Interreg
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North-West Europe
DGE-ROLLOUT

Report Financial Risk Management

Deliverable T1.3.2

Burcu Tasdemir (GD NRW)
Martin Arndt (GD NRW)

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Disclaimer

The purpose of the following report is to give a short overview of financial risk management of DGE projects. It should provide general information to local, regional, and national public authorities, project developers, politicians and enterprises with heat demand. However, this report does not replace the own independent research on this topic. Appropriate financial risk management is the fundament of a successful DGE project and has to be done carefully by a professional to avoid insufficient work which ultimately leads to financial losses.

We cannot guarantee on the accuracy, reliability, correctness or completeness of the information and materials given in this report and accept no legal responsibility. For further readings, more information and the accuracy on the here exemplarily mentioned support schemes and financing methods please refer to the literature mentioned herein.

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List of abbreviations

ADEME: Agency for ecological transition (FR)

BAFA: Federal Office for Economic Affairs and Export Control (DE)

BMUB: Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (DE)

BMWi: Federal Ministry for Economic Affairs and Energy (DE)

BVG: German Geothermal Association (DE)

CCS: Carbon Capture & Storage

CF: Cohesion Fund

DGE: Deep Geothermal Energy

DRIEE: Regional and Interdepartmental Directorate for the Environment and Energy

EAFRD: European Agricultural Fund for Rural Development

EC: European Commission

EDF: European Development Fund

EEG: Renewable Energy Sources Act (DE)

EEWärmeG: Renewable Energy Heating Act (DE)

EGEC: European Geothermal Energy Council

EGRIF: European Geothermal Risk Insurance Fund

EGS: Enhanced/Engineered Geothermal System

EIA: Energy Investment Allowance (NL)

EIB: European Investment Bank

EMFF: European Maritime and Fisheries Fund

EP-Plus: Ecology Plus (NL)

ERDF: European Regional Development Fund

ESF: European Social Fund

ESIF: European Structural and Investment Fund

ETIP-DG: European Technology & Innovation Platform on Deep Geothermal

EU ETS: European Emission Trading Scheme

FIP: Feed-in premium

FIT: Feed-in tariff

GEF: Global Environment Facility

GEODEEP: French Geothermal Cluster for Heat and Power

GEOELEC: Geothermal Electricity in Europe Project

GeoFAR: Geothermal Finance and Awareness in European Regions

GEORiMi: Geothermal Risk Mitigation System

GHG: Green House Gas

GNI: Gross National Income

GRI: Geological Risk Insurance

IEE: Intelligent Energy Europe

IRENA: International Renewable Energy Agency

JV: Joint Venture

KfW: German Development Bank (DE)

LCOE: Levelized Costs of Energy

LTR: Long-term risk

MAP: Market incentive programme (DE)

NER300: New Entrant's Reserve 300

NWE: North-West Europe

PPA: Power Purchase Agreement

PPP: Public Project Partnership

Q: Flow rate

R&D: Research and Development

RD&I: Research, Development and Innovation

RE: Renewable Energy

REScoop: Renewable Energy Sources Cooperation

SET: Strategic Energy Technology

SME: Small and medium-sized enterprises

STR: Short-term risk

STRES: Strategic ecology support (NL)

T: Temperature

TRL: Technology Readiness Level

UDDGP: United Downs Deep Geothermal Power Project

VLAIO: Agency for Innovation and Entrepreneurship (NL)

VLIF: Department for Agriculture and Fisheries (NL)

Introduction

In times of climate change and its unpredictable impact on our environment, alternatives for lignite-fired power plants and heating systems emitting GHG's are needed in North-West Europe (NWE). Although the demand for renewable energy increases, the potential of deep geothermal energy (DGE) as a local source of cost-effective and baseload capable energy received less attention by now. One major source of CO_2 is the production of electricity and heat by the combustion of fossil fuels. This, could, at least in parts, be replaced by deep geothermal energy (DGE). Other advantages are the production of electricity and heat by a cascade approach where remaining thermal energy can be used for e.g. district heating, heating of industrial processes, thermal baths etc. Such a cascade system increases the financial profitability of a project (Fraser *et al.,* 2013). Compared to other renewable energy alternatives, geothermal is suitable for baseload production by having the ability to continuously feed into the energy system, i.e. a flexible generation of electricity and heat/cold is the main advantage of geothermal.

However, the exploration of DGE in most NWE regions requires specific expertise and technologies in the complex geological situations (e.g. strongly faulted highly permeable carbonates and clastic rocks) across the borders between France, Belgium, Germany, and the Netherlands.

The vision of the DGE-ROLLOUT project, as part of the EU-funded Interreg programme, is to foster the expansion of deep geothermal energy as a climate and environmentally friendly energy resource in North-West Europe, and subsequently nurture the regions economics and the wellbeing of the citizens. DGE can be used in NWE for large-scale infrastructures requiring high-temperature heat supplies to cover their basic energy loads. This will be achieved by the work packages Mapping and Networking (WP T1), by the application of innovative decision, exploration strategies of Work package T2 and testing for production optimization (Work package T3).

Deliverable 3.2 is part of Activity 3 (Legal framework and outlooks) within the work package WP T1 (Mapping and Networking). It aims to prepare the market by providing information about possible financial barriers, needs, and risk factors of deep geothermal technologies in Europe and their respective management. The financial schemes and insurance funds shown here differ per country.

Approach

The aim of this report is to present an overview of different existing financial instruments that can be used by geothermal project developers, local/regional/national public authorities and enterprises to fund DGE projects and reduce costs. It provides guidance for project planning, geological risk management, the decision of the right finance scheme and gives recommendations on how to improve the existing funds. The collected data is based on existing work on DGE, near-surface geothermal energy, previous and current projects (e.g. GEOELEC, GeoRisk, EGEC), and the contributions of the project partners (Belgium, France, Netherlands and Germany) regarding finance insurance schemes in their countries. Therefore, the report will include a comprehensive picture detailing the cost structures of geothermal projects by considering three case studies with different reservoir approaches and data of active geothermal heat and power plants in Munich. After estimating the expenses and revenues, the different financial support schemes are given and discussed by pointing out two existing insurance principles. The available public support schemes are sorted by technology and market maturity, since not every support scheme suits the market needs, it is essential to choose the right scheme to overcome related subsequent costs. Innovative financing methods – a relatively new and promising support instrument which should attract the private funding – will be described and further discussed.

However, the presented schemes are still generalized incentives and do not include the large variety on the scale of technology, final utilization, or degree of maturity. There is still improvement in existing finance frameworks needed, which will be part of the last chapter in this report together with other challenges that deep geothermal energy projects generally face.

1. Geothermal Project Development

In this section, the implementation stages of a geothermal project are shortly described. They require precise work stages, consisting of an initial conceptual investigation, a preliminary planning stage, the execution of a pre-feasibility study, drilling of exploratory boreholes and ultimately the exploitation of the geothermal reservoir. During the initial stages of the project planning phase (Fig. 1), existing geological and seismic data is used to select and define areas with a high probability of geothermal potential. Before the initiation of the first drilling operation, the geological feasibility of the reservoir

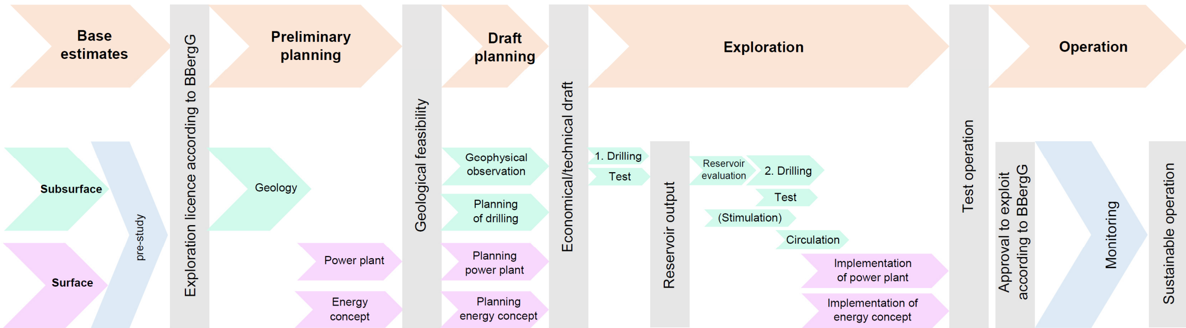

Figure 1: Schematic representation of a geothermal project development in Germany (modified after VBI Tiefe Geothermie, 2010). The different stages (orange) can be subdivided in subsurface (green) and surface (purple) investigations.

is evaluated by considering both the geological parameters (e.g. thickness of the potential reservoir, fractures, permeability and porosity etc.) and economical sustainability (see chapter 1.1 “Preliminary planning”). Together with the obtained permits and licences, the exploration phase starts with the first drilling operation to confirm and investigate reservoir characteristics and outputs (e.g. lithological characteristics and petrophysical parameters). If the results lead to a negative outcome, the project may be abandoned at this stage. However, if the first exploration drilling is successful further drilling operations will be initiated to collect more data concerning the subsurface conditions. The surface facilities including the power plant are implemented at the end of the exploration phase and are commissioned after a testing and approval phase. The average geothermal project requires between four to seven years which is more than to deploy other renewable technologies (1.5 years) or conventional sources such as oil and gas (3.5 years).

The following sub-sections describe the development stages in more detail.

1.1 Preliminary planning

This development stage represents the basis for conducting a transparent and reasonable geothermal project approach. It begins with surface and subsurface investigations by considering geological and hydrogeological aspects as well as energy and utility engineering. For the basis evaluation, the subsurface conditions are investigated with existing geological and seismic data including: lithological sequences, thickness of the potential reservoir, permeability and porosity, orientation of known fault systems, thermal and hydraulic conditions, and hydrochemical characteristics of the groundwater. These data can generally be obtained by the State Geological Surveys. For a long-term evaluation of the geothermal heat/power plant, comprehensive fluctuation measurements and modelling of the reservoir characteristics which could lead to a decrease in heat supply are also part of this project stage. Prior to the implementation of the power plant, a suitable reinjection temperature has to be estimated within the scope of a sustainable reservoir exploitation. The distance of the wells together with the holder length, depends both on the results of the mentioned parameters as well as on the geological and thermohydraulic subsurface models. Also, a geothermal-economic feasibility study mainly considering geological, petrophysical, engineering, mine surveying and potentially social aspects has to be carried out during the preliminary project planning. This feasibility study serves as a basis for the subsequent technical concept which aims to provide information about sustainable utilization of geothermal energy aboveground. It also includes a demand analysis for different consumption purposes considering the annual useful heat, thermal output (i.e. heating load), a sorted load duration curve, and the allocation of the flow and return temperature within the local heating grid. Uncertainties regarding the reservoir temperature and flow rate which depends on different geothermal reservoirs are also involved in the analysis.

For a suitable heating and power system, the possible supply technology must be examined by aspects of ecology, exploitation, investment, security of supply, required space, flexibility, and public visibility. After the system selection, the current account, the energetic balance, the CO_2 abatement costs as well as the primary energy balance and the emissions balance should be adapted. Other profitability calculations include different levelized energy cost scenarios, sensitivity analysis for interest rate, and possible expenses, which will be further discussed in section 2 “Cost structure”. Prior to the following exploration phase, existing geophysical data are evaluated, reprocessed and if necessary complemented by additional seismic exploration in the target area. With these seismic data, the thickness and depth of the potential geothermal reservoir can be estimated prior to the first drilling operation, thus preventing drilling failures.

1.2 Exploration and exploitation phase

The exploration phase is a crucial part of a successful geothermal project and starts after permits and licenses are obtained as well as a technical and economical draft is developed for the investigation area. The initial part of this exploration phase is mainly equity-based and financed due to loans with an indemnification clause. It starts with the first drilling operation which either fits the theoretic 3D models or exhibits a non-viable reservoir in terms of temperature and flow rate. If the drilling reaches the potential reservoir during this phase, borehole measurements and well tests are carried out. In case of low capacity due to a reduced flow rate, stimulation operations can be considered to improve the permeability of the reservoir. This stage of the project takes several years (Laenen *et al*., 2019) depending on the accessibility of the geothermal field with the first drilling operation and the reservoir conditions (Micale *et al*., 2014). After the first successful exploration drilling, the reservoir is evaluated and the well field is being developed with a minimum of one production and injection well (doublet). With the well field development, the main stage of financial risk is overcome (see. Fig 4) and the implementation of an energy concept and the construction of the power/heat plant is initiated. With the beginning of the commissioning phase, the project owner ensures carrying out necessary maintenance work to mitigate long-term effects on wells and the plant itself. On average, a power/heat plant operates 20 to 30 years (Micale *et al.*, 2014).

1.3 Risk components

The implementation of a geothermal project requires the collaboration between various overlapping fields of knowledge (such as geology, engineering, and plant operation), which causes a wide variety of risks. Therefore, thoughtful management and careful preparation play a major role for the success of such a project. The crucial point for each investor is the first drilling which constraints the productivity of the geological source and thus validates the feasibility of the project. Even with the best preparation and most advanced drilling technologies, there is no absolute certainty that the source will cover the necessary heat and flow rate to feed the demand. However, there are many other risks that can be omitted or reduced for the most part, if the management and the communication within and about the project are thoroughly carried out.

The most important step for risk reduction is the evaluation of all available data, tests and analyses. It is also recommended to get and stay in contact to proven experts throughout the project. A good preparation saves a lot of costs, especially in drilling (Jacobi and Neu, 2014). Preliminary studies amount for about 7% of the total costs of a geothermal project. The first drilling is considered to cost up to 30%, the second drilling 20%. The remainder is needed for the power plant construction. The results of preliminary studies may lead to the cancellation of the project; however, they potentially prevent the investment from an expensive and unsuccessful drilling campaign (Jacobi and Neu, 2014). With a careful preparation, the risk of the first drilling may be reduced a little. After the validation of the source's productivity, the risks for the second drilling and the power plant installation are reduced significantly.

Despite all efforts that are put into one geothermal project, there is always a residual risk, which affects the investment into one power plant more than the investment into several (Jacobi and Neu, 2014). Large-scale investments therefore promise a higher probability for success. It is recommended to calculate a sufficient reserve for the investment between 15% and 30% to cover unforeseen costs. This number is verified and used by different companies for drilling and building (Jacobi and Neu, 2014).

In the following subchapters, a selection of possible risks is presented in the light of project and finance management, the geological reservoir and the power plant operation. A more detailed overview is given by Jacobi and Neu (2014).

Project risk

Project risks can arise at any point of the project. They comprise the organization of the project as well as political, economic, legal and social aspects.

Frequently underestimated risks arise from approval procedures, which may cause severe delays. If the investment is time-bound, the investor needs to ensure the contact to the respective authorities and needs to be prepared for possible obligations to react accordingly. Contracts and responsibilities should clearly be assigned and leave no grey areas. Last but not least, the public should be informed in all possible ways in advance to prevent citizens initiatives.

Financial risk

The financial risk of a geothermal project can be subdivided into two main components: Liquidity risk and interest rate risk (Jacobi and Neu, 2014). Although not all of these risks are likely to occur and the following support schemes do not cover all of these particular risks, they still have an impact on the success of the project and have to be considered in the risk management. The liquidity risk involves payment defaults, diminishing returns, and increased expenditures, which are related to different reasons. These reasons can be, for example, the unavailability of liquid means, bad debt losses, extended date of payment or bad profitability. The interest rate risk concerns wrong interest deadlines, inconvenient margins of interest, and inconvenient interest structures as the result of, for instance, credit raise, high interest costs during refinancing purposes, and changing of interest structure, among others.

Resource risk

The resource risk is determined by the following aspects:

- Reduced productivity (flow rate, temperature)
- Low Injectivity
- Chemical composition
- Unintended secondary production (carbohydrates, radioactivity)

Despite all modern analytical methods, it is not possible to make reliable predictions before the test drilling. According to experiences, about 30% of the drillings do not deliver the expected results. This is still a small number compared to the average error ratio of 50% in worldwide exploration practice. If the reservoir is not productive, the well has failed. If the productivity is reduced (to a certain degree), technical solutions (e.g. the implementation of a binary system) may secure the project from failing. It is recommended to consider all possible aspects of productivity parameters and define feasibility boundaries before the first drilling (Jacobi and Neu, 2014).

Drilling risks

Drilling risks may have a geological, technical or human background. Cutbacks in the drilling budget may cause unforeseen consequences. Insufficient supplies of tools and chemicals can cause the delay in drilling and thus increasing costs. The main reasons for drilling delays are, among others, poor knowledge of the subsurface, unexpected fault zones, wrong depth of the reservoir, flushing-losses, drill pipe failure, loss of drill bit, secondary productions, dropped tools into the borehole.

Plant operation risk

Plant operation risk begin with the conception of building the power plant. Failures in planning, unclear agreements and contracts as well as poor time management can lead to delayed delivery of important components. Therefore, a concept should be designed and regularly checked while the power plant is operating. During the operation of the plant, the operator should be prepared for the loss of production and needs to enforce concepts for work safety, health protection and environmental issues.

2. Cost structure

Deep geothermal projects are, compared to other renewable technologies, capital-intensive initiatives during the early stages of project development. They require large upfront investments to cover the resource risks (Section 1.3 “Risk components”) without a proven viability of the project, which often prevents private financing and full competition with conventional and established technologies. This likely means, that 25-50% of project costs must be invested when there is a very high level of uncertainty on success of the project. In addition, the return of equity investments can add up depending on the time span of the development stages and the actual start of operation.

For this section, the possible costs of both the drilling and plant operation is summarized. Since not every geothermal reservoir has the same efficiency, electricity can be produced in many different processes a short repetition of possible geothermal energy types is given. They are crucial for the variable cost structures of geothermal projects and should strongly be involved in financing incentives. There are four different geothermal energy types that can be distinguished:

(1) conventional high temperature,

(2) low temperature,

(3) enhanced geothermal system (EGS), and

(4) supercritical fluids.

The main target use for high temperature geothermal energy is electricity generation by dry steam or flash steam plants due to a water saturated reservoir with temperatures above 180°C. It is also used for district heating if a heating grid is installed and for agriculture applications (e.g. Greenhouses: Gemüsebau Steiner in Kirchweidach[1], Munich; Wijnen Square Crops[2], Venlo). In case of low temperature geothermal reservoirs, the heat is directly exploited for urban heating purposes. Heat pumps are added to optimize the exploitation of the reservoir. It can also be used for electricity production by the implementation of a binary plant (Organic rankine cycle (ORC)[3] and Kalina cycle[4]) which usually operates with water-temperatures from 75 to 180°C.

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[1] The greenhouses of Gemüsebau Steiner in the region of Kirchweidach (Munich, Germany) with a total farmland of 11.4 ha are sustainably heated by the nearby geothermal heat plant (95%) and through their own biogas plant (5%). The geothermal heat plant also provides district heat to the municipal of Kirchweidach and the return flow is also provided to the greenhouses (Gemüsebau Steiner, 2020).

[2] The Wijnen Square Crops in the Netherland uses geothermal energy to heat their greenhouses located in the region of Californië. The temperature of the reservoir at a depth of nearly 3,000 m reaches 78°C and is supplied by two separate wells. Through the usage of geothermal as sustainable heating source, the company has reduced their annual CO2 emissions by nearly 90% (Wijnen, 2020).

[3] ORC is a thermodynamic cycle almost similar to a steam plant, expect the actual steam is replaced by an organic fluid (e.g. butane or pentane) with a low boiling point. Through heat supply, the very fluid vaporizes isothermally and runs the connected turbine. The latter is activating a generator which supplies electricity to the nearby grid. After passing the turbine, the work fluid is cooled in a condenser within a cooling tower and is used again (VBI Tiefe Geothermie, 2010).

[4] The Kalina process is based on the change in concentration of an ammonia-water mixture which reacts with desorption during heat supply and absorption when heat is removed i.e. the decrease in ammonia concentration lowers the boiling point of the fluid. Compared to steam plants, Kalina systems have the advantage that they can

Enhanced or engineered geothermal systems (EGS) are underground reservoirs that have been created or improved artificially. They are mainly used for power production. The supercritical zones are geothermal fields with very high temperatures up to 500°C at relatively shallow depths (<5 km). It is expected that these reservoirs can provide 5-10 times more energy per volumetric flow compared to geothermal power plants using condensing turbines.

In the following, three different types of geothermal power plants are compared in regard of their capital cost: (1) 20 MW_e (high temperature flash plant), (2) 5 MW_e (EGS plant), (3) 10 MW_{th} (district heating plan, based on doublet technology) (Laenen *et al.*, 2019). At the beginning of the project with activities such as screening of the reservoir, permitting, planning, financing of project costs, the upfront costs can come up to 10 Million €. The planning and exploration phase with examination of surface structures, geophysical measurements, 3D modelling and drilling operations can approximately reach up to 7 Million € without considering the drilling and development costs of the power plant (20-30 Million €).

The cost for the power plant construction depends on the capacity and technology, which is used (5-15 Million €). While a high-temperature power plant with a capacity of 20 MW_e can reach 33-62 Million € (Fig. 2), an EGS power plant with a lower capacity can cost up to 47 Million €. A doublet-based power plant with a capacity exceeding the one of the EGS plant can range between 13 Million € and 20 Million €. Also, for the heat plant construction (5 Million €), the installation of a district heating grid has to be considered (1 Million €/km) in the cost structure.

Compared to hydrothermal technologies, the EGS reservoirs require stimulation, which bears a high-risk component owning to the uncertainty on potential capacity. The capital costs for different technological maturities, represent a key factor in the final price of the geothermal power or heating/cooling plant. Besides this, the costs are determined by the costs of each project phase, i.e. a more expensive exploration can lead to a reduction of the subsequent drilling costs. It is also defined by the size of the plant, the temperature of the reservoir and the geographical location. Compared to low temperature plants, higher reservoir temperatures lead to decreased levelized investment costs[5]

run at low temperatures making them more viable. However, ammonia in high concentrations is toxic which makes Kalina cycles a less attractive way to produce electricity (VBI Tiefe Geothermie, 2010).

[5] Levelized cost of energy (LCOE) is the average cost of constructing and operation a plant per unit of total electricity generated.

of the projects (Micale *et al.*, 2014). Therefore, technologies for low temperature reservoir have to be improved to lower the investment costs.

The GGSC has also analysed the costs of a geothermal heat plant with a capacity of 41 MW for a small municipal in Munich with an average of 12,000 citizens and a small existing heating network which had

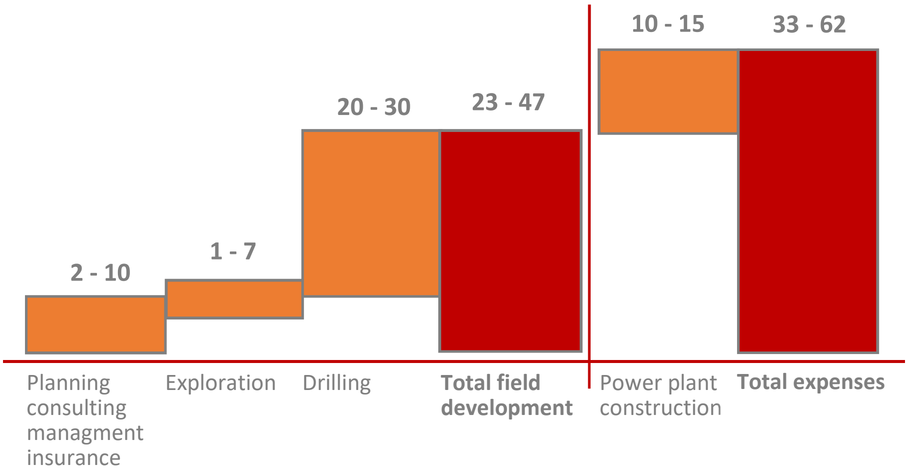

Figure 2: Cost range of the development of a 20 MWe convetional high temperature geothermal power plant (Laenen *et al.*, 2019).

to be completely constructed. The overall investment for such a project can at least come up to 46-97 Million €. By breaking down the overall costs, the main investment is consumed by the heat distribution and delivery to the costumer (10-66 Million €). The exploration phase with planning, drilling and doublet can range between 10 and 11 Million €. The main investment arises during the first years of a DGE project with nearly 50% cost to cover. Revenues are achieved successively due to grid extensions which leads to a lagged delivery to the costumers. However, the redemption of high initial investments together with the negative cashflow can aggregate to at least 3.5 Million €. To overcome the high equity and low rate of return offered by national banks (3.5-5%), a revenue support is needed additional to the national risk insurance schemes which are presented in section 4 "Mechanisms for funding".

Despite the capital intensity of geothermal power/heat plants mentioned herein, these technologies have low costs per unit of electricity generated in respect of their high capacity factors[6] (EGEC, 2017), which can go up to about 90%. The average levelized cost of energy (LCOE) for geothermal energy is the cheapest among renewable energy options (see Fig. 2 in Dumas and Angelino, 2015) (Fig. 3) i.e. it has low operation costs and high production revenues. There are also no extra costs neither regarding back up requirements, transmission nor for the distribution infrastructure.

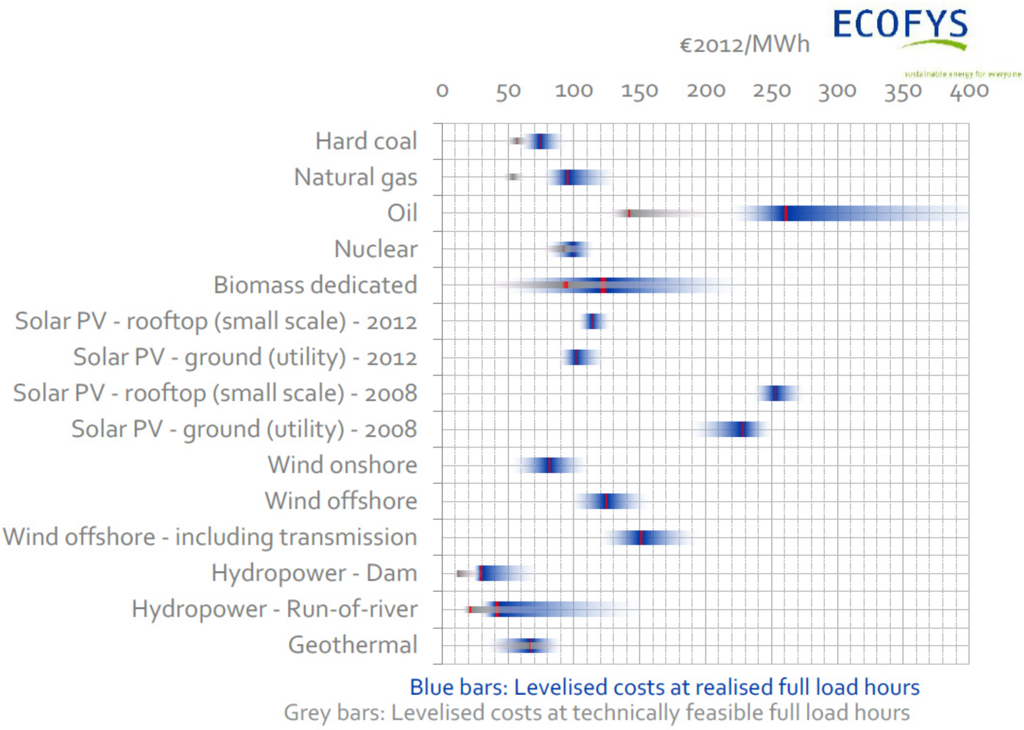

Figure 3: Levelized costs of energy for different technologies for the year 2012 (ECOFYS, 2014). Red lines indicate the median value for the range.

[6] Capacity factor is the ratio between the annual electrical energy production and the maximum technological production.

3. Risk insurance schemes

The main motivation for risk insurance schemes is to compensate for energy market failure, unfair competition in the existing electricity sector and the creation of a secure investment environment for geothermal projects. However, developers struggle to find public or private insurance schemes for the resource risk, since many countries count no sufficient number of geothermal operations in the EU to provide statistical data for success measurements (Dumas and Garabetian, 2019). Nevertheless, specific financial factors like poor knowledge of the deep subsurface, no access to private funding due to high requirements in commercial viability on technological progress and possible cost reductions of

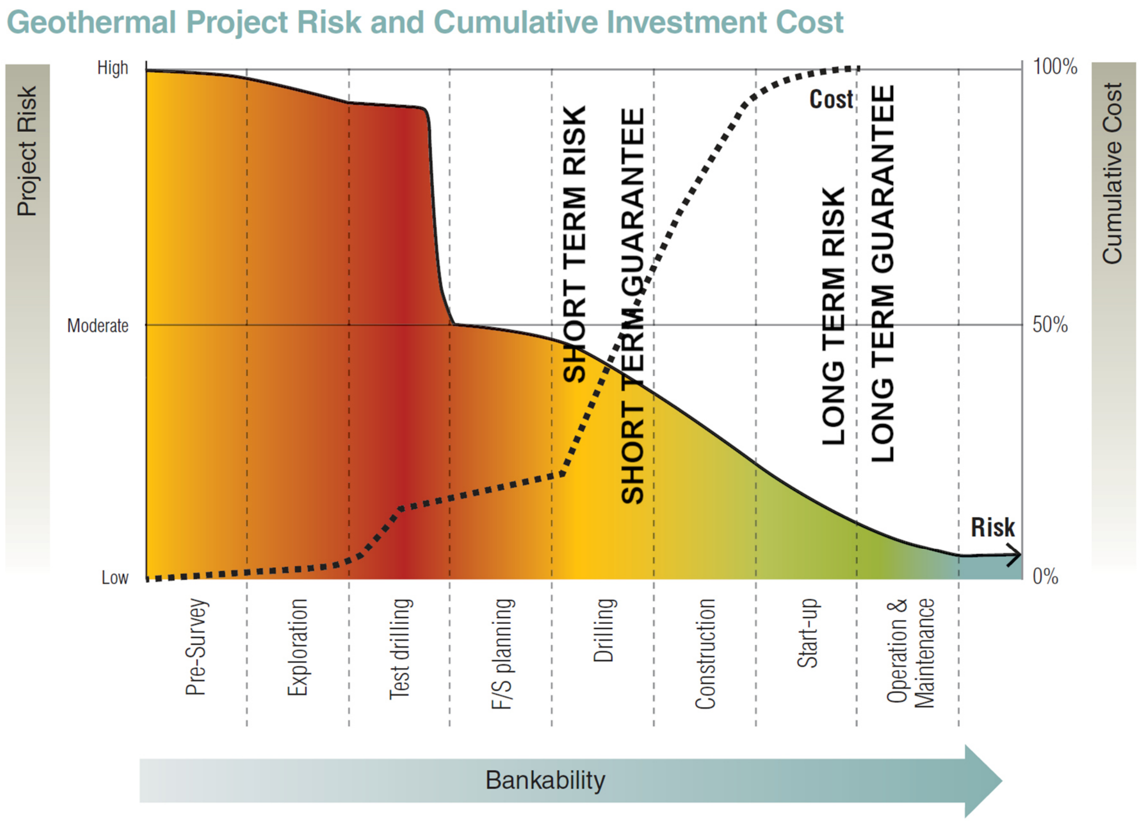

Figure 4: Diagram showing the project risk of a deep surface exploration and cumulative investment cost (modified after Gehringer and Loksha (2012)).

electricity (Levelized costs of energy; LCOE) need to be insured. There are still some public support schemes to mitigate the resource risk and to alleviate shortage of insurance policies. These public schemes are supported by public money as seed capital. After reaching maturity of the geothermal market, the support is supposed to phase out and, in theory, become replaced by private schemes (Dumas and Angelino, 2015). The private sector involves financial institutions, insurance companies and private stakeholders. After a fund is launched, the insurance system then relies on different sources of income: premiums, fees, proceeds of investments made with treasury, taxes on electricity transmission and public funding. The more diversified the income sources are, the more stable the fund (Fraser *et al.*, 2013).

The application to such a fund requires different technology readiness levels (TRL)[7] and is examined with regard to the following eligibility criteria. The latter can be divided into technical, financial/economical and legal criteria. The technical criteria involve the expected parameters (flow rate and temperature) of the reservoir, a reservoir development concept, the drilling path and well design, a stimulation concept, an estimation of probability of success to generate expected flow and temperature, and the planned use of energy depending on achieved parameters. The financial/economic criteria require available financing, a business plan, and the expected return on investment. The last part of the eligibility check are the legal criteria, which include necessary permits and licenses, information on contractors and key personnel, as well as a legal form and identity of the operating company. However, these criteria lie in the terms of contract signed between developer and fund/insurance company and should be clearly displayed within the insurance process (Fraser *et al.*, 2013). In some countries (e.g. France and Germany) stimulation measures have to be undertaken. After submitting the application, experts are deciding on basis of parameters set in the reference contract if insurance should be released. The obligation to the developers is to report that the project's execution is clear and transparent.

It is essential to consider the project cost relatively to the risk of the various stages of project development (Fig. 4). The elevated level of financial risk is coupled with the test drilling, which can account for up to 30% of the overall capital cost at a stage in the project development when the risk of non-viability is highest (Jacob and Neu, 2014). After successfully passing the first drilling operation, the project risk decreases significantly, making it more reliable than in the beginning of the project. This means, that the project phase which needs to be considered in investment incentives is the test drilling phase with the highest financial risk leading to a more or less exponential increase of capital costs. However, according to Gehringer and Loksha (2012) the test drilling phase represents a missing link within the financial options, implying that only high- or middle-income countries can overcome this project phase by equity or private funding. In some countries (e.g. France) the public authorities provide repayable advance for this phase, while others offer grants to support the exploration drilling (Fraser *et al.*, 2013). Besides these, there are two relevant insurance patterns settled by governments,

[7] Technological readiness level defines the maturity of a new technology based on a comprehensive analysis. The TRL ranges from 1 to 9, with only basic principles being observed (TRL 1) to systems being proven in operational environment (TRL 9) (see RHC, 2020).

which should be part of any elaborate national fund: a post-damage guarantee and a guaranteed loan. The post-damage guarantee allows geothermal developers to attract external capital. The fund will only be released when a risk occurs which means that the guarantee is in fact being granted but frozen until the event takes place (e.g. up to 90% of the drilling costs are covered in case of total failure). This ensures many projects to be covered at the same time giving the fund a financial relief. Contrary to this scheme, the guaranteed loan represents an upstream source of financing and provision of insurance. The loan is granted when risk occurs and eligible expenses will then be refunded up to a contractually set level. Granting of the loan is given by state or financial institutions, whereby the financial responsibly falls upon the state which guarantees the loan.

3.1 Short-term risk (STR) insurance principle

The short-term risk insurance principle (STR) is part of the French guarantee system for covering geological risk (1980). It is based on the same scheme as the post-damage guarantee to secure the projects profitability in spite of the geological models' uncertainty (Bézèlgues-Courtade and Jaudin, 2008). The principle was developed to compensate and manage the failure of the first drilling which depends on the reservoir conditions. Failure occurs when the planned operation cannot proceed under economically satisfactory conditions because of insufficient temperature (T) or flow rate (Q). Both of these parameters define the success-failure curve (Fig. 5) according to which the degree of success can be determined (Boissavy, 2017). This curve is calculated on the basis of the project's economic sensitivity study. In case of total success, there is no compensation paid compared to a partial success where a partial compensation is granted to reach profitability. Anyhow, for subscripting to the STR insurance, two conditions have to be acknowledged. Firstly, the project must be accepted by a technical committee analysing economic, financial and juridical components (for more details see Fraser *et al.*, 2013). Secondly, the developers have to pay 1,5% of the covered cost (Bézèlgues-Courtade and Jaudin, 2008).

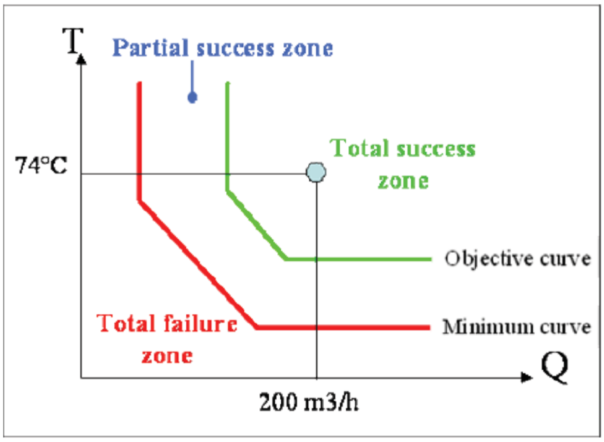

Figure 5: Success-failure curve to determine a reliable project (Bézèlgues-Courtade and Jaudin, 2008). Success appraisal is based on the reservoir temperature and flow rate.

3.2 Long-term risk (LTR) insurance principle

This insurance principle is mainly based on the long-term behavior of the geothermal reservoir as well as on the related chemistry effects of the well (see section 1.3 “Risk components”). These risk components are summed up in the term “exploitability degradation”. The LTR covers the wells, specific equipment and material, the geothermal loop and the quality of the geothermal source which is clearly defined in the beginning (Bézèlgues-Courtade and Jaudin, 2008). Compared to the STR insurance, the duration of the LTR insurance contract is 15 years. Developers can apply for this insurance if they have benefitted from the STR guarantee or can provide all relevant results of the drilling phase. A fixed fee of 12,000€ to 13,000€ per year could be charged according to the estimated resource risk (Fraser *et al*., 2013). In case of a partial damage, the compensation is calculated by considering the plant’s lifetime and power loss, which are both part of the contract reference. But the amount of compensation is based on contractual details an differs from insurance company to insurance company. A total damage will be compensated according to the defined contractual ceiling and the plants residual value (Bézèlgues-Courtade and Jaudin, 2008). These long-term factors are only covered if they are related to natural depletion of the reservoir or standard technical issues. The insurance does not cover: (1) an excessive depletion due to ill-positioned reinjection wells that cool the inflow zones, (2) poor reservoir surveillance or management, and (3) an excessive production leading to pressure-drop and low inflow performance. These negligent exploitation behaviours are preventable and thus not necessarily need to be covered. Another alternative for an LTR insurance can be a production tax credit system (Fraser *et al*., 2013).

4. Mechanisms for Funding

In the following section, funding incentives will be introduced and described in terms of cost coverage of DGE projects. The funds and risk insurances have been the main actuator for the growth of the geothermal sector by providing insurance and the opportunity of the technology to progress along its learning curve. Anyhow, each project relies on a combination of development capital (equity) to cover business risk and investment capital (debt) to cover financial and credit risk (Micale *et al.*, 2014). A promising approach is equity support at the beginning of the project, which can lead to a positive leverage[8] (i.e. project profitability exceeds the interest on borrowed funds) and therefore to an increased availability of debt. Despite the amount of available insurance schemes and revenue

[8] A method where debt is used rather than equity during the purchase of asset. The borrowed fund can positively influence the return on equity of an investment if debt is provided under affordable conditions.

supports, DGE technologies own a capital-intensive financing structure. In addition, the market conditions in the EU electricity and heat sector indicate an unfair competition with the gas, coal, nuclear and oil sectors, which prevents DGE from reaching full competitiveness. Gas and electricity prices are regulated with no clear billing, and the fossil fuel and nuclear sector are receiving subsidies. These funds are therefore essential for DGE to overcome these monopolistic market structures – especially in countries with an energy-only market and to achieve particular goals with respect to future GHG emission targets. A suitable financing scheme needs to be implemented individually to each geothermal project. There are several conditions that have to be considered before choosing an insurance fund (Fraser *et al*., 2013):

- Whether the insurance covers heat or electricity production
- Whether the insurance process is handled by public authorities or private entities
- Whether the insurance mechanism is purely insurance-related or receives financial support
- Whether the insurance is made available on national stage only or also in foreign countries

Additional to these conditions, not every geothermal reservoir has the same efficiency meaning that a generalized incentive does not reflect and also face the large scale of available technologies. This generalized incentive can then fail to provide the benefit the project needs and do more harm than good (Dumas and Garabetian, 2019). Therefore, more than one support model is needed to accommodate different technology profiles and to result in a most cost-effective deployment. The number of geothermal projects per country is somewhat depending on both the enthalpy of the reservoir and the establishment of suitable support schemes, notably risk insurance funds which are somehow lacking in many European countries. The support mechanisms that are offered by the EU will be part of the following sub-sections.

4.1 Public support schemes

As already said in the previous section, financing of geothermal is challenging in terms of uncertainty of revenues and economic viability. The public financing schemes are a complement to private financing and should encourage the private institutions to fund into geothermal projects by creating a secure investment environment. The seed capital of these public funds is usually filled with funding from the European Union, the Member States, the regional level authorities of Member States, insurance companies and brokers, private and public financial institutions, and other reliable stakeholders (Fraser *et al*., 2013). However, the last three institutions (private funding) are mostly included in a more mature geothermal market structure which is able to overcome the project risk (technical, economical, commercial, organizational, and political) due to a higher number of geothermal operations. The latter goes hand-in-hand with the level of risks that can occur. If only a small number of geothermal operations are going on, the risk of failure is very high. That leads to no or a small number of available and affordable public support or private mitigation schemes – primarily in countries with less statistical basis on geothermal project success (Laenen *et al.*, 2019). Therefore, risk insurance is a prerequisite for developing DGE projects together with financial subsidies which could phase-out after the technology reaches full competitiveness (Dumas and Garabetian, 2019).

The support schemes are ordered according to the level of geothermal market maturity, i.e. from a juvenile to intermediate and finally mature (Fig. 6).

In respect of market maturity, there are three main revenue aids that can be distinguished: (1) Investment aids for juvenile market, (2) Feed-in tariff for intermediate market, and (3) Hybrid support schemes (feed-in premium) for a nearly mature market structure (Dumas *et al.*, 2019). In addition to these mostly public funds, there are also other innovative financing schemes like Green Bonds, crowd funding, cooperatives or even auctions which will be part of section 5 "Innovative financing". For the juvenile market with less than 3 plants in operation (see Table 2) repayable grants for seismic exploration, slimholes, and the first well are offered. Feed-in tariff represents a support scheme for intermediate markets with not more than 10 plants in operation but leading to a lower level of risk compared to the juvenile market. According to Fraser *et al.* (2013) a market is defined as mature when

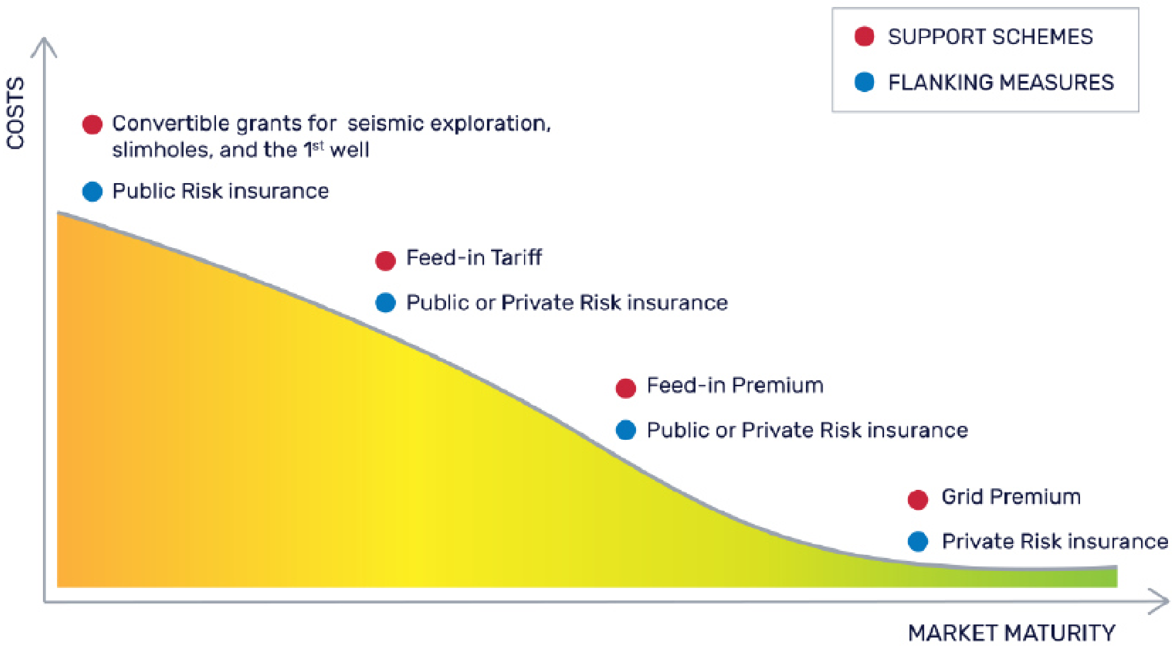

Figure 5: Different risk mitigation schemes in relation to market maturity and cost structure (EGEC, 2016). The red dots are displaying the recommended support schemes and the blue dots are flanking measures by EGEC (2016).

both electricity and district heating systems are developed all over the country. A Feed-in premium and grid premium is then an effective support scheme. However, these revenue support schemes solely concentrate on the operation phase of a geothermal project and do not address the risk in the exploration and field development phase (Micale *et al.*, 2014). Insurance for this phase will be provided by the European Risk Insurance Fund (EGRIF) and other European Funds. For mature geothermal markets, developers are able to appeal to private insurance policies (e.g. in France or Germany). In the Netherlands, the resource risk is partly insured by a national fund and by an insurance company (private) which is a highly recommended approach according to Fraser *et al*. (2013). In this case, the national fund insures the exploratory phase and the pre-feasibility study.

The funds can rely on four different combinations of responsible people: (1) Exclusive management by EU institution, (2) Shared management between EU institution and national insurance fund, (3) Shared management between EU institution and national authorities, and (4) Exclusive management by national authorities (Fraser *et al*., 2013).

4.1.1 R&D support

The Research and Development (R&D) or Research, Development and Innovation (RD&I) support scheme is a grant-based funding method which supports the development of innovative products,

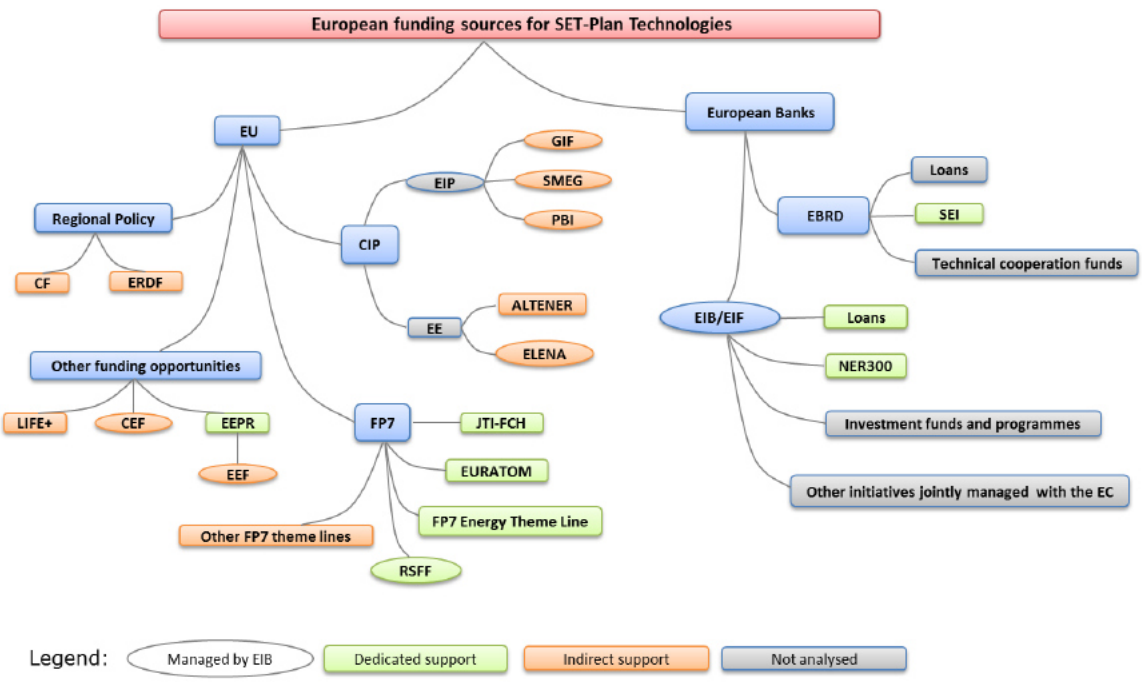

Figure 7: Financing sources for R&D projects offered as part of the SET-Plan on a European level (Corsatea *et al*., 2015). For abbreviations and a more detailed description, see Lepsa (2015).

services or processes which have competitive advantage in a company's target market. The aim is to accelerate low-carbon energy technology development by also raising awareness of emerging geothermal applications to achieve particular climate change goals. The fund was initially implemented as part of the Strategic Energy Technology (SET) Plan. Involved in the process of financing R&D activities is the European Commission (EC), the European Investment Bank (EIB) and the European Bank for Reconstruction and Development (EBRD) (Lepsa, 2015). These funds are not in particular designed for geothermal but rather enable the funding of a wide range of technologies, which categorize them as more generalized initiatives. Hence, they are less suitable for financing geothermal projects. Figure 7 shows an overview of such European funded incentives. The grant rates can reach from 25% to 50% depending on the company size and inclusion of collaboration[9].

Nevertheless, there are two R&D support schemes which will be explained in more detail, since they seem to fit the needs of geothermal projects according to ETIP-DG[10] (Laenen *et al*., 2019). These two are supported by the European Investment Bank[11] (EIB), whereas the Structural and Investment Funds (ESIF) are mainly covered by the EU. The latter will be part of the last section of this chapter.

Horizon 2020

The Horizon 2020 initiative was part of the EU R&D programme and will conclude at the end of 2020. It initially started in 2014 with a total fund of 80 Billion € for a project time period of 7 years which makes it the biggest R&D fund that was ever offered by the EU. The aim was to promote Europe's competitiveness in innovation by funding multiannual work programmes which were prepared by the European Commission to cover different EU priorities, from education to climate action as part of the Green Deal and digital economy[12]. Its scope was also to make it easier for the public and private sectors to cooperate and work together to further develop the European Research Area. After the huge success story of Horizon 2020, the EU has decided to implement a second funding programme namely the Horizon Europe, which will succeed Horizon 2020 with a budget close to 100 Billion €[13]. This EU funded programme will launch at the beginning of 2021.

[9] RD&I Fund, 2020.
[10] The European Technology & Innovation Platform on Deep Geothermal (ETIP-DG) is an open stakeholder group under the Strategic Energy Technology Plan (SET-Plan) aiming to enable deep geothermal technology to reach its full competitiveness everywhere in Europe.
[11] European Investment Bank is owned by the Member States and works closely with other EU institutions to implement EU policy. Its priorities are climate action and strategic infrastructures (ETIP-DG, 2019).
[12] ETIP-DG, 2019
[13] Horizon Europe, 2020.

Innovation Fund (former NER300)

The main difference between the Horizon 2020 programme and the Innovation Fund, which has replaced the more restricted NER300 programme (New Entrant's Reserve), is that it originates from the Emission Trading Scheme (ETS) of the EU, which is the largest existing carbon market. Funding is provided due to revenues from the ETS to support clean energy technologies and Carbon Capture & Storage (CCS) projects. Other than its predecessor (NER300), which was mainly funded by grants that had to be repaid, the Innovation Fund has a different allocation of funding. The main advantages of this type of financing instrument is that it takes the form of a first loss guarantee, provide cheaper loans to risky projects and could contribute up to 75% of a given project (Laenen *et al*., 2019). Nevertheless, the amount of financing depends on the carbon price and revenues are only allocated to projects through calls. In addition, none of the projects (e.g. GEOSTAS, Geothermae, South Hungarian EGS Demonstration) that received NER300 financing have come online yet. This is mainly because of the priorities set by the different projects: increasing the market maturity of innovative geothermal technologies (e.g. EGS) or increasing the market uptake of geothermal in new markets (EGEC, 2019). According to Laenen *et al.* (2019) the NER300 fund was most favourable for lower LCOE projects (i.e. less innovative technologies related to the allocation of funding by grants, which do not contribute to the mitigation of financial risk owing to the uncertainty of subsurface conditions). Besides the NER300, the Innovation Fund is also based on a more generalized purpose (not specifically targeting technology), which is not suitable to meet any geothermal project requirement. The allocated support can be calculated as follows (EGEC, 2019):

Grant = 50-75% {Cost [Innovative Project] – (Cost [Conventional project] + Operational Cash Flow)}

The fund can only be provided when the projects take place in countries that are part of EU ETS.

4.1.2 Feed-in tariff (FIT)

The Feed-in tariff (FIT) is a policy mechanism to foster investments in renewable energy technologies by offering long-term contracts, cost-based compensation and price certainty to producers. It is a fixed energy price (output-based) that is paid to the producers in respect of the energy they have produced and injected into the grid. The contractually determined price leaves the investor's risk very low. The provision includes guaranteed grid access, long-term contracts, and cost-based purchase prices which remain independent from the offered market price for electricity or heat[14]. The producers are paid for

[14] FIT, 2019.

the renewable power they supply to the grid and this enables RE technologies to develop by providing reasonable returns to the investors. The revenues are mostly depending on the region, size, performance and technology of the power plant. In some cases, the level of FIT can also be determined by the LCOE produced from the RE. After a certain amount of competitiveness is reached, the FIT declines over time giving the technology the chance to progress along its learning curve. Therefore, the total duration of the purchase agreement does not exceed 25 years (15-25-year period). While the Power Purchase Agreement (PPA)[15] is usually below the retail rate, the FIT compensation is above the retail and decreases with the increase of consumers. Nevertheless, the FIT is often part of a PPA and is usually paid by system or market operators. In a more generalized point of view, a FIT causes problem regarding global energy trading since it only covers the region of the power plant. This policy instrument has still many advantages when it comes to long-term contracts guaranteed by the government which decreases investment risks and financial costs and therefore leading to a more stable RE market development. Nevertheless, a suitable FIT determination by public and private sector for a specific geothermal technology is essential. The FIT and FIP are the most widely adapted RE policies resulting in a high investment security and long-term guarantee for producers.

4.1.3 Feed-in premium (FIP)

A Feed-in premium (FIP) is a revenue scheme under which electricity is sold on the spot market and producers receive a premium on top of the market price. The FIP can either depend on the evolution of the market price (sliding) or stay constant. The latter has the disadvantage of a fluctuating electricity price meaning that the risk is high in terms of over or under compensation when market prices are high or low, respectively. For prevention, constant FIP can be combined with predetermined minimum ("floor") and maximum ("cap") levels for the FIP or the total amount of rewards. If the FIP depends on market prices it is calculated on the basis of market prices and predefined FIT [16]. There can also be a minimum market price defined to reduce the costs in case of low or even negative market prices. The producer than receives the spot market price. The minimum levels for fixed FIP provides security about minimum revenues that can be expected and gives the RE investor a guarantee. High rewards are guaranteed when the market price increases and there is also a possibility to receive bonuses on top of the FIP which gives it a higher profit margin compared to FIT. Generally, the FIP does have many

[15] The Power Purchase Agreement (PPA) is a long-term electricity supply contraction (bilateral) between the developer and the costumer who consumes the electricity at the other end of the grid. The electricity price is contractually set at a predetermined price and gives the advantage to both: the costumer for receiving electricity at a stable price in the long-term and the producer for having a stable customer.

[16] KGDI, 2012.

advantages as a market-based support scheme and is well suited for baseload and full load energy technologies such as geothermal. There still remains the greater investor risk regarding the uncertainty of the long-term evolution of the market prices resulting in higher financing costs. Therefore, minimum and maximum levels should be set in order to prevent this risk. In many countries, the RE producers have the opportunity to shift from FIT to FIP and back again on an annual or monthly basis[17]. This is generally preferred in comparison to constant FIP. Besides the FIT and FIP, additional incentives are also combined with these policies.

4.1.4 European Geothermal Risk Insurance Fund (EGRIF)

The European Geothermal Risk Insurance Fund (EGRIF) is a national risk insurance scheme, which should mitigate resource risk by alleviating shortage of private insurance policies and ease investments in geothermal projects (Fraser *et al*., 2013). It is a recommendation established by the GEOELEC[18] project to raise the awareness into the advantages of risk insurance schemes for geothermal. They address policy makers and governments to establish a risk insurance at the EU level. The herein described fund briefly exhibit the impact of such a financing instrument regarding the geological risk of a geothermal project and gives recommendations for the implementation of such a fund according to existing public and private risk insurances in France, Germany, and the Netherlands.

The EGRIF contributes to the compensation for market failure and prevents unfair competition in an energy-only market. The aim is to create a secure investment environment to allow the progression of the technology along its learning curve by a gradual reduction of the support. This financial scheme highly addresses less well-developed geothermal regions where developers are not able to manage the possible risk components of a DGE project: technical, economical, commercial, organizational and political. With this fund, the uptake of geothermal energy is promoted and particular goals with respect to GHG emission targets can be achieved. According to Fraser *et al.* (2013) and their GEOELEC project, the EGRIF should at first be supported by public money and after reaching a particular maturity this fund could be replaced by a private scheme.

The EGRIF covers both, the short-term and long-term risk and particularly the exploration phase. The latter is insured in the form of a repayable advance to overcome the depletion of the fund since it should further be used for the next project phases (Table 1). The fund covers the exploration drilling

[17] FIP, 2019.
[18] The "Develop Geothermal Electricity in Europe to have a renewable energy mix" is a project which was dedicated to foster geothermal electricity and heat in the EU with the cooperation of 10 partners. It was co-funded by the Intelligent Energy Europe (IEE) during a project period of 3 years (2011-2013).

and tests as well as exploration costs which are specific to EGS. As soon as the production starts, the advance has to be reimbursed together with a contractually set interest rate.

Table 1: Summary of the EGRIF proposal on geothermal electricity technologies (Fraser *et al.*, 2013).

Market Maturity	Juvenile	Intermediate	Mature	After 2020
criteria	0-6 deep geothermal wells are existing < than 3 plants are operational	6-60 deep geothermal wells exist < than 10 plants are operational	Both geoelec & geoDH systems are developed all over the country	Costs reach grid parity with around 10 €ct/kWh
Level of risk	Very high	high	medium	Low
Costs: High temperature Low temperature EGS	 na 18 25	 7 16 25	 6 15 25	 5 10 12
Support schemes	(repayable) Grants for seismic exploration, slimholes, and the 1st well	Feed-in Tariff	Feed-in Premium	Grid premium
Flanking measures	**Public Risk insurance**	**Public or Private Risk insurance**	**Public & private Risk insurance**	**Private Risk insurance**

4.1.5 GeoFund and GeoFAR

The GeoFund and GeoFAR are regional programmes for Europe and Central Asia to mitigate the barriers for the development of geothermal projects owing to the large financial obstacles and lack of information. The GeoFund (Geothermal Energy Development Programme) was financed by the Global Environment Facility (GEF) over an eight-year period with a total budget of 25 Mio. USD. Its main purpose was both to insure technical components (the short- and long-term risks during the exploration phase) and to offer guaranteed and affordable loans (as well as to allocate grants). Part of this programme is the Geological Risk Insurance (GRI) which partly covers failure during the exploration phase and disburses eligible costs in case of insufficient thermal capacity of the reservoir. In the scope of this programme, two geothermal projects were financed in Hungary and Turkey, respectively (Seipp *et al*., 2016).

The GeoFAR (Geothermal Finance and Awareness in European Regions) programme was initially established in 2008 by the European Commission aiming to promote geothermal electricity generation by developing financing approaches at a regional level[19]. This financial instrument includes a risk insurance (GeoRiMi[20]) which covers the feasibility study and allocates partial guarantees for both the exploration drilling and production well (Seipp *et al*., 2016). Eight partners from Europe were involved in this programme (see Seipp *et al*., 2016).

4.1.6 EU Structural and Investment Funds (ESIF)

There are still some support schemes offered by regional cohesion policy[21] as part of the European Structural and Investment Fund (ESIF) among the aforementioned funds and public incentives. They comprise the European Development Fund (ERDF), the European Agricultural Fund for Rural Development (EAFRD) and the Cohesion Fund (CF) solely to name a few. Other than the NER300, which is a grand-based incentive, these structural funds rely on financing instruments including technical support, soft loan schemes or revolving funds. In addition, a bottom-up deployment of a financing instrument either through a managing authority of the ESIF or the project leader is able to provide them the opportunity to fit their purposes (ETIP-DG, 2019). These funds are a direct aid to invest in companies to create sustainable jobs and are the main source of public financial support – usually together with national funding programmes. The European Commission is in charge of the management of these funds and foster the regional and local development of projects. However, the EU fund is not paid directly by the European Commission but rather by national and regional authorities of the Member States. As the European Social Fund (ESF), the European Agricultural Fund for Rural Development (EAFRD) and the European Maritime and Fisheries Fund (EMFF) do not particularly fit as a financing instrument for DGE, they are not further considered.

[19] GeoFar, 2020.

[20] GeoRiMi is a geothermal risk mitigation system by the GeoFAR which contributes to the early stages of geothermal project development and how to finance it (GeoFar, 2020).

[21] The main scope of the Cohesion policy is to promote economic, social and territorial cohesion. It is managed by regional or national bodies (decentralized).

Cohesion Fund (CF)

The Cohesion Fund serves as an incentive to raise the development of sustainable technologies in Member States with a gross national income (GNI) per citizen of less than 90%. It is allocated by seven-years programming period based on the European budget and started simultaneously to the Horizon 2020 incentive (2014-2020). Infrastructure projects are supported under the Connecting Europe Facility[22] to create energy efficient environments by using RE. Compared to the FIT od FIP, the Cohesion Fund does not only rely on GHG reduction but also invests into social projects and other innovative technologies[23]. EU Member States that could apply for this support are: Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia and Slovenia.

European Regional Development Fund (ERDF)

The European Regional Development Fund is also based on the cohesion policy of the different Member States and aims to strengthen economic and social cohesion by reducing disparities between regions and Member States of the EU as well as enabling territorial cooperation. The fund is allocated with the purpose to invest in the infrastructure of underdeveloped regions to optimize competitiveness and attract private sector investments. The investments of the ERDF mainly focus (80%) on four specific areas e.g. innovation and research, digital agenda, support of small and medium-sized enterprises (SME), and low-carbon economy[24]. Interregional, transnational and cross-border projects based on the European territorial cooperation objective are also funded. The region of the projects has a high impact on the fund which has to be invested in at least one of the mentioned priority areas. For more developed countries, 80% of the fund must focus on these priority areas, whereas for less developed or transitional regions at least 60% or 50% of the fund must be incorporated, respectively[25]. In some cases, depending on the regional policy targets, the ERDF must specifically incorporate low-carbon economy projects. In many countries, the ERDF is not directly payed by the European Commission but rather provided by the regional authorities.

[22] The Connecting Europe Facility (CEF) is a funding incentive by the EU to raise infrastructure investments at European level regarding transport, energy and digital services.
[23] ESIF, 2020.
[24] ERDF, 2020a.
[25] ERDF, 2020b.

5. Innovative financing

The term innovate financing defines a financing scheme that is mostly based on cooperatives and private funding initiatives which can improve the previous investment structures by involving the private sector. It is used when the available traditional aid flows are insufficient in addressing development challenges. The cooperation of the private sector can lead to both social acceptance and attract private support by increasing the interest rate. This shared ownership could provide an active responsibility of private entities in the insurance handling process. Nevertheless, the following incentives are not meant to be used without public schemes and should be seen more as a supplement to them. The innovative financing involves crowd funding, cooperatives and auctions (Dumas and Garabetian, 2019). In addition to them, there also will be a small section about corporate sourcing of geothermal and Green Bonds.

Crowd funding

Crowd funding is not as prevalent in the geothermal sector than it is for other energy sources. The United Downs project[26] in the UK, for example, was financed by using such a finance scheme. It relies on small investments by a number of investors or contributors. The main advantage of this private financing scheme is the role it plays in facilitating public acceptance of industrial projects through shared ownership. It refers to open calls to the public to finance geothermal projects due to different incentives. There are four kinds of crowd funding transactions or relations that can be distinguished: donations, rewards, lending, or equity (Laenen *et al.*, 2019). A donation is provided by a supporter or fan without any contractual reward. A client would purchase a contract for a product or a service the developer offers, i.e. the client would get a reward if the deployment is successful. Lending would be offered to the developer by a creditor, who would draw up a credit contract and the credit will then be repaid together with the contractually set interest rate when operation of the plant begins. The highest position is filled by the investor, who would give equity, meaning that a shareholding contract would be set up and equity-like instruments or revenues would be conducted (Laenen *et al.*, 2019). This business model can be taken as the “first loss taker” segment of the financing structure of a project.

[26] In the scope of the United Downs Deep Geothermal Power Project (UDDGP), the very first power plant was constructed in the UK. Heat and power are produced from the hot granite rocks beneath Cornwall at the United Downs Industrial Site. 28% was covered by crowd funding as a private financing scheme (UDDGP, 2020).

Cooperatives

Available cooperatives involve REScoop which is a cooperative for renewable energy (RE). It represents a hybrid business model, which allows citizens to jointly own and participate in RE projects and simultaneously to foster energy efficiency projects. Cooperatives like REScoop are citizens investment funds (VC or Venture Capital[27]), which finance its subsidiaries through a loan and equity participation (Laenen *et al.*, 2019). After becoming a member by purchasing a cooperative share, members share the profits and usually are offered to buy electricity or heat at a lower price. Besides, they have the opportunity to actively participate in the cooperation and decide on the investment targets of REScoop and are included when setting the energy prices. Through these business models, citizens are more involved in the process of investment decisions and other creative processes, giving them the sense of belonging to their local community. The positive side effect is to facilitate the acceptance for energy projects.

Auctions

Although auctions are not used for geothermal in particular, it is still a common business model in respect to receive investments and tackle the expansion of geothermal energy technologies. According to the report by IRENA (2019)[28] this financial scheme is highly suitable for developed markets owing to the high investor confidence in the market. These auctions are also known as “demand auctions” or “procurement auctions” and are taking place when there are enough actors involved in the bidding process. The project developers are submitting a bid with a price per unit of electricity or heat at which they are able to conduct the project. After the auctioneer has evaluated every offer, a power purchase agreement is signed between him and the successful bidder.

IRENA has studied the impact of auctions as a financing scheme and how to design them to achieve objectives beyond price discovery. Offering electricity at the lowest price seems valid but it is insufficient for reaching specific country goals such as the integration of higher shares of RE into the grid and energy mix or ensuring greater participation of communities as well as maximizing the socio-economic benefits of RE. The mentioned goals have the main scope as for the implementation of auctions. Also, countries with no previous experience with auctions seem to be driven by the reported

[27] Venture capital is off-market equity capital offered by a community for a risky project or enterprise. Generally, the capital represents an equity-like instrument such as mezzanine capital which is an unsecured, subordinated debt or stock. These are used by smaller companies to gain a higher level of leverage than would be the issue for other financing options.
[28] The International Renewable Energy Agency (IRENA) provides renewable energy solutions especially insights for policy makers in respect of geothermal power generation (IRENA, 2019).

success of this scheme in attaining low prices and enabling country-specific needs to be in the focus. Nevertheless, auction systems are based on the prices alone, which results in a higher participation when solar and wind energy is involved leaving geothermal far behind. The fluctuating production of these technologies, however, leads to higher prices in the end, except for geothermal since this technology provides baseload capacity. At the end of the day, it is the responsibility of the energy policy of a country that determines the energy pricing and the valid interest for it. Policy makers are therefore able to expand geothermal technologies by affordable auctions for the private sector. Outside of Europe, auctions are a successful financing scheme for renewables including geothermal. In Indonesia, auctions are used to finance geothermal projects proceeding in two stages. During the first stage, the eligibility of the bidders is evaluated on the basis of viability of funding and technical aspects. After this stage, the winner is being announced based on the offered price for electricity or heat per plant. In the case of Indonesia, the plants will be commissioned 7-8 years after the results of the auctions have been announced[29].

Corporate sourcing of geothermal

The power and heat supply of renewable energies to industry is secured by e.g. a Power Purchasing Agreement (PPA), a Public Project Partnership (PPP) or Joint Ventures (JV) (Dumas and Garabetian, 2019). These corporate arrangements have been used more conventionally by utilities to source power capacity and provide certainty for both energy producers and costumers. The energy producer has a more stable income with a costumer at a predetermined price. This costumer benefits from energy supply as well as a stable price in the long term. Such a corporate PPA can be the necessary element to enable the investment in a renewable energy project. Moreover, a PPA can provide support in terms of a joint venture or by reducing the financial risk for project developers and hence reducing the capital cost. The PPAs, on the one hand, can be “virtual” where the electricity is fed at the one end of the grid and consumed at the other or be “physical” with a direct connection of the plant and costumer. A good example for a successful corporate sourcing via a PPP is the ECOGI Project[30] in France, where the Rittershofen plant supplies geothermal heat to a biorefinery (Dumas and Garabetian, 2019). With this heat plant, 25% of process heat which is needed can be covered (Baujard *et al*., 2014). In case of self-consumption, a direct investment for the deployment of geothermal energy systems is possible. Many companies prefer to generate power or heat for their own use, but they have to take the responsibility

[29] IGA, 2016.
[30] The geothermal project ECOGI is located in the Upper Rhine Graben and was initiated in 2011 providing a total capacity of 25 MWh to the biorefinery in Beinheim. The plant site is located 6 km east of Soultz-sous-Forêts, France. It was supported by ADEME, SAF Environment and Conseil Régional d’Alsace (Baujard *et al*., 2014).

for the entire project life cycle. Greenhouse managers in the Netherlands are developing and operating geothermal projects for their own use as well as pharmaceutical companies like Janssen Pharmaceutica which is part of Johnson & Johnson Pharmaceutical Research and Development (J&J PRD) in Belgium (Dumas and Garabetian, 2019).

Green Bonds

Green Bonds are a sustainable mean of financing to promote renewable energy projects beyond public support in a more mature geothermal market. Their main difference to conventional bonds is their purpose of investing in sustainable or "green projects" which e.g. aim to reduce GHG emissions. The latter can either be an energy transition project promoting renewables or a project targeting to protect the environment. The main actors for Green Bonds are: commercial banks, public authorities (government), large companies, and public financial institutions (Fraser *et al*., 2013). To gain access into this financing scheme and to be considered as eligible, the project has to be deemed sustainable. For geothermal, this is usually the case, expect for specific technologies and their possible impact on the environment. In Iceland, Kenya and Indonesia, Green Bonds have successfully been used as an alternative financing method for geothermal.

6. Supportive Policies and Financial framework per country

The geological risk is a notorious issue all over Europe. However, each Member State of the EU has to approach this problem according to their respective knowledge and experience. Collaboration between the Member States would save a lot of money.

The level of supportive policies and financing of deep geothermal energy within each Member State of the EU depends on different factors. Even within a country of the EU, the financing of a geothermal project may be restricted to certain regulations or concentrates only on regions with approved geothermal potential. The most important factors that affect the market maturity are:

- Experiences with geothermal energy (or number of successful projects)
- Experiences and expertise with explorations in the deep subsurface (mostly inherited from the oil and gas industry)
- The knowledge about the geothermal reservoir in the subsurface (structure, depth, thickness, temperature, flow rate)

Some countries, such as France, already have extensive experiences with geothermal energy whereas others are just about to begin to deal with this topic but already know much about the subsurface due to the extensive explorations of the oil and gas industry, like the Netherlands. Germany is known for the high level of investments into RD&I, however, geothermal energy did not receive as much attention as other renewable energy branches, except for the area around Munich. In Belgium, a showcase project in Mol, which is financed for the most part by the Flemish research facility VITO, shall pave the way for the feasibility of a geothermal project.

Risk insurance funds for the geological risk already exist in some European countries like France, Germany and The Netherlands (Fraser *et al.*, 2013). In Belgium, however, no funding scheme for geothermal projects has been established yet.

In the following subchapters the supportive schemes and policies for each of the aforementioned countries will be summarized, respectively. A detailed summary of the existing incentives can be found in Appendix 1.

6.1 France

France has a long tradition of utilizing geothermal energy and a large network for district heating, especially around Paris. It is also investing a lot into new innovations for geothermal energy, notably in Alsace and in Soultz-sous-Fôret. In 2018 the total thermal installed capacity in France was estimated to 600 MW_{th} and an electricity capacity of 17 MW_e with 60 plants in operation (ETIP-DG, 2019; AFPG, 2019).

The energy objectives of France are defined by the Multiannual Energy Planning (*Programmations Pluriannuelles de l'Energie*). The current period (2018-2023) aims for the development of each energy technology. For geothermal energy in particular, the programming builds on the establishment of a geological risk insurance scheme and on support tariffs for geothermal electricity. The use of geothermal heat is planned to be extended beyond the area around Paris by the GEODEEP Fund (ETIP-DG, 2019). The different financing schemes will shortly be explained in the following.

Investments for the Future (*Investissements d'Avenir*)

This financing programme is managed by the Agency for Environment and Energy Management (*Agence de l'Environnement et de la Maîtrise de l'Energie*; ADEME). It is responsible for energy innovations and ecological transition (ETIP-DG). Specific proposals may be addressed on geothermal development or demonstration projects. Vast investments have been dedicated to the implementation of pilot projects on renewable and carbon-free energies. Financial support is realized by subsidies, reimbursable advances and equity holdings in companies (ADEME, 2012). The global budget for these projects encompasses 3.174 Billion € (ETIP-DG, 2019). As a response to this energy transition policy, research facilities such as the Institutes and Laboratories of Excellence were created in 2015 (Boissavy *et al*., 2019). These facilities receive support through public-private partnerships and carry out experimental research and developments focusing on market requirements.

The National Fund and GEODEEP

For more than 30 years, the National Fund ensured post-damage guarantees (Fraser *et al*., 2013). It compensated the lack of private insurances and allowed the development of geothermal heat by risk pooling (ADEME, 2012).

GEODEEP is a fund for geothermal well producing water >110° for heat or power generation in onshore France. The shareholders are public (ADEME, 2012) and private (3 developers and *Caisse des Dépôts* et *Consignations*). The fund was recently approved by the European Commission and has started this year (2020). The fund is based on a maximum repayment for one single well of 16.5 Million €. A project is submitted to a technical committee. Royalties are project dependent and range between 2 to 4, 5% of the turn-over of the plant for 15 years.

Renewable Heat Fund (*Fonds chaleur renouvelable*)

Another financing programme that is managed by ADEME is the Renewable Heat Fund (*Fonds chaleur renouvelable*), which was established in 2009 and had a budget of 1.2 Billion € for the 2009-2013 period (ADEME, 2012). It is dedicated to the funding of projects that produce heat from renewable energies to reach competitiveness among conventional energies. Regarding geothermal energy, the Renewable Heat Fund supports deep geothermal energy installations with and without heating networks, installations with heat pumps on surface water bodies and on probe fields. Approaches for aid could be used in the upstream phase of projects for the implementation of feasibility studies, thermal response tests or experimental drilling (ADEME, 2012).

The funding for the energy production is based on an analysis of the cost price of producing renewable heat compared to fossil fuel with a maximum of 7 €/MWh for a project without heat pump and 14 €/MWh with heat pump on a 20 years period.

The inter-ministry fund for competitive clusters

Competitive clusters bring together parties from different fields of research, industry and companies that cover an entire value chain, thus uniting public and private innovation capacities on projects with high potential. These clusters are supported by the French local authorities and benefit from special tax regulations. There are about ten clusters operating in the field of renewable energies. The Avenia cluster, for example, is dedicated to geoscience issues such as industrial geothermal energy, underground sources, responsible development of fossil energy sources and storage of CO2. The geothermal aspect focuses on heating networks in particular (ADEME, 2012).

Guarantee Fund for geothermal risks

The geothermal energy sector benefits from a guarantee fund managed by SAF Environment (a subsidiary of *Caisse des Dépôts et Consignations*). The coordination institute is assisted by a technical committee, which comprises representatives of the French energy agency (ADEME, 2012), the French Geological Survey (BRGM) as well as industrial private and public actors, regional representatives and representatives of the Department of Environment and Energy in the Ile-de-France region (DRIEE).

The "short-term" guarantee compensates the owners if the results of the first drilling do not allow the planned operation to be carried out under satisfactory economic conditions. The "long-term" guarantee covers project owners during the operational phase of their operation. Heat projects in deep aquifers are eligible for funding. A subscription fee of 3.5% to 5% of the drilling costs is asked and a 20% grant is provided in the case of failure or partial success. In addition, a guarantee or partial guarantee (max 65% combined) is provided.

AQUAPAC

The AQUAPAC was created due to a collaboration of ADEME with BRGM and the French Electricity Board (EDF). This risk insurance represents a guarantee for heat pumps using ground water i.e. is mainly restricted to near-surface geothermal reservoirs and bases on the principle of a double guarantee fund covering two risk: one that is concerning the short-term risk and the other one covering the long-term risk over a 10 years-period. The latter is not solely regarding natural depletion but also technical failures that are not fully measurable (e.g. drying up of the well, hardware accidents etc.). The developer has to pay a guarantee fee to receive the fund. This fee is proportional to the system costs but small compared to other private risk insurances (IEE, 2008).

6.2 Belgium

In the past years, the Belgian government has put some effort into the development for geothermal energy. There are three geothermal heat plants operating in the Walloon part of the country, which supply 19 GWh/y of thermal energy. In Flanders, two geothermal plants are now under development. They are estimated to produce 164 GWh of thermal energy. Furthermore, the feasibility of geothermal energy production is being investigated at five other locations in Antwerp and Limbourg (ETIP-DG, 2019). Programmes for the funding of geothermal energy in either part of the country are shortly be described in the following.

6.2.1 Wallonia

In the Walloon region geothermal projects do not receive any support on the governmental level to date. However, there are some support schemes which will be implemented in the near future. These will be direct supports by the Department of Energy and Sustainable Building (*Département de l'Energie et du Bâtiment durable*) and by the Department for the Coordination of Structural Fonds (*Département de la Coordination des Fonds structurels*), which will support demonstration and development projects in the context of the European Regional Development Fund (ETIP-DG, 2019).

Regional guarantee scheme

Another support scheme which might be approved in 2021 by the Walloon government is the regional guarantee system. This decree can be divided into two aids. The first one is the regional guarantee scheme which should cover the risk based on a technical committee. Eligible costs will be reimbursed after its decision. The second aid will be a “geothermal guarantee” section in the Kyoto Fund. It will be used to compensate for failure of a geothermal project. The developer has to pay a premium to get access to the fund and the insurance. It covers the initial investments of a DGE project and the first drilling of the doublet. This decree, as part of a legal framework for underground resource management should consider deep geothermal as an economic resource and encourage industrial investments into DGE (Lagrou *et al*., 2019).

6.2.2 Flanders

For the Flemish region, the support schemes have become more concise recently. Once the “*Waarborgregeling voor het opsporen en winnen van aardwarmte in de diepe ondergrond*” by the Environmental Department (*Departement Omgeving*) is in forces, financial guarantees will be paid for investors if the realized capacity of a geothermal plant is lower than expected. However, it covers only the geological risk associated with the output of the system. Other risks, such as technical complications during drilling, the co-production of oil and gas, or the risk of induced seismicity are not insured (ETIP-DG). The maximum amount per project that can be covered is 18.7 Million €. Only 85% of the eligible costs can be insured. A participation fee of 7% on this amount must be paid. The applicant must validate the expected thermal power (P90 value) by a set method and perform adequate testing to prove the outcome.

There is a Flemish subsidy for geothermal heat and power – the Green Heat Call (*Call Groene Warmte*). It is managed by the Flemish Energy Agency (*Vlaams Energie Agentschap*) and supports geothermal energy projects with a minimum capacity 1 MW_{th} of geothermal heat or a minimum gross power of 300 kW of geothermal electricity. The budget per technology category is set prior to each call (ETIP-DG, 2019).

Strategische ecologiesteun (STRES)

The *Strategische ecologiesteun* (STRES) supports (large) investments in innovative green technologies that cannot be standardized because of their unique company-specific character. It is managed by the *Agentschap Innoveren en Ondernemen* (VLAIO) and provides a budget of 20 to 40% of the accepted additional investment depending on the (cost) performance and the type of organisation (ETIP-DG, 2019).

Ecologiepremie (EP-Plus)

The *Ecologiepremie* (EP-Plus) supports investments for the use of geothermal heat of smaller installations up to 5 MW. It is also managed by the *Agentschap Innoveren en Ondernemen* (VLAIO) and provides a budget of 15 to 55% of the additional investment costs depending on the technology and the type of organization (ETIP-DG, 2019).

Departement Landbouw & Visserij

The *Departement Landbouw & Visserij* (Department of Agriculture and Fisheries) supports investments in geothermal energy in agriculture via the VLIF-steun (support), which covers 30% of the investment with a maximum of 1 Million € (ETIP-DG, 2019).

6.3 Germany

The majority of deep geothermal energy projects are mostly located in the southern part of Germany in the Molasse basin, although high geothermal potentials can also be found in the North German Basin, the Upper Rhine Graben as well as in the Rhenohercynian Basin (Arndt *et al*., 2020). Since 2019, there are 37 geothermal plants in operation, mostly generating heat with a total capacity of 336.51 MW_{th}[31]. Only 8 of the plants generate electricity with 37.13 MW_e[32] of electrical capacity installed.

[31] BG, 2019
[32] BG, 2019

Germany plays a key role for the development of deep geothermal in Europe – especially local authorities such as Munich aim to supply fully renewable based district heating by 2040 (BMWi, 2019). In addition, Germany represents the most advanced market in terms of TRL as being the very first one in developing EGS projects (ETIP-DG, 2019).

In 2019, nearly 10.5 Billion €[33] were invested into renewable energy projects, which is by far less than the amount invested in 2009-2011 (23.5-27.8 Billion €), but Germany still remains the world leader in renewable energy investments. These high investments should help meeting particular GHG-emission targets, mitigating climate change, and protecting the environment as part of the *Energiewende* and *Wärmewende* (see EEG, 2017 for details).

For the expansion of geothermal as a renewable energy source, existing policies were improved by the Federal Environmental Ministry. This mainly includes the Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz* (EEG)) and the establishment of risk insurance schemes in 2009 to mitigate geological risk.

Policies for renewable energy development

The Renewable Energy Sources Act (EEG) was initially developed in 2000 (precursor: Electricity Feed-in Act, *Stromeinspeisungsgesetz*) as the contribution to Germany's long-term climate protection goal. It enables the energy market to develop and offer a sustainable energy mix by raising the share of renewable power generations. The objective of the EEG is to expand the amount of renewable energies (RE) to at least 40% by 2025 and raising this target to 55-60% by 2035 (EEG, 2017). In addition to these expansions, the EEG fosters affordable energy supply and aims to save fossil energy sources. To reach these targets, there are two aspects established by law (EEG, 2012[34]): (1) Network operators are indentured for the uptake of renewable energies into their electricity network, and (2) Revenues should also contain market premiums that depend on the average monthly spot market prize for electricity. New homeowners are also indentured to use renewable energies according to the *Erneuerbare-Energien-Wärmegesetz* (EEWärmeG).

For operating RE plants, the EEG guarantees a long-term uptake of energy and provides security for the investment in RE projects as well as for the RE producers. Part of the EEG is a governmentally set feed-in tariff that was also initially introduced in Germany. It provides rewards above the retail of electricity and encourages the progression of RE technologies. The tariff rates, however, depend on

[33] Statistica, 2020.
[34] EEG, 2020.

the system size, technology and location. Today's basis compensation for geothermal energy is around 25.20€cent/kWh[35] with an annual decrease of 5% (§45 EEG, 2017) since 2018. This degression will be postponed to 2022 as has been decided through the latest EEG 2021 amendment of the Bundestag. Additionally, the tariff will decrease by 0.5% and will be set to 2% when reaching an installed capacity of 120 MW[36]. With the expansion of the EEG compensations for geothermal electricity generation, the thermal capacity installed also increased threefold. Therefore, the EEG is a key element for the expansion of geothermal electricity and heat/cooling in Germany.

Financing of deep geothermal

To meet particular GHG-emission targets, Germany has implemented generalized financing schemes for renewable energy projects. These schemes contain specific financing tools to precisely cover a specific technology. For deep geothermal energy projects three public financing incentives will be described in the following. Figure 8 shows the funding for geothermal energy projects.

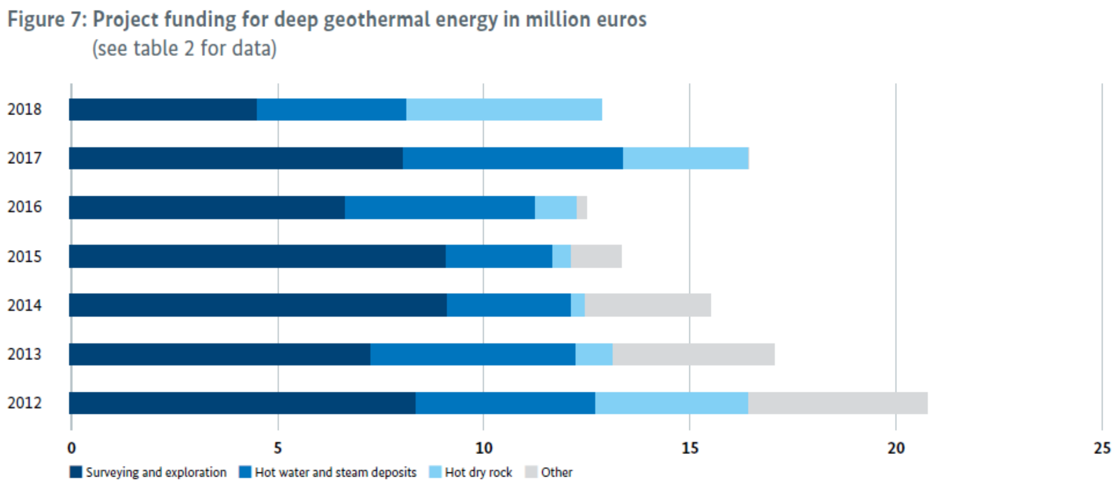

Figure 8: Funding for deep geothermal energy projects between 2012 to 2018 (BMWi, 2019). The total amount is given in million euros.

MAP (*Marktanreizprogramm*)

The incentive MAP is funded by the Federal Office for Economic Affairs and Export Control (BAFA) and commissioned by the BMWi to expand the renewable-based heating and cooling in Germany. It was developed in 1999 with a total funding volume of 3 Billion €. With the objective to raise the amount of renewable energies in the heating sector to at least 14% by 2020, the MAP is a key element in providing

[35] EEG-Geothermie, 2017.
[36] EEG, 2021.

funding for this transition not only for municipalities but also for private usage. The funding is allocated with grants for private households in case of changing e.g. the oil-fired heating with a more energy-efficient alternative or regarding municipalities when new heating grids are constructed for the use of renewable-based heat. The MAP mainly focuses on modernization of existing buildings as part of the EEWärmeG. The fund can be allocated either by the BAFA through a direct investment subsidy or by the KfW through a loan with redemption subsidies[37]. In case of deep geothermal, the MAP does not seem to be a compatible incentive, therefore has to be improved according to BVG (2019).

KfW-Programm „*Erneuerbare Energien Premium*“

The KfW is a development bank which is owned by the Federal Republic of Germany and the States of Germany with the Federal Ministry of Finance acting as the legal supervisor. Besides different investment focuses, the KfW also provides funding for renewable energy projects especially regarding the heat transition. One of these incentives is the KfW-Programm "*Erneuerbare Energien Premium*" (271/ 281/ 272/ 282) which was established together with the BMWi. For details on application and eligible technologies as well as on funding conditions, this programme offers a leaflet for applicants (KfW, 2020). The programme promotes deep geothermal energy projects with a reservoir temperature of at least 20°C and a heat capacity of at least 0.3 MW_{th}. Although heat supply is the major target of the programme, combined energy and heat generation is also promoted. During the financing period, the constructed plant has to operate and generate heat for at least 7 years even in case of disposition. The KfW grants a maximum of 25 Million € per proposition and promotes up to 80% of the eligible costs regarding deep geothermal projects (100% for geothermal). The duration of the fund and the fixed interest rate depends on the used interest-only years. The promotion can be separated into three categories: (1) Funding of the plant, (2) Funding for drilling, and (3) Funding for additional expenditures (KfW, 2020). However, even if the KfW funding covers the most of the costs during the exploration phase, it does not provide funding for investigation purposes at the beginning of the project (1st drilling). Other than that, it is possible to combine the subsidy with other funds of the KfW and EU-programmes, but there are restrictions which need to be discussed with the Housebank that provides the fund.

7th Energy Research Programme of the Federal Government

The Federal Government has implemented the 7th Energy Research Programme (energy policy framework) to enable the research and development (R&D) of energy technologies to mitigate climate

[37] MAP, 2020.

change and provide an economically viable energy supply. The aim of this programme is to primarily foster the use of renewable energies to meet the requirements of the energy transition by funding research and innovation in the energy sector. It also aims to be largely greenhouse-gas neutral by 2050.

Regarding geothermal projects, the R&D fund focuses on demonstration projects, the development of heating and cooling storage, the development of geological database, modelling and simulation of geothermal systems to overcome financial risk and the development of technologies in terms of cost reduction due to increased efficiency plants (BMWi, 2018). The funding includes projects of research companies and institutions as well as energy suppliers and municipal utilities. 6.4 Billion € will be provided for R&D projects with new thematic priorities given in the strategic lines by the Federal Government[38]. This budget is financed from the federal budget and the Energy and Climate Fund (ECF[39]) as a direct funding scheme.

Konjunkturprogramm

The *Konjukturprogramm* by the Federal Government is related to the stabilization policy which aims to boost the economy and to stabilize a financial system. One of the many target points in this programme, for example, is the financing of energy-efficiency projects during the Corona crisis. The Federal Government provides 100 Million € for municipalities for climate protection purposes until the end of 2021. In addition, three existing municipal funding programmes were also changed in respect of the National Climate Protection Initiative[40] (NKI).

Risk insurance schemes

The first insurance scheme for geothermal projects was established in 2009 by the KfW on behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMUB) as part of the MAP to promote RE projects. Since then, developers can choose between federal risk insurance and private market-based insurance schemes. The latter was issued in 2003 for the Unterhaching project in Munich and was covered by the Munich Re Group[41]. Many insurance companies took the success story of Munich as an example to offer insurance for the resource risk. The majority of these

[38] BMWi, 2020.
[39] The Energy and Climate Fund was initially established in 2011 by the German government to foster the energy transition. The fund will be filled with extra profits of nuclear power plant operators, partly by the nuclear rod tax and by auctioning of emission allowances. (EKFG, 2010)
[40] The National Climate Protection Initiative is a national scale funding programme developed by the Federal Environment Ministry to promote measures for climate protection. The programme is allocated to municipalities, economy, private consumers and education institutions (BMU, 2012).
[41] The Munich Re (Munich Reinsurance) is a reinsurance company in Munich.

private insurance companies, however, are insuring projects located either in the Molasse basin or in the Valley of the Upper Rhine Graben.

KfW – Fündigkeitsrisiko Tiefengeothermie (228)

As already mentioned, the „*Fündigkeitsrisiko Tiefengeothermie*“ insurance was initially developed in 2009 by the KfW and is supported by the Munich Re Group. The insurance is based on the principle of a revolving fund i.e. returns from revenue components of investments are reinvested into new projects resulting in the recycling of this funds. To overcome outage of the fund in terms of a high probability of risk occurrence, the application requirements to developers are severe and expensive. For the comprehensive application stage, examinations fees (up to 65,000 €), commitment fees (45,000 €), a high interest rate, debt discount, and provision commission have to be considered for each drilling project. The programme aims to promote sustainable energy supply by saving fossil fuels and using regional, baseload geothermal energy instead. Therefore, risk insurance is provided to mitigate investment barriers owing to the exploration phase. The insurance provides up to 16 Million € per drilling operation. In case of non-viability of the reservoir (contractually defined), the eligible expenses are partly reimbursed by the insurance (max. 80%). The remaining 20% must be covered by the developer and cannot be financed through public funds (share of risk). The duration again depends on the interest-only years which was also the case for the KfW programme. Eligible costs are two drillings (operation and injection well) and stimulation operations for EGS plants. Exploration drilling is not covered by this scheme.

Private risk insurance

Additional to the public insurance scheme offered by the Federal Ministry (BMUB), private insurances can also be found especially in regions with a high market maturity regarding geothermal technologies – usually in Munich. The market maturity has a large influence on the insurance actors according to their improved know-how in risk mitigation due to many active projects. As it already says, the private insurance schemes are provided by insurance companies acting either as a direct insurer (e.g. Munich Re, Swiss Re, AXA etc.) or as insurance broker (Marsh, Willis) (Fraser *et al*., 2013). The insurability mainly depends on the project and the risk it might face. However, EGS is still considered as too risk-prone and is not insured by private insurance schemes. The insurance itself relies on premiums meaning that the developer must pay an insurance premium which is contractually set for the drilling costs (post-damage guarantee). The premium decreases relatively to the probability of success. In terms of total failure, eligible costs are payed by the insurance company (max. 85%). The private risk insurance usually covers the first project stages including drilling, stimulation and test programme.

Insurance will only be allocated if the probability of success exceeds 80% for the project (for further reads: Boissavy, 2020 and Fraser *et al.*, 2013). The very first risk insurance for geothermal in Germany was established for the Unterhaching project in 2003 on the basis of a scheme provided by the Munich RE. The project was managed by Rödl & Partner (consultants) and implemented by the Federal Environmental Ministry together with the municipality of Unterhaching.

6.4 The Netherlands

For the Netherlands, geothermal technology is an opportune and cost-efficient way for the decarbonisation of heating and cooling. It is a key resource in the Dutch Energy Agenda. In 2017, the total geothermal district heating installed capacity in the Netherlands was 142 MW_{th}. Although little emphasis is put on developments of electricity production, there are different support schemes for geothermal heat production (ETIP-DG, 2019). These are not solely governmentally driven but also private considering debt from private banks to finance larger projects.

Subsidies by the government

The government is offering subsidies for different innovation programmes, for example, the use of greenhouse as energy producer (KaE) managed by the Marketing board Horticulture or the Intensification programme energy challenges 2020 (IP2020), which focuses on the realization of more applications for renewable energy and more energy savings (ETIP-DG, 2019). Another incentive, the Energy Investment Allowance (EIA) is provided by the Netherlands Enterprise Agency and concerns companies by offering them tax benefits by investing into energy-efficient technologies and sustainable energy. The total budget for the EIA amounts 147 Million € and it provides a tax reduction of 11%[42].

Further, the state investor EBN supports solid and safe projects with an aid intensity of 40% for heat projects. As shareholder, EBN is monitoring the performance of the projects.

Revenue support

The Netherlands Enterprise Agency offers the feed-in-premium tariff *Stimulering Duurzame Energieproductie* (SDE++[43]), which should encourage the production of renewable energy, notably for geothermal and other heat technologies. 3 Billion € have been committed to geothermal energy in 2016 (ETIP-DG, 2019).

[42] EIA, 2020.
[43] SDE, 2020.

Risk management fund

In 2009, a risk management fund for geological risks was launched by the Ministries of Economic Affairs and Agriculture together with the NL Agency and TNO. The scheme (*Risico's dekken voor Aardwarmte*) intends to support projects getting started by ensuring financing with a quick and non-profitable insurance process. It is considered as a transparent and objective benchmark of the market and should encourage private insurances to take over on a more mature market (Fraser *et al*., 2013). Up to 85% of well costs are refunded in case the thermal output is below 90% of the estimates; the cost for being covered are 7% (ETIP-DG, 2019).

7. Financial Barriers and Needs of Geothermal Technologies

As the project GEOELEC with their recommendation on risk insurance schemes at a European level clearly indicates, the biggest barrier for geothermal projects is the absence of adequate coverage against the resource risk. The failure of drilling would require to charge back the taxpayers leading to a loss-making business for developers. The success of such a project therefore depends on both the properties of the geothermal reservoir and the availability of an affordable insurance for the first drilling work. The latter is usually not covered by public insurance schemes but through private insurance companies in well developed countries. Until today, public schemes fail to insure the test drilling since this project stage has no clear success and failure criteria and therefore does not need to be insured according to Fraser *et al.* (2013). But this project phase still remains risky for investors especially regarding the private sector. Banks are exclusively looking for zero risk. Thus, the investment in deep geothermal projects without an insurance for the test drilling prevents many private finances to happen. Furthermore, geothermal is a capital-intensive technology which needs time to develop usually twice as long as other renewables (Micale *et al.*, 2014). Therefore, the exploration phase is usually supported by public financing due to repayable grants. Post-damage guarantees and revolving funds are mainly granted during production drilling (e.g. KfW Programme). After the risky project phases in the beginning of the development, the private sector is incorporated. However, there is still improvement needed in respect of high interest rates for loans and expensive application procedures. Another solution would be the implementation of an insurance scheme at the EU level as it is indicated by the GEOELEC project. Eligible costs and a comprehensive description of such a fund is given in their report (see Fraser *et al*., 2013).

The high-risk factor at the beginning of a DGE project mainly relies on the insufficient knowledge about the deep subsurface which can be prevented due to the expansion of the available database through many drilling operations as part of the implementation of geothermal plants. A better knowledge about the reservoir would encourage the private sector to invest without cooperating public funds (Seipp *et al.*, 2016), but this is still a long way to go.

According to Dumas and Garabetian (2019), support schemes must either be temporary or should be replaced with a private scheme as technology reaches full competitiveness allowing the technology to progress along its learning curve.

In terms of national support schemes, many of the above described funds are not designed for a specific scope but are rather generalized to cover as many innovative key subjects as possible. This does not seem to have long-term impact on specific objectives, but for geothermal projects these incentives do not reflect the large scale of technology, utilization and market maturity. Meaning, that these support schemes need to go beyond the one-size-fits-all approach and have to be redesigned to fit the specific needs of geothermal (Dumas and Angelino, 2015). However, support schemes are still essential even if they are generalized by creating a secure investment environment for geothermal and favoring the progress towards cost-competitiveness.

Other factors, that prevent geothermal from fully entering the energy mix as a baseload and regional energy source is todays energy market structure. According to Dumas and Garabetian (2019), conventional technologies developed under monopolistic market structures where the taxpayer is in charge of cost reduction and probable risk. Additionally, gas and electricity prices are regulated and the fossil fuel and nuclear sector receive many subsidies in many countries. All of these factors combined, prevent geothermal from fully competing with fossil fuel-based technologies in an energy-only market. Therefore, support measures for geothermal technologies are needed.

Although revenue support schemes such as feed-in tariff schemes may help geothermal to evolve, their disadvantage are their impacts on trade. Its implementation can affect industries in other countries. Therefore, a global coordination of such a scheme is necessary.

Another big challenge, that none of the funds addressed is the social impact of the decarbonization of the European economy regarding work places. For this, the ETIP-DG (2020) wrote a report with recommendations for the European Energy Transition Fund. The latter aims to fund “green” projects promoting the energy transition in coal regions by contributing 4.8 Billion €. Geothermal is among the key technology solutions for this purpose and displays some similarities to conventional extractive industries regarding drilling work. The expertise of mining workers in e.g. geosciences, management of drilling operations, and district heating design etc. are essential for the development of geothermal technologies. The transition to renewable energies should therefore include the retraining of coal workers (ETIP-DG, 2020).

8. Conclusions

All of the partner countries in this report comprise many financing incentives to foster the expansion and the implementation of DGE in the heating and energy market. There is still a noticeable discrepancy regarding the number of financing options and risk insurances. This is usually related to the number of geothermal plants operating in the different countries. France, for example is a key country for utilizing geothermal energy, especially around Paris. Therefore, many financing incentives and policies were established to boost the uptake of geothermal energy both in the heating and electricity sector. It contains the Investment for the Future, the Renewable Heat Fund and the Guarantee Fund with the GEODEEP and AQUAPAC insurance schemes. Both of these insurance schemes cover not only risks in terms of deep geothermal energy projects but also heat pumps using ground water.

In Belgium, financial schemes are not very common, especially in Wallonia. However, in 2021 the Walloon government is planning a decree to cover the financial risk of geothermal projects. With this scheme, Wallonia wants to implement more incentives and guarantees especially regarding the underground resource management. For Flanders, financial support is provided through subsidies, risk insurance and premiums (e.g. STRES, EP-Plus). They are managed by the Flemish Energy Agency or by the Agency Innovation and Entrepreneurship (VLAIO). Risk that is being covered by the Flemish insurance schemes is restricted to the geological risk.

In Germany, financing of renewable energy and innovative technology is common. Among renewable energy policies (EEG), there are also different subsidy incentives, R&D supports, fixed feed-in tariffs and insurance schemes. Additional to the herein mentioned national schemes there are also schemes concerning different federal states where the funding is provided by the different energy agencies as part of the climate protection target of Germany. The EEG provides a secure long-term uptake of renewable energies and fosters investments into clean energy and heat (*EEWärmeG*). The main benefit is the fixed feed-in tariff. As part of this policy and the heat transition, the MAP was established focusing on renewable-based heating. Insurance is provided either through a private insurance company or by the KfW (third largest Bank in Germany).

In the Netherlands, financing of geothermal is possible through subsidies for different innovation programmes (EIA) and revenue supports such as feed-in premium schemes (SDE++). Risk is covered through a Management Fund by the Ministries of Economic Affairs and Agriculture.

All of these different financial support schemes were established to create a secure investment environment for renewable energy projects and geothermal. However, most of them are generalized incentives and need improvement in terms of geothermal energy technologies. Only a few schemes are particularly designed for geothermal, especially the risk insurance schemes. But not all of them are covering the test drilling phase, which is the riskiest part of a DGE project (e.g. KfW "*Fündigkeitsrisiko Tiefengeothermie*"). To overcome this risk, more drilling operations are needed. When it comes to cover the long-term risk only the French and German schemes include it in their risk insurance.

These discrepancies can be negotiated by establishing a risk insurance scheme at the EU level, as being recommended by the GEOELEC project.

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Appendix 1

Summary of the existing financial incentives in the partner countries

<table>
<tr><th colspan="2">Country</th><th colspan="2">Name</th><th>Objectives</th></tr>
<tr><td colspan="2" rowspan="6">France</td><td rowspan="4">Financing incentive</td><td>Multiannual Energy Planning</td><td>Policy: aims to expand the geothermal energy market.
Establishment of risk insurance schemes and tariffs as revenue support.</td></tr>
<tr><td>Investments for the Future</td><td>Policy: managed by ADEME. Financing of demonstration projects is possible.
In scope of this policy, the Géodénergies Institute of Excellence was created in 2015 and finished its work in 2020.
Aid for: Implementing geothermal projects.
Total budget: 3.174 Billion €.</td></tr>
<tr><td>Renewable Heat Fund</td><td>Fund: managed by ADEME.
Dedicated to heating purposes.
Deep geothermal energy is funded with and without heating networks.
Aid for: Initial project phase (covers feasibility study, thermal response tests, experimental drilling)
Total budget: 1.2 Billion €</td></tr>
<tr><td>Inter-ministry fund for competitive clusters</td><td>Fund: by French local authorities
Aid for: Heating networks
10 clusters are operating in the field of renewable energy</td></tr>
<tr><td rowspan="2">Risk insurance</td><td>Guarantee Funds
(e.g. GEODEEP)</td><td>Risk insurance: managed by State and ADEME
To foster investments in renewable energies
Eligible costs: Project feasibility study and investment costs
Conditions: Aid should not exceed 80% of the project costs

GEODEEP: Fund for power and heat generation.
Premium of 2-4.5% must be paid.
For geothermal wells producing >110°C</td></tr>
<tr><td>AQUAPAC</td><td>Risk insurance: by ADEME, in collaboration with BRGM, EDF
for heat pumps using ground water (well depth lower than 100 m)
Eligible costs: Double guarantee:
Short-term: covers first drilling
Long-term: covers plant operation during a period of 10 years
Conditions: Developer must pay a guarantee fee</td></tr>
<tr><td colspan="5">For more information, please see: https://www.ademe.fr/en/mediatheque</td></tr>
<tr><td rowspan="2">Belgium</td><td rowspan="2">Wallonia</td><td>Financing incentive</td><td>Supports by Department of Energy</td><td>R&D support: granted by Department of Energy, Sustainable Building, Department for the Coordination of Structural Funds
Aid for: demonstration and development projects
As part of the ERDF</td></tr>
<tr><td>Risk insurance</td><td>Regional guarantee system</td><td>Legal framework: still in progress; might be implemented by the Walloon government in 2021
Two decrees:
• Regional guarantee scheme → eligible costs are granted after the technical committee's approval
• "Geothermal guarantee" in the Kyoto Fund → compensates geothermal projects
Eligible costs: first drilling and initial investments
Conditions: premium have to be paid</td></tr>
</table>

Country			Name	Objectives
	Flanders	Financing incentive	Green Heat Call	**Funding:** managed by the Flemish Energy Agency Subsidy for heat and power **Aid for:** geothermal energy projects with a minimum capacity of 1 MWth or a gross power of 300 kW
	Flanders	Financing incentive	Strategische ecologiesteun (STRES)	**Funding:** managed by the *Agentschap Innoveren en Ondernemen* **Aid for:** investments for innovative green technologies **Budget provided**: 20-40% of eligible costs
	Flanders	Financing incentive	Ecologiepremie (EP-Plus)	**Funding:** managed by the *Agentschap Innoveren en Ondernemen* Funding will be granted together with a premium **Budget provided**: 15--55% of additional investment costs
	Flanders	Risk insurance	*Waarborgregeling voor het opsporen en winnen van aardwarmte in de diepe ondergrond*	**Risk insurance:** by the Environmental Department **Eligible costs:** geological risk which is associated with output of the system (85% of the costs can be reimbursed) **Maximum coverage:** 18.7 Million € **Conditions:** Participation fee of 7% must be paid
For more information, please see: http://www.res-legal.eu/search-by-country/belgium/				
Germany		Financing incentives	Renewable Energy Sources Act (EEG)	**Policy:** established by the Federal Environment Ministry **Aid for:** It fosters renewable energies and a sustainable energy mix **Revenue support:** Fixed Feed-in tariff for geothermal: ~25 ct/kWh (§45 EEG) **Duration:** 20 years **Complement:** Renewable Heating Act
Germany		Financing incentives	Marktanreizprogramm (MAP)	**Funding:** provided by the Federal Office for Economic Affairs and Export Control (BAFA) **Aid for:** Raising number of renewables in the heating sector **Type of incentive:** • BAFA through direct investment subsidy • KfW through loan with redemption subsidies **Provided budget:** depends on the developer (private household, municipality, industry etc.)
Germany		Financing incentives	KfW-Programm "Erneuerbare Energien Premium – Tiefengeothermie"	**Funding:** provided by the KfW **Aid for:** geothermal heating and power production **Conditions:** eligible for energy projects with at least 20°C and 0.3 MWth **Maximum coverage:** 25 Million € (80% of eligible costs for deep geothermal)
Germany		Financing incentives	7th Energy Research Programme	**R&D support:** implemented by the Federal Government **Aid for:** demonstration and development projects **Total budget:** 6.4 Billion € Provided by Federal budget and Energy and Climate Fund as direct funding
Germany		Financing incentives	Konjunkturprogramm	**Policy:** implemented by the Federal Government A stabilization policy during crisis like COVID-19 Part of this programme is climate protection **Maximum budget:** 100 Million € for municipalities

Country	Name		Objectives
	Risk insurance	KfW “Fündigkeitsrisiko Tiefengeothermie”	**Risk insurance:** managed by the KfW Type of fund → revolving fund **Aid for:** deep geothermal heating and power production; it covers the production drilling **Maximum coverage:** 16 Million € per drilling operation (80% of eligible costs will be covered; 20% remains as equity of the developer) **Duration:** depending on interest-only years **Conditions:** high application fees for feasibility studies and eligibility approval though a technical committee
		Private risk insurance	**Risk insurance:** provided by risk insurance companies **Aid for:** mature geothermal energy markets, where private companies are willing to take the financial risk of such a project • It covers the test drilling and operation drilling **Maximum coverage:** 85% of eligible costs is covered by the insurance company **Conditions:** a premium must be paid by the developer
Hesse		Funding by LEA	**Grant:** provided by the Energy Agency Hesse (LEA) It is a grant that is provided additional to the insurance premium Insurance is provided due to a private insurance company **Maximum coverage:** 500k € per operation (40% of eligible costs are covered)
North Rhine Westphalia		Funding by EnergieAgentur.NRW	**Funding support:** provided by the State NRW or by the Federal **Type of aid**: Competitions are also part of this incentive: e.g. EnergieInnovationspreis.NRW, European Energy Award (EEA) etc. **Programmes:** Progres.NRW
For more information, please see: https://foerdernavi.energieagentur.nrw/			
The Netherlands	Financing incentives	Energy Investment Allowance	**Subsidy:** managed by the Netherlands Enterprise Agency It encourages private and industrial companies to invest in energy-efficient technologies **Aid:** average tax reduction of 11% **Total budget:** 147 Million €
		Sustainable Energy Transition (SDE++)	**Subsidy:** managed by the Netherlands Enterprise Agency It is a feed-in premium **Aid for:** feasible and affordable energy transition **Total budget:** 5 Billion € **Duration:** 12-15 years
		Multiannual Mission-oriented Innovation Programme (MMIP)	**R&D support:** by the Climate Agreement and Integrated Knowledge and Innovation Agenda **Aid for:** renewable heat and cooling (MMIP 4, 7) program
	Risk insurance	Risk management fund	**Funding:** by the Ministries of Economic Affairs and Agriculture Should provide a non-profitable insurance process **Maximum coverage:** 85% of well costs **Conditions:** premium fee of 7% must be paid
For more information, please see: https://english.rvo.nl/subsidies-programmes			

PROJECT PARTNERS

PROJECT SUP-PARTNERS

MORE INFORMATION

Dr Martin Salamon (Project Manager)

Martin.Salamon@gd.nrw.de

+49 2151 897 230

www.nweurope.eu/DGE-Rollout

@DGE–ROLLOUT

SUPPORTED BY

europiZe UG

Dr Daniel Zerweck

+49 176 6251 5841

www.europize.eu