CROWDTHERMAL DELIVERABLE 3.4

DRAFT STRUCTURE OF A PLAY TYPE INDEPENDENT GEOTHERMAL EXPLORATION RISK MITIGATION SCHEME

Summary:

This Deliverable summarises the activities and findings of CROWDTHERMAL's Task 3.3 "Design of auxiliary and alternative pathways to risk mitigation" and concludes WP3. It presents the conceptual framework for a European geothermal exploration risk mitigation scheme that can complement and facilitate alternative financing solutions in the geothermal market.

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GLOSSARY

Name	Definition
Bond	A bond is a special form of loan. The main difference to a loan is that a bond is usually tradable. The ownership of this instrument can be transferred in a secondary market (i.e. can be bought, for example from the state and sold to others for a price determined in the secondary market). Special forms of bonds are social or green bonds. A green bond is a bond that is specifically earmarked to raise money for climate and environmental projects.
CAPEX	Capital expenditure. Funds used by a project developer for assets such as property, plants, buildings, technology, or equipment. This can for example be drilling costs to build a well.
Community funding	Community funding is a financing method where funding is raised from the public, meaning that the funding is delivered by the community. Community funding is the umbrella for alternative finance methods for community projects.
Community Investors	Private individuals (or sometimes also small businesses) who, in the context of sustainable and responsible investing, participate in the financing of a project, with small contributions to crowdfunding or direct lending campaigns, usually in the order of magnitude of a few hundred or a few thousand Euros. Another term for community investors is retail or non-professional investor.
Crowdfunding	Crowdfunding is the most commonly used form of community funding where funds are raised directly from the community without going through a bank in return for a set interest rate (loan), dividends (equity), or rewards (reward-based). Depending on the contract set up, crowdfunding can either be risk-sharing or risk-absorbing.
Debt / Loan	Debt is capital that is given in the form of a loan for which an interest rate has to be paid. The main amount has to be repaid after a certain time. Community funding method examples of debt financing are crowdfunding (loans) or direct lending.
Direct lending	Direct lending is lending by a financial intermediary without a banking license that attracts funding and uses this funding to give out loans to other parties.
EBITDA	Abbreviation for earnings before interest, tax, depreciation, and amortization. It denotes a company's profits in a particular period, before taking away amounts for interest paid, tax paid, and the decrease in the value of things that the company owns.[1]
EGS	Enhanced or engineered geothermal system. An EGS is a man-made geothermal reservoir in areas where hot rocks are present, but insufficient or little natural permeability and/or fluid saturation is found. An EGS is typically created by hydraulic or chemical stimulation to

[1] https://dictionary.cambridge.org/de/worterbuch/englisch/ebitda

	generate or enhance permeability at reservoir depth. EGS are sometimes also referred to as HDR (hot dry rock) or petrothermal (as opposed to hydrothermal) systems.
Equity	Equity, as opposed to debt, refers to the amount of capital contributed by the owners of a company, usually in the form of shares. By buying shares of a company, the shareholder becomes part-owner of the company and shares in its profits and losses. A community funding method example of equity financing is equity crowdfunding.
GDF	Geothermal Development Facility for Latin America
GGDP	Global Geothermal Development Plan
GRMF	Geothermal Risk Mitigation Facility for Eastern Africa
Guarantee	A third party (e.g. the government) can give a guarantee, which means they guarantee that they will repay e.g. a loan if the original borrower cannot repay it. This provides more security to the lender that the loan will be repaid.
OPEX	Operating expenditure. Ongoing costs of a project developer for running a project. This can e.g. be maintenance costs for pumps or costs for consumables like scaling inhibitors.
PPP	Public-private partnership. A PPP is a co-operation between the public and private sector (i.e. governmental entities and businesses) to develop a project or to provide services. PPPs are frequently used for infrastructure projects.
Project Developer	The public or private entity (or even individual) developing a geothermal project. This can for example be a municipal utility or a specialised geothermal development company. In many cases, the project developer is also the main investor of the geothermal project. The project developer may also have external main investors, e.g. institutional investors such as pension funds or banks. The project developer can also be the operator of a geothermal project, or there can be multiple project developers, e.g. for the subsurface vs. surface works.
RMF	The proposed CROWDTHERMAL Risk Mitigation Fund
UNFC	United Nations Framework Classification for Resources

1 EXECUTIVE SUMMARY

The exploration risk as the risk of not finding a geothermal reservoir in sufficient quality or quantity for commercially viable exploitation significantly contributes to the investment reluctance and the relatively slow development of the deep geothermal industry. Several exploration risk mitigation facilities and insurance schemes with different regional foci and various risk-sharing concepts have been established or are currently being developed internationally.

So far however, none of the existing or envisaged schemes comprises the possibility to combine exploration risk mitigation and alternative financing solutions for geothermal projects. Yet, alternative finance methods can be vital elements of the funding plan for the high-risk and cost-intensive early phases of deep geothermal projects. They can close the financing gap and reduce the requested amount of equity. At the same time, they can improve public project ownership and mitigate the risk of project failure due to non-acceptance.

New approaches to financing for geothermal developments also bring about new types of risks. Community investors in geothermal projects basically face the same exploration risk as project developers. Unless the drilling success is secured by a risk mitigation scheme, retail investors are also in danger of losing their investment in case of project failure. In order to be able to use a large array of alternative financing methods matching different levels of risk appetite of investors, an accompanying mechanism is needed that can keep the exploration risk away from non-technical community investors with relatively little risk level willingness, typically investing in loan-based instruments rather than in equity products.

Alternative financing approaches necessitate the expansion of risk mitigation concepts beyond what has been traditionally considered within the geothermal sector. The vision of CROWDTHERMAL Work Package 3 thus was to develop a framework for a novel exploration risk mitigation scheme to complement alternative financing solutions for deep geothermal projects throughout Europe.

In this Deliverable, we present the draft structure of such an exploration risk mitigation mechanism that can facilitate public participation in geothermal funding, protect private investors' interest and encourage new geothermal project developments.

The requirements specifications for the proposed framework mainly stem from the cluster dialogues and demand analysis performed in CROWDTHERMAL Task 3.1. Some of the most promising alternative finance risks' mitigation tools that were identified in CROWDTHERMAL Task 3.2 inspired the shaping of the framework, as did various discussions with CROWDTHERMAL Advisory Board members, consortium internal and external experts.

On the basis of the previous results and given the current geothermal market conditions, it is recommended to set up a CROWDTHERMAL Risk Mitigation Fund, that should ideally be financed by a European, public funding source. The fund shall be a pan-European support instrument mitigating the financial risks associated with subsurface uncertainties of geothermal projects. It shall be applicable to deep geothermal projects that are partly funded by the public via loan-based alternative financing methods.

The proposed support framework includes a grant-based, co-financing component in the form of matchfunding and a risk-sharing component in the form of loan guarantees. The matchfunding shall be paid as a grant to the project developer prior to exploration drilling. It shall match the amount of funds that can be raised from the crowd. The loan guarantees shall mitigate both the short-term exploration risk in the drilling phase and the long-term subsurface risks during operation. In case an economically viable project operation is not or no longer possible, they secure the (partial) repayment of community investors' loans.

In case it is needed, the loan guarantee amount will be paid from an ear-marked Trust Fund. Payments from the Trust Fund will be made through the financial intermediary facilitating the community funding process. This procedure ensures that the loans of community investors are not subordinated. The decision over project success or failure is made on the basis of project-specific reservoir and economic parameters. Successful project are required to pay back royalties, thus making the fund both a risk- and profit-sharing facility. The importance of mechanisms for alignment of interest and quality assurance is highlighted, and concrete suggestions are given.

The proposed support framework tackles the main barriers to geothermal market development. The co-financing component addresses the lack of risk capital in the early project development phases. It encourages deep geothermal project developers to apply alternative financing and serves as both incentive and leverage for successful community funding.

The loan guarantee significantly reduces the financial risks for project developers and community investors alike. It prevents exploration risk-related financial losses, thus making the investment more attractive for crowd-based retail investors. At the same time, it can lower return expectations that project developers have to fulfil.

On a larger scale, adding a guarantee to alternative financing loan instruments introduces more flexibility in investment opportunities in the early project phases. The applicability of loan-based community funding schemes and solutions is broadened, and people with a lower risk appetite can also be given the opportunity to be part of the project from the beginning.

The proposed framework supports deep geothermal projects of all resource types and sizes, regardless of their geological and structural settings. Following such a Geothermal Play Type-independent approach, geothermal developments can be more equally attractive and distributed throughout Europe. A promotion of new geothermal developments in all regions and for various application scenarios can help achieving a critical mass for community-financed geothermal projects.

This Deliverable concludes CROWDTHERMAL Work Package 3. Future Work Package 4 Tasks will include an economic assessment of the presented framework as well as the search for possible financiers for the scheme.

To sum up, the proposed support framework considers the needs of both geothermal and alternative finance industry, of both project developers and community investors. It is designed to optimally assist community-funded deep geothermal projects and to encourage public participation in geothermal funding. Once implemented, it is expected to act as an important market incentive and to contribute to an accelerated geothermal project development in Europe.

2 INTRODUCTION

2.1 GENERAL CONTEXT

Despite its huge potential to supply sustainable, decentralised, and low-carbon baseload energy for electricity, heating, and cooling, deep geothermal still plays a marginal role in the European energy mix. Like in any other energy technology, harnessing geothermal involves a variety of challenges, impacts, and risks. One of the main challenges for deep geothermal projects – and therefore one of the largest barriers for geothermal market development internationally – is the so-called exploration risk.

The exploration risk (also geological, resource or discovery risk) is the risk of not finding an economically viable amount of energy, defined by temperature and productivity[2] of a geothermal reservoir. Sometimes, also the risk of a technically challenging chemistry of the geothermal brine is subsumed under the exploration risk. While an adverse chemistry can usually be tackled by technical measures and subsurface temperatures can relatively well be predicted, the largest uncertainties are associated with the flow rate that can be delivered from a geothermal reservoir. Results from a recent survey amongst various geothermal stakeholders throughout Europe, conducted by the Horizon 2020 research project GEORISK, confirmed that the top three overall risks for deep geothermal projects are fluid-related (i.e. insufficient fluid in formation, low or degrading flow rate, see GEORISK 2019).

Even when best practice exploration codes are followed, actual reservoir parameters can only be verified after at least one full-size well has been drilled to target depth. By that time, funds in the order of magnitude of several million Euros have already been spent. The high exploration risk that is especially present in the early stages of geothermal project development (see Section 5.2), makes it difficult to mobilise the required risk capital for funding early exploration surveys and first drillings. In order to facilitate broad investments in geothermal, it is necessary to provide sufficient investment security by mitigating the exploration risk (e.g. Wendel et al. 2010, Robertson-Tait et al. 2015).

Several mechanisms have been developed for risk-sharing of the geothermal resource risk between the public and private sector. Countries like Germany, Switzerland, the Netherlands, and France have established governmental support or guarantee schemes mitigating the geothermal exploration risk for national projects (e.g. Fraser et al. 2013, Bonfait et al. 2018, Boissavy 2019). Beyond the national schemes, a number of larger, transnational risk mitigation mechanisms (e.g. the Geothermal Risk Mitigation Facility for Eastern Africa (GRMF) or the Geothermal Development Facility for Latin America (GDF)) were implemented in various regions worldwide. A variety of initiatives is underway to establish further geothermal exploration risk mitigation schemes internationally.

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[2] The productivity index of a geothermal well is calculated from the flow rate in l/s per pressure reduction in bar.

Existing risk mitigation schemes reduce the resource-related risks in different project development phases. They can:

- support the exploration phase prior to first exploration drilling (e.g. the ARGeo (African Rift Geothermal) risk mitigation fund for Eastern Africa),
- mitigate the risk of not finding an adequate resource in the first exploratory drilling phase ("the short-term risk", e.g. the GRMF drilling grants, support from the Global Geothermal Development Plan (GGDP) of the World Bank Group / ESMAP),
- mitigate the risk that a resource cannot be sustainably produced in the operation phase ("the long-term risk"), e.g. the French SAF Environnement Long Term Fund[3].

So far, none of the existing or envisaged schemes accounts for the opportunity to combine risk mitigation and alternative finance solutions for geothermal projects. Yet, alternative finance methods can be vital elements of the funding plan for the high-risk and cost-intensive phases of deep geothermal projects. They can close the financing gap and reduce the requested amount of equity. At the same time, they can improve public project ownership and mitigate the risk of project failure due to non-acceptance.

New approaches to financing for geothermal developments also bring about new types of risks (see CROWDTHERMAL Deliverable 3.2). Community investors in geothermal projects basically face the same exploration risk as project developers. Even with appropriate and best-practice risk mitigation strategies in place, those measures and concepts cannot reduce the risk completely.

Unless the drilling success is secured by a risk mitigation scheme, retail investors are in danger of losing their investment in case of project failure due to a "dry well". The exploration risk is therefore not only one of the main challenges for deep geothermal project developers, but also the largest financial risk for community investors in geothermal projects. An unsuccessful project will also have huge effects on the further willingness of retail investors to contribute and invest in future geothermal projects. If public participation in geothermal community funding shall be encouraged, the exploration risk needs to be kept away from the non-technical community investors. This is especially important for loan-based instruments that are typically chosen by investors with relatively low risk appetite.

One of the main requirements for the risk mitigation framework to be developed within CROWDTHERMAL is therefore to protect private investors' interest. Exploration risk-related financial losses for crowd-based community investors shall be prevented. The framework shall account for the needs of alternative financing methods and complement alternative financing solutions.

A key feature that distinguishes risk mitigation mechanisms is how the funds are disbursed, either as a grant also supporting the project finance (co-financing) or as risk coverage

[3] Strictly speaking, the long-term risk does not fall under the actual exploration risk present in the early project development phases.

(insurance) which is only paid out if the energy produced from the wells is less than planned. We propose a combination of both components:

- In general, grant-based schemes are considered the most appropriate support mechanism for juvenile markets (Seyidov 2020). We suggest implementing a matchfunding co-financing approach, which was identified as one of the most promising concepts in CROWDTHERMAL Task 3.1 and 3.2. Matchfunding means that a public or private organization or institution matches financial contributions from the crowd with the same amount (or a percentage of it), thus increasing both the total project budget and the trust in a project (for details see CROWDTHERMAL Deliverable 3.2).
- The risk-sharing component shall consist of a loan guarantee for loan-based alternative financing instruments. It shall secure and guarantee the (partial) repayment of loans from community investors in case of project failure. The loan guarantee shall be realized via a Trust Fund concept and a co-operation with crowdfunding platforms.

A current research project ("Unlocking the Crowdfunding Potential for the European Structural and Investment Funds (ESIF)"[4]) with the participation of CROWDTHERMAL partner CFH investigates the collaboration of public authorities with the crowdfunding industry and has compiled existing examples for similar co-financing and guarantee approaches in the sector. These examples show that the proposed concepts are both needed and feasible. There are no legal objections or problems regarding the implementation of matchfunding schemes. Also, government organisations are very interested to setup guarantee schemes complementing crowdfunding solutions, even more, because the new European Crowdfunding Service Providers regime (ECSP) will provide a harmonised and pan-European crowdfunding regulation from November 2021, within the European Capital Markets framework.

Applications like the AIG Crowdfunding Fidelity insurance product, the co-operation of the Dutch guarantee scheme BMKB-C with crowdfunding platforms or the EaSI Guarantee Instrument of the EIF (AIG 2016, EIF 2019, CROWDTHERMAL Deliverable 3.2) furthermore show that crowdfunding platforms are equally interested in offering projects with guarantees attached to them, even if this means a certain degree of extra effort and/or costs. Guarantees will make the projects more attractive to community investors. It is not expected that platforms would require a fee for services associated with a guarantee.

The geothermal potential and geothermal resources are not equally distributed over the world. Along with the specific resource type, the site- and project-specific geological, technical, and financial risks of deep geothermal developments largely vary. This is also true for the all-dominating exploration risk.

Some existing geothermal exploration risk mitigation schemes tend to support large-size projects tapping into favourable geothermal resource types (Kreuter & Baisch 2018). High

[4] More information on this project can be found at: https://etendering.ted.europa.eu/cft/cft-display.html?cftId=5907

enthalpy reservoirs in volcanic regions for instance can be exploited very efficiently by installing a high number of wells. Consequently, the risk can be spread over a large portfolio of wells and can thus be handled more easily by a private market-based insurance company or any risk-sharing facility. For low enthalpy resources like they are present in many European regions, on the other hand, there often exists no exploration risk mitigation option.

However, small- to medium-size (heat) projects in less favourable, medium- or low-temperature settings are equally important for a decentralized, community-based energy supply. In order to open the door for projects of all resource types and project sizes, a project-specific scheme that works for all deep geothermal resources, regardless of their geological/structural setting is proposed. The cluster analysis in Task 3.1 confirmed that a new risk-sharing mechanism to complement alternative financing solutions should support different project sizes and allow for site-specific characteristics in risk profiles. The CROWDTHERMAL risk mitigation framework thus shall be a mechanism independent of the respective Geothermal Play Type[5]. It shall facilitate a broad market uptake and make deep geothermal (more) equally attractive for all resource types.

The main challenge for a new risk mitigation scheme will expectedly be to find a financing source. Even if an appropriate sponsor can be found, funding will certainly be limited. The proposed exploration risk mitigation framework shall therefore focus its support on deep geothermal projects for which the fluid-related exploration risk is seen as the main barrier to investment and implementation. For this reason, only open, fluid-extracting geothermal systems – as opposed to closed-loop technical solutions – shall be eligible for the proposed scheme (see Section 4). This is consistent with the Play Type concept that neither comprises closed-loop systems.

[5] Moeck and Beardsmore (2014) define a Geothermal Play as a model of a geothermal system classified on the basis of both structural position and geologic setting (see Section 4).

2.2 DELIVERABLE OBJECTIVES

This Deliverable "D3.4 - Draft Structure of a Play Type independent geothermal exploration risk mitigation scheme" summarises the activities and findings of CROWDTHERMAL's Task 3.3 "Design of auxiliary and alternative pathways to risk mitigation".

Within this Deliverable, we present the conceptual framework for an exploration risk mitigation mechanism that can complement alternative financing solutions in the deep geothermal market. The proposed framework is based on the demand analysis of geothermal risk mitigation (Task 3.1) and the identification of specific risks being associated with alternative financing methods for geothermal projects as well as their possible mitigation (Task 3.2). The framework is embedded in the Play Type concept for the classification of deep geothermal resources (Section 4) and in the holistic representation of geothermal project development phases, associated risks, and alternative financing options developed within CROWDTHERMAL WPs 2,3, and 5 (Section 5.2).

The Deliverable describes the requirements specifications (Section 5.1) and key characteristics (Section 5.3.1) of the proposed mechanism. It provides details on the proposed application and operation processes (Sections 5.3.2 and 5.3.4) and elaborates on quality assurance issues (Section 5.3.6). The applicability for the CROWDTHERMAL WP5 Case Studies is assessed in Section 5.4. Section 5.5 gives an outlook on the next steps that would be necessary to achieve the establishment of the scheme in the market. The conclusions of this Deliverable are summarized in Section 6.

Deliverable 3.4 concludes WP3 "Auxiliary and alternative pathways to risk mitigation" which terminates with M18. Together with the results of Tasks 3.1 and 3.2, the draft structure of the auxiliary risk mitigation scheme will serve as input for the development of the actual implementation framework and feed into the CROWDTHERMAL core services in WP4.

In the subsequent Task 4.4.4 "CROWDTHERMAL Toolbox for risk-evaluation and mitigation", economic efficiency calculations will be performed for a number of projects in order to assess the economic implications of the proposed risk mitigation scheme. Within the scope of Task 4.4.4, a list of possible financiers of the proposed risk mitigation mechanism will also be compiled.

3 METHODOLOGY

The first assignment within Task 3.3 was to summarize the requirements for the risk mitigation framework to be developed that were compiled in previous WP3 Tasks. The requirements mainly stem from the conclusions of the demand analysis performed in Task 3.1 and presented in CROWDTHERMAL Deliverable 3.1. Additionally, some of the most promising concepts identified in Task 3.2 and presented in CROWDTHERMAL Deliverables 3.2 and 3.3 (in particular: the matchfunding approach and the insurance solution "Crowdfunding Fidelity" by the global insurance organisation AIG) inspired the shaping of the proposed framework.

Further suggestions were drawn from written feedback from the CROWDTHERMAL Advisory Board and discussions during the Advisory Committee Workshop in September 2020. The following members of the CROWDTHERMAL Advisory Board provided input to this subject:

- Marit Brommer, Executive Director, IGA
- Philippe Dumas, Secretary General, EGEC
- Janos Szanyi, Associate Professor, University of Szeged (Hungary)
- Matthias Tönnis, Underwriter, Munich RE

Supplementary networking activities and desktop research on past and present geothermal de-risking initiatives were conducted. Based on the so-compiled requirement specifications, a first sketch for a conceptual framework of a new risk mitigation mechanism was developed.

The design of the framework was reviewed by and discussed with experts from different disciplines, both within and outside the CROWDTHERMAL consortium:

- Subcontractor gec-co (Th. Weimann) with regard to the economic implications of the proposed scheme and the feasibility of an integration into existing financial modelling software for the economic assessments to be performed within WP4
- Partner CFH (R. Kleverlaan) contributing expertise on crowdfunding procedures, the functioning of crowdfunding platforms, and on loan guarantee schemes
- Member of the Advisory Board M. Tönnis from the global insurance provider Munich RE with extensive experience in international public and private geothermal risk mitigation schemes

The conceptual framework was also presented to the CROWDTHERMAL consortium via its collaborative platform. All partners were asked to review, and several comments were provided. During the consortium review, possible application options for the CROWDTHERMAL Case Studies were checked.

Within the scope of Task 3.1 already, networking interviews on the subject of geothermal risk mitigation and alternative finance were conducted with key experts being involved in past and ongoing geothermal de-risking schemes or community financing projects. Within Task 3.3, their recommendations regarding exploration risk mitigation for community-funded geothermal projects were further analysed. Interviews with the following geothermal experts were integrated into this Deliverable:

- Gordon Bloomquist, international geothermal expert and technical consultant to the GRMF
- Katrin Brandes, Senior Project Manager, KfW Development Bank (German Reconstruction Loan Corporation)
- Magnus Gehringer, CEO Consent Energy LLC, Consultant to the World Bank Group
- Meseret Zemedkun, ARGeo Program Manager (Regional Office for Africa), UNEP (United Nations Environment Programme)

4 THE GEOTHERMAL PLAY TYPE CONCEPT

As elaborated in Section 2.1, the CROWDTHERMAL risk mitigation framework shall be a de-risking mechanism that can be applied to all Geothermal Play Types.

A Geothermal Play is a model of a geothermal system classified on the basis of both structural position and geologic setting (Moeck & Beardsmore 2014). The Play Type classification considers geological factors such as the reservoir rock unit, and properties such as the heat source, the dominant heat transport mechanism, a possible regional top seal or caprock and the geographic extent of the Play. Key parameters of the catalogue are whether heat transfer is dominated by conduction or convection, and regional-scale characteristics of e.g. the heat source, the reservoir rock, the porosity-permeability properties and the fluid type (Table 1).

The specific Geothermal Play Type widely affects factors like the appropriate exploration and exploitation techniques, possible project sizes, typical energy production costs as well as geological, technical, and financial risks associated with the development and use of a geothermal resource. Defining a Play Type alone however does not define the project (and hence cannot suffice to assess the risk). The same Play Type can in principle be exploited in many different engineering ways.

The Geothermal Play Type concept provides a globally applicable geological framework for geothermal systems. It does however only include deep geothermal resources and works on a regional rather than local scale.

It only considers open geothermal systems (i.e. fluid-recovering systems) that face a fluid flow-dependent exploration risk in terms of not being able to yield / recover enough thermal fluid for commercial use. Closed-loop systems like borehole heat exchanger that are commonly used in shallow (<400 m) geothermal projects in contrast do not depend on the sufficient presence and recovery rate of fluids[6]. In case of ground-coupled heat pumps, a thermal-response-test is typically carried out in advance. When the results of the thermal-response-test are available, the resource-related risk becomes comparatively low.

The Play Type concept however comprises both hydrothermal and petrothermal (HDR / EGS) resources. Using EGS technologies, not only permeable rocks with natural steam and/or brine content can be exploited to produce energy, but also rocks with low matrix and fracture permeability – if they feature physical properties that allow the successful application of hydraulic and/or chemical stimulation techniques.

Based on our work in Task 3.1, part of the conclusions of CROWDTHERMAL Deliverable 3.1 was that the risk mitigation concept to be developed should focus on hydrothermal (as opposed to petrothermal) projects, because EGS projects still show a lot of R&D characteristics, and not many reference cases exist. Due to the high risks and uncertainties associated with them, EGS projects are also excluded by some insurance solutions.

[6] This also applies for deep borehole heat exchangers or other deep, closed-loop solutions like the Eavor-Loop™ technology (see Appendix).

Table 1: Geothermal Play Type Classification according to I. Moeck and G. Beardsmore (OpenEI 2014).

Type			Geologic Setting	Heat Source	Dominant Heat Transport Mechanism	Storage Properties of Reservoir	Regional Topseal or Caprock	Examples
Convection Dominated	**CV-1:** Magmatic	**CV-1a:** Extrusive	Magmatic Arcs, Mid Oceanic Ridges, Hot Spots	Active Volcanism, Shallow Magma Chamber	Magmatic-hydrothermal Circulation	---	Extensive Low Permeability Clay-rich Layers	*Java*
		CV-1b: Intrusive	Magmatic Arcs, Mid Oceanic Ridges, Hot Spots	Active Volcanism, Shallow Magma Chamber	Magmatic-hydrothermal Circulation, Fault Controlled	---	---	*Taupo Volcanic Zone*
	CV-2: Plutonic	**CV-2a:** Recent or Active Volcanism	Convergent Margins with Recent Plutonism (< 3 Ma), Young Orogens, Post-orogenic Phase	Young Intrusion+Extension, Felsic Pluton	Magmatic-hydrothermal Circulation, Fault Controlled	---	---	*Larderello*
		CV-2b: Inactive Volcanism	Convergent Margins with Recent Plutonism (< 3 Ma), Young Orogens, Post-orogenic Phase	Young Intrusion+Extension, Felsic Pluton, Heat Producing Element in Rock	Hydrothermal Circulation, Fault Controlled	---	Low Permeability Caprock	*The Geysers*
	CV-3: Extensional Domain		Metamorphic Core Complexes, Back-arc Extension, Pull-apart Basins, Intracontinental Rifts	Thinned Crust+Elevated Heatflow, Recent Extensional Domains	Fault Controlled, Hydrothermal Circulation	---	---	*Basin and Range, Soultz-sous-Forêts*
Conduction Dominated	**CD-1:** Intracratonic Basin		Intracratonic/Rift Basins, Passive Margin Basins	Lithospheric Thinning and Subsidence	Litho/Biofacies Controlled	High Porosity/Low Permeability Sedimentary Aquifers	---	*North German Basin*
	CD-2: Orogenic Belt		Foreland Basins within Fold-and-thrust Belts	Crustal Loading and Subsidence Adjacent to Thickened Crust	Fault/Fracture Controlled, Litho/Biofacies Controlled	High Porosity/High Permeability or High Porosity/Low Permeability Sedimentary Aquifers	---	*Southern Canadian Cordillera, Molasse Basin*
	CD-3: Crystalline Rock - Basement		Intrusion in Flat Terrain	Heat Producing Element in Rock, Hot Intrusive Rock	Hot Dry Rock, Fault/Fracture Controlled	Low Porosity/Low Permeability Intrusive Rock (Granite)	Insulating Caprock	*Fenton Hill*

Even though they might not be best suited for community funding, we propose to reconsider this restriction. If the risks are communicated properly, community investors should also be given the opportunity to invest in and be part of EGS projects. Consequently, petrothermal projects should also be eligible for the CROWDTHERMAL risk mitigation framework. The proposed mechanism can reduce the risks of EGS projects for the community investors to an acceptable extent. It can also encourage the financial participation of the crowd in EGS projects, which in turn can increase the social acceptance of such projects.

The idea of a Play Type-independent risk mitigation scheme has been published by Kreuter et al. (2014) and Kreuter & Baisch (2018). This first concept envisaged that:

- The funding should be grant funding and given in the drilling phase to solve the problem of funding the first, high-risk exploration and reservoir confirmation works.
- The grant size should be defined so that an externally specified and fixed price for the kWh of produced geothermal energy is met which is acceptable to the country and its financial and social situation, i.e. the mechanism would work in a fashion similar to a feed-in-tariff.
- The size of the grant should be calculated based on a financial model with input parameters depending especially on the resource type (high, medium, or low enthalpy), resource quality (temperature and production rate), and CAPEX (infrastructure, power plant and drilling costs).

During the design of the proposed CROWDTHERMAL risk mitigation framework, we adjusted the initial concept in the following way:

- We still propose early grant funding as one of the components of our framework. The grant shall be given as matchfunding for community-funded contributions and shall be paid as direct co-financing support to the project. The grant funding component shall be supplemented by a risk-sharing instrument in the form of loan guarantees mitigating the short- and long-term exploration risk for community investors (for details see Section 5.3).
- We refrain from using a country-specific energy sales price to determine grant sizes. The CROWDTHERMAL risk mitigation mechanism shall be a European solution applicable for deep geothermal projects in all European countries. The economic benchmark parameters used to determine the amount of funding support will therefore be compiled on a project-specific rather than country-specific level.
- We still propose to base the support on a financial model with site-specific input. A project-specific, 20 years financial model will be used to assess a project's eligibility and feasibility, to define success/failure thresholds, to ascertain whether the loan guarantee will be required to step in and for monitoring and audit purposes. The financial model will continuously be updated during the term of the funding agreement.

A Play Type-independent exploration risk mitigation scheme can act as an important market incentive and contribute to an accelerated geothermal project development. The following Section 5 presents the key parameters of the proposed support framework.

5 THE CROWDTHERMAL RISK MITIGATION FRAMEWORK

5.1 REQUIREMENT SPECIFICATIONS

According to the vision of WP3, the CROWDTHERMAL risk mitigation framework to be developed shall be able to facilitate the development of deep geothermal projects that apply community funding. As such, it shall address the main barriers for market development and shall:

- Tackle the lack of risk capital for geothermal developments
- Facilitate public participation in geothermal crowdfunding
- Complement alternative financing solutions
- Protect private investors' interest
- Mitigate the exploration risk
- Make geothermal (more) equally attractive for all Geothermal Play Types

Previous WP3 work identified the following specific requirements that shall be fulfilled by the new risk mitigation mechanism:

- The CROWDTHERMAL risk mitigation framework shall focus on the exploration risk of deep geothermal projects as the risk of not finding an economically viable amount of energy, defined by temperature and productivity of a geothermal reservoir for a minimum of two wells per project.
- It shall furthermore consider scaling / corrosion and other long-term subsurface operational risks like the risk of decreasing energy production e.g. due to declining flow rates or thermal break-through.
- By addressing the resource risk in different project phases, it shall facilitate sustainable developments throughout the project lifetime.
- While it shall not be the primary focus, it shall still consider drilling risks and drilling-related cost overruns.
- It shall support different project types and sizes and allow for specifics of risk quantification. It shall be a Play Type-independent scheme encouraging the development of deep geothermal projects with high, medium, and low enthalpy resource types.
- The risk mitigation scheme shall be a pan-European, country-unspecific support mechanism.
- The market maturity (juvenile, not enough risk capital for early project phases) requires grant-based support in the drilling phase and a high involvement of national governments or transnational financing bodies in the funding of the scheme (for Details see CROWDTHERMAL Deliverable 3.1).
- The whole system shall be designed so that small retail investors are not subordinated in case of a failure, meaning that in case the exploration risk occurs, community investors shall be repaid first.

5.2 RISK MITIGATION PHASES AND TYPE OF FUNDING

One of the main eligibility criteria for the CROWDTHERMAL risk mitigation framework shall be that applicants must demonstrate that a certain portion of their project costs is provided by financial contributions of community investors (see Section 5.3.2). Following the classification determined within WP5, the most common forms of community funding are crowdfunding (loans), crowdfunding (shares/equity), crowdfunding (reward-based), direct lending/green bonds and leasing (for details see CROWDTHERMAL Deliverable 3.2).

The most suitable type of financial instrument for an individual project depends on many factors like the technical characteristics, the current project development phase, the specific financial characteristics (i.e. type of capital, financial risk, amount of capital required), and the social context. Within Task 3.2, we identified specific advantages, risks and mitigation measures of the different alternative finance methods, each from a project developer and community investor perspective. They resulted in a very general guide regarding the most appropriate type of alternative finance as a function of the geothermal project phases and associated risks and costs (Figure 1).

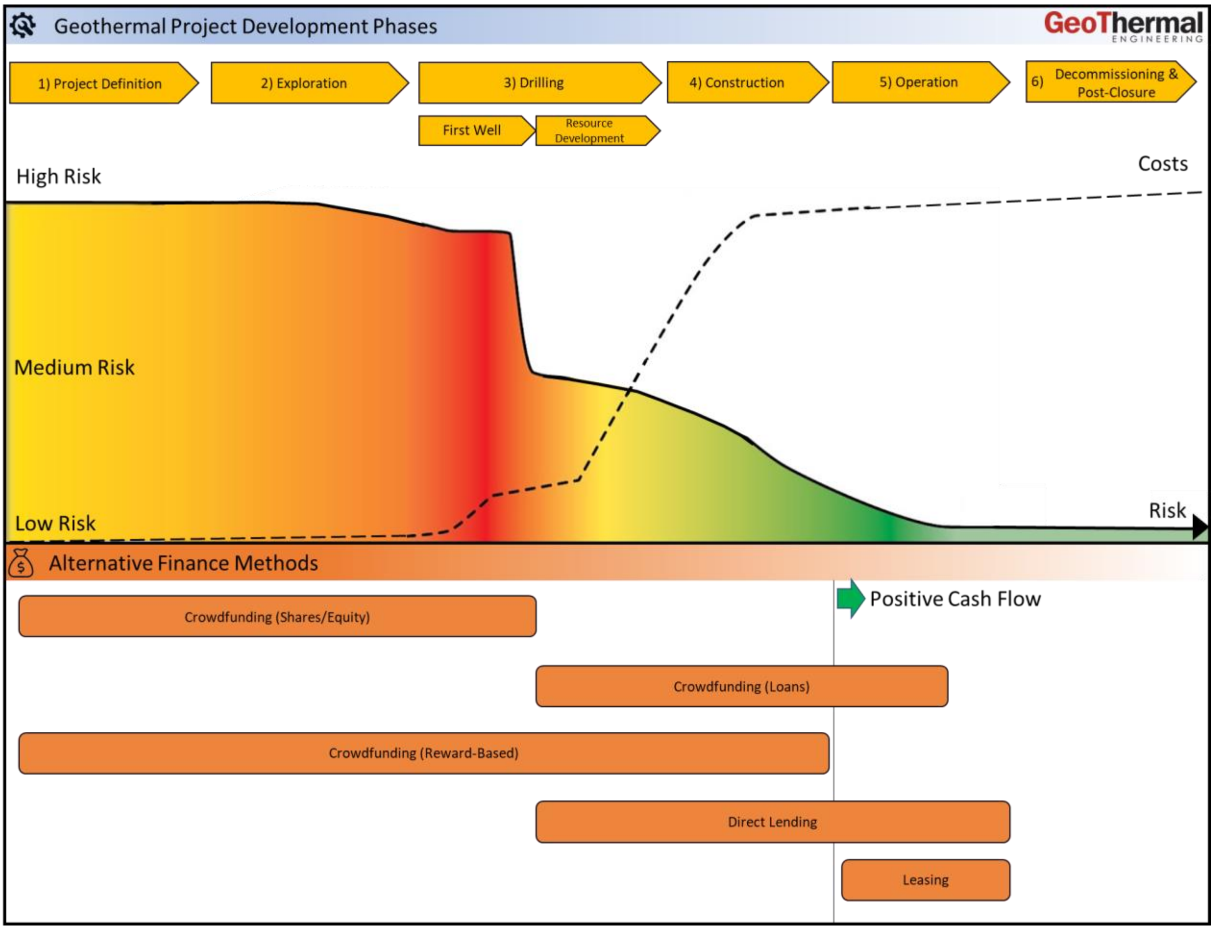

Figure 1: Technical geothermal project development phases, associated risks, costs, and most appropriate alternative finance methods (modified after ESMAP 2012 and Altfinator.eu 2020).

As can be seen in Figure 1, each technical geothermal project development phase has different risk levels and characteristics. Especially in the early high-risk phases of a geothermal development which represent the bottleneck in traditional financing, alternative finance methods like crowdfunding can close the risk and financing gap until the geothermal resource is proven. After a first successful well has been drilled, the resource-related risk significantly decreases and access to bank finance gradually becomes easier.

Geothermal crowd investments are suitable for people who want to support sustainable and environmentally friendly activities. Within this pool of potential contributors, there are however different kinds of community investor groups. Some have a high affinity to risk, others will be more risk-averse, but still motivated to be financially involved. From a project developer perspective, it would be desirable to be able to choose from different alternative financing options, depending on the risk appetite and return expectation of the retail investors.

The resource-related risk has a direct impact on the community investors' financial risk. The early, exploration and drilling phases of a deep geothermal project have the highest risk of failure and thus require risk capital. For this reason, Figure 1 suggests crowdfunding (equity) as one of the most appropriate alternative financing methods until the first well has successfully been drilled[7]. Equity instruments are typically used by investors that are willing to take a high level of risk. These investors can help projects to come to financial closing in the exploration phase. But, with a large chance to fail, expectations on return will be high, too.

Community investors with lower risk appetite will rather look for less risky investments in loan instruments with fixed interest rates. But, from a project developer's perspective, loan instruments are challenging in the early project phases when it is difficult to predict the project timing and results. Both crowdfunding loans and direct lending debts need to be repaid at fixed dates, even in case a geothermal project fails, for example, due to a dry well. Figure 1 thus suggests loan instruments only after a successful first well. At this point in time, the exploration risk has significantly decreased, and project developers can more reliably serve debts with fixed conditions.

If the opportunity to be part of the projects from the beginning shall however also be offered to investors with lower risk appetite (tending to use loan instruments), it is a prerequisite to keep the possibility of total financial losses due to the exploration risk off such community investors. To make loan instruments more suitable for early project development phases, we suggest the application of loan guarantees securing the (partial) reimbursement of community investors' loans in case of project failure as part of the proposed support framework.

In presence of an accompanying loan guarantee, the bars of the loan instruments' applicability in Figure 1 could be moved forward (Figure 2). Adding a loan guarantee to alternative financing loan instruments can thus introduce more flexibility in investment opportunities in the early project phases. It can offer more risk-averse investor groups the opportunity to be part of

[7] Reward-based crowdfunding is typically only done on a very small and local scale.

geothermal developments from the beginning. As another possible advantage for project developers, the lower risk level in presence of a guarantee can also lead to lower return expectations from community investors.

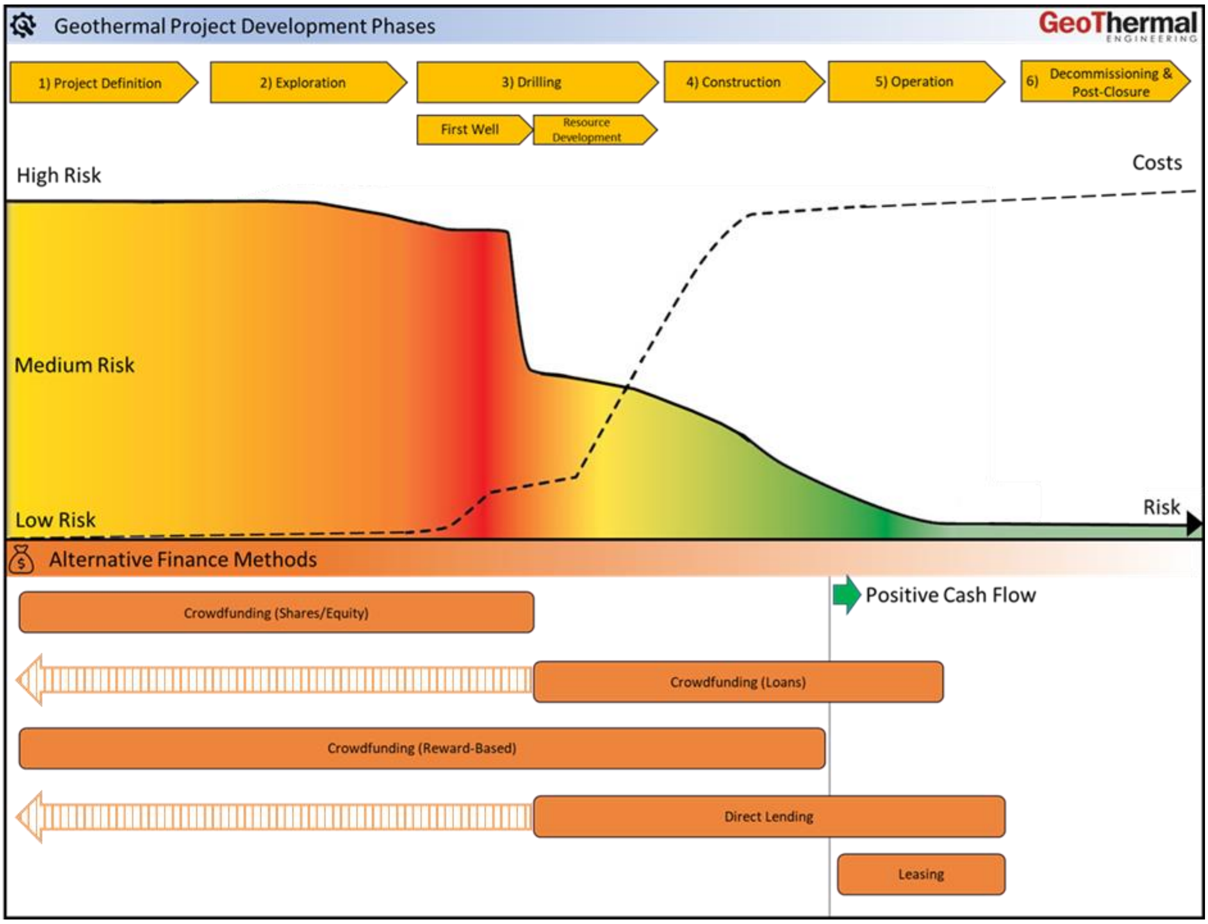

Figure 2: Technical geothermal project development phases, associated risks, costs, and most appropriate alternative finance methods in presence of a loan guarantee (modified after ESMAP 2012 and Altfinator.eu 2020).

Based on the above considerations, the applicability of the proposed CROWDTHERMAL risk mitigation framework for specific alternative financing methods was checked in co-operation with partner CFH / WP2. It was agreed that the proposed risk mitigation framework shall:

- be applicable to projects that apply community funding via loan-based alternative financing methods (crowdfunding (loans), direct lending or green bonds).
- not be applicable to crowdfunding (equity). Equity investors share in a project's profit, but also basically share the same risk of project failure as the project developer. To a certain degree, equity investors must accept these high risks in exchange for a chance

of high returns. A guarantee which involves public funds should be a "last resort" and not an instrument to provide security for high return expectations[8].

- not be applicable to crowdfunding (reward-based). Reward-based crowdfunding typically depends on a small pool of local enthusiasts involving only small amounts of funds from individual community investors that commonly do not require a guarantee. Furthermore, reward-based crowdfunding has not been applied in the geothermal industry yet.
- not be applicable to leasing concepts, which are so far only used in isolated cases in the geothermal industry. In the existing cases, the leasing model did not involve any exploration risk for the Lessee.

[8] Within Task 4.3, a sale and buy back option as a potential risk mitigation mechanism for crowdfunding (equity) shall be further explored in co-operation with CROWDTHERMAL partner CFH. A publicly funded sale and buy back scheme could guarantee that in case a project failed, the aid-granting authority would buy shares back from community investors for the price that they were bought for at the end of a specified period. In case of project success, shares would not need to be sold and there would be no costs involved for the funding agency. With the implementation of a sale and buy back concept, the advantages of equity instruments (like more direct participation in project strategy, higher commitment) could be used without fully waiving the mitigation of financial risks for community investors in equity products.

5.3 PROPOSED STRUCTURE

Section 5.3 describes the key parameters and procedures of the proposed CROWDTHERMAL risk mitigation framework.

5.3.1 Key Characteristics

It is envisaged to set up a CROWDTHERMAL Risk Mitigation Fund (the RMF). This fund shall ideally be financed by European, public aid-granting entities, for example, a transnational financing body, national or regional governments, or authorities. Private sponsors like large energy providers or oil and gas companies can also support the financing of the RMF. In the long term, the RMF shall aim to be sustained through a profit-sharing funding scheme with revenue-based royalties that need to be paid back by successful projects.

The RMF shall be a support instrument mitigating the financial risks associated with subsurface uncertainties of deep geothermal projects. It is applicable for deep geothermal projects that are partly funded by the public (community investors) via loan-based alternative financing methods.

The mechanism includes a grant-based, co-financing component (matchfunding) and a risk-sharing component (a loan guarantee) which is designed to mitigate both short- and long-term subsurface risks, see Figure 3).

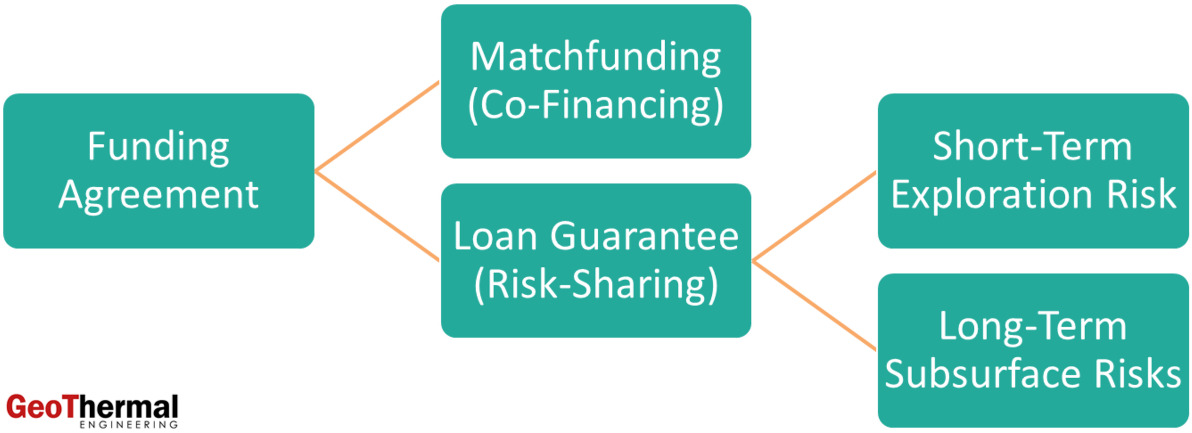

Figure 3: The Components of the Proposed Risk Mitigation Framework.

The proposed framework covers several geothermal project phases and addresses different barriers for the deep geothermal industry (Figure 4). In order to tackle the lack of capital in the early project phases, the matchfunding concept is implemented prior to drilling. The loan guarantee focuses on the resource risk and covers both the short-term exploration risk of the first and second well[9] and the long-term subsurface risks during 20 years of operation. In order to support successful projects, the funding encompasses all best practise project development steps.

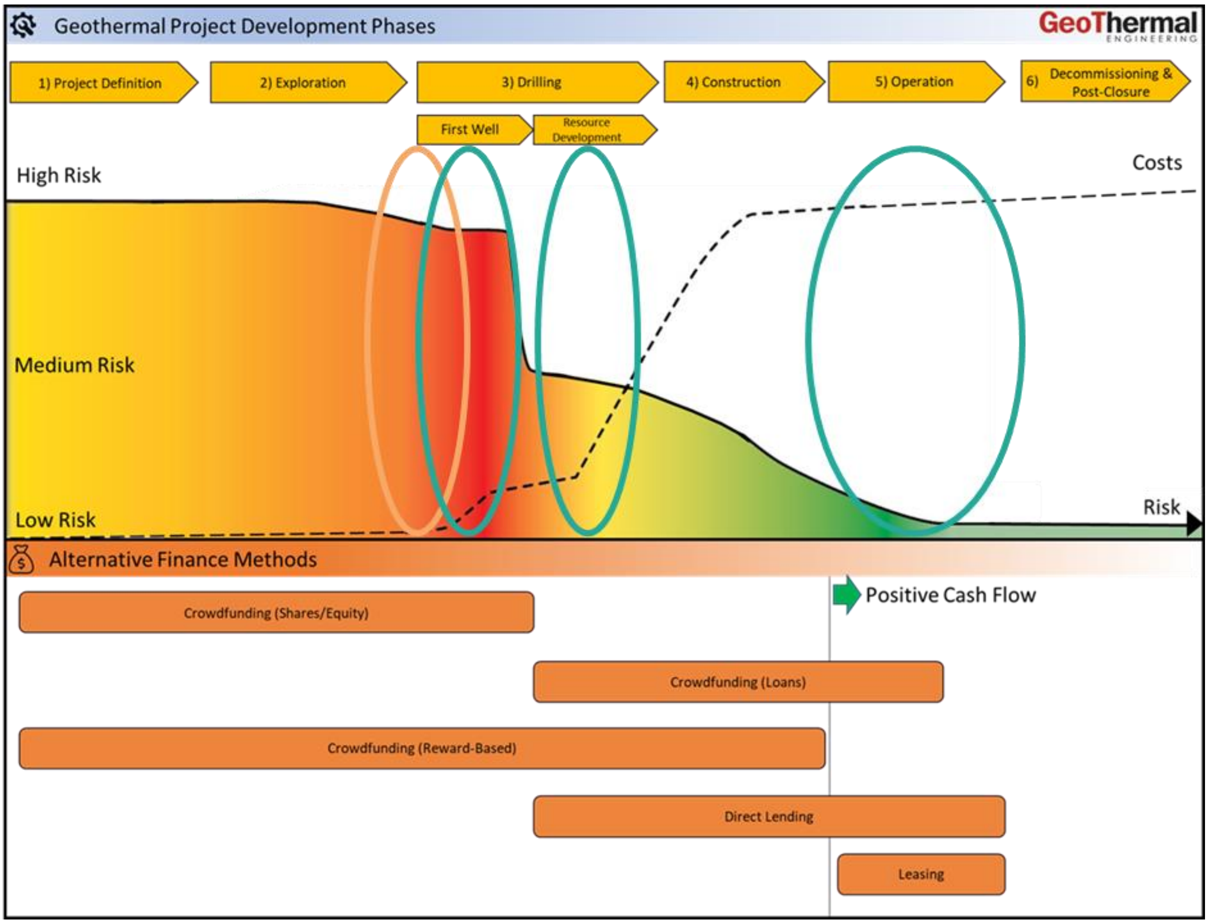

Figure 4: Timing of the Support from the Proposed Risk Mitigation Framework. Orange circle: co-financing support, green circles: loan guarantee range.

Figure 5 depicts the proposed CROWDTHERMAL risk mitigation framework. The co-financing funding support shall be given as matchfunding of the amount of loan-based community funding that can be mobilised. This means that the RMF tops up the funds that were contributed by community investors by the same amount, thus doubling the overall funding for the project. This approach is an incentive for project developers for successful financial community engagement. The matchfunding shall be paid as a grant directly to the project developer prior to drilling.

[9] In many cases, geothermal developments will include the drilling of more than two wells, with several risks reducing as more subsequent wells are drilled. The short-term loan guarantee shall focus on the wells that face the highest risk and therefore be limited to the first and second well.

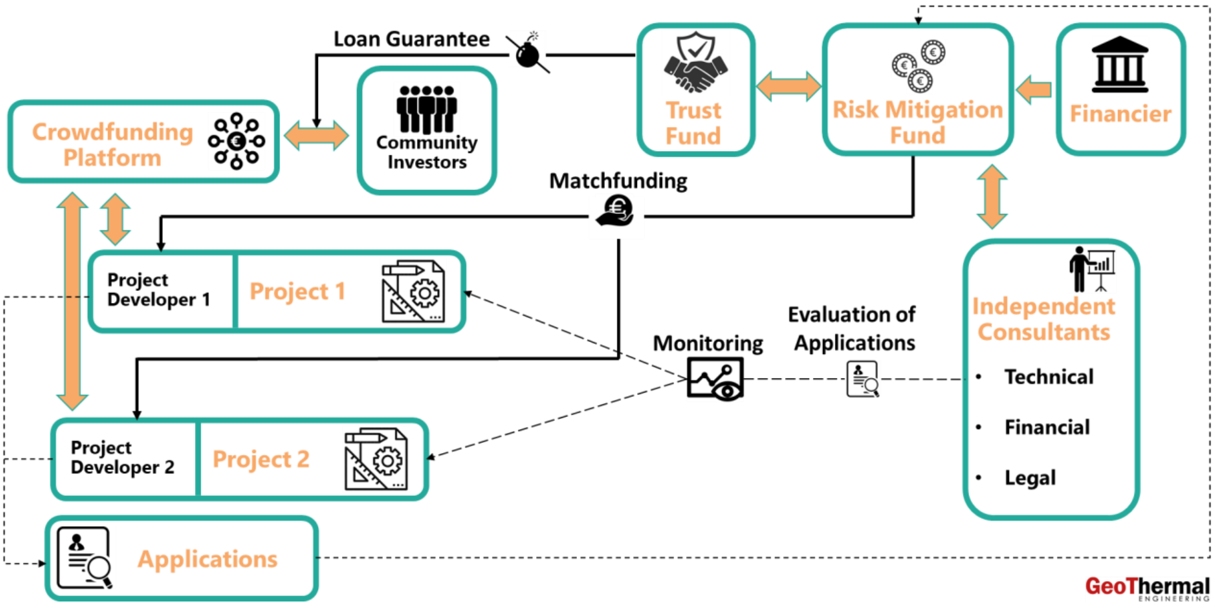

Figure 5: The Proposed CROWDTHERMAL Risk Mitigation Framework.

The risk-sharing loan guarantee shall be provided for a share of 80 % of the community investors' loans. It secures and guarantees the (partial) repayment of loans to the retail investors in case of project failure.

A separate, ear-marked Trust Fund shall be set up to reserve the amount corresponding to the loan guarantees for supported projects. In case of project failure, the community investors shall receive 80% of their investment (without returns) back from the Trust Fund.

The reimbursement shall be processed via the crowdfunding platform or financial intermediary used and shall not involve the project developer. The crowdfunding platform or financial intermediary will reimburse the community investors, just as in the normal repayment process of crowdfunding loans. This procedure ensures that the loans of community investors are not subordinated.

The establishment and implementation of the RMF shall be accompanied by an expert committee of external, independent consultants or advisors (technical, financial, legal).

5.3.2 Application Process

The application process shall consist of two phases: a prequalification / expression of interest phase and an application phase. It is suggested that applications to the scheme shall be accepted continuously, not restricted to fixed dates or application rounds, and that applications are assessed on a case-by-case basis. The following eligibility criteria and application procedure are proposed:

5.3.2.1 Eligibility Criteria

- Public, private or PPP developers of deep (> 400 m) geothermal projects in Europe shall be eligible for the RMF.

- Only open-loop (fluid-extracting) geothermal projects that face a fluid flow-related exploration risk shall be eligible. Closed-loop systems shall not be eligible (see Sections 2.1 and 4).
- A minimum of 5 % of the project CAPEX must stem from loan-based community funding instruments (i.e. crowdfunding (loans), direct lending, green bonds). Crowdfunding (equity) or (reward-based) shall not be eligible (see Section 5.2). The portion of loan-based community funding exceeding 25 % of the project CAPEX shall not be eligible for support (i.e. the amount taken into account for the different support components is limited to 25 % of the project CAPEX).
- In order to ensure alignment of interest of the project developer on the one side and community investors and the risk mitigation fund on the other side, an overall project minimum equity/debt ratio of 25 % is required.

5.3.2.2 Prequalification Phase

A symbolic structuring fee of 5.000 € needs to be paid by the applicant with the submittal of the prequalification documents.

Expressions of interest shall comprise the following documents:

- Description of the company and business model
- Project plan including a conceptual model of the geothermal system and drilling targets
- Business case and financing plan including details on the envisaged community funding.

The expression of interest will be assessed by the independent consultants of the RMF:

- Technical
- Financial
- Legal

The assessment will lead to either denial, adjustment request, or acceptance for application of the expression of interest.

5.3.2.3 Application Phase

An application fee of 20.000 € needs to be paid by the applicant with submittal of the application documents. The fee shall ensure that project developers carefully consider possible implications, opportunities, and risks of the support scheme prior to application. The application fee can be used to partly pay the consultants in the application process.

In order to facilitate a broad market stimulation and not only support projects with a lot of reference wells in known geothermal regions, relatively “lean” requirements are proposed. They should still as a minimum consist of:

- Details on the company, key personnel, business model and legal structure
- Details on permits, licenses, concessions as well as HSE procedures

- Project plan including time schedule
- Exploration results (e.g. surface studies, numerical reservoir modelling) and a conceptual model of the geothermal system
- Drilling plan
- Details on the planned type of energy use and conversion
- Business case with 20 years economic calculation
    - 20 years operating plan indicating all CAPEX (initial costs but also investments like new pumps) as well as OPEX
    - 20 years financing plan including the envisaged community funding part and the envisaged matchfunding support from the RMF (to assess overall feasibility and community funding part of CAPEX)
    - The financing plan needs to demonstrate enough funds at least until the end of the second well. It shall include details on contingency planning, possible power plant financing options and overall expected debt service coverage ratio.
    - Sufficient funds (reserves) for decommissioning, dismantling, plugging and abandonment of any unsuccessful wells need to be demonstrated. In case of project funding, the plug and abandonment funds will be kept on a separate escrow account.
    - Economic success curves defining the success/failure thresholds for the performance of the first well and the long-term circulation of the geothermal system (see Section 5.3.5)
- Details on how temperature and flow rate will be tested and assessed
- Flow chart on any reservoir enhancement / reservoir engineering procedures planned ("stimulation concept"), including decision criteria, processes, and costs (see Sections 5.3.5 and Appendix)
- An estimate of the probability of success to reach the envisaged reservoir temperature and productivity
- An assessment of a project's geological, technical, financial, social, and environmental risks including details on planned mitigation measures
- Information on the crowdfunding platform or financial intermediary facilitating the community funding process

The application will be assessed by the independent consultants of the RMF:

- Technical
- Financial
- Legal

The assessment will lead to either denial, adjustment request, or acceptance for funding. Any funding approval should be given prior to drilling.

In case of funding approval, a funding agreement is set up and signed between the RMF and the project developer, specifying the obligations to one another.

5.3.3 Funding Limits

The loan-based community funding amount eligible for matchfunding is limited to 25 % of the project CAPEX. Under the new European crowdfunding directive and regulation that shall apply as per 10 November 2021, any project developer will furthermore be limited to the threshold of 5 Mio. € per a twelve month-period for crowdfunding (see CROWDTHERMAL Deliverable 2.2). This means that the maximum matchfunding support from the proposed scheme also amounts to 5 Mio. €.

The proposed loan guarantees shall only be given to retail / community investors as opposed to "accredited investors" and be limited to individual investment amounts up to 50.000 €. As for the matchfunding, the loan-based community funding amount eligible for the loan guarantees is also limited to 25 % of the project CAPEX. The maximum aggregated loan guarantees amount to 4 Mio. € (i.e., 80 % of the maximum aggregated crowdfunding loans).

The maximum support for one specific project would therefore add up to 9 Mio. €. This is the same order of magnitude as for example the maximum support from the German market incentive programme for deep geothermal heat projects with two wells (9.5 Mio. €) or the possible support for drilling programmes including continuation premium from the GRMF in East Africa (grant volume for example Karthala (Comoros): 10,870,124 US$, GRMF 2021).

5.3.4 Operational Process

The funding agreement comprises the matchfunding support that will directly be paid to the project developer, and the short- and long-term loan guarantees which, in case they are needed, will pay the guarantee amount from the Trust Fund.

Figure 6 shows the operating principles of the proposed loan guarantee component.

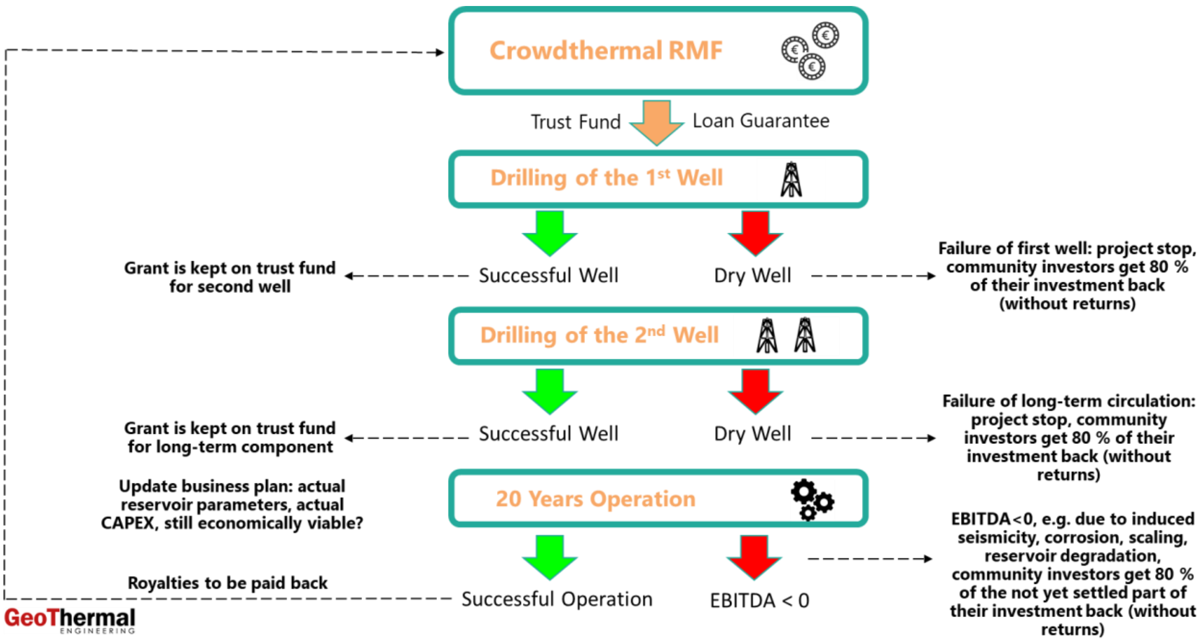

Figure 6: Operating Principles of the RMF Short- and Long-Term Loan Guarantee.

The following procedure is suggested for the short-term loan guarantee mitigating the exploration risk of the first and second well:

- Drilling of the first well
  - Well testing and potential reservoir enhancement measures according to the project-specific stimulation concept.
  - Decision over success or failure according to the project-specific success curve for the first well performance.
  - The decision criteria and measures will be closely monitored and independently assessed by the economic and technical consultants of the RMF.
  - Failure of first well: project stop, community investors get 80 % of their investment back (without interest payments) from the Trust Fund.
  - First well successful: project continues: grant is kept on the Trust Fund for the drilling of the second well.
- Drilling of the second well
  - Well testing and potential reservoir enhancement measures according to the project-specific stimulation concept.
  - Decision over success or failure according to the project-specific success curve for the long-term circulation.
  - The decision criteria and measures will be closely monitored and independently assessed by the economic and technical consultants of the RMF.
  - Failure of long-term circulation: project stop, community investors get 80 % of their investment back (without interest payments) from the Trust Fund.
  - Second well successful: project continues: grant is kept on the Trust Fund for long-term guarantee.

The following procedure is suggested for the long-term loan guarantee mitigating the subsurface risks during 20 years operation:

- After drilling, testing, and potential enhancement of all wells, the business plan shall be updated based on real costs and actual reservoir parameters. It thus compensates in retrospect for cost overruns while drilling (CAPEX is updated in business plan) as well as the possibility of partial success (see Sections 5.3.5 and Appendix).
- The business plan shall continuously be updated during the term of the funding agreement. By this approach, long-term subsurface risks such as corrosion / scaling, degradation of the reservoir over time or induced seismicity during circulation can all be captured.
- The long-term risk mitigation component shall ensure that all obligations towards community investors are properly met. Therefore, a threshold is specified above which it is likely that project developers can duly fulfil all their obligations towards community investors.
- As benchmark parameter for such a threshold, a positive EBITDA is suggested. With a positive EBITDA, it is expected that a project developer will be able to repay all loans.

- If a negative EBITDA occurs, the RMF shall step in. In that case, community investors would get 80 % of the not yet settled part of their investment back from the Trust Fund (without interest payments, i.e. 80 % of the losses of the loans / the default).
- If the project runs successfully, the RMF remains liable until the point in time when all community investors' loans have been paid back by the project developer. At this point in time, the plug and abandonment funds from the escrow account are released to the project developer.
- For a limited period, the successful project shall be obliged to pay back a certain percentage of its revenues as royalties to the RMF. As a first rough guide, a period of 10 years from the start of a positive cash-flow and a share of 2% of the EBITDA per year are proposed. The real-world economic assessments foreseen in CROWDTHERMAL Task 4.4.4 can help to verify whether this can be a feasible royalty level.
- In any case of disbursement of the short- or long-term loan guarantee, the RMF should reserve the right of a transfer of ownership of the already drilled well(s) from the project developer to the RMF. It should also reserve the right to use the funds kept on the separate escrow account for plug and abandonment of the already drilled well(s). The transfer of ownership and use of the reserves should be the last means to ensure alignment of interest as well as the proper abandonment of a failed well with respect to the environment and the local community.
- The funding agreement is terminated when all obligations of the project developer and the RMF towards one another have been met.

5.3.5 Definition of Success

It is desirable that project developers meet all obligations towards community investors on their own, without support from a risk mitigation mechanism. The proposed RMF shall only be a last resort that steps in if nothing else is possible. Any intentional misuse of public funds shall be avoided to the largest possible extent. In this context, the clear definition of success and failure respectively is a core issue.

The determination of success/failure criteria in risk-sharing instruments like guarantee schemes can be difficult and time-consuming. We suggest deriving the success/failure threshold from the project-specific, 20 years economic calculation. This calculation shall deliver economic success curves, one for the performance of the first well and one for the long-term circulation of the geothermal system after drilling of the second well. The success curves specify the absolute minimum values for temperature and flow rate (at a specified maximum drawdown)[10] that need to be reached for an economically viable project. Economically viable in that regard means that a project can pay back all investments during the term of the 20 years economic calculation.

[10] The performance of a geothermal well is determined from a combination of the parameters temperature and flow rate according to the formula $P = \rho_F \, c_F \, Q \, (T_i - T_o)$, where P denotes the capacity of the well (in MW_{th}), ρ_F the density of the brine, c_F the specific heat capacity of the brine, T_i the production temperature and T_o the reinjection temperature. The minimum thermal capacity for project success should be defined for a specified maximum drawdown.

An example of such a success curve from the French geothermal risk mitigation scheme can be seen in Figure 7. In contrast to what is shown in Figure 7, the RMF shall not consider a partial success zone. A partial success is e.g. if a power project was planned, but the reservoir parameters only allow for a heat project.

Partially successful projects shall be treated as a success by the RMF if the revised project is still economically viable by itself. Economically viable by itself means that: assuming that all assets are already there at no costs or reduced costs, the revised project is able to pay back the new investments that would still need to be made in a revised 20 years economic calculation. If the revised project is not economically viable by itself, the project will stop, and the Trust Fund will step in with the loan guarantee.

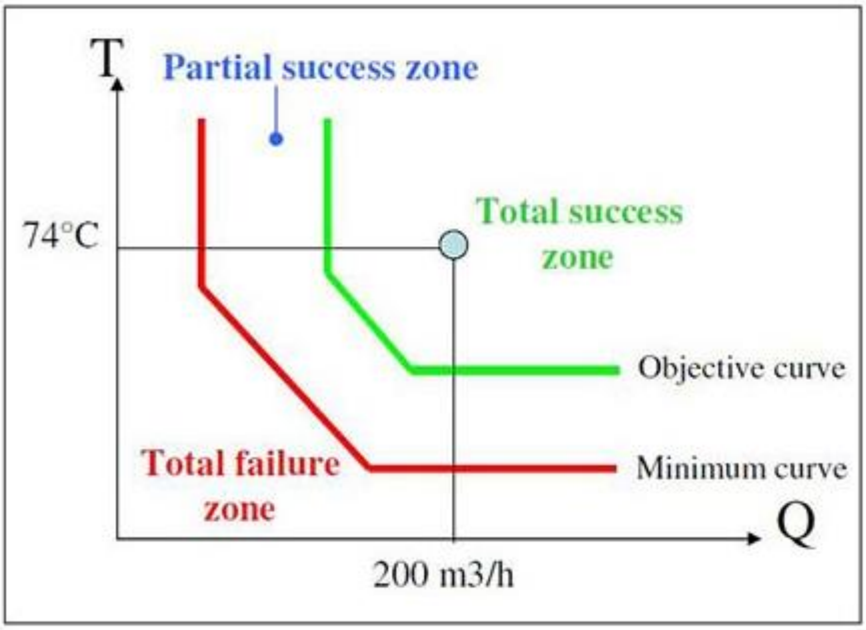

Figure 7: Success/Failure Curves for the French Short Term Fund for Geothermal Risk Mitigation (Boissavy 2017).

In many cases, there may be a need for reservoir enhancement or reservoir engineering procedures to keep a project running and to reach a partial or full success. Technical operations like stimulation measures or side-tracks involve significant costs that need to be accounted for from the project start. The required application documents shall therefore include a flow chart of a site-specific, realistic stimulation concept specifying the decision criteria, processes, and costs.

The stimulation concept shall determine the minimum requirements that a project developer must fulfil (and the minimum funds that need to be spent) before a failure of a well can be claimed against the RMF. As such it shall become part of the funding agreement. Decision points and technical measures need to be closely monitored and assessed by the independent economic and technical consultants of the RMF. Figure 8 shows an example of a flow diagram for a stimulation concept. Different possible enhancement and engineering options for (partially) failed wells are described in more detail in the Appendix.

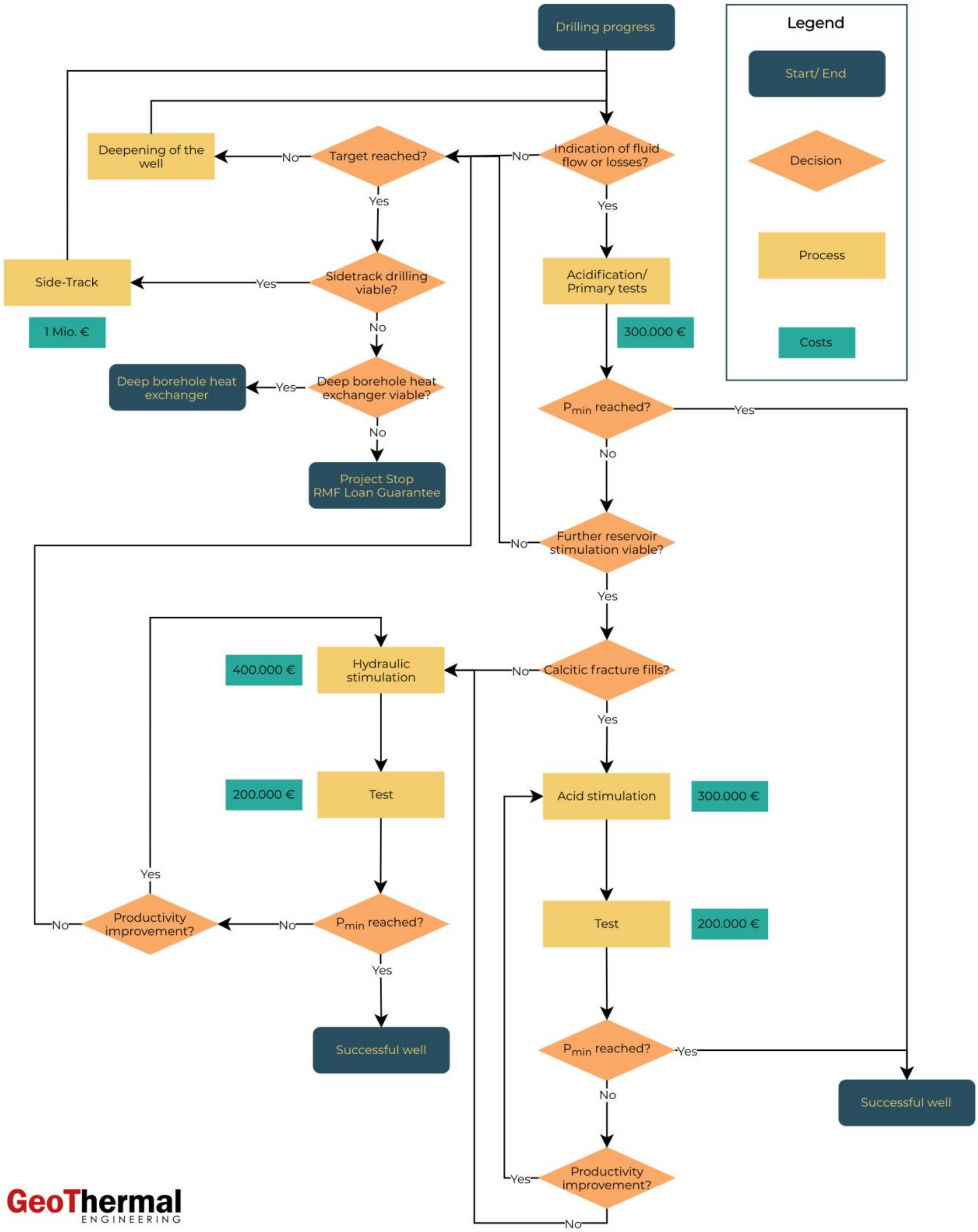

Figure 8: Exemplary Flow Diagram of a Stimulation Concept. P_{min} is the minimum thermal capacity in MW that constitutes the success/failure threshold in the project-specific economic success curve for the first well performance.

5.3.6 Quality Assurance

The topic of quality assurance is a central yet delicate one. Only high quality standards in all aspects of a risk mitigation scheme can ensure that (public) funds that are made available for a support mechanism are spent in the most efficient way, and that any misuse is prevented to the largest possible extent. Quality standards and legal requirements for quality assurance mechanisms are however subject to geographical variability. This is even more true in the (still) relatively unregulated and unstandardised geothermal context where experience is generally rather limited.

The quality management specifics of a new geothermal risk mitigation scheme can only be determined after the operational structure of the scheme is put in concrete terms, regarding inter alia the properties and structures of the aid-granting entities, the regional scope, and the underlying legal framework. Based on the experience from established geothermal risk mitigation schemes, the following suggestions for possible quality assurance mechanisms and processes can be made as first indications.

The management of a risk mitigation scheme requires a clear governance structure and appropriate stewardship, which should ideally be handled by an independent institution (Lupi and Siddiqi 2019). To provide transparency on decisions and the use of funds, a technical review meeting and/or annual external audit of the scheme is recommended. The integration of a possible supervisory board of supported projects can be considered. An annual audit can also be useful to derive performance indicators of the scheme.

The establishment and implementation of a geothermal risk mitigation scheme should be accompanied by an expert committee of external, independent consultants or advisors with industry-specific expertise in technical, financial and legal matters. The competency of the independent consultants is a central element for the quality assurance of the scheme. The call for consultants should therefore be put out for international tender. For the terms of reference and competency requirements, the "Guidance Note on Competent Person Requirements and Options for Resources Reporting" and "Guidance Note to support the United Nations Framework Classification for Resources Specification for Evaluator Qualifications" for the United Nations Framework Classification for Resources (UNFC) can provide valuable input (UNECE 2017a, b).

The independent consultants shall ensure a due diligence of the projects to be funded. The assessment of applications shall draw upon existing industry benchmarks and standards like for example the UNFC[11] code for assessing geological, technological, and financial risks (UNECE 2016). It shall also check whether a respective project addresses and duly includes all applicable and advisable best practise requirements. Ideally, clear tender procedures and costing

[11] The UNFC is a resource project-based and principles-based classification system for defining the environmental-socio-economic viability and technical feasibility of projects to develop resources. It provides a consistent framework to describe the level of confidence of the future quantities produced by a project.

guidelines will be developed for projects supported by the risk mitigation scheme to avoid excessive CAPEX estimate or claims.

The funding agreement shall specify the obligations of the project developer during (and where appropriate: even after) the term of the funding agreement. This can for example include the obligation to disclose new geodata that has been collected by the supported project (in order to increase the database for future projects), the adherance to certain HSE standards and the compliance with project-specific schedules, work programmes and reporting requirements.

With regard to the proposed RMF procedures, the external consultants shall verify the technical and economic information that forms the decision basis for the payment of the short- and long-term loan guarantees. To prevent manipulation of the business plan and/or the EBITDA, the regular monitoring of costs by the financial consultant (accountant/auditor) against benchmarks from former geothermal projects is especially important for the long-term loan guarantee.

Another possible quality assurance measure to avoid the hazard that projects might be "calculated down" could be the implementation of a separate escrow account as it has been done for loans of large gas projects. Such a protected account could be accessed by the project developer only under certain conditions. The earnings of a project would be paid into the escrow account. Project developers could take OPEX from it, but profits could only be taken out once a certain amount (or all) of the community investors' loans have been served or a corresponding minimum amount is reached on the account.

5.3.7 Additional remarks:

- Due to expected size limits of the RMF, the eligibility for the proposed support framework is currently restricted to open-loop geothermal systems that face a fluid-related exploration risk as the main barrier for market development. The presented framework would – with minor modifications – however also be applicable for closed-loop systems. Depending on the specific goals of a potential RMF sponsor, and on further market development, the scheme could be broadened to also include closed-loop systems like deep borehole heat exchangers in the future.
- Several existing risk mitigation facilities try to realize a revolving fund that can operate sustainably without further funding aid. This can be achieved by charging premiums that need to be paid by supported projects. Experience has however shown that the geothermal industry can hardly afford high premiums in a project phase characterised by a lack of capital. We therefore suggest an alternative approach where successful projects must reimburse a certain percentage of their profit as royalties to the RMF in retrospect. This makes the proposed scheme both a risk-sharing and profit-sharing facility.
- The proposed framework consists of different components. Depending on the size of the RMF, it might not be possible to implement all of them at the same time. Of the three components, the short-term loan guarantee is considered the most important for market development, followed by the matchfunding component, and lastly the long-

term loan guarantee. The long-term funding agreement would however be important if it shall be ensured that enough royalties are paid back to sustain the RMF.

- Matchfunding does not necessarily have to be given for the same amount that has been mobilised. It could also be given for e.g. only 50 % of the amount that has been raised from the crowd.
- The risk-sharing component is designed with the intention that it shall be a final guarantee if everything else goes wrong. A project should not be sold as "risk-free". An accompanying guarantee must therefore not be too large. A balance needs to be found so that community investors will not lose too much of their investment, but still carry some risk in exchange for a better return rate than can be achieved with a savings account. In the proposed support framework, a guarantee level of 80% of the loans is suggested. The guarantee level could however be set between 50 % and 100 % by the sponsor of the RMF, depending on the specific objectives and performance indicators of the scheme.
- Even though they are not the focus of the CROWDTHERMAL risk mitigation framework, operational risks like (energy) cost risks, lack or loss of clients, pricing uncertainties etc. are also captured by the approach suggested for the long-term loan guarantee.
- If local crowdfunding initiatives without intermediary platforms shall also be given the possibility to apply, the project developer would need to assign an accredited trustee for the loan guarantees for the community investors.
- Depending on the size of the RMF as well as the number and risk profile of supported projects, the sponsor of the scheme could also give out loan guarantees like an insurance instead of reserving the sum of loan guarantees on a special Trust Fund. This option would reduce the amount of funds that need to be kept as "dead money".

5.4 CASE STUDIES' APPLICABILITY

Within Task 3.3, possible application options for the proposed risk mitigation framework were checked for the CROWDTHERMAL Case Studies (WP5). For each Case Study, the applicability of the framework was assessed with the involvement of the respective responsible project partners.

Unfortunately, there is no immediate perspective to apply the proposed mechanism to any of the primary CROWDTHERMAL Case Studies. This is due to the following reasons:

- Madrid (ES) is a successful example for the use of shallow geothermal resources for heating, cooling and domestic water supply in several building complexes. The proposed risk mitigation framework however is earmarked for deep, open geothermal systems for which the fluid-related exploration risk is the core issue. Closed-loop systems like boreholes heat exchanger do not face this type of all-dominant exploration risk. After the performance of a thermal response test, the uncertainty about the geothermal resource is significantly reduced (compare to Section 4). Since the Madrid projects are already in operation, no major resource-related risk exists anymore (for details on the risk assessment of the Madrid Case Study, see CROWDTHERMAL Deliverable 3.1).
- The community greenhouse project in Húsavík (IS) as it is currently conceptualised will not involve the drilling of an own well, but can just tap into an existing district heating network that is heated by geothermal energy. This means that also in this Case Study, there is no exploration risk involved that would need to be mitigated by the proposed framework. Additionally, it is not yet clear in which form and quantity the project will be able to apply community funding.
- The geothermal district heating project of Szeged (HU) finally is a vibrant example for diverse and creative public relations and social engagement activities. It does not and expectedly will not apply community funding, though. This is mainly due to the national energy pricing policy with regulated and fixed energy prices (for details see CROWDTHERMAL Deliverable 2.2). However, integrating a significant share of community funding into the financing plan is one of the main prerequisites for projects to be eligible for the proposed support framework (for details on the eligibility criteria see Section 5.3.2).

Summing up, each of the Case Studies is unique and valuable for the CROWDTHERMAL project, but none of them shows the typical characteristics of the projects that shall be supported by the proposed exploration risk mitigation framework.

Having said that, the search for projects that could potentially apply the CROWDTHERMAL risk mitigation framework is meant to continue in the future. During WP4, partner EFG with the help of Linked Third Parties will compile a database of planned geothermal projects that intend to apply community funding. We expect that most of them will be the typical projects that could theoretically use the proposed risk mitigation mechanism. We plan to further analyse several of them in the economic assessment foreseen in Task 4.4.4.

5.5 FUTURE STEPS

After the draft structure of the proposed risk mitigation framework has been developed, the next step will be an assessment of its economic implications for project developers. Within Task 4.4.4, economic efficiency calculations will be performed for a number of projects in different Geothermal Play Types or countries and of different sizes. For this purpose, existing financial modelling software for geothermal feasibility studies will be adapted. Even though there is no immediate perspective from the primary CROWDTHERMAL Case Studies to apply the proposed framework, possible application options for other projects will be checked as part of this work. Some of the suggestions in this Deliverable regarding e.g. the level of application fees and/or royalties might be revised after real-word cases have been calculated in the economic assessment.

The largest challenge for the establishment of a new exploration risk mitigation scheme for geothermal projects however is to find a funding source. The CROWDTHERMAL risk mitigation framework shall be a pan-European scheme. Given the market conditions currently present in most of Europe, the involvement of public funding sources would be most appropriate. The ideal sponsor would therefore be a public aid-granting entity that is based on European regulation, for example a transnational financing body like the EIB/EIF.

In WP4, we will elaborate on the question which European funds could potentially be mobilised to support the RMF. Blueprints on this topic are currently being developed by CROWDTHERMAL partner CFH in the framework of the European project ("Unlocking the Crowdfunding Potential for the European Structural and Investment Funds (ESIF)") with which synergies will be sought.

Through the CROWDTHERMAL Advisory Committee, a co-operation with EGEC will also be sought to identify potential financiers of the proposed RMF. EGEC continuously works on paving the way for a European risk mitigation scheme through various initiatives on national and European levels (e.g. the Horizon 2020 project GEORISK).

In the long term, a risk-sharing system between the RMF and the private market-based insurance sector could be aimed at, too. A first consultation with Munich RE has already taken place in the framework of Munich RE's participation in the CROWDTHERMAL Advisory Board.

After a financier has been found, the structure of a new risk mitigation scheme will further need to be refined in the light of the specific objectives of the aid-granting authority. The framework conditions are ideally summarized in handbooks like Operational Guidelines and/or a Developer Manual, as they were for example developed for the GRMF programme in Eastern Africa.

Deliverable 3.2 of the GEORISK project (Lupi and Siddiqi 2019) identifies five key aspects of a risk mitigation scheme that should be considered by any entity willing to establish a new risk transfer scheme for geothermal projects:

1. Legal and regulatory boundary conditions, e.g. the legal basis justifying the engagement, the form, scope and duration of the risk mitigation scheme as well as its organisational and management structures. A European risk mitigation mechanism like the proposed CROWDTHERMAL risk mitigation framework needs to consider different legal and financial requirements for all European countries. Financial and legal experts thus need to be involved from the beginning. The specific legal and regulatory boundary conditions for the establishment of a risk mitigation scheme are currently being revised for some European target countries by the GEORISK project. The need for an EU-level common legislation for financial support of geothermal exploration is stressed.
2. Definition of the risk(s) to be addressed, i.e. the exact description of the risks to be transferred (see Sections 5.1 and 5.3).
3. Funding, i.e. the capital and financial structure of the risk mitigation scheme and the funding source, for example: revenues of public institutions, levies on fossil fuels, seed capital from various sources, fees, premiums or royalties paid by project developers.
4. Procedural aspects including a clear definition of what is expected from the applicant, how and by whom the requests for aid are processed and how the contractual relationship is managed in case of an award. Section 5.3 already suggests several specific procedures for the proposed RMF. Additional definitions that need to be established prior to the launch of the RMF include e.g. the methodologies for evaluating expressions of interest and applications including assessment criteria with a scoring system to determine which projects shall be funded.
5. Performance indicators like the number of (successful) applications, the evolution of the installed capacity, saved emissions, long-term employment, increase of subsurface data etc.

Alongside the definition of these key aspects, it is suggested that the sponsor or aid-granting entity also performs an assessment of the financial sustainability of the risk mitigation scheme to be launched. A suitable tool for a 10-year cash flow calculation of a geothermal de-risking scheme has been developed in the framework of the GEORISK project (Kujbus et al. submitted). The tool analyses whether and under which conditions a risk mitigation scheme could work sustainably or when and for which amount further (public) funding support is needed. The simulation is based on the specification of scheme parameters like its launching amount and operating costs as well as the risk coverage, fees/premium and success rate of the supported projects. The GEORISK simulations for schemes to be launched in Hungary, Greece and Poland showed that a risk mitigation scheme can be an effective and not too expensive means to support the geothermal sector. As opposed to the proposed RMF, these envisaged schemes do however involve a premium that supported projects need to pay upfront. The RMF, on the other hand, shall ideally be sustained by a revenue-based financing model including royalties to be paid back by successful projects.

6 CONCLUSIONS

Based on the results of Tasks 3.1 through 3.3, the conceptual framework of a new support mechanism for deep geothermal projects that apply community funding was designed. Experiences from former and current de-risking schemes led to a concept for a European, Geothermal Play Type-independent exploration risk mitigation scheme.

It is suggested to establish a CROWDTHERMAL Risk Mitigation Fund, ideally financed by a European, public funding source. The Risk Mitigation Fund shall be a support instrument mitigating the financial risks associated with subsurface uncertainties of geothermal projects. It shall be applicable to public, private and PPP deep geothermal projects in Europe that raise a minimum of 5 % of their project CAPEX from community investors through loan-based alternative financing methods (crowdfunding (loans), direct lending or green bonds).

The proposed framework focuses on the exploration risk and tackles the main barriers for the development of deep geothermal resources. It gives support in several project phases and assists sustainable developments.

The support comprises a matchfunding component and short- and long-term loan guarantees. The matchfunding shall be paid as a grant to the project developer prior to exploration drilling and shall match the amount of funds that the crowd contributes. The risk-sharing component consists of loan guarantees mitigating both the short-term exploration risk in the drilling phase and the long-term subsurface risks during 20 years operation. In case an economically viable project operation is not or no longer possible, it ensures that the repayment of community investors' loans is still secured.

In case it is needed, the loan guarantee amount will be paid from an ear-marked Trust Fund. Payments from the Trust Fund will be made through the crowdfunding platform or financial intermediary facilitating the community funding process. This concept ensures that the obligations towards community investors are duly met first. The risk-sharing component does not guarantee returns but acts as a last resort in case everything else goes wrong. An equity/debt ratio of minimum 25 % as part of the eligibility criteria shall achieve alignment of interest of the project developer on the one side and community investors and the risk mitigation fund on the other side.

The proposed risk mitigation mechanism considers the site-specific geothermal resource characteristics, the project-specific business plan, and individual success parameters. The decision over project success and failure is made on the basis of project-specific reservoir and economic parameters. The short-term loan guarantee will step in in if the actual reservoir parameters do not allow an economically viable project. The threshold for the long-term loan guarantee to step in is a negative EBITDA during operation. Concepts for reservoir enhancement and the alternative use of initially unsuccessful wells have been presented.

The application process consists of a prequalification and an application phase. The proposed scheme does not involve a premium that needs to be paid by project developers. It does however involve small application fees and revenue-based royalties that shall be paid back by successful projects. The establishment and implementation of the risk mitigation framework should be accompanied by an expert committee of external, independent consultants or advisors with technical, financial, and legal expertise.

The proposed support framework offers the following benefits:

- It encourages deep geothermal project developers to apply alternative financing solutions.
- The matchfunding support is an incentive for project developers for a maximum use of financial community engagement. At the same time it positively leverages community funding.
- Providing matchfunding grants prior to exploration drilling reduces the amount of (equity) risk capital needed by project developers. The co-financing contributes to the project budget that can be used for early phases' CAPEX and helps to close the financing gap.
- With the proposed loan guarantee, the financial risk to be carried by individual community investors becomes much more predictable and acceptable. The investment will become more attractive.
- Adding a guarantee to alternative financing loan instruments introduces more flexibility in investment opportunities in the early project phases. It also gives people with lower risk appetite the opportunity to be part of the project from the beginning.
- By the guarantee, the applicability of loan-based community funding solutions is broadened. The bars for the suggested application of loan-based instruments in the CROWDTHERMAL graphic of geothermal project development phases and appropriate alternative finance methods can be moved forward.
- For project developers, crowdfunding is relatively costly. Due to the high-risk profile of deep geothermal projects, investors usually expect high returns. A loan guarantee reducing the risk level for community investors can entail lower return expectations that have to be met by project developers.
- For project developers, the guarantee helps to pay back loans in case of project failure. It considerably reduces the financial risks associated with subsurface uncertainties. Besides the focus on the exploration risk, other subsurface risks like drilling risks, corrosion, scaling, or long-term degradation of the reservoir are also captured by the proposed approach.
- The Trust Fund concept and the co-operation with platforms or financial intermediaries ensure that the loans of community investors are not subordinated.
- The loan guarantee can help to secure confidence and peace of mind for project developers, platform operators/financial intermediaries, and community investors alike.
- The scheme can help to pool geothermal projects that apply alternative finance solutions for knowledge exchange, the use of synergies, and to obtain a critical mass.
- The presented framework is applicable to all Geothermal Play Types. It supports different deep geothermal project types and sizes and can equally encourage the development of low, medium, and high enthalpy resources.

Once established, the presented CROWDTHERMAL exploration risk mitigation framework for deep geothermal projects can achieve a significant reduction of the main risks that are faced by both project developers and community investors, thus leading to increased funding and project realisation. It can be an effective way to assist the geothermal sector and to facilitate European market development.

7 BIBLIOGRAPHIC REFERENCES

AIG (2016): Crowdfunding Fidelity product data sheet. https://www.aig.com/content/dam/aig/america-canada/us/documents/business/management-liability/crowdfunding-overview-us-final-2016-0801.pdf, accessed on 10.02.2021.

Altfinator (2020): Types of Alternative Finance by entrepreneurial venture's lifecycle & finance sources. https://www.altfinator.eu/resources/Types-of-Alternative-Finance-by-entrepreneurial-venture's-lifecycle-and-finance-sources, accessed on 03.08.2020.

Boissavy, C. (2017): The successful geothermal risk mitigation system in France from 1980 to 2015. European Geologist Journal 43 – Geothermal – The Energy of the Future

Boissavy, C. (2019): "Report reviewing existing insurance schemes for geothermal", GEORISK, Deliverable n°3.1

Bonfait, J. Kreuter, H. and Chardon, A. (2018): How to Attract Investors in Geothermal Projects? The Risk Mitigation Funds Benchmark, GRC Transactions, Vol. 42, Reno, USA

Eavor (2020): https://eavor.com/press-release/eavor-announces-commercial-eavor-loop-project-be-built-geretsried-germany, accessed on 01.02.2021

Eavor (2021): https://eavor.com/media-kit, accessed on 02.02.2021

EIF (2019): https://www.eif.org/what_we_do/microfinance/easi/easi-guarantee-instrument/index.htm, accessed on 10.02.2021.

Fraser S., Calcagno P., Jaudin F., Vernier R. and Dumas P. (2013): European Geothermal risk Insurance Fund – EGRIF. GEOELEC Deliverable n° 3.2., Report on risk insurance

GEORISK (2019): Risk Assessment Results, Ranking of all risks for all countries. https://www.georisk-project.eu/assessment/, accessed on 25.02.2021

GRMF (2021): https://grmf-eastafrica.org/wp-content/uploads/2020/02/2018_10_GRMF-Booklet-%E2%80%93-Projects-Overview-and-Activities.pdf, accessed on 19.2.2021

Kreuter, H., Kraml, M. and Jodocy, M. (2014): Managing Expectations in the Development of Geothermal Resources in East Africa, Proceedings 5th African Rift Geothermal Conference Arusha, Tanzania

Kreuter, H. and Baisch, C. (2018): Lessons Learned from the German Risk Mitigation Schemes and a Concept for Different Geothermal Play Types. GRC Transactions, Vol. 42, Reno, USA

Kujbus, A., Kępińska, B., Karytsas, S., Boissavy, C., Mendrinos, D., Karytsas, C. and Miecznik, M. (submitted): GEORISK Project: 10 Years' Operation and Financial Simulation of New Geothermal

Risk Mitigation Schemes in Three Target Countries, submitted to World Geothermal Congress WGC 2020+1, Reykjavik

Lupi, N. and Siddiqi, G. (2019): “Risk mitigation tools: Framework conditions for establishing a risk mitigation scheme”, GEORISK, Deliverable n°3.2

Moeck, I.S. and Beardsmore, G. (2014): A New 'Geothermal Play Type' Catalog: Streamlining Exploration Decision Making. Proceedings Thirty-Ninth Workshop on Geothermal Reservoir Engineering, Stanford, USA

OpenEI (2014): Moeck-Beardsmore Play Types. https://openei.org/wiki/Moeck-Beardsmore_Play_Types, last modified on 16 September 2014, accessed on 09.02.2021

Robertson-Tait, A., Jayawardena, M., Sanyal, S., Berman, L. and Huttrer, G. (2015): An Evaluation of Risk Mitigation Approaches for Geothermal Development. Proceedings World Geothermal Congress 2015, Melbourne, Australia, 19-25 April 2015

Seyidov, F. (2020): Presentation “WP 3.3 Transition in geothermal derisking schemes” at GEORISK Stakeholder consultation webinar / Transition in geothermal derisking schemes on 7.1.2020

UNECE (2016): Specifications for the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) to Geothermal Energy Resources. United Nations Economic Commission for Europe. https://unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/UNFC_GEOTH/UNFC.Geothermal.Specs.pdf, accessed on 25.02.2021

UNECE (2017a): Guidance Note on Competent Person Requirements and Options for Resources Reporting. Prepared by the Bureau of the Expert Group on Resource Classification. United Nations Economic Commission for Europe. https://unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/UNFC-Guidance-Notes/Guidance_Note_on_Competent_Person_Requirements_and_Options_for_Resource_Reporting.pdf, accessed on 25.02.2021

UNECE (2017b): Guidance Note to support the United Nations Framework Classification for Resources Specification for Evaluator Qualifications. Prepared by the Bureau of the Expert Group on Resource Classification. United Nations Economic Commission for Europe. https://unece.org/fileadmin/DAM/energy/se/pdfs/UNFC/UNFC-Guidance-Notes/Guidance_Note_on_Competent_Person_Requirements_and_Options_for_Resource_Reporting.pdf, accessed on 25.02.2021

Wendel M., Hiegl M., Jaudin F. and Poux A. (2010): GEOFAR – Financing Geothermal Energy in European Regions. Proceedings World Geothermal Congress 2010, Bali, Indonesia, 25-29 April 2010

APPENDIX

Opportunities for (Partially) Failed Wells

OPPORTUNITIES FOR (PARTIALLY) FAILED WELLS

CROWDTHERMAL Deliverable 3.1 (M6) described the case study of the geothermal project Geretsried in the Southern German Molasse Basin as an example for project failure highlighting the importance of concepts for the alternative use of initially unsuccessful wells. It was announced to present options for the re-use of (partially) failed wells in the context of the CROWDTHERMAL risk mitigation framework.

If the result of a geothermal well is below expectation or even dry, the following strategies can be applied to still come to a partial or full success:

- Certain reservoir formations can be stimulated by an acid injection. Acidification can dissolve some minerals like calcite. Calcite frequently fills the open spaces between fractures and faults and can therefore significantly reduce the flow rate. Acids like HCl can dissolve calcites and re-open potential flow zones. In areas like the Southern German Molasse Basin in the greater Munich area, where the main aquifer is composed of Jurassic carbonates, this stimulation technique can be very efficient.
- Hydraulic stimulation techniques require the injection of fluid under a certain pressure to re-activate or open fractures or faults mechanically through the increase of hydraulic pressure. Depending on the local geological structures and stress field, hydraulic stimulation can imply a risk of induced seismicity which can lead to the loss of social acceptance if not properly mitigated.
- The drilling of a side-track into a secondary target is another possible option. By drilling from a certain point of the existing well into a different direction within the zone of interest, alternative geothermal reservoir types or structures can be reached to potentially improve the flow rate.
- The installation of a deep borehole heat exchanger into a failed geothermal well can be an option to minimize the financial losses of an otherwise failed geothermal project. A deep borehole heat exchanger uses the heat stored in the rock in a closed, single-well system (pipe in pipe construction). A heat transfer medium circulates in a cased borehole without coming into direct contact with the surrounding rock. The advantage of deep borehole heat exchangers is that they do not depend on the sufficient presence and recovery rate of reservoir fluids. The limitation of this technology however is that, as opposed to open geothermal systems, the heat is extracted via conduction instead of convection. Only a smaller portion of the rock surface area can contribute to the heat exchange. This results in lower energy output. Another limiting factor is the diameter of the deep borehole heat exchanger itself. If its diameter is larger than the last section of the well, which is usually tapping into the hottest interval of the reservoir, the deep borehole heat exchanger is installed at a lower depth, where lower temperatures are present.
- A further emerging technology is the so-called Eavor-Loop™. This concept consists of multiple lateral wells that are drilled within deep reservoir zones. Each pair of lateral wells is connected to each other and basically creates a subsurface radiator. No permeability of the host rock is required, and the wells are sealed with a special fluid to not interact with the formation water. With such a deep closed-loop Eavor system, the

flow rates and the permeability are designed and engineered upfront, so there is no exploration risk associated with uncertain flow rates in an aquifer.

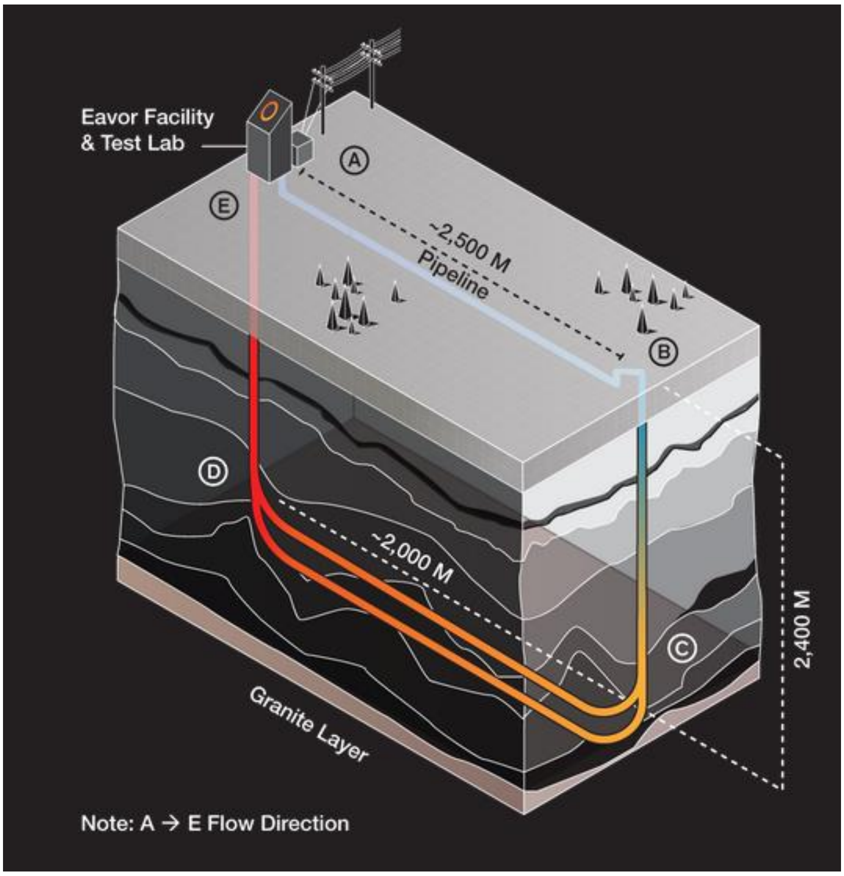

Figure 1: Eavor-Lite™ demonstration site in Calgary, Canada (Eavor 2021).

Figure 1 shows the Eavor-Lite™ demonstration site in Canada. Two wells, which are approximately 2500 m apart, were drilled into the reservoir at 2400 m depth. When having reached the sandstone reservoir, the wells were highly deviated and horizontally drilled towards each other. Ultimately, the wells were connected to each other. The same procedure was applied to a pair of lateral wells. After the successful drilling, water was circulated through the engineered subsurface radiator, and the geothermal heat could be extracted. The purpose of this project was the proof of concept and to show the technical capability of the technology. The Eavor-Lite™ demonstration site in Calgary can be visited virtually at: https://eavor.com/about/technology.

The Eavor-Loop™ technology is currently also planned to be used in Geretsried south of Munich, to revive the failed hydrothermal geothermal project where a well drilled into the Upper Jurassic carbonate aquifer in 2013 proved to be dry (Eavor 2020, also see CROWDTHERMAL Deliverable 3.1). In 2017, the project developer decided to drill a side-track to reach a secondary target (fault zone), but the flow rates were below expectations again. Neither of the two wells was able to deliver enough brine to enable the economic development of a traditional geothermal project. However, both wells confirmed a geothermal gradient sufficient for the commercial development of an Eavor-Loop™ project for electricity and heat production. Figure 2 shows the commercial layout in Geretsried, where both vertical wells are drilled from one drill site. This configuration saves space and allows to spare the surface piping which is used at the demonstration site in Calgary. The multiple lateral wells are specifically designed in size and dimensions to meet the requested power and heat demand of the project developer.

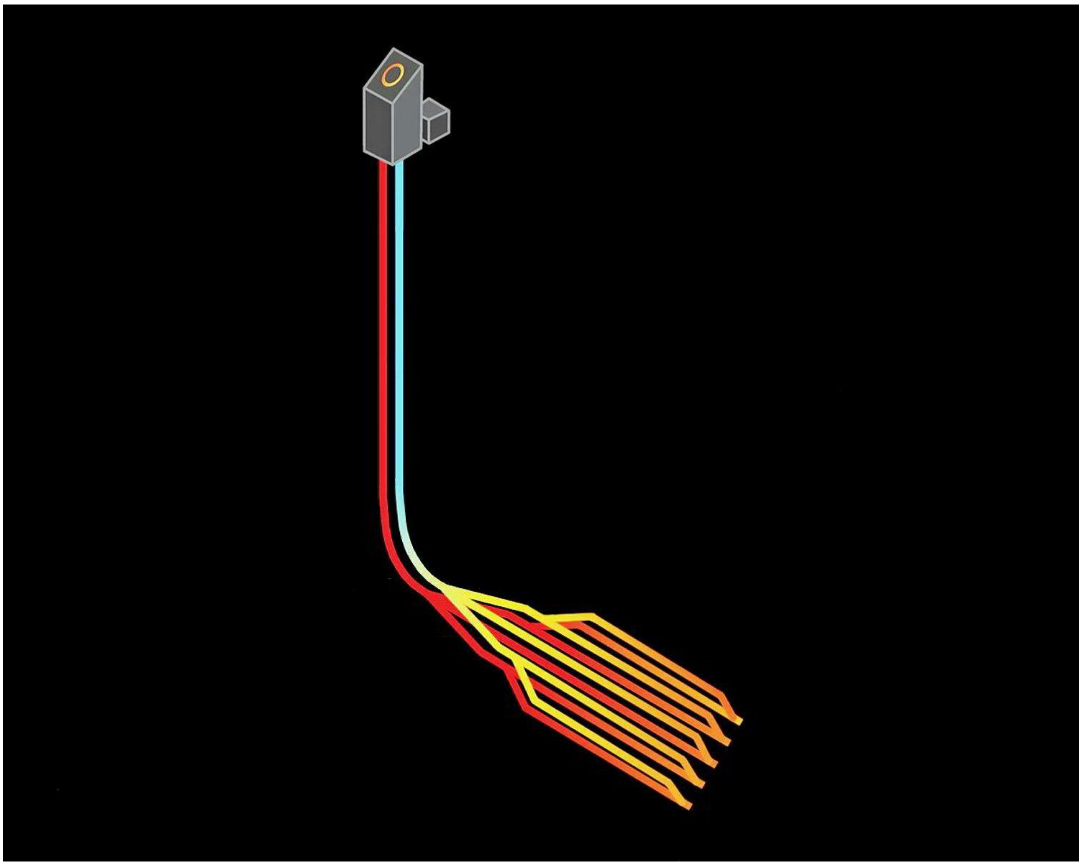

Figure 2: Eavor-Loop™ James-Joyce design for the geothermal project Geretsried (Eavor 2021).