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Geothermal Investment Guide

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An Investment Guide on Geothermal Electricity

In spite of widely available geothermal resources, the European gross geothermal electricity production only reached 11.5TWh in 2012. This is only a small portion of the enormous economic potential. As a matter of fact, with recently developed technologies harnessing Europe's geothermal resources for electricity generation has become viable from both the technical and the economic point of view.

Among all renewable energies, geothermal is the most reliable. With a load factor of more than 90%, the fact that it can produce a steady output around the clock makes geothermal power competitive with newly built conventional power plants, in areas where high-temperature hydrothermal resources are available.

However, it is a capital-intensive technology that needs 5-7 years to become operational from the start of the permitting process until commissioning. The significant upfront investment is related to the drilling and to the need to cover the geological risk at the beginning of the exploration. This is true for all deep geothermal projects.

Realising the geothermal potential will therefore require massive investment. Indeed, public support for geothermal energy, e.g. through a feed-in tariff, is available today to compensate for market failures and mobilise private financing. This will allow emerging geothermal technologies to progress along their learning curve and reach full competitiveness in the next few years.

Against this background, a greater involvement of the private sector is essential. Yet not all financial institutions and private investors are familiar with the complexity of geothermal technology, its challenges, and environmental and economic benefits. A diffident approach towards the sector is needed as that lack of capital, notably during the early project- stages, has commonly been a barrier hindering the growth of geothermal power. It should be added that the current capital crunch obstructs the necessary financing even further.

It is clear that a pre-requisite to facilitate such a private financing mobilisation is a thorough understanding of how a geothermal project is planned and developed over several years, including the nature of its specific risks. Developers need to know their financing options while investors need to have basic knowledge of and confidence in these emerging technologies. Additionally, a mutual understanding between developers and investors is of the utmost importance, especially due to the initial investment required in a geothermal project.

To this end, this GEOELEC investment guide is addressed to private investors and banks to provide them with solid background knowledge on the different phases of a geothermal project, their distinct features, inherent risks, and financing options.

How This Guide Works

Chapter 1 of this *GEOELEC Investment Guide on Geothermal Electricity* provides the essential background to the reader by spanning the range of existing technologies, highlighting their many attractive benefits, and taking a snapshot to the current market development and future economic potential of geothermal electricity.

Chapter 2 is an overview of the several phases of, and of the necessary interdisciplinary expertise needed for, a geothermal electricity project.

Chapter 3 analyses the crucial factors for the economic success of project, the different level of risks involved in the various phases and the options to finance each of these phases. This chapter also presents a breakdown of the significant capital costs in these kind of project.

Chapter 4 looks at the revenues of a geothermal power (or cogeneration) plant, including the incentives in place in Europe.

Chapter 5 deals with the legal requirements and legal authorisations needed for developing a geothermal project. This is relevant as any hitch or legal barrier can result in delays and additional costs.

Finally, for a better understanding of the economics of geothermal electricity, **Chapter 6** shows two concrete –though theoretical- case studies: an EGS project in Germany and a hydrothermal plant in Iceland.

Chapter 1: Background to Geothermal Electricity

Technologies

Until a century ago, the exploitation of geothermal resources was primarily for leisure purpose; hot springs and geothermal baths. It was at the beginning of the 20th century that active exploitation of geothermal resources for electricity supply purposes was inaugurated. Successful production of electricity from geothermal heat was first achieved in Larderello, Italy, in 1904.

Since this period, the production of geothermal electricity has steadily increased, though has been concentrated in areas where high temperature hydrothermal resources are available. The technological systems for geothermal electricity production can be subdivided in three large categories, which are also linked to the temperature ranges:

Minimum production temperature: 80°C (Medium Enthalpy resources): this range of temperature is appropriate for use with binary plants (Organic Rankine or Kalina cycle), with typical power in the range 0.1-10 MWe. These systems are also suitable for heat & power co-generation, typically for single edifice to small towns heating;

Minimum production temperature: 150°C (High Enthalpy resources): temperatures in this range can be exploited with dry steam, flash and hybrid plants, with typical power in the range 10-100 MWe. These systems also allow heat cogeneration for large towns' district heating. Above 200°C, these resources are generally limited to volcanic areas.

Minimum production temperature 390°C (Supercritical unconventional resources): temperatures in this range, limited to volcanic areas, generally involve superheated dry steam plants, with power per unit volume of fluid up to one order of magnitude larger than conventional resources.

Besides the temperature range, the methods of exploitation can be further subdivided in two categories: conventional (dry steam and flash steam turbines) and low temperature (binary) geothermal electricity.

Conventional geothermal electricity: dry steam and flash steam turbines

Operating with large hydrothermal reservoirs at high temperature, i.e. above 150°C, such as those found in Tuscany (Italy) and Iceland, this technology has 100 years of history and is fully competitive today with a full cost of about 7€ct/kWh including systems costs and externalities.

Flash: The high temperature, water at high pressure is brought to surface, where it is enters a low pressure chamber and 'flashes' into steam. The pressure created by this steam is channelled through a turbine, which spins to generate electrical power. Once the steam has exited the turbine, it is either released into the atmosphere as water vapour, or it cools back into liquid water and is injected back underground.

Dry Steam: dry steam power plants utilise straight-forwardly steam which is piped from production wells to the plant, then directed towards turbine blades. Conventional dry steam turbines require fluids of at least 150°C and are available with either atmospheric (backpressure) or condensing exhausts.

Regrettably, it is very unlikely that new large geothermal reservoirs will be discovered in Europe. Therefore new projects need to be adapted to smaller and cooler resources.

Low temperature, hydrothermal geothermal electricity: Binary: ORC and Kalina Cycle

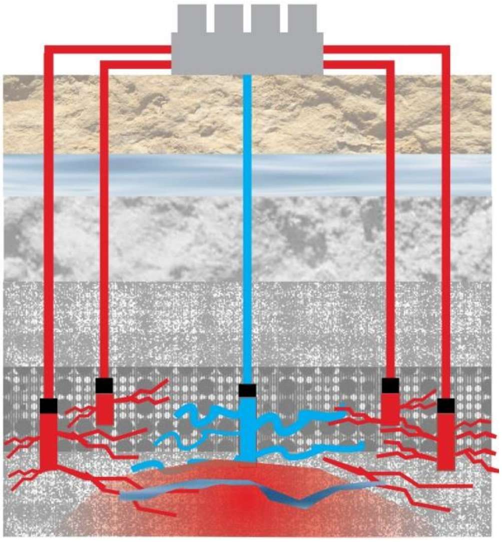
Binary, known also as organic Rankine cycle (ORC) or Kalina Cycle, plants operate usually with waters in the 100 to 180°C temperature range. Working fluid selection, in cooperation with beneficial conditions such as access to effective cooling, may allow power production from as low temperatures as 80°C.

In a binary system, the heat of water is transferred to a separate liquid with a lower boiling temperature. The separate liquid is called a 'working fluid'. When the hot geothermal water is brought to surface from deep underground, it is run through a 'heat exchanger' which transfers the heat from the geothermal water to the liquid working fluid. Because the working fluid boils at a low temperature, it vaporises readily with less geothermal heat, and this vaporization produces enough pressure to drive a turbine. What makes a binary system unique is that it operates as a two closed-loops (hence, binary); neither the geothermal water nor the working fluid are exposed to the surface environment. All the water that is brought to surface has to be re-injected, and after vaporizing, the working fluid is cooled to its liquid state, so it may repeat the process. There are no-emissions in the binary geothermal cycle.

Beyond Hydrothermal: Enhanced Geothermal Systems – EGS

Geothermal energy has the potential to make a more significant contribution to the European electricity mix through the development of advanced technologies, especially the development of hot rock resources using enhanced geothermal system (EGS) techniques that would enable thermal energy recovery from more of the Earth's crust.

An Enhanced Geothermal System (EGS) is an underground reservoir that has been created or improved artificially. The EGS concept is going to greatly increase geothermal potential as it allows for the production of geothermal electricity nearly anywhere in Europe with medium and low temperature.



An Enhanced Geothermal System (EGS)

This concept involves:

- Using the natural fracture systems in the basement rocks
- Enlarging its permeability through stimulation
- Installing a multi-well system
- Through pumping and lifting, forcing the water to migrate through the fracture system of enhanced permeability ("reservoir") and use the heat for power production.

Benefits of Geothermal Electricity Production

BOX 1: Benefits of Geothermal Electricity
✓ A BASE LOAD AND FLEXIBLE RENEWABLE ENERGY SOURCE
✓ ENSURING PRICE STABILITY
✓ INCREASING SECURITY OF SUPPLY
✓ SCALABLE
✓ PROVIDING CLEAN ELECTRICTY
✓ OR COMBINED HEAT AND POWER
✓ AND SUPPORTING LOCAL AND SUSTAINABLE ECONOMIC DEVELOPMENT

A base load and flexible renewable energy source (no intermittency)…

Geothermal energy has many obvious qualities. A remarkable one is that it is not dependent on climate conditions as wind or solar energy may be. As a result, it is also base load. Among all renewable energies, this makes geothermal the most reliable, as plants are able to operate up to 95 per cent of the time. Such a load factor makes geothermal competitive with fossil fuel and nuclear power plants.

But geothermal electricity is also flexible as it can be ramped up or down on demand, thereby contributing to the stability of the grid. Furthermore, geothermal plants can be productive for many years. Typically they have a 30 to 50 year life before the equipment wears out. Indeed the world's first geothermal power plant at Larderello, Italy was commissioned in 1913 and is still productive.

Ensuring price stability…

Developing and utilising geothermal resources for electricity can help to protect against volatile and rising electricity prices (Figure 1). The costs for fuels used to generate electricity influence the final price of the electricity produced. On the one hand, fossil fuels have traditionally been low priced, but their cost is increasing. On the other hand, the costs of geothermal power mainly depend on capital costs, as the fuel is free of charge and operation and maintenance costs are very limited. Emerging geothermal technologies hold significant potential for cost reduction and will reach full competitiveness in 2030.

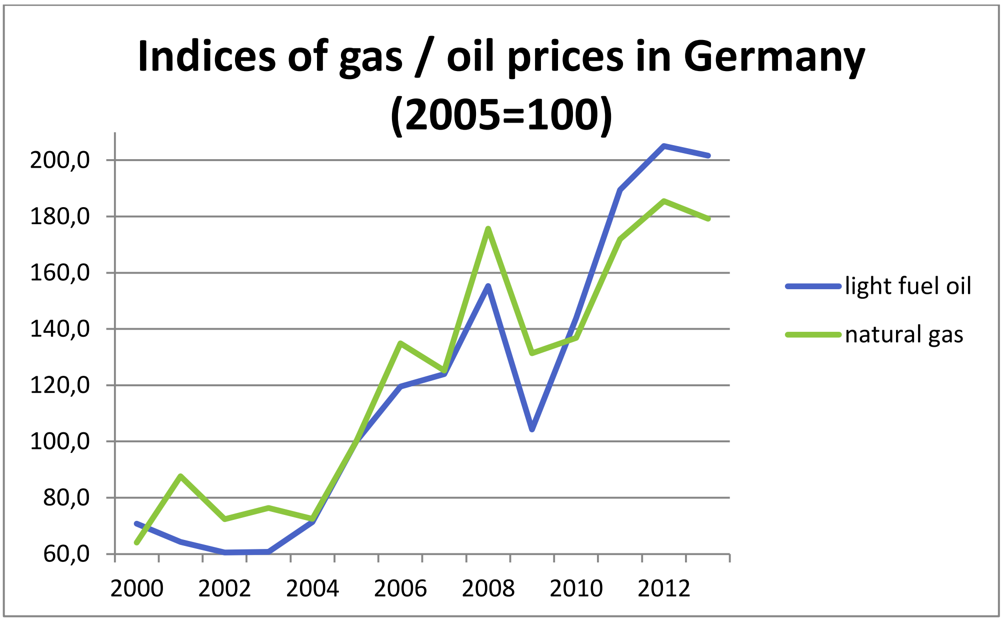


Figure 1: Development of energy prices in Germany (Source: Destatis)

Increasing security of supply…

As a renewable and domestic resource, geothermal enables a diversification of the electricity mix. Making use of this source reduces the amount of fuel that countries have to import and thereby increases their security of supply.

Scalable…

Geothermal power production is scalable. It is possible to have a very small geothermal project, for instance owned and run by a municipality, so it is necessary to have scale specific policies in place. Plants are scalable from around 1 MWe to 50 MWe.

Providing Clean Electricity…

All mankind activities have an impact on nature. But compared to other energy sources, Geothermal has a negligible environmental footprint (see GEOLEC report "Environmental study on geothermal power"). Indeed, Geothermal power systems involve no combustion. Therefore they emit only a small amount of greenhouse gases and if one takes CO_2 as a benchmark, then geothermal closed-loop-binary plants emit 0 CO_2. Furthermore, Geothermal power plants produce only a small amount of air emissions compared to conventional fossil fuels and unlike other renewable energies such as solar or biomass, it has a very small land-use footprint.

Or Combined Heat and Power…

In a combined process the geothermal resources can be used for generating electricity and heat. Producing heat and electricity means optimising the efficiency factor of the energy production and upgrading cash flows. There are many types of direct use applications for the geothermal heat: greenhouses, aquaculture, industrial processes, agricultural processes, baths and spas, and district heating and cooling.

… And Supporting Local and Sustainable Economic Development

Using geothermal resources can provide economic opportunities for countries in the form of taxes, royalties, technology export and jobs. Because of specific geological conditions, these jobs require a thorough knowledge of the local conditions and cannot be exported. Therefore, investments in geothermal power can boost local economies and improve urban environment conditions alike.

Market Development

Geothermal electricity in Europe is growing continuously, not only in traditional areas but also in areas with low-medium temperature resources through the utilisation of binary plants technologies. Indeed, after some years of slower paced development in Europe, the geothermal electricity market has seen a renewed momentum in the last 5 years.

Currently there are 68 geothermal power plants in 6 European countries (Italy, Iceland, Turkey, Portugal, France, Germany, and Austria) for a total installed capacity now amounting to around 1.8 GWe, producing some 11 terawatt-hours (TWh) of electric power every year.

According to the EGEC Geothermal Market Report 2013 there are 74 projects currently under development in Europe, which would increase the total installed capacity to a total of 2.7 GWe in 2017. In addition, 144 projects are now being explored. Figure 2 depicts the installed and projected geothermal power plants in Europe up to 2020.

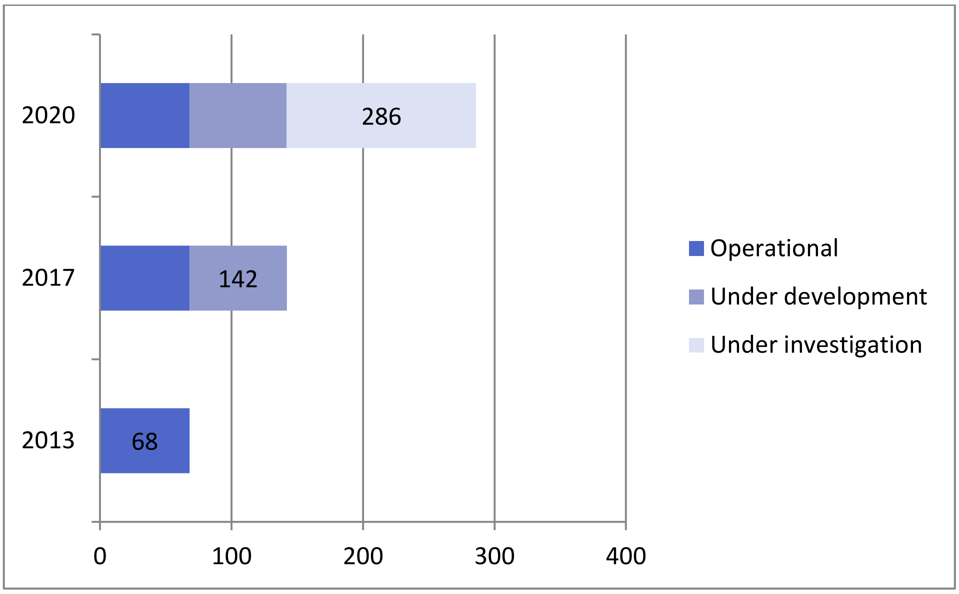


Figure 2: Number of geothermal power plants in Europe. Source: EGEC Geothermal Market report 2013/2014.

Italy dominates the market with more than 50% of the European capacity, i.e 875 MWe. After the liberalisation of the Italian geothermal market (legislative decree n. 22, 2010), more than 130 applications for research permits for geothermal exploitation and development have been submitted. Many new players are now operating in exploration activities, preparing for the future development of geothermal energy in the country.

Iceland has installed 7 power plants representing a capacity of 662 MWe. Nearly 300 MWe are currently being developed with 5 new projects. In addition 5 more projects are being investigated, notably one, the Iceland deep drilling project, which could provide a very large amount of electricity if successful in exploiting supercritical resources.

In **Turkey**, the market is booming. According to the projects under development and investigation, the installed capacity should grow from 242 MWe today (10 plants) to triple by 2016 and to reach 1GWe in 2020.

France (Guadeloupe) and **Portugal** (Açores) have been developing geothermal electricity power plants on Atlantic islands since the 1980s; this development is continuing with the Geothermie Bouillante 3rd unit and the Pico Vermelho plant for 2016. France is the home of the first EGS pilot project (Soultz) which was inaugurated in 2008.At least 12 other EGS projects are being investigated with more and more permits for research and exploration being awarded by the government. Figure 3 shows a breakdown of the current and expected installed capacity in Europe by country.

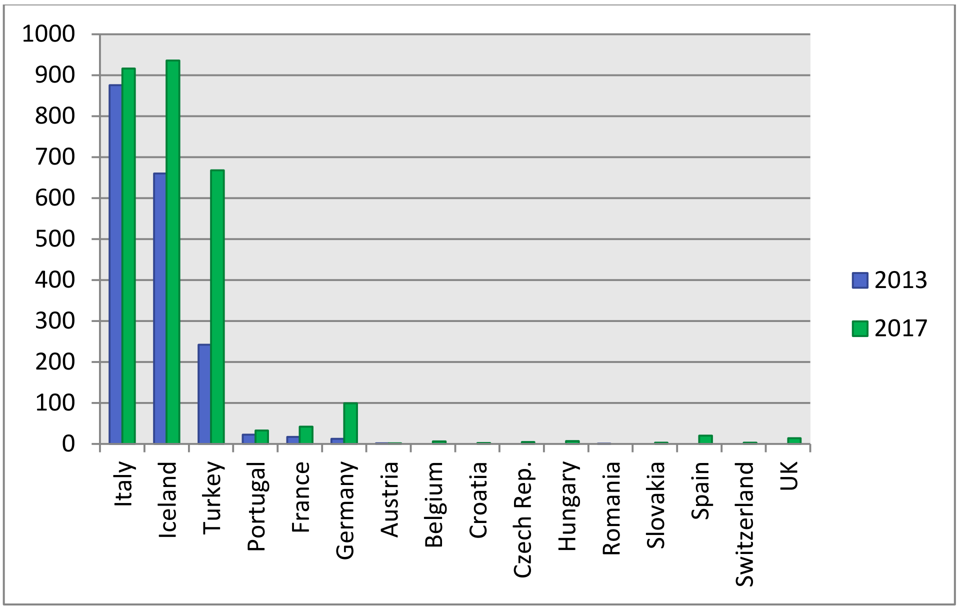


Figure 3:Breakdown of installed capacity in Europe by country (MWe). Source: EGEC Geothermal Market report 2013/2014.

But what is worth highlighting is that geothermal electricity is developing beyond traditional geothermal countries. In Germany, with the inauguration of 3 new geothermal plants in 2013, there are now 8 plants in operation representing a capacity of 28 MWe. Several geothermal power projects are expected to be commissioned in the next years. A total of 15 projects are under development and 28 under investigation, most of which are concentrated in Bavaria and in the Upper Rhine Graben area. According to the EGEC Market report, in 2013/2014 in total, geothermal power development in Germany can be estimated to reach about 180-190 MWe installed capacity by the end of 2020.

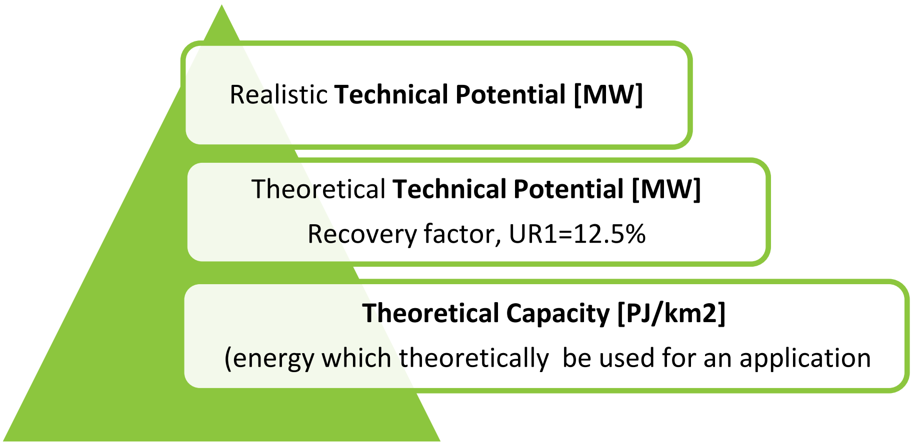
Greece is another important newcomer in the geothermal electricity market with 13 projects being investigated, mainly on the Greek islands. They are expected to become operational by 2019.

Finally, 7 EGS projects are being developed and 37 EGS projects are being investigated in Belgium, Croatia, Czech Republic, France, Germany, Hungary, Latvia, Romania, Slovenia, Spain, Switzerland and the United Kingdom.

Economic Potential until 2050

The Geoelec project has created a European map showing an overview of the location of geothermal resources which can be developed in 2020, 2030 and 2050. The map is based on a unified reporting protocol and resource classification for geothermal resource assessment.

The resource assessment of the geothermal potential for electricity generation is the product of the integration of existing data provided by the EU-28 countries and a newly defined methodology building on Canadian, Australian, and American methodology.



The geological potential (heat in place) is translated to an economical potential, using a Levelised Cost of Energy (LCoE) value of less than 150 €/MWh for the 2030 scenario and less than 100 €/MWh for the 2050 scenario:

The production of geothermal electricity in the EU in 2013 is 6 TWh

The NREAPs forecast a production in the EU-28 of ca. 11 TWh by 2020 but the economic potential for geothermal power is much higher in 2020: 21.2 TWh for the EU-28 and 70.8 TWh for the total potential in Europe

The total European geothermal electricity potential in 2030 is 174 TWh

The economic potential grows to more than 4000 TWh in 2050

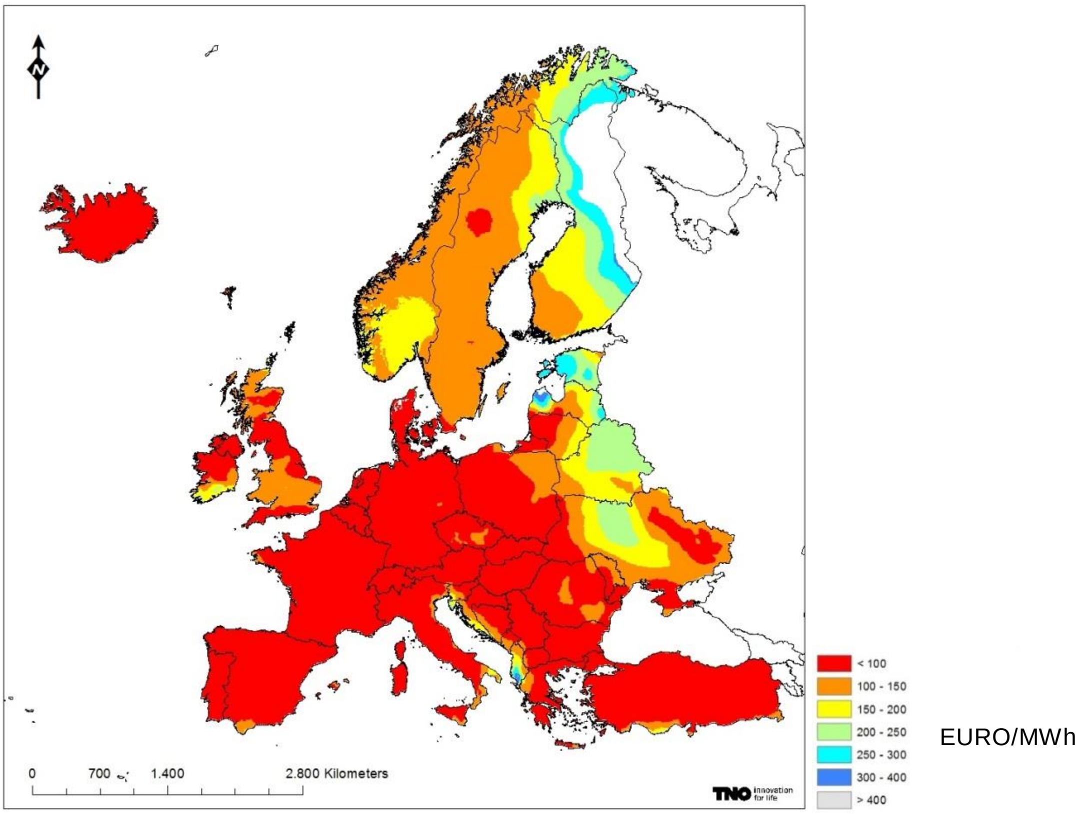


Figure 4 The economic potential for geothermal power in 2050

See GeoElec Report 'Prospective study on geothermal potential in the EU in 2020-2050'

Chapter II – Geothermal Project Development: Phases and Expertise

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. This chapter will introduce the different phases of a geothermal project and the wide array of skills required for its successful implementation.

The phases of a geothermal project at a glance

It is possible to divide a geothermal project into 4 key phases: exploration, resource development, construction, and commissioning, operation and maintenance.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8
Exploration	Exploration & test drilling							
Resource development			Drilling					
Construction					Engineering & construction			
Commissioning & operation							O&M	

Figure 5 Phases of a geothermal project

Exploration Phase

Based on experience, it takes about 5-7 years to bring a geothermal power plant online.

In the “Exploration Phase” of a new project, (which is subject to an exploration permit usually granted by the mining authorities), available geological data is reprocessed and analysed.

Following a preliminary survey, detailed geophysical, geological and geochemical studies will be needed in order to identify drilling locations in the defined area and to estimate the geothermal potential. Exploration strategies should be designed for each site with the specific geological setting in mind but could involve the following (Bruhn et al. 2010):

- Assessment of the geologic and geodynamic setting;
- Geochemistry including fluid and rock isotope chemistry;
- Structural analysis of faults, fractures, and folds;
- Determination of the regional stress field;

- Potential methods, mainly gravity and magnetic surveys;
- Electrical and electromagnetic methods;
- Seismic methods, both active and passive.

Significant effort is put into exploration, attempting to minimise drilling uncertainties, combining magnetotelluric (MT) surveys. In Germany, there is a tendency to use of 3D seismic methods, even for projects of a few MW potential. Indeed, this is the best technology available today to identify fractured areas, but cheaper technology is necessary to bring the cost of geothermal development down, it is therefore important that 3D seismic studies are correlated with other technologies.

Another key step in the exploratory phase is the test drilling. At this stage a drilling programme is designed to develop a target to confirm the existence and potential of the resource. Within the geothermal industry there is a discussion on whether or not to use slim holes since a successful exploration well can turn into a production well. It should be answered on project basis taking into account the existing knowledge of the region and project economics. A slimhole can f.ex. reach up to 1.5 km depth with a diameter up to 15 cm., this requires lighter drilling rigs thereby limiting the costs.

Beside the geoscience and engineering, the legal and market framework conditions of the area have also to be studied and evaluated in a so-called "feasibility study", the outcome of which will confirm the technical and economic viability of the project. The funding and the insurance concepts of the project will also stem from this phase. Hence, **banks / investors / sponsors and also insurance companies have a role to play from the beginning.**

Resource development

Based on the feasibility studies, project developers can take the decision to start the active phase of "Resource Development". This phase includes the drilling of the production and injection well(s) and the connection of the wells to the power plant. After the long-term flow test the potential of the geothermal resource is known.

Construction

Upon completion of the drilling activity and associated tests, the construction phase begins. At this point the power plant must be planned, constructed and connected to the electricity grid. A detailed design of the power plant can start with the knowledge of the long-term flow test. With lower efficiency factors, standardised plant modules can be ordered without completed flow-test. In this case, the financing of the power plant should be possible through equity capital. Currently, there is no known bank financing the power plant without the guarantee of the results of long-term flow tests.

Commissioning and Operation

Following the construction phase, the power plant is commissioned and initial tests are run. Once all tests have been completed successfully, the power plant is fully operational and can sell the electricity (and/or heat in the case of cogeneration plants) generated. Maintenance of both plant and geothermal resource will be needed throughout the lifecycle of the power plant.

Project team and interplay between disciplines

A number of different players are involved in a geothermal project over several years of project development and implementation (Figure 6).

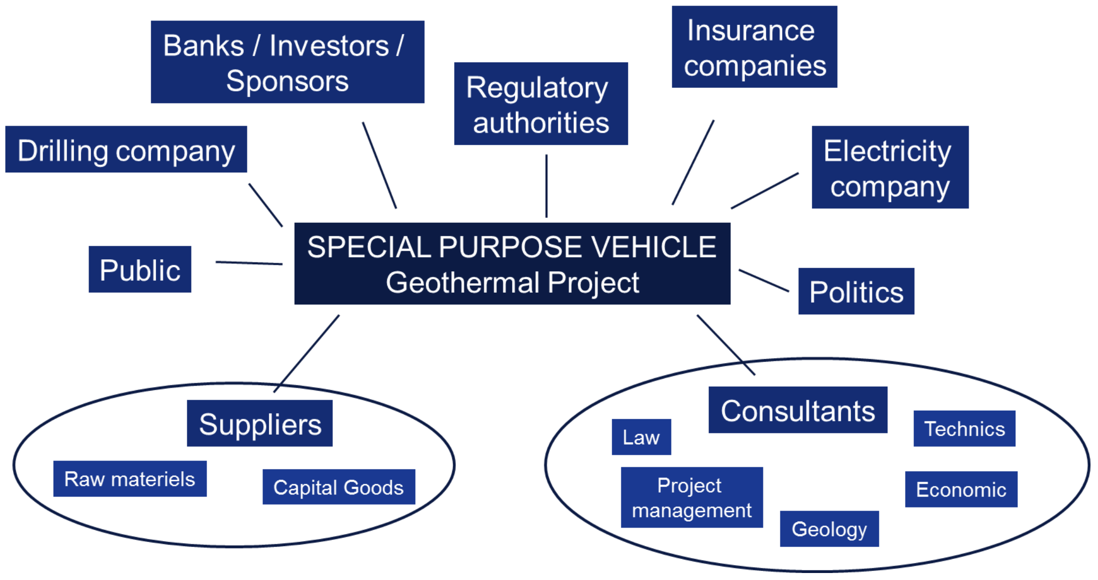


Figure 6 Players of a geothermal project development

The project manager plays a key role for the (economic) success of a project, especially in the early stage. He has to comply with the complex requirements related to structuring, developing and risk mitigation.

A team of consultants is needed to assist the project team. They need to have an enormous variety of skills, abilities and personality types. A team of financial experts, legal experts and technical experts, e.g. geoscientists, reservoir engineers, and drilling specialists, power plant engineers, environmental experts... must be established at an early phase. Figure 7 takes a snapshot of the interplay between disciplines required. The challenge is to keep the complexity of the project under control and to reflect the technical aspects and the course of the project correctly in the cash flow. Also the interaction between individual disciplines, the definition of the interfaces and the on-going and active exchange of information must be perfectly organised.

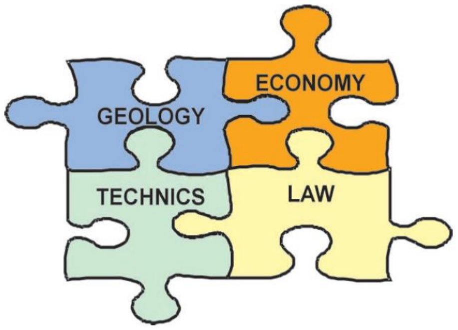


Figure 7 Geothermal Project team – interplay between disciplines

Chapter III – Financing a Geothermal Project

Private financing in the geothermal market can be still considered in its early stage. Significant investment, higher level of risk, long project development cycle and long expectation for the return of investments (RoI) are the key challenges of a geothermal project. Every project has its individual financing requirements due to the specific project parameters related to geology, finance, politics and technique. The crucial factors for the economic success of a geothermal power project are shown in Figure 8 below.

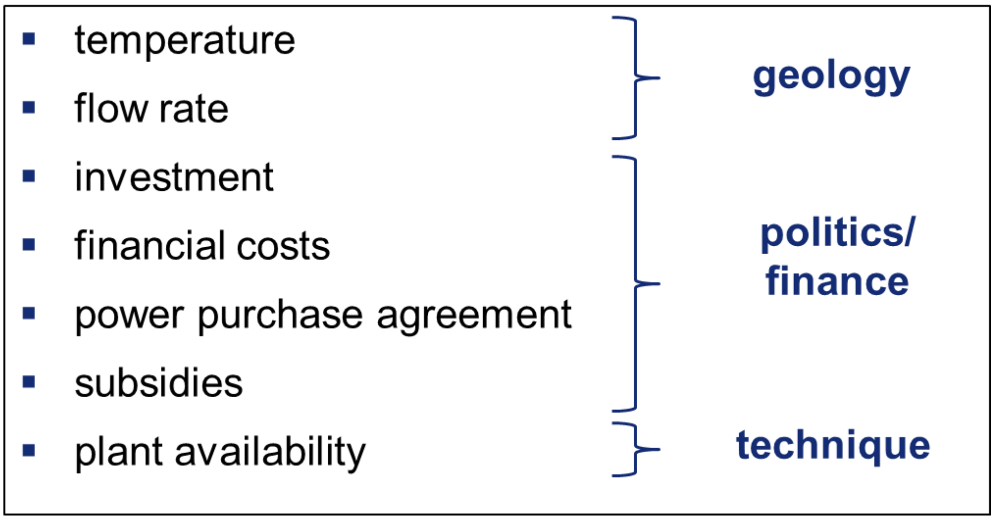


Figure 8 Crucial parameters for the economic success

Widespread development of geothermal energy will require high investment. The involvement of the private sector – banks, sponsors and investors is needed.

Financing geothermal projects depends on the stage of the project. It has to be structured in two steps. Project investors are financially responsible for the geological risk, until debt financing by banks is possible following the completion of the long-term flow tests. From experience, a special purpose vehicle (SPV) for the geothermal project should be founded to develop the project finance and to define the project risks.

Project finance

Because of the varying level of risk implied, diverse financial tools are used to fund the different phases of a geothermal project. This is shown in Figure 9.

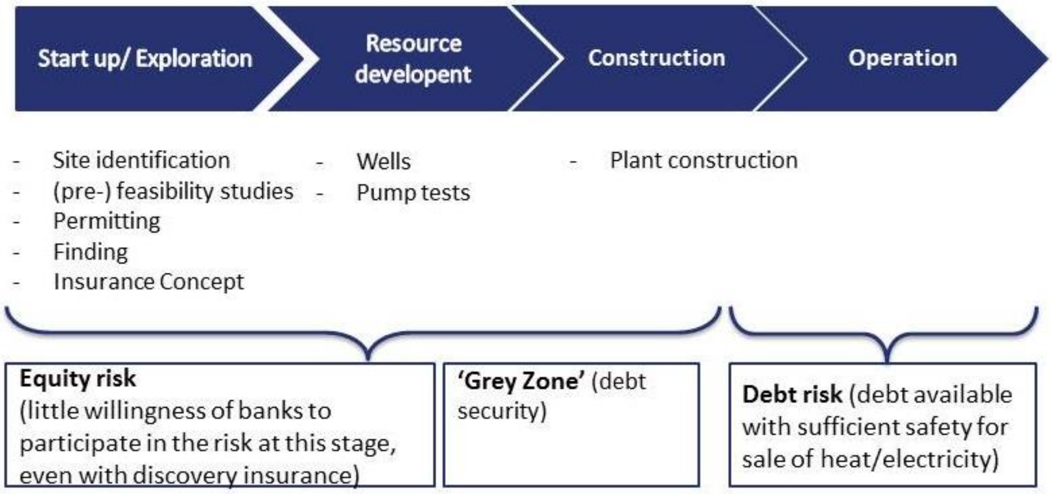


Figure 9 Financial instruments used to finance different phases of a geothermal project

Financing a geothermal project is indeed more difficult in the initial phase of project development as the geological risks during the exploration and drilling phases have to be taken by equity.

If the construction phase begins before the results of the pumping-tests are available, the financing of the power plant is in a "gray zone", in most cases debt financing cannot be constituted. With the completion of the long-term flow test project finance by banks is possible.

The basic idea of project finance is that the project should finance itself. The investors must have a credible perspective on an adequate equity yield rate and creditors need guarantee on the return of their credit capital. Cash flow-related lending, Risk-sharing and Off-Balance-Sheet financing are the central characteristics of project finance.

The special purpose vehicle (SPV) of the geothermal project should be established by the project initiators to have legal capacity and to be creditable. With it, the vehicle can obtain debt capital, whilst the sponsors can only participate as investors according to the amount of their deposits (Figure 10).

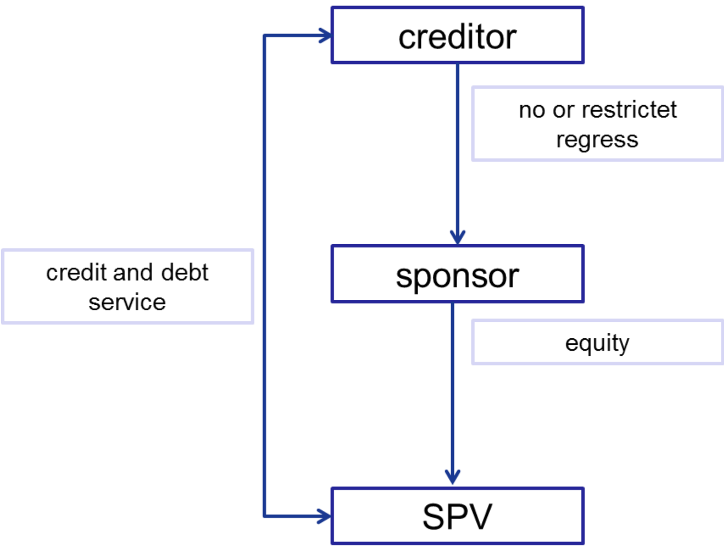


Figure 10 Project finance of a special purpose vehicle (SPV)

Project credits are allocated in the balance sheet of the geothermal SPV, whereas the annual accounts of the sponsors should not be affected (Off-Balance Sheet-financing).

The credit check is directly focused on the economic viability of the project because of the lack of economic history and the high specifics of each project. The cash-flow must be sufficient for the operation costs and the debt service. The orientation to the cash-flows by the credit check is called "cash flow-related lending". Only the two sources of collaterals - the assets acquired within the project and the expected cash-flows - are available.

The usual requirements of banks for geothermal projects are listed in Box 3.

BOX 3: REQUIREMENTS OF A BANK FOR FINANCING A GEOTHERMAL PROJECT

- ✓ COMPLETED FLOW-TEST
- ✓ SHARE OF EQUITY OF AT LEAST 30% OF THE BALANCE SHEET (AFTER SUCCESSFUL DISCOVERY)
- ✓ TERM: 15-20 YEARS DEPENDING ON THE TECHNICAL LIFETIME OF THE FACILITY
- ✓ SERVICE COVERAGE RATIO : >1,2
- ✓ CAPITAL SURPLUS, e.g. for dry hole, pump replacement
- ✓ APPROPRIATE KNOW-HOW AND EXPERIENCE
- ✓ PROJECT STRUCTURE WITHOUT INTERFACE RISKS
- ✓ PROVEN TECHNOLOGY
- ✓ RISK MITIGATION
- ✓ INDEPENDENT FEASIBILITY STUDIES
- ✓ AVAILABILITY OF SUBSTITUTE MATERIALS
- ✓ FEED-IN TARIFF AGREEMENTS / SECURE SALE GUARANTEE

Another characteristic of project finance is risk-sharing. It assumes that the single risks are identified with their consequences and allocated to the project partners. This issue will be discussed in chapter 3.3 of this guide.

Financing the resource development

As previously mentioned, the financing of a geothermal project in its initial phase has to be constituted in most cases by equity. This lack of debt capital - for the exploration and development phase of the resource - hinders the growth of geothermal power.

Yet, a good example to overcome this barrier was implemented in Germany by the national development bank '*Kreditanstalt für Wiederaufbau* (KfW)' through the credit scheme "*Fündigkeitsrisiko Tiefengeothermie*" (i.e. Geothermal short-term risk) to overcome the investment barrier caused by the lack of long-term financing because of the discovery risk and by assumption of the short-term geothermal risk.

The fund for the credit scheme was initially filled by the *Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit* (Federal Environment Ministry) with €60 Million through the Renewable Energy Incentive Program MAP. The re-insurance company Munich Re supports the credit scheme with risk assumption and yielding knowledge.

The application fee amounts to €65.000 covering the assessment of the documentation by Munich Re and KfW. Further € 45.000 is charged for auditing and expert monitoring of the project progress. A high interest rate is charged until termination of the drilling work, stimulation measures and hydraulic tests.

Developers of heat, power or combined hydrothermal projects can benefit of this credit scheme. These developers may be public (e.g. municipalities, local authorities), semi-public (e.g. private companies whose majority is owned by municipalities) or private (e.g. small and medium-sized companies, non-commercial investors).

Projects can apply for a loan for up to € 16 Million per drilling (one doublet), covering a maximum of 80% of the eligible costs. Applications have to be submitted by the project developers to their affiliated bank. This bank conveys the application forms and guarantees the payback of the loan to KfW.

This support approach is recommended to be developed for EGS projects in collaboration with the affiliated banks, the national business development bank and insurance companies respectively.

Risk management

A geothermal power project is based on the estimated geothermal power that can be generated from the reservoir and the estimation of costs and revenue streams related to each individual project. Estimating prospective costs and revenue streams involves uncertainties and risks.

Financial backers are sensitive to project risks especially because of the Basel-II-principles and the lack of knowledge about geothermal projects. Therefore, solid project planning and risk management are essential elements of a developing project, and need to be implemented at the earliest stage. Risk management does not necessarily imply the elimination of risks, but rather their systematic management and mitigation (Figure 11).

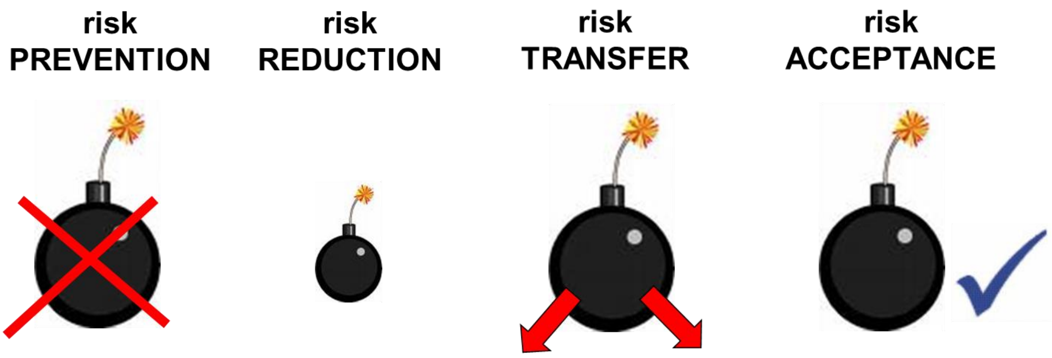


Figure 11 The right risk strategy

Risks have to be identified and evaluated in terms of their probability and the (economic) consequences of their occurrence. Once these assessments have been made, strategies for risk management need to be developed. Sometimes, it will not be possible to avoid risks by means of appropriate and "affordable" measures. Often, risk reduction is satisfactory. Some risks may be passed on to third parties, for example through insurance (Figure 12).

- business liability insurance
  - inkl. mining regulations
- constructors all risk insurance
  - damage-related costs for lost in hole of equipments, by-pass etc.
  - damage-related giving up of the borehole
- discovery insurance
  - coverage of the thermal capacity / energy potantial

⇨ <u>necessary</u>: agreement of insurance coverage

⇨ <u>helpful</u>: supporting throught experienced broker

Figure 12 Insurance coverage concept for deep geothermal projects

Lastly, there are risks that the company will categorise as (financially) acceptable and cover with equity capital directly.

Most of the investment falls into the high-risk phase of the geothermal project (Figure 13). While the project is being developed, the required budget changes successively. And with increasing effort in exploration, more and more knowledge about the resource is acquired and the risk of failure decreases accordingly.

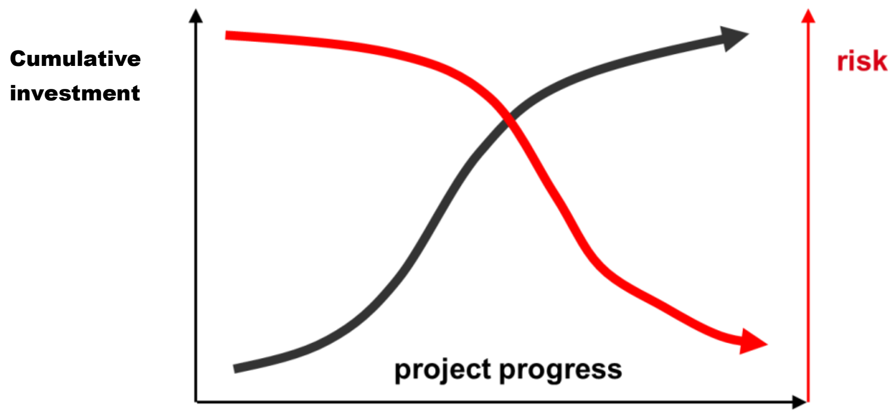


Figure 13 Risk and cumulative investment during the project progress

Finally, beyond exploration, the bankability of a geothermal project is threatened by the geological risk. Risk insurance funds for the geological risk already exist in some European countries (France, Germany, Iceland, The Netherlands and Switzerland). The geological risk is a common issue all over Europe. Collaboration between Member States is desirable; it can allow them to save money and trigger the uptake of a valuable technology alike.

For this reason the GeoElec project has made proposals for a Geothermal Risk Insurance Fund at the EU level, which is of the utmost importance for the deep geothermal sector in Europe.

See GEOLEC report "European Risk Insurance Fund – EGRIF"

Cost analysis

The total costs of a geothermal project are dominated by the capital costs at the beginning of the project. The range of the main capital costs are depicted in Figure 14&15, though the actual investment of specific project can differ from these ranges.

Reservoir exploration and development

The investment for the exploration and development of the reservoir (i.e. drilling) makes up the largest part of the whole investment. A general assessment of these costs is difficult because of varying geological conditions that influence the drilling, the completion, and the reservoir stimulation in the case of EGS. Investment estimations of the reservoir at an early stage of a geothermal project are usually based on existing data from other drilled and completed wells. Detailed cost calculations use geological site information. Such calculations should also consider an additional values for unforeseen problems - typically between 10% and higher in unknown geological areas.

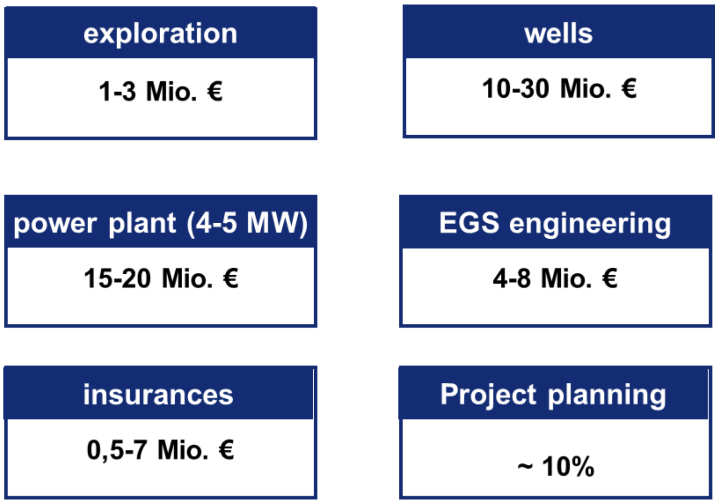


Figure 14 Breakdown of capital costs in a 5 MWe EGS projects in Germany (see case study)

Cost Category	Approximate percentage of CAPEX
Preparation & drilling	54%
Turbine-generator & auxiliary systems	13%
Steam supply system	10%
Design & supervision	11%
Buildings & ancillary systems	7%
Roads & camps	3%
Electrical, control & protection systems	2%

Figure 155 Example from a 5MWe low enthalpy binary Power Plant in Central-Europe

The **drilling costs** can be split into the following:

The rig rent is usually paid on a daily rate. It depends on its specifications such as load and depth capacity. A drilling rig with larger progress of the well entails a decrease of the term of lease. Therefore, the choice of the drill rig must be a compromise between rig capacity, drilling progress and technical reliability.

The material costs include the expenses especially for casing and cementation. These costs depend on the borehole design (aperture, depth and well course) as well as on the site-specific geological strata set. Also the investments for the drilling site preparation must be budgeted.

The energy for the operation of the drilling rig and the drilling mud pumps must be considered.

The service costs include the borehole-related services (e.g. installation of the casings, cementation, mud logging) and drilling-site activities (e.g. installation and dismantling of the drilling rig, drilling site preparation).

Drilling makes up a very significant part of total capital costs of a geothermal project. Therefore, the drilling market can directly influence the development of the sector. There is a developing trend, driven mainly by new players in the geothermal industry and unfamiliar with drilling process, which is to ask for a turn-key or Engineering, Procurement, Construction (EPC) contract from a single contractor. Such a development has induced some changes in the services and activities offered by drillers, which has led to the transfer of some risk and overheads to the driller, from the developer, which gives the impression of inflation in drilling costs. It is possible to see a growing number of EPC contractors evaluating the opportunities for entering into the geothermal market, which is positive news as it would see competitiveness improve and lower prices.

In addition, a number of companies in Europe and beyond are working at optimising drilling technologies, the traditional suppliers are improving their drill bits for hard rocks, and also new players working on innovative technologies (spallation, laser, etc.) which may possibly provide a break-through in the drilling industry.

See GEOLEC report on "Geothermal drilling"

Reservoir engineering costs for EGS

EGS allows to exploit low temperature areas by increasing the permeability of rocks nearly anywhere. Stimulation techniques based on high pressure water injection have the objective to generate a high permeability to extract as much mass flow as possible. Depending on the site specification and the estimated power stimulations costs between 4 and 8 € Million must be considered.

Surface Installations

The investment costs for the surface part of a geothermal project include the costs of the geothermal fluid supply system and the costs of the power plant unit and, if applicable, the extra costs for a heat plant unit).

The investments for the geothermal fluid supply system contain the costs for the equipment such as pumps, pipes, valves, separators (where it applies) and filters. The costs depend on the flow rate of the geothermal fluid, temperature and pressure in the gathering system. Further parameters affecting cost are chemical compositions, gas content and topography of the steam field.

The investment for a power plant generally depends on the installed capacity. The specific investments decrease with larger capacity. The main items are the turbine and generator unit, the heat exchangers and the cooling unit.

Other costs

From past experience, project planning including design can take up to approximately 10% of the overall capital costs. In addition, the costs for consulting (legal and economic, project management) and for the licensing procedure must be budgeted. Further investment costs are, for example, e.g. noise protection, office, clerical equipment, infrastructure, outside area. Insurances covering the geological risk, business liability insurance or constructors all risk insurance are further cost factors which must be considered.

Operational & Maintenance costs

The annual operating costs during the operating phase of a geothermal electricity plant include mainly the costs for personnel, consumption material, overhaul and maintenance. Costs for the consumption of the auxiliary power demand need to be considered if the required power is not provided by the power plant itself. Unlike for fossil fuels and biomass, at this point no costs for fuels are to be included.

Business Models

The geothermal industry has a collection of different business models, **involving actors such as** developers, suppliers, academics, and service provider, drilling services etc. These different business models for geothermal power plants vary from a fully integrated single national public company to an independent private developer. Many Public-Private Partnerships (PPPs) can be developed between these two 'extreme**s'.**

Historically, geothermal power plants in Europe have been developed by Public national utilities (for example, ENEL in Italy). As Public utility company, they are vertically integrated. Firstly developed in Iceland, a scheme involving both National and Municipal public entities is today also popular: several public entities perform across the value chain.

PPPs can have different forms, from a Public authority offering fully drilled brownfield sites to the private sector, to a public authority funding the exploration phase including test drilling and offering the successful field for private development, or with an Independent Power Producer (IPP) sharing the risks of exploration and construction with the Public authorities.

In geothermal power development, a PPP can be especially effective if it covers all major project phases including test drillings, field development, and power plant construction, especially the most risky. This allows for a tailor-made arrangement in which the public sector concentrates its contribution of resources in the riskier upstream phases, while the private sector partner finances the bulk of the capital costs in the more mature phases.

Finally, some EU countries developed other models where this risk is allocated to the private developer. Two basic options can be considered:

(a) inviting proposals from private companies to develop new geothermal sites through concessions or PPPs in which more of the resource risk is taken by the private investor/developer; and

(b) introducing attractive off-take prices through a Feed-In Tariff/Premium policy.

Chapter IV – Revenues of a Geothermal Project

Support schemes for geothermal electricity

A critical element in the project development is to guarantee stable revenues through the sale of the electricity produced. Especially for an independent producer, (i.e. not a utility), negotiating a convenient **power purchase agreement (PPA)** is key. A PPA is a long-term contract (between 5 and 20 years) with a third party, usually a utility, to sell the electricity generated by a power plant. It is essential to secure a long-term stream of revenues.

In the EU, Directive 2009/28/EC (RES Directive) has set the target of 20% renewable energy in gross final consumption of energy for 2020. This general target was broken down into binding national targets. To facilitate the achievement of these targets Article 3 of the RES Directive allows Member States to make use of national mechanisms of support for the promotion of energy from renewable sources provided they are compatible with the State aid guidelines for environmental protection.

A wide range of public policy mechanisms are currently in place These can be distinguished between investment support (capital grants, tax exemptions or deductions on the purchase of goods) and operating support (regulated prices, renewable energy obligations with green certificates, tender schemes and tax reductions on the production of electricity).

The most widely used incentive in EU countries is the **feed-in-tariff**, which guarantees a fixed price per kWh electricity. These payments are mostly guaranteed to the electricity producer for 10-20 years thereby geothermal power producers the problem for negotiating and signing a PPA. This investment security and the guarantee of cash-flows allows them debt financing at more convenient conditions; this is essential for the financing of capital intensive projects like geothermal power projects.

Figure 16 provides an overview of the feed-in tariff systems in place in 11 European countries (EGEC, 2012). However, they differ in terms of length and other conditions. For more detailed information, the competent national authorities should be contacted.

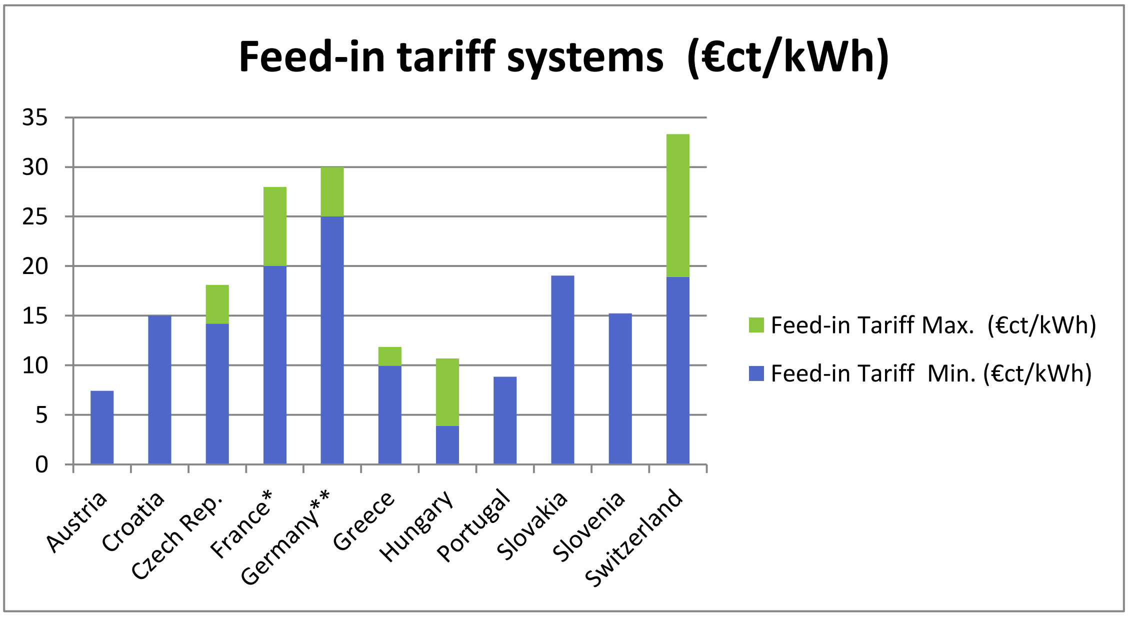


Figure 16 Feed-in tariff systems in the Europe. Source: EGEC Geothermal Market Report 2012 **Applies to the produced net power** Applies to the produced gross power*

An alternative, more market-oriented, incentive is a system called feed-in premium, which gives the electricity producer a fixed financial payment per unit of electricity produced from renewable energy sources for the green value. On top of that the producer receives the market price for physical energy. Figure 17 shows that 4 countries promote geothermal power generation through feed-in premium mechanisms.

Lastly, Flanders, a region in Belgium, Romania, and the UK promote geothermal electricity by means of quota/certificate systems (Figure 18).

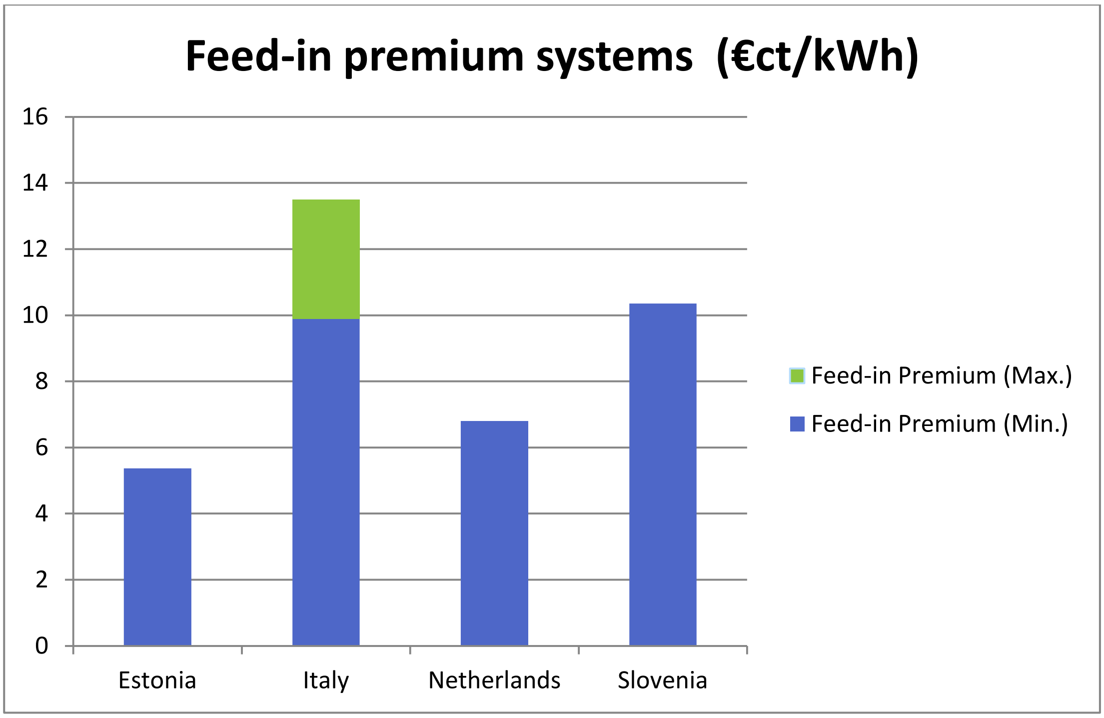


Figure 16 Feed-in premium systems in Europe. Source: EGEC Geothermal Market Report 2012

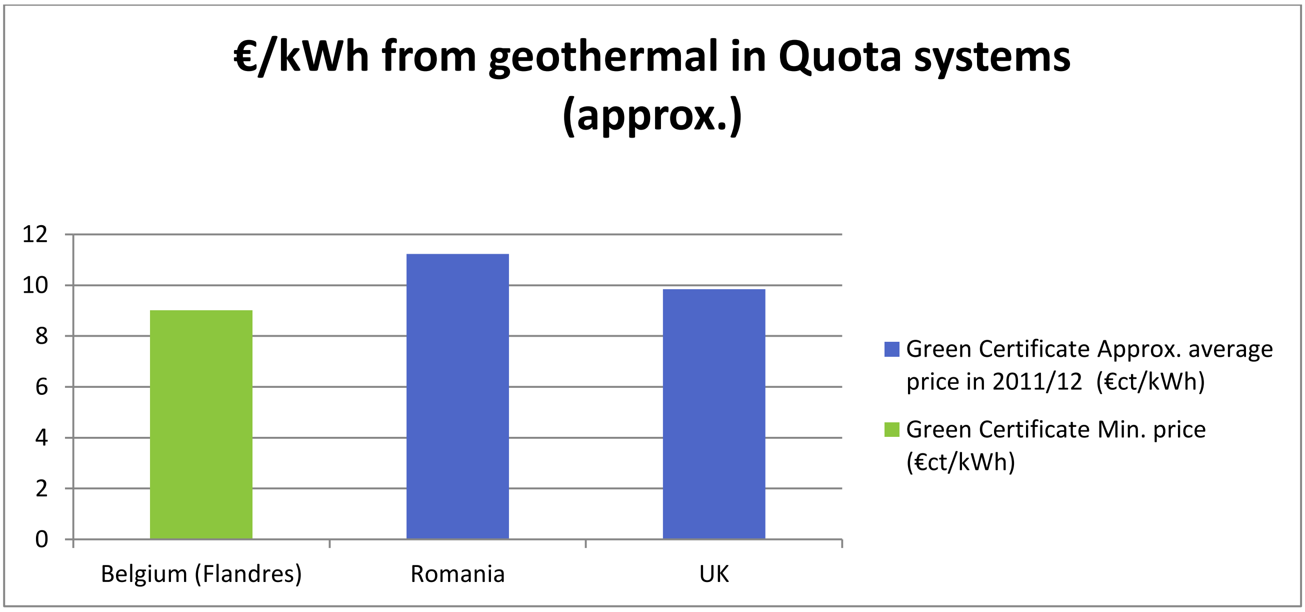


Figure 178 Quota systems in Europe. Source: EGEC Geothermal Market Report 2012

The added value of cogeneration

Combined heat and power projects improve their economics by selling heat at market prices in competitions with other heat sources (Figure 19).

Since the drilling for geothermal fluid is a high risk and costly phase, the results should be utilized to generate as many income streams as possible to create a beneficial project. Geothermal CHP is nothing new. As a matter of fact, a low temperature (81°C) geothermal resource has been exploited, since the late 1960's, at Paratunka, Kamchatka, Russia, Combining power generation and direct uses of the waste heat for soil and greenhouse heating purposes; Actually, heat maybe regarded as a by-product of geothermal power production in terms of either waste heat released by the generating units or excess heat from the geothermal source.

In Germany there are regulations and laws which privilege the utilisation of renewable energy heat (e.g. EEWärmeG).

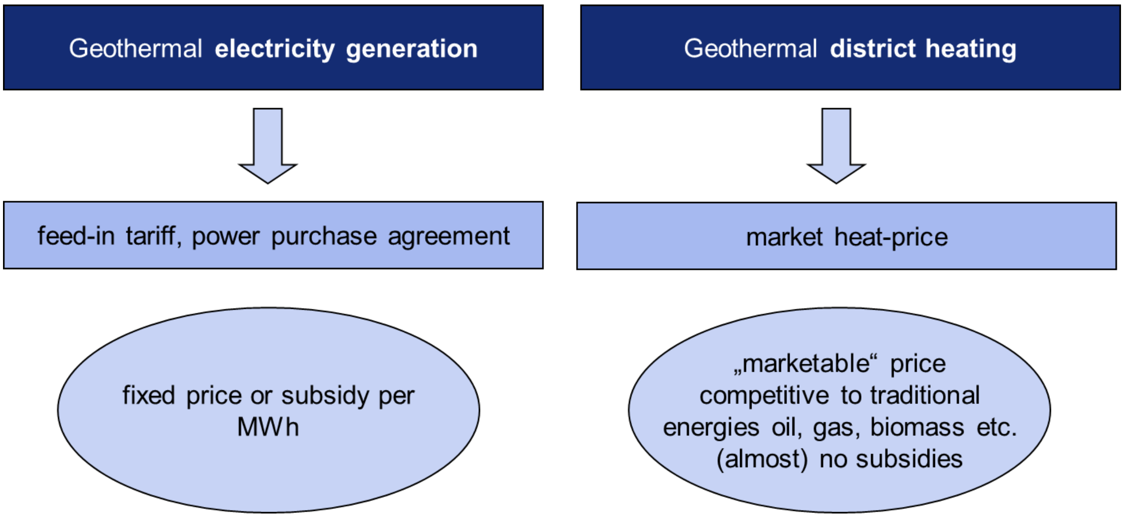


Figure 18 Revenues of a geothermal project – heat and electricity

In the case of a combined heat and power project, the revenues earned by heat are determined by the heating capacity provided to the network. The expansion of usual district heating networks, including subsequent increased density of coverage, usually takes 15 to 20 years; only then is the final level of sales achieved. A natural limit is imposed on the price by the competing sources of energy oil, gas, wood chips, etc. And the heat tariff must be designed so as to give consumers an incentive to switch.

Chapter V - Legal Requirements

Developing a geothermal project requires several authorisations and the compliance with a number of national and regional regulations. For project developers regulatory barriers can also result in additional costs. Hence, it is crucial that a fair, transparent and not too burdensome regulatory framework for geothermal is in place. On the other hand, investors and sponsors and banks need to know that all legal requirements are met and all necessary permits and concessions are available.

The GEOELEC "Report on Geothermal Regulations" provides an in-depth analysis about legal requirements and licensing procedure, and other specific issues. Furthermore, this report puts forward key recommendations for policy-makers on how to improve the regulatory framework in Europe and avoid additional and superfluous costs.

See GEOLEC report on 'Geothermal regulations'

Resource licencing

The main requirements / permits of a geothermal project development are listed below:

- Water, mineral and mining rights;
- Exploration permits;
- Well construction permit;
- Exploitation rights;
- Payment of royalties;
- Environmental impact assessment (EIA);
- Building permit for the power plant;
- Dismantling permit.

In total, the legal procedure today in Europe varies from country to country and can take between 6 and 24 months, on top of the time needed for collecting the supporting documents required. Issues like micro-seismicity and hydraulic stimulation add a new step to the process. The public entities involved to cover geological, water, energy aspects can be numerous: Mining authorities (national, regional), environmental agencies, local authorities etc.

Typically, the exploration permission is firstly given for a period (4-6 years) and for a specific area; and then an exploitation authorisation is attributed for 30 years or more, with in each case possibility of extension. Permits should be granted for a period of time which is long enough to allow for exploration and proper production, but should prevent speculations and fake exploratory projects.

Resource ownership and protection

In the beginning of any geothermal project, it is essential to be aware of the legal provisions about resource ownership and the protection of the resource against other uses/users. A clear definition of exploitation rights over a sufficient period is crucial.

In this regard, three situations can be found in European countries. In some countries where plants are operational, the issue is covered by the adoption of mining law or mineral resources law. The procedure mentions that the State / the crown gives a concession to project developer for exploiting the resource. It is a good option if licensing is regulated properly but it creates difficulties if it is included in water legislation.

In other countries, the owner of the surface also has ownership of the underground resource. It creates difficult situation as for a larger project multiple owners will be concerned. For deep geothermal project this is very time consuming.

In juvenile markets there are no specifications about ownership. Licenses allow the protection of an area and to avoid competitors using the same underground resources. Traditionally, a first come - first served approach is in place; with the exception of states where a priority is given by law to a specific resources: water, energy etc. Moreover, a licensing regime defines the frame for dispute solutions.

Environmental regulations

The rules protecting the environment in geothermal regulatory frameworks cover principally water protection, control of emissions, impact assessment and landscape assessment. The main categories are briefly summarised below.

Water protection

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

The protection of groundwater is important during the drilling phase. The groundwater is to be managed sustainably and permits according to water law are required.

Environmental impact assessment

An environmental assessment is a procedure which aims to ensure that the environmental implications of decisions are taken into account before the decisions are made. Environmental assessments can be undertaken for individual projects on the basis of Directive 2011/92/EU (EIA Directive) or for public plans or programmes on the basis of Directive 2001/42/EC (SEA Directive). The common principle of both Directives is to ensure that plans, programmes and projects likely to have significant effects on the environment are made subject to an environmental assessment prior to their approval or authorisation. The projects and programmes co-financed by the EU, including through Structural Funds have to comply with the EIA and SEA Directives to receive approval for financial assistance (Angelino 2013).

According to the EIA Directive it is for the national authority to determine whether and which geothermal drilling projects should be subject to an environmental impact assessment. As a result, practise in European countries can differ widely.

Landscape and Habitats Protection

Geothermal projects have to comply with landscape and habitat protection rules. It should be noted here that geothermal plants have very low visual impact as most of the infrastructure can be hidden beneath the ground. A significant benefit of geothermal energy and heat generation is that minimal land use is required during construction, with an area of only one or two acres necessary.

The main visual impact during the construction phase is the presence of a drilling rig, but once a project is in the production phase the rig is not required and the energy centre footprint is very small. The visual impact will also be minimal as the permanent energy centre can be constructed sub terrain.

As far as the habitats protection is concerned, a geothermal project shall comply with Directive 92/43 on the conservation of natural habitats and of wild fauna and flora (Habitats Directive). If a proposal is considered to have a significant effect on the conservation objectives of a Community Site an appropriate assessment will be required. In light of the conclusions of the assessment of the implications for the site, the competent national authorities agree to the plan or project only after having ascertained that it will not adversely affect the integrity of the site concerned. Emissions, noise and the impact on water (surface or groundwater) are likely to be among the factors to be analysed in the context of a deep geothermal project.

Emissions

All geothermal plants have to meet various national and local environmental standards and regulations, although emissions are not routinely measured below a certain threshold, which emissions from geothermal plants typically fall below. The pollution control regulations provided for EGS systems are no major obstacles for permit granting. Only noise limits may be of relevance, with regard to the cementation of the pipes and the hydraulic test work.

Grid access

For a geothermal power project, grid access is a key preliminary condition to sell the electricity produced and secure revenues. For this reason there is a need of clear and non-discriminatory rules: on the European level the RES Directive addresses these issues in Article 16:

Art. 16, 2

(a) *Member States shall ensure that transmission system operators and distribution system operators in their territory guarantee the transmission and distribution of electricity produced from renewable energy sources;*

(b) *Member States shall also provide for either priority access or guaranteed access to the grid-system of electricity produced from renewable energy sources;*

Art. 16, 3

Member States shall require transmission system operators and distribution system operators to set up and make public their standard rules …

The above provisions constitute specific legislation for the connection and dispatching of electricity generating installations using renewable energy sources. They are complementary to Directive 2009/72 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC which setting the "*lex generalis*" for the electricity sector and thereby applies to geothermal power plants as well.

It is of the utmost importance that these provisions are correctly implemented on a national level.

Chapter VI – Implementing a geothermal project: case studies

Having in mind the basics, the necessary expertise requires, risks, costs and financial instruments for each phase of a geothermal project as well the legal requirements to be met, the following chapter shows two concrete –though theoretical- case studies: an EGS project in Germany and hydrothermal plant in Iceland.

The Case for an EGS project in Germany

This first case-study shows the economics of a standardised EGS project in North-Germany, with about 50 litres of water per second, at a temperature of at least 165°C, exploited at a vertical depth of up to 5,500 meters by means of a double well. An ORC (organic Rankine cycle) process is employed, with cooling to about 60°C; the annual average output of the power station amounts to about 3 MW_e (Figure 20).

„Simulation" of an EGS electricity project in Germany

Project features	
geothermal gradient in °C/100m	2
flow rate in l/s	50
delivery temperature in °C	165
temperature after power plant process in °C	60
number of wells	2
drilling depth per well in m	5.500
geothermal nominal capacity in kW_{th}	**21.000**
electricity generation nominal capacity in kW_{el}	**3.040**
degree of efficiency	14,75%

Figure 19 Project parameters of the sample EGS project

For a three-megawatt project with ORC process, an investment of about € 48 million, including the negative cash-flow (interest) during the construction period, is required. Thus, the costs per installed MW come to about € 16 million (Figure 21).More than half of the investments are used for the drilling (Figure 22).

	year 1	year 2	year 3	year 4	
seismics / preparatory arrangements	1.000.000	0	0	0	
land, drilling site	0	1.500.000	0	0	
wells, reservoir stimulation	0	0	26.800.000	0	
discovery and builders risk insurance	0	0	4.060.000	0	
delivery, injecting pumps	0	0	0	1.020.000	
power plant	0	0	0	12.170.000	
grid connection	0	0	0	500.000	
planning, consulting, project management	0	450.000	450.000	450.000	
SUM	1.000.000	1.950.000	31.310.000	14.140.000	48.400.000

=> ca. 2 Mio. € / 1.000 m MD
(wells >5.000 m TVD and 6 1/8" diameter at total depth including stimulation measures and contingencies)

constructors all risk insurance including lost in hole for both wells, discovery insurance for one well

plus reinvestment of ca. 12 Mio. € for pumps and power plant field (if it is considered reasonable)

Figure 20 Investment overview of the sample EGS project

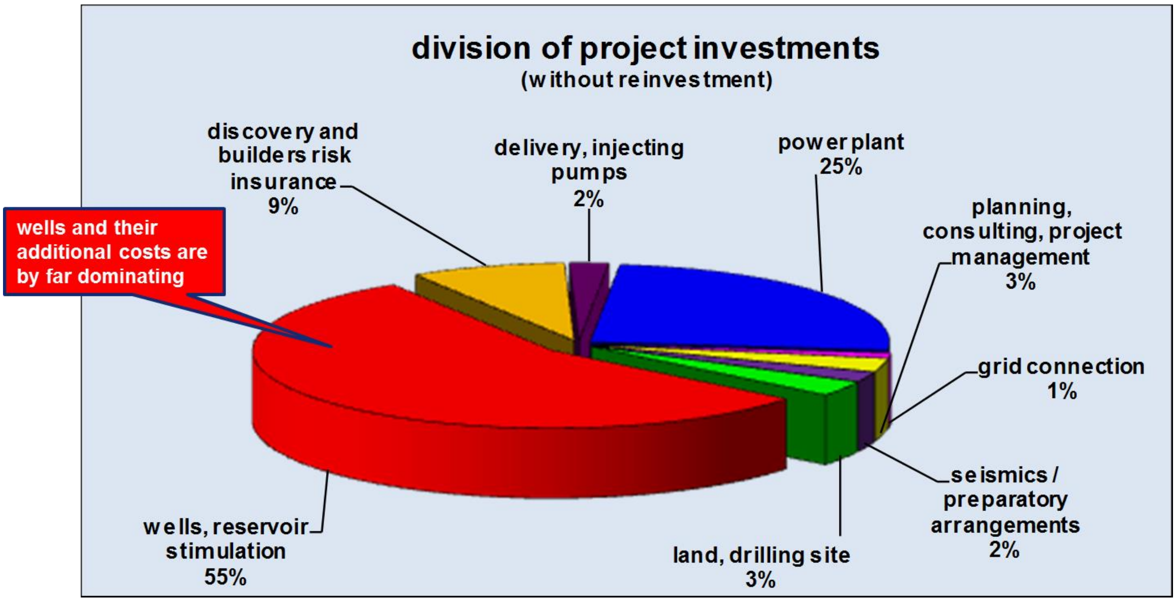


Figure 212 The apportionment of the investments of the sample EGS project

Boreholes to depths of > 5,000 m present particular challenges and risks. Because of the exploration risks, the project will need to be entirely or largely self-financed, even when risk insurance is obtained — for which proven policies are available — until after the successful completion of the long-term pumping test, before the shift from exploration to project financing can take place (s. Figure 23). In this case-study country-dependent support schemes are not considered.

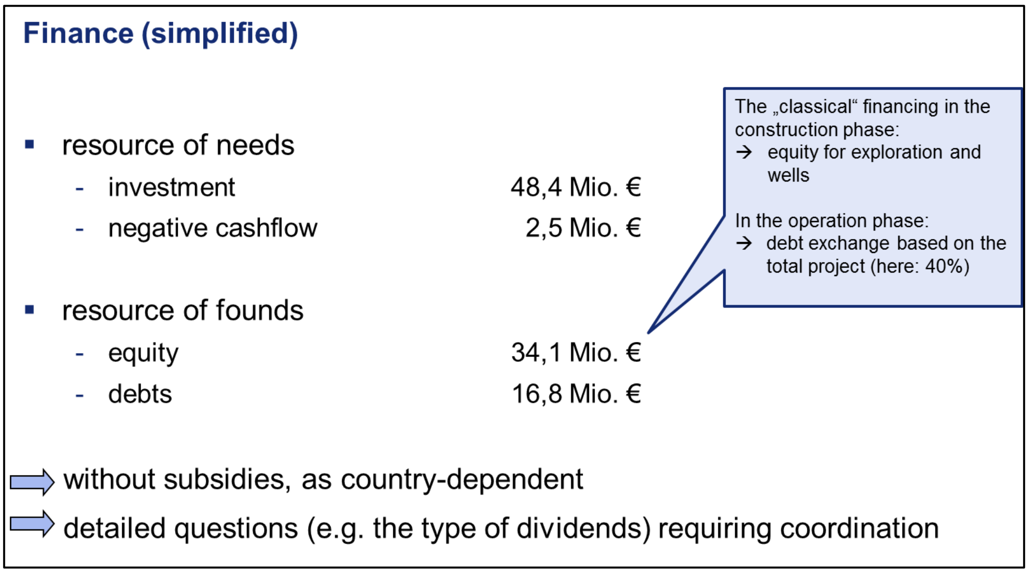


Figure 223 Financing of the EGS sample project

Starting operation in project year 5, sales revenues of €30 per MWh will be derived from the EEG feed-in tariff (year 2012). The example assumes an electricity price rate increase of 4%. From an economic point of view, this would mean that a portion of the electricity could be used onsite - in particular for the thermal water pump and general operating power - beginning in the project year 21. The electricity would not have to be sold on the open market until after the end of the EEG feed-in-tariff payments, which is 20 years plus the year of commissioning (project year 26). Depending on how the market develops, the transition could be made earlier if electricity prices increase at a faster rate.

On the expenditure side, the picture is shaped by the debt service (interest and depreciation) and cost of materials for purchased electricity until project year 21, after which self-generated electricity is consumed onsite (Figure 24).

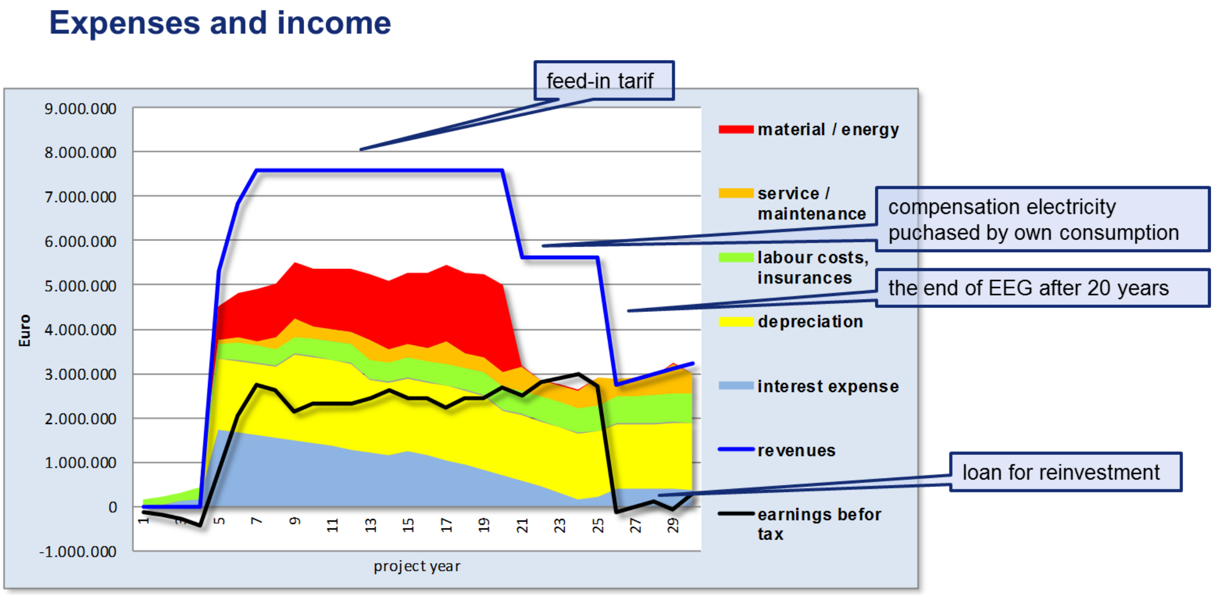


Figure 234 Expenses and incomes of the EGS sample project

Assuming a planning, construction and commissioning phase of 4 years, this project will reach the break-even point in project year 5, i.e. the first year of operation. In the diagram (Figure 25), this is illustrated by the fact that the EBT (earnings before taxes) curve is positive from the start of operations. Because the feed-in tariff remains constant, the profits in the electricity project rise only once the decrease in interest payments more than compensates for the increasing cost of materials . A falling EBITDA curve (earnings before interest, taxes, depreciation and amortisation) is therefore typical of electricity projects. The EBITDA should also continue to remain significantly higher than the payment burden for the debt service and any reinvestments, so that the borrowing capacity of the project is sustainably ensured from the bank's perspective. The kink in the curve after 21 years of operation marks the end of the feed-in-tariff payment period and takes the sales back to (slightly lower) market prices.

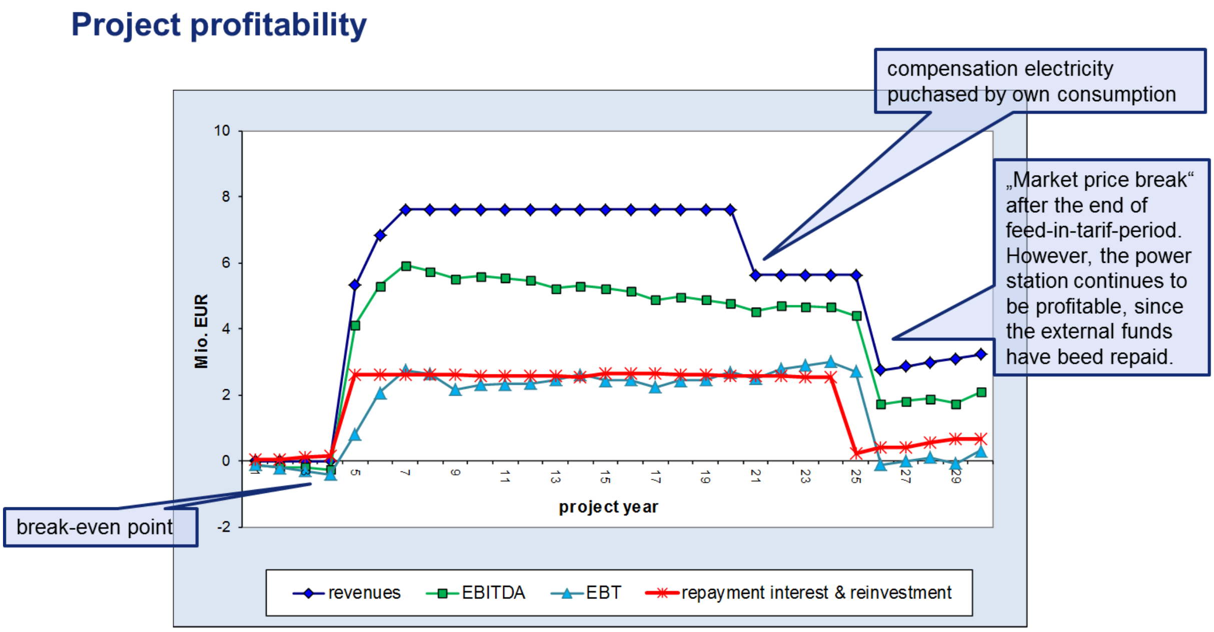


Figure 245 Project profitability of the EGS sample project

The internal rate of return on the free cash flow — the project rate of return before financing — during the analysis period of 30 years is for this project around 7% before tax. The calculations show how essential the feed-in-tariff is for the geothermal electricity generation.

A Hydrothermal project in Iceland

In this second case-study, the economics of a standardised power project in Iceland is showed. About 83 kg of water per second with the enthalpy of 1700 kJ/kg, are exploited at a vertical depth of up to 2500 meters. Each well can provide around 5 MW_e and the annual average output of the power station amounts to about 45 MW_e (s. Figure 26).

Project features	
flow rate in kg/s	83
delivery enthalpy in kJ/kg	1.700
number of production wells	9
number of injection wells	2
drilling depth per well in m	2.000-2.500
electricity generation nominal capacity in kW_{el}	**45.000**
parasitic load in kW	2.000
operation duration in h/year	8.322

Figure 256 Project parameters of the sample flash project

The time duration for such a project is around four years (s. Figure 27).

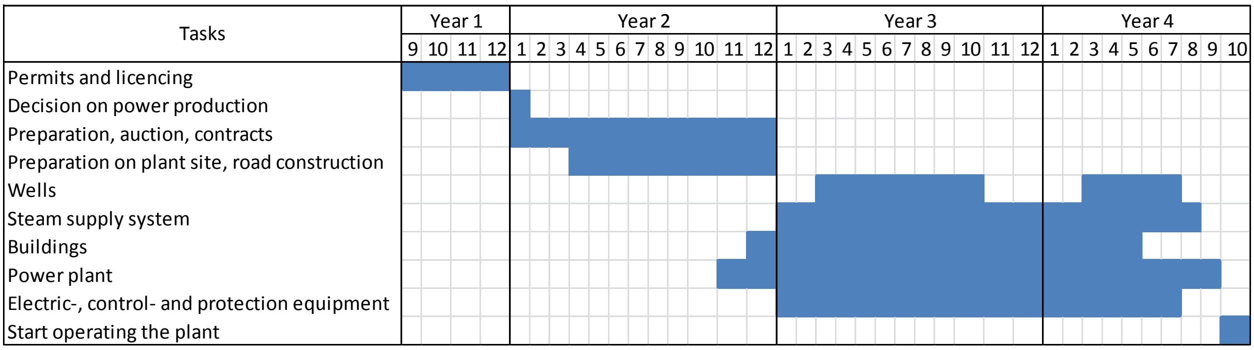


Figure 267 Time schedule for the sample flash project

For the 45 MW_e project with flash power process, an investment of about € 103 million during the construction period, is required. Thus, the costs per installed MW come to about € 2,3 million.

	year 1	year 2	year 3	year 4	Total sum
wells, reservoir stimulation	10.320.000	9.920.000	0	0	20.240.000
fresh water supply	0	500.000	170.000	0	670.000
buildings	1.170.000	7.010.000	2.340.000	1.170.000	11.690.000
steam supply system	640.000	4.300.000	3.580.000	0	8.520.000
power plant	0	3.150.000	26.760.000	1.570.000	31.480.000
grid connection	0	2.760.000	3.600.000	0	6.360.000
planning, consulting, project management	2.770.000	2.770.000	2.770.000	2.770.000	11.080.000
contingency	3.180.000	3.180.000	3.180.000	3.180.000	12.720.000
SUM	18.080.000	33.590.000	42.400.000	8.690.000	102.760.000

Figure 278 Investment overview of the sample flash project in €

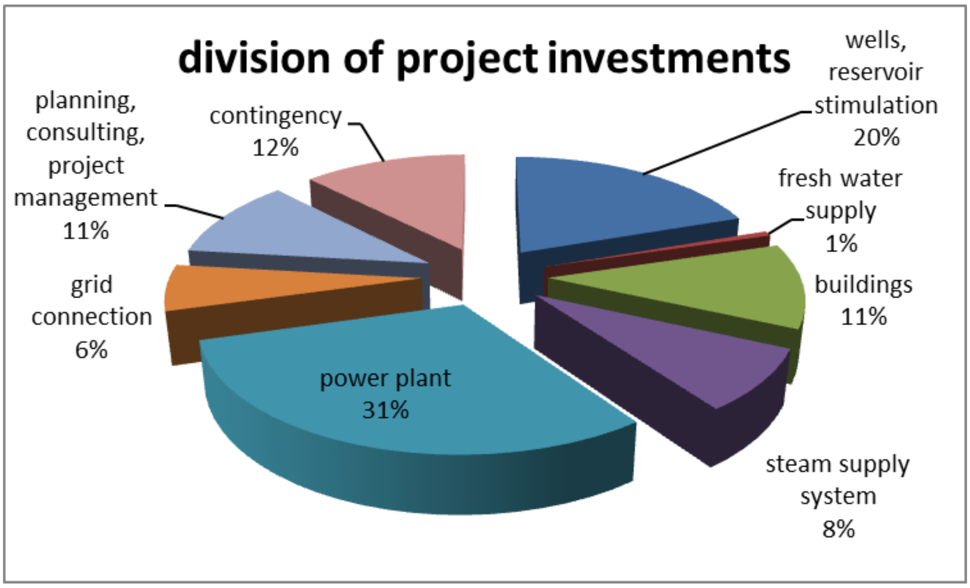


Figure 289 The apportionment of the investments of the sample flash project in €

The Levelised Cost Of Energy methodology is described in the chapter for the EGS case study in Germany. The LCOE of this project is calculated with the following equation:

$$LCOE = \frac{Equity\ share\ [€] - Discount\ revenue\ [€]}{Discounted\ energy\ sales\ [MWh]} = 32\ €/MWh$$

Here the *Equity share* is 20% of the total investment cost, the *Discounted revenue* for a 30 years interval and the *Discounted energy sales* are the Net Present Values (NPV) of the sold electricity for 30 years.

As mentioned before, the average LCOE for geothermal projects is between 30-145 €/MWh so this project has a rather low LCOE for a geothermal project. The taxes for geothermal projects in Iceland are relatively low and this is a flash power plant with high efficiency.

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