical prospection - 2-D-Seismic → planning, execution, analysis - Definition of target areas	6 months
Determination of location	- 3-D-Seismic→ planning, execution, analysis - Determination of location	6 months
Development of location	- Development of location with all necessary activities	6 months
Drilling period	- Drilling of the production holes and the injection holes	12 months
Building of the power station	- Building of the power station with all necessary activities	12 months
Total		**48 months**

14.5 Presumptions for calculation

The following presumptions have been made for the overview calculation:

- Within a permission field, only one power plant can be constructed.
- The geothermal power plant can only feed power into the grid. A heat complementation is encouraged, but is not taken into account for the calculation.
- The power plant is operational before 01.01.2016; therefore, the compensation per kilowatt hour amounts to € 0,20/kWh.

Table 7: Presumptions for the Construction Period		
Milestone	**Budget in Mio. €**	**Cumulated Budget in Mio. €**
Conception of Project	0,3	0,3
Definition of target areas	0,6	0,9
Determination of location	0,7	1,6
Development of location	1,5	3,1
Drilling period	15,0	18,1
Building of the power station	14,2	32,3
Total investment	**32,3**	**32,3**

Until the power plant becomes operational, a budget of € 32,3 Mio. is planned.

Table 8: Presumptions for Calculation	
Water temperature in the reservoir	154 °Celsius
Capacity per second	110 Litres
Numbers of well	2 production wells 1 injection well
Drilling depths	~ 3.500 Meters
Capacity of power station	4,6 MWel
Production hours per year	7.500 (~ 85% of theoretical potential)
Own energy consumption	1,4 MWel
Construction period	36 mounts
Operating time	20 years

For the preparation of the overview calculation, a conservative calculation approach has been chosen, since the geothermal temperatures at every drilling in the Upper-Rhine-Valley from a depth of > 2.600 m are above 160°C and the flow rate for the project in Landau amounts to about 70 litres per second and drilling.

Table 9: Costs of Operating Phase – Presumptions for Calculation		
Costs of Operating Phase	**in €**	**Inflation Rate p.a.**
Energy purchase	1.050.000	1,5%
Cost of operation	200.000	3,0%
Maintenance geothermal	300.000	3,0%
Maintenance power station	250.000	3,0%
Insurance machinery	50.000	3,0%
Insurance	130.000	3,0%
Personnel costs	50.000	3,0%

14.6 Results of calculation

The following table shows the expected cash-flow in the first 20 years of operation. Aspects relating to tax issues have not been taken into account in this overview.

Table 10: Calculation – 20 Years of Operation

Year	2012	2013	2014	2015	2016	
Turnover	6.900.000	6.900.000	6.900.000	6.900.000	6.900.000	
Energy spendings	-1.050.000	-1.065.750	-1.081.736	-1.097.962	-1.114.432	
Costs (ex Interests)	-980.000	-1.009.400	-1.039.682	-1.070.872	-1.102.999	
Cash Flow	**4.870.000**	**4.824.850**	**4.778.582**	**4.731.165**	**4.682.570**	
Year	**2017**	**2018**	**2019**	**2020**	**2021**	
Turnover	6.900.000	6.900.000	6.900.000	6.900.000	6.900.000	
Energy spendings	-1.131.148	-1.148.115	-1.165.337	-1.182.817	-1.200.559	
Costs (ex Interests)	-1.136.089	-1.170.171	-1.205.276	-1.241.435	-1.278.678	
Cash Flow	**4.632.763**	**4.581.713**	**4.529.386**	**4.475.748**	**4.420.763**	
Year	**2022**	**2023**	**2024**	**2025**	**2026**	
Turnover	6.900.000	6.900.000	6.900.000	6.900.000	6.900.000	
Energy spendings	-1.218.568	-1.236.846	-1.255.399	-1.274.230	-1.293.344	
Costs (ex Interests)	-1.317.038	-1.356.549	-1.397.246	-1.439.163	-1.482.338	
Cash Flow	**4.364.394**	**4.306.604**	**4.247.355**	**4.186.607**	**4.124.319**	
Year	**2027**	**2028**	**2029**	**2030**	**2031**	**Total**
Turnover	6.900.000	6.900.000	6.900.000	6.900.000	6.900.000	**138.000.000**
Energy spendings	-1.312.744	-1.332.435	-1.352.421	-1.372.708	-1.393.298	**-24.279.850**
Costs (ex Interests)	-1.526.808	-1.572.612	-1.619.791	-1.668.384	-1.718.436	**-26.332.967**
Year	**4.060.448**	**3.994.953**	**3.927.788**	**3.858.908**	**3.788.266**	**87.387.183**

Table 11: Results of Calculation	
Overall Turnover	€ 138 Mio.
Return on assets	~ 11%

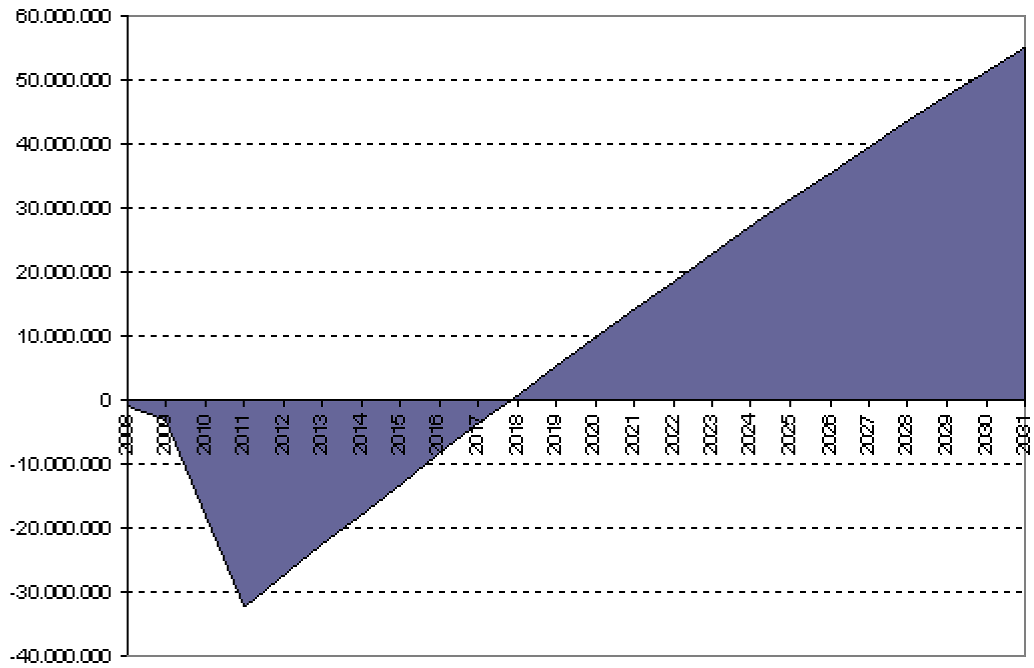

Figure 15: Results of Calculation

The calculation shows that the break-even point is reached in the 7. year of operation.

15 Social consideration

An infrastructural project in the size of a geothermal power plant cannot be realised without any influence on its surroundings. These influences can be noise, dust and dirt generation as well as other issues. In addition to these influences, there are usually reservations of residents and authorities against the planned project based on the used technology or the overall project. During the realisation of a geothermal project it is important to use an offensive communication strategy. This can help to reduce preconceptions and fears. Through information and reinforcing positive opinion, attempts should always be made to defuse exaggerated or baseless fears.

An example of a measure taken to promote positive opinions is an organised meeting or a question and answer session for residents at the beginning of the project. In such a meeting, the construction project is presented and the future utilisation is described. During the meeting it is possible to directly reach a large number of the affected people. From experience it can be said that rumours, which reinforce fears but are not based on real facts, are damaging the public image of the project. In most cases it is enough to check the respective local citizens´ forums internet site to get and idea of the current public opinion.

It must be noted that there is no single way for communication with the public. Nevertheless, for the frictionless realisation of the project it is important to influence public opinion positively right from the beginning to minimize complaints.

16 Conclusions

Geothermics – the renewable energy of the future? This thesis tries to give an insight into the topic of geothermics with a concentration on the Upper-Rhine-Valley.

The overall aim of this thesis is a clear arranged collection of the main facts and Information's about the geothermal potential in the Upper-Rhine-Valley. Step by step this process is explored. At the beginning of this thesis the readers gets a general overview over the topic. Important aspects are explained in the various chapters or digressions. At the end of the thesis the exemplary calculation for a single geothermal power station is shown.

In addition to the advantages and positive aspects that are doubtlessly given by an operating geothermal power plant (for instance: base load capacity or local net product), different problems and risks have been shown in this thesis.

Other branches of renewable energy have experienced a boom in recent years, but geothermics has not yet been able to take this decisive step although there. On the one hand the thesis points out some difficulties: there are geological and technical uncertainties which can not be calculated; there are regions with a higher geothermal potential than the Upper-Rhine-Valley. On the other hand the Upper-Rhine-Valley offers a number of advantages. Let's outline some examples: first of all there is the Renewable Energy Act in Germany which guaranties a fixed feed into the grid tariff for 20 years of operation; second the Upper-Rhine-Valley offers a very good infrastructure; third there are a big number of potential heat consumers.

The thesis tries to figure out that the realisation of a geothermal power station should be possible in the Upper-Rhine-Valley. Of course, there are uncertainties and risks and the possibility of a failure can not be rationalized. At the moment it is clear that the realisation of a geothermal project in the Upper-Rhine-Valley poses a large amount of entrepreneurial risks.

When we want to use this enormous energy reservoir beneath the earth's surface in a sustainable and an economical way for power generation and heat production we have to face all the risks and uncertainties and solve them. A part of the work is done, but there is still a lot to do.

References

Law

RENWABLE ENERGY ACT (REA) – Erneuerbare Energien Gesetz (EEG)

FEDERAL MINING ACT – Bundesberggesetz (BBergG.), Germany

Literature

RENEWABLE ENERGY IN CENTRAL AND EASTERN EUROPE

Postgraduate MSc. Program, Continuing Education Center, Technische Universität Wien, 2007

MODULE 4: Geothermal Energy, April 20th and 21st, 2007

MODULE 4: Geothermal Energy, Wind Power, Small Hydro Power, June 7th - 9th, 2007

LUND, John

Geothermal, Renewables and Global Warming; Source: Bertani, R., 2005; World Geothermal Power Generation in the Period 2001-2005; Geothermics, Vol. 34, No. 6 (Dec.) Elsevier, Amsterdam, Netherlands, pp. 651-690

MILICS, Gábor

Module 4: Geothermal Energy, Wind Power and Small Hydro Power; Renewable Energy in Central and Eastern Europe, April 20th, 2007; source: http://www.europeanenergyforum.eu/graphs/DV20050528-21.jpg

NITSCH, Dr. Joachim

Leitstudie 2008; Weiterentwicklung der "Ausbaustrategie Erneuerbare Energien" vor dem Hintergrund der aktuellen Klimaschutzziele Deutschlands und Europas; Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU); October 2008

SASS, Prof. Dr. Ingo

Seismizität und mögliche Probleme – Darstellung am Beispiel Basel; Im Rahmen des 2. Tiefengeothermie-Forums in Darmstadt; September 2007

VALDIMARSSON, Prof. Dr. Pàll

Module 4: Geothermal Energy, Wind Power and Small Hydro Power; Renewable Energy in Central and Eastern Europe, April 20th, 2007

WÄCHTER, Dipl.-Ing. Dipl.-Wirt.-Ing. Tilo

Geothermieprojekt Dürrnhaar; Geothermiekongress Bochum; October 2007

Newspapers

DIE WELT; Issue: January 13th, 2007

PFÄLZER TAGBLATT; Issue: November 22nd, 2007

Internet

U.S. DEPARTMENT OF ENERGY

Energy Efficiency and Renewable Energy; Geothermal Technologies Program

www.eere.energy.gov

http://epod.usra.edu

www.geothermie.de

www.geox-gmbh.de

www.mw-zander.com

www.soultz.net