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GEOTHERMICA – Increasing the Pace of Coordinated Research and Innovation in Geothermal Energy

Gudni A. Johannesson, Harpa Petursdottir, Hjalti P. Ingolfsson, Gunter Siddiqi, Gerdi Breembroek, Sigurdur Bjornsson, Stephan Schreiber, Paul Ramsak, Daniel Ruiz Iruela and Alicja W. Stoklosa

Orkustofnun, Grensasvegi 9, 108 Reykjavik, Iceland

info@geothermica.eu

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ABSTRACT

Europe aims to increase the share of renewable energy for direct heating and cooling, industrial processes, power generation and energy storage. Geothermal energy today is only utilised in choice market sectors and few regions. It is an under-utilised, but widely distributed, clean, low carbon footprint and continuously available energy resource. Thus, it is uniquely positioned to substantially contribute to safe and secure energy supply of Europe's Energy Union.

GEOTHERMICA's objective is to promote research and innovation in geothermal energy to make geothermal energy reliable, safe and cost-competitive. GEOTHERMICA combines the financial resources and know-how of 20 geothermal energy research and innovation programme owners and managers from 16 countries and their regions. Together with financial support from the European Commission, GEOTHERMICA has launched a call that has resulted in eight joint projects. Mobilising close to €44 million of private and public investment, GEOTHERMICA aims to demonstrate and validate novel concepts of geothermal energy deployment within the energy system, and that identify paths to large-scale commercial implementation. A second call, now with the participation of new partners from as far away as the United States of America, has been launched in 2019 with projects awarded by 2020.

GEOTHERMICA's ambition to represent the bulk of Europe's coordinated national and regional funding agencies has a two-pronged approach: firstly, to launch joint actions that demonstrate and validate novel concepts of geothermal energy utilisation within the energy system and that identify paths to commerciality. Secondly, GEOTHERMICA builds a tightly interconnected and well-coordinated network of European funding agencies that fosters knowledge sharing and coordinated strategy development. Ultimately, GEOTHERMICA strengthens Europe's Energy Union, its geothermal energy sector and supports the implementation of Europe's Strategic Energy Technology Plan on geothermal energy. To this end, GEOTHERMICA cooperates closely with the European Commission, Europe's Energy Research Alliance and the European Geothermal Energy Council as well as other key stakeholders even beyond Europe.

1 INTRODUCTION

Launched in 2017, GEOTHERMICA is a collaboration project of research and innovation funding organisations from sixteen countries that are joining forces to make funds available for research and innovation actions related to geothermal energy. Together with financial support from the European Commission, GEOTHERMICA launched in 2018 the first series of joint projects that demonstrate and validate novel concepts of geothermal energy deployment within the energy system, and that identify paths to large-scale commercial implementation. GEOTHERMICA is the outcome of a European Research Area Network that ran from 2012 to 2016 named the Geothermal ERA-NET. During this period, a large number of European (national and regional) geothermal research program owners and managers worked towards identifying and formulating a common research agenda.

The following, alphabetically listed countries and regions participate in GEOTHERMICA: Belgium/Flanders, Denmark, France, Germany, Iceland (Orkustofnun as coordinator), Ireland, Italy, the Netherlands, Portugal, Portugal/Azores, Romania, Slovenia, Spain, Switzerland and Turkey. Moreover, GEOTHERMICA's consortium has broadened for a second Joint Call, with Norway and USA joining. GEOTHERMICA's weight and influence serves to accelerate the development of geothermal energy not only in Europe but, owing to the close alignment of research priorities and complementarity of skills and facilities, also increasingly globally (Figure 1).

This joint call initiative is under the umbrella of the GEOTHERMICA ERA-NET Cofund (ERA-LEARN, 2019). The European Commission encourages the cooperation of national and regional geothermal energy research program owners and managers. The European Commission incentivizes this cooperation in principally two ways: the European Commission contributes financial resources to a first joint call, and secondly the European Commission supports research program owners and managers financially to work towards a common platform of research and innovation actions that are common to the vast majority of all partners in the GEOTHERMICA consortium. The national and regional funding agencies participating in GEOTHERMICA initially supported by funding from the Horizon 2020, the EU Framework Programme for Research and Innovation Programme under grant agreement No 731117. This incentive by the European Commission has radically changed the way national and regional research program owners and managers by identifying and harnessing the synergies among consortium partners.

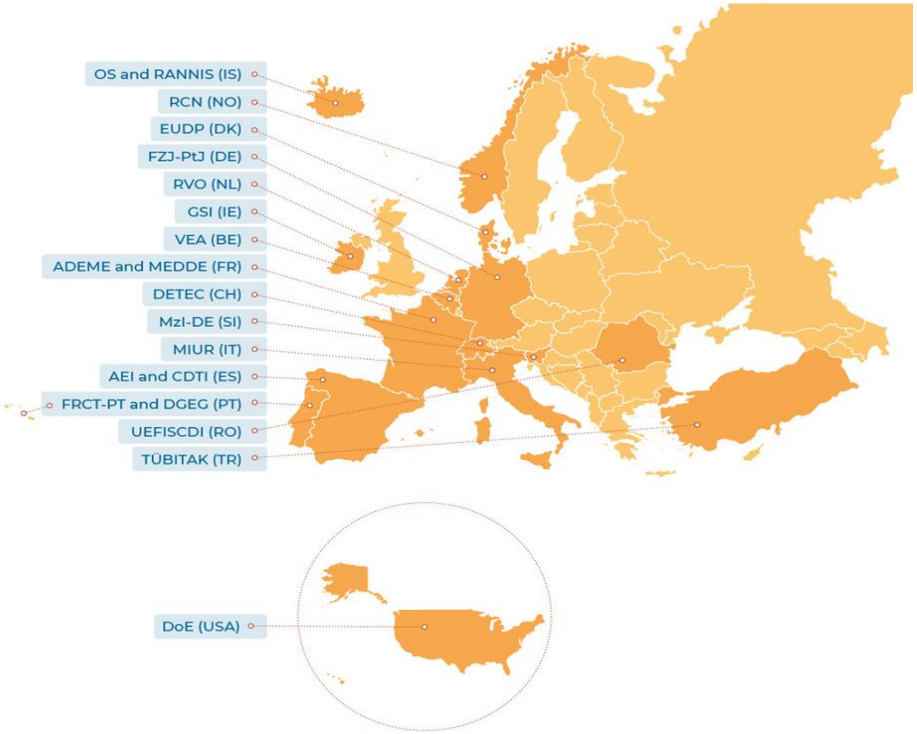

Figure 1: GEOTHERMICA Partners in 2019.

In the following sections, we first describe the joint calls for transnational innovation projects. Subsequently, we describe some of the additional activities that are being undertaken to forge closer links among national research program owners and managers across Europe and beyond.

2 JOINT CALLS FOR INNOVATION PROJECTS

GEOTHERMICA's joint calls focus on demonstration projects bringing innovative geothermal energy solutions closer to commercial deployment and encourage industrial participation to leverage public sector investment. Secondly, the project builds on the experience of the participating organisations in previous ERA-NET programs and strengthens the core idea by developing further the additional activities "knowledge, strategy and support" from a continuation of Geothermal ERA-NET Joint Activities (ERA-LEARN, 2019). It is crucial to maintain and grow Europe's leading position in geothermal energy and move geothermal development commensurate with its vast, yet untapped potential (Figure 2).

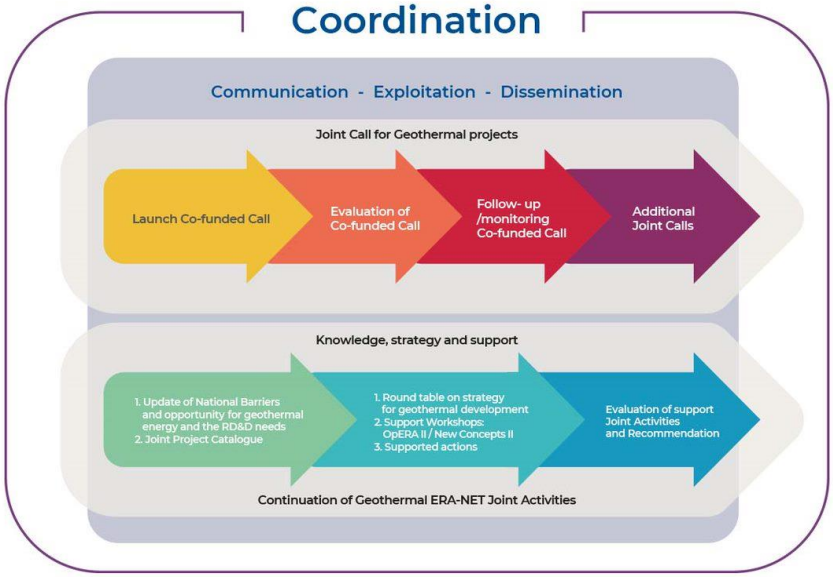

Figure 2: Overview of work streams of GEOTHERMICA.

GEOTHERMICA plans and executes joint calls for transnational innovation projects. Importantly, GEOTHERMICA also serves to forge increasingly closer links among geothermal energy research program owners and managers by many additional activities that address the innovation cycle for geothermal energy.

2.1 Concepts of GEOTHERMICA calls

GEOTHERMICA focuses on three main technological themes, which cover all stages in the development cycle of secure, sustainable, competitive and affordable geothermal installations (Figure 3):

- Identification and assessment of geothermal resources
- Geothermal resource development (drilling, completion, materials and equipment)
- Supply and smart integration into the energy system and operations

Over-arching these themes are four cross-cutting, non-technological thematic aspects of high importance for GEOTHERMICA; sustainability, knowledge sharing, public perception of a robust geothermal sector as well as obtaining policy-relevant outcomes from GEOTHERMICA's activities.

Innovation and development in all technological themes are essential to realising the aim of GEOTHERMICA, either by reduction of risk and cost, or expansion of viable applications of geothermal energy by developing new concepts and new ways for integration into the energy system. Successful projects in GEOTHERMICA are expected to contribute to the relevant crosscutting, non-technological themes (Berg et al., 2019).

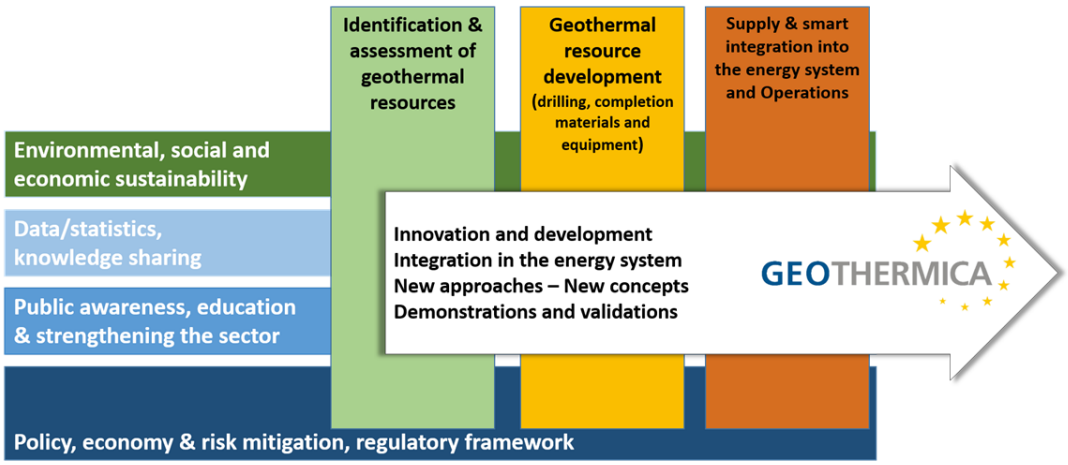

Figure 3: GEOTHERMICA's thematic concept features three technological and four cross-cutting innovation thematic aspects

Building on work to coordinate research and innovation programming among GEOTHERMICA's membership, GEOTHERMICA has identified shared and common interests in several thematic areas relevant to the technological themes (Table 1). GEOTHERMICA's calls are designed to support projects that deliver on the stated aims in each of the thematic areas.

Table 1: GEOTHERMICA Joint Call focuses on four thematic areas derived from three technological aspects.

Thematic areas	Aim
Identification and assessment of geothermal resources, reserves and reservoirs	Innovative and improved prospecting and exploration techniques and modelling methods to identify and assess geothermal resources.
Geothermal resource and reservoir development	New drilling and well completion technologies, reservoir stimulation and innovative systems to control induced seismicity during the reservoir stimulation phase.
Supply and smart integration into the energy system	Innovative concepts are illustrating geothermal energy as part of the energy system; geothermal reservoirs for heating, cooling and storage; innovative power cycles.
Operations	Novel approaches to improve well injectivity, as well as reliability and availability of injection operations; novel equipment and materials for lowering and optimising operating expenses; novel smart reservoir management technologies as well as innovative approaches to managing induced seismicity during production.

GEOTHERMICA has a prevailing interest to fund projects that pilot or demonstrate innovative concepts. GEOTHERMICA recognises the highly non-linear nature of innovation and thus encourages fundamental oriented research in support of specific pilot

and demonstration activities. Projects self-declare and justify their Technology Readiness Level (TRL) prior to their work program and indicate by how many levels the technology readiness advances in case of a successful outcome of their project. Projects funded by GEOTHERMICA, pilot and demonstration projects as well as technology development projects, should improve business cases based on research and innovation and thus contribute to commercial readiness. Targeted and funded projects occupy the TRLs 5-9 space with sub-ordinated work packages, possibly at lower TRLs to account for the non-linear dynamics of innovation. Besides advancing TRLs, projects need to demonstrate the vast, untapped potential of geothermal energy and raise awareness of the benefits of geothermal energy.

2.2 Procedural aspects of GEOTHERMICA Joint Calls

The Joint Call procedure of GEOTHERMICA was designed in very close alignment with recommendations put forward by ERA-LEARN, an initiative of the European Commission to ensure that good practices are shared among the plethora of ERA-NETs (ERA-LEARN, 2019). A large number of call features adopts from the methods of the European Commission in the context of its research framework programs, in particular, Horizon 2020 (for the period 2014-2020). Adherence to well-established procedures was one of many conditions for receiving co-funding from the European Commission for GEOTHERMICA's first call. Adopting established good practices contributed to the efficient and effective call design.

In the case of GEOTHERMICA's 1st joint Call, the formulation of a robust call text took approximately eight months before the launch on 15 April 2017. Work package participants comprised the writing team, who with increasing frequency towards the finalisation of the call text, sought input from all GEOTHERMICA participants. Once the GEOTHERMICA team accept the call text, the GEOTHERMICA Board approved it and authorised the publishing of the call timeline. By the end of January 2017, GEOTHERMICA released an announcement informing Europe's geothermal community about the 15 April 2017 launch date of a co-funded GEOTHERMICA call.

A two-stage process followed the GEOTHERMICA joint call. The first stage was a short pre-proposal which needed to be prepared and submitted before the deadline of July 10, 2017. In line with good practices, the time for consortia to be formed and pre-proposals to be developed was about three months, which exceeds the generally accepted minimum period of 2 months. Pre-proposals had to be submitted to GEOTHERMICA's Electronic Submission System (ESS). The Icelandic Centre for Research (RANNIS) administered on behalf of Iceland's Ministry of Education, Science and Culture competitive funds in the fields of research, innovation, education and culture, as well as strategic research programmes. RANNIS was thus ideally positioned to utilise existing IT infrastructures to host GEOHTEMRICA's ESS.

Within three working days the GEOTHERMICA Office, the administrative unit of GEOTHERMICA, collected and shared pre-proposals with GEOTHERMICA's membership. Pre-proposals were subsequently assessed by regional and national funding organisations, based on national/regional eligibility criteria. In a hypothetical example, a pre-proposal comprising ten partners from five countries would be checked by the national and regional funding organisations from the five specified countries and regions. Each funding organisation would check the eligibility of "their" regional or national partners. The eligibility check varied widely from one country/region to another because national and regional rules are highly variable. Some national and regional funding organisations focused only on checks to confirm formal compliance with national and regional rules, while others had to consider other factors adding to declare the national/regional component of a project eligible. Factors included the availability of funding, a qualitative assessment of innovative ideas, an assessment of the fit with the objectives of the call, of the composition of the consortia, of the potential impact of the project, and the relevance to the respective national program objectives (see also lessons learnt in Section 2.3 below).

The following Table 2: and Figure 4 show the transnational cooperation of the projects. In 35 pre-proposals, 153 different entities from 13 different countries participated. Netherlands, Italy, Iceland, Denmark and Switzerland showed a high percentage of collaboration at 1st stage.

Table 2: Number of pre-proposals submitted in the course of GEOTHERMICA's first call and national entities participating in pre-proposals sorted by partner countries; including a percentage of participation.

Country	Number of preprposals submitted as a coordinator	Total number of entities participating in preproposal stage	Percentage (%) of participation of entities from different countries in the pre proposal stage.
Netherlands	7	33	20
Italy	5	15	14
Iceland	4	7	11
Denmark	4	19	11
Switzerland	4	11	11
France	3	14	9
Germany	3	16	9
Belgium	2	11	6
Ireland	1	5	3
Spain	1	10	3
Portugal	1	4	3
Turkey	0	3	-
Slovenia	0	5	-
Total	**35**	**153**	

In the second stage, a group of successful pre-proposal was invited to submit a full proposal. As in the case of pre-proposals, full proposals had to be submitted to GEOTHERMICA's Electronic Submission System (ESS) hosted by the Icelandic partner, RANNIS. Full proposals were re-checked for national/regional eligibility. Eligible full proposals were then evaluated in an open competition in which an independent international expert panel evaluated proposals according to the programme's evaluation criteria followed by the ranking of the proposals. Only full proposals with confirmed positive national/regional eligibility checks were ranked.

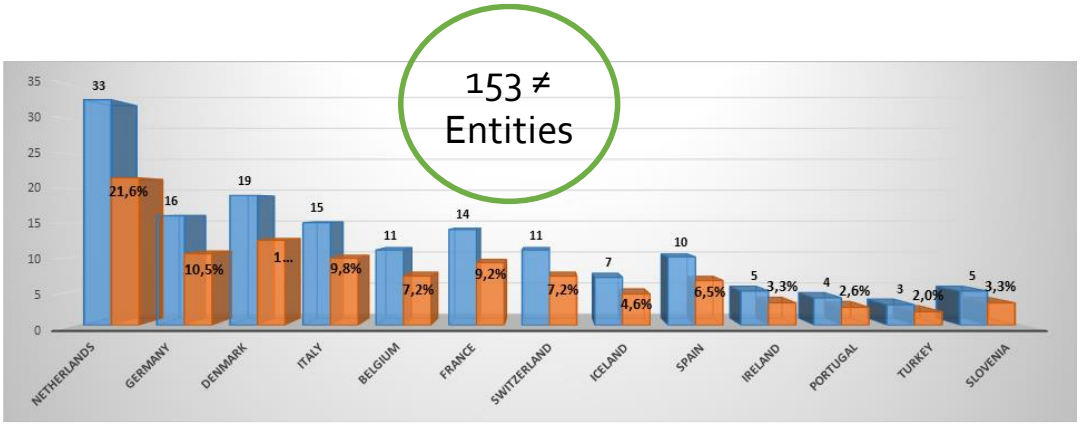

Figure 4: Number of different entities participating in the joint call by country.

The results showed that from the 21 pre-proposals invited to submit a full proposal by November 24, 2017, only fifteen submitted a full proposal. After evaluation and ranking by the expert panel, finally, nine proposals were eligible for funding. The following Table 3 and Table 4 show the number of projects related to the TRL (Technology readiness levels, a method for estimating the maturity of technologies) distinguishing large projects (named as A) and small projects (named as B). The top half of the figure refers to all proposals, and the lower half relates to the projects selected for funding.

Table 3: In total, 15 projects (6 type A and 9 type B) submitted at the 2nd stage.

Topic	Type A Nº Project	Type A TRL	Type B Nº Project	Type B TRL
Geothermal resource development	3	8/7/7	2	6/6
Identification and assessment of geothermal resources	1	7	3	7/5/6
Operations	1	7	2	6/9
Supply and smart integration into the energy system and operations	1	8	2	9/9
Total/ Average	**6**	**7,3**	**9**	**7**

Table 4: In total, 9 proposals eligible for funding after evaluation.

Topic	Type A Nº Project	Type A TRL	Type B Nº Project	Type B TRL
Geothermal resource development	2	8/7	2	6/6
Identification and assessment of geothermal resources	0	-	1	7
Operations	1	7	**1**	6
Supply and smart integration into the energy system and operations	1	8	1	9
Total/ Average	**4**	**7,5**	**5**	**6,8**

The additional GEOTHERMICA Joint Call is to launch projects in 2020 that accelerate the piloting, demonstration and validation of novel concepts of geothermal energy supply within the energy system, and to identify paths to commercially viable deployment. Projects may also address oriented research that underpins novel concepts and pathways to commerciality.

2.3 Lessons learned from 1st call

The overall aim of the GEOTHERMICA project is to accelerate the deployment of geothermal energy in Europe by pooling national funds, financially incentivised by the European Commission, to fund innovative projects with a focus on improving business cases for geothermal energy. Secondly, the aim to encourage a long-lasting strategic collaboration of national geothermal research and innovation program owners and managers of the GEOTHERMICA consortium.

The main challenge for selecting pre-proposals was a wide range of processes and definitions that national and regional program owners and managers were subject to constitute "eligibility" of pre-proposals (and full proposals). Some funding organisations focused solely on purely formalistic aspects while others were mandated to perform additional checks such as compliance and alignment with national research priorities or financial checks on potentially funded organisations. Despite attempts being made to coordinate and harmonise processes, national legal constraints did not permit the establishment of one set of standard rules. Still, GEOTHERMICA plans to improve this aspect of "eligibility" checks by better coordination between national contact points and clarity for the applicants of the risks associated for the overall project with not adhering to national eligibility in each partner country. In addition to GEOTHERMICA's call procedures, some countries needed to run additional funding opportunity announcements on a national or regional level to ensure alignment with national programs whose budget was used to finance ultimately successful GEOTHERMICA full proposals. Ring-fencing budgets for GEOTHERMICA only was not permissible for some national or regional funding organisations.

Overall the execution of GEOTHERMICA first joint call was highly successful with 9 projects to be funded; one proposal withdrew during contract negotiations, and in the end, eight projects were financed with an investment from research funding organisations in the range of € 23 million and a total investment mobilized amounting to €44 million (partner and another financing).

2.4 Launch of the 2nd joint call

The 2nd joint call launched in June 2019 builds on the success of the 1st call and incorporates lessons learned. The context of the 2nd joint call has changed. Europe's Strategic Energy Technology Plan (SET-Plan) has been gaining increasing traction among national and regional funding organisations as an umbrella to coordinate essential aspects of energy research at a European level with the goal to maximise the impact of energy research and innovation to the benefit of Europe's Energy Union. One element, particular to geothermal energy, is a Deep Geothermal Implementation Plan (DG-IP) within the framework of the SET-Plan (Johannesson et al., 2018; Manzella et al., 2016). The DG-IP calls for work on eight research and innovation activities as well as work on two non-technical barriers and enablers. A cornerstone is improved and increased technology performance, as well as the reduction of the cost of technologies as strategic targets for deploying geothermal energy. Against this backdrop and a re-analysis of national barriers and opportunities in conjunction with national research priorities, GEOTHERMICA's consortium has been expanded to include Norway and the USA. It ensures that the research and innovation space dedicated to geothermal energy is abundant and attracts excellent talent giving GEOTHERMICA the weight to influence and accelerate the development of geothermal energy not only on the European scale but progressively more internationally.

The objective of GEOTHERMICA's second joint call remains the acceleration of the development of geothermal energy, by combining the financial resources and know-how of its respective partners, as well as expanding the utilisation of clean and renewable low carbon geothermal energy beyond its traditional markets and regions. Besides, GEOTHERMICA seeks to explore the optimisation of direct geothermal use and power generation, including innovative integrated and combined systems.

The project may additionally address cross-cutting themes related to health, safety and environment, as well as social acceptance and policy-relevant aspects. Within the three technological main aspects, several thematic areas have been identified (Figure 5).

The available budget for GEOTHERMICA's 2nd joint call totals approximately €19 million. The schedule of a Second Joint Call proposal has three significant steps. The submission of pre-proposals is due by September 13, 2019. Next, on November 11, 2019, eligible pre-proposals receive an invitation to submit projects full proposals with a deadline of January 31, 2020, (Figure 6).

Participants of the new joint call must meet the specifications of the GEOTHERMICA second joint call in addition to the funding rules and regulations of their home countries or regions. To create a consortium, it is required to have at least three eligible applicants from at least three participating countries.

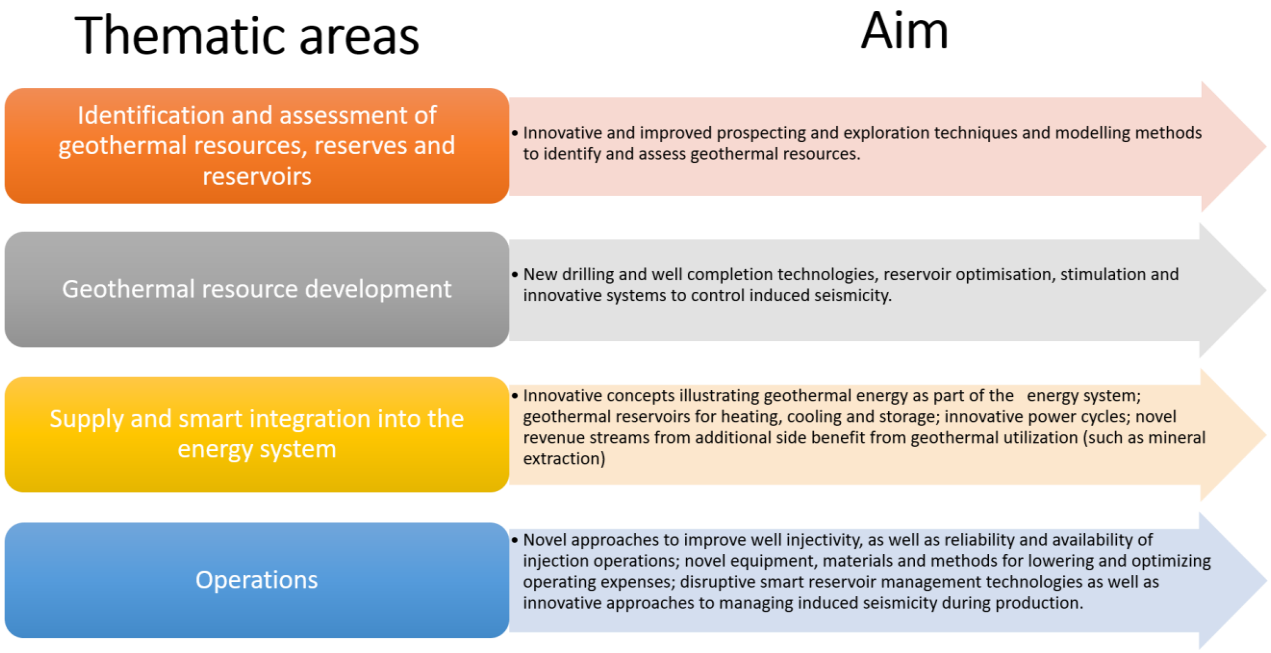

Figure 5: Four thematic areas derived from three technical aspects for the GEOTHERMICA call.

Figure 6: Deadline for project pre-proposals submission for the Second Call.

3 MONITORING

GEOTHERMICA monitors the progress of funded projects. The guiding principle of the monitoring builds on national procedures for monitoring according to payment plans.

At the European level, GEOTHERMICA's progress monitoring relies on half-yearly traffic light reports. Project leads specify their progress per individual work package by indicating progress to be 'green' 'yellow' or 'red'. In case of any yellow or red, the project lead reports what remedial measures are put in place to remedy delays or insufficient technical progress. If needed, the funding agency in the lead country of the particular project will work with the project to overcome challenges in a project progress.

Also, GEOTHERMICA undertakes a mid-term review for large projects where GEOTHERMICA contributes more than €2 million. The mid-term evaluation for GEOTHERMICA's 1st call project is planned for early 2020. This review is formal, where project and work package leads are invited to an in-person meeting with those funding agencies who support the project. The meeting will result in a consensual evaluation in written form, which is shared with the project. Compliance with regional, national and GEOTHERMICA reporting requirements add a layer of complexity, an improvement of which will be gradual and will be implemented in an iterative and stepwise fashion.

GEOTHERMICA-granted projects are obliged to participate in knowledge-sharing workshops organised by GEOTHERMICA. Monitoring of progress is more remarkable because the projects will need to deliver in time as projects co-funded by the European Commission have an irrevocably fixed duration of 36 months with the threat of funding from the European Commission being withheld if timelines are not met.

4 ADDITIONAL ACTIVITIES

In addition to the support and financing of transnational geothermal projects, the GEOTHERMICA consortium's centrepiece is a work package on "knowledge, strategy and support". This work aims at broadening the scope and scale of strategic cooperation as carried out in the precursor project "GEOTHERMAL ERA-NET". The primary goal of this work is to enhance the information and knowledge exchange between all relevant stakeholders within the community and to compare, discuss and, where possible, streamline the strategic goals of the different interest groups. The following Figure 7 illustrates the various tasks planned in GEOTHERMICA's WP7 "Knowledge, strategy and support".

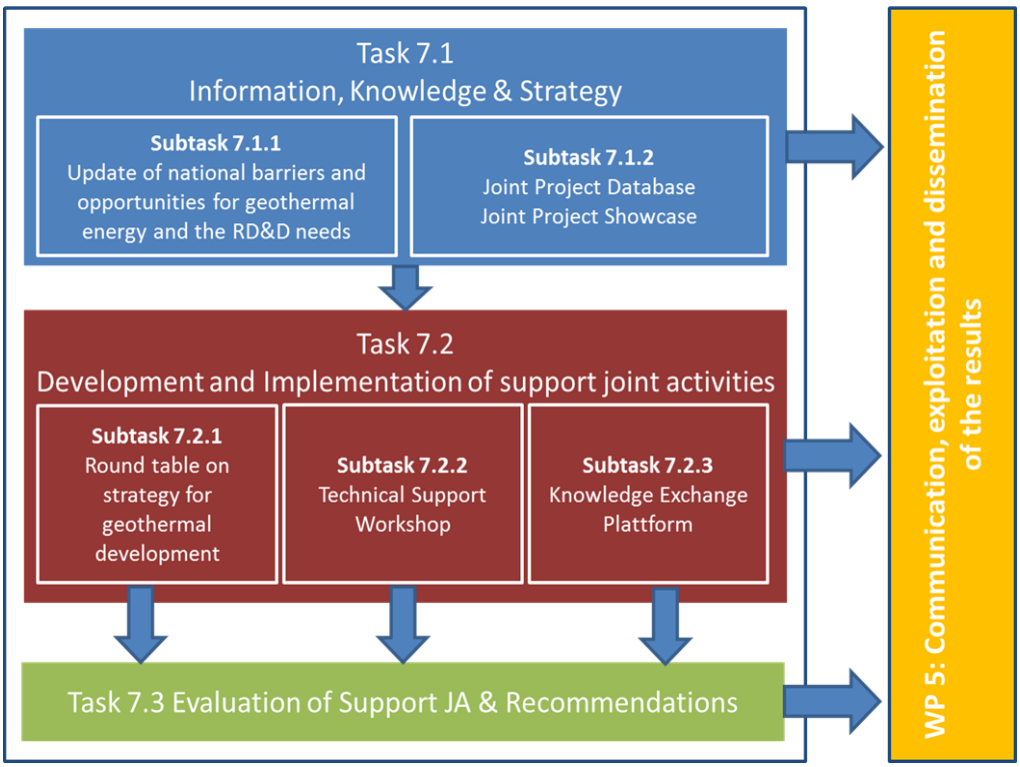

Figure 7: Structure of GEOTHERMICA WP7 "Knowledge, strategy and support" and relations within the overall structure.

The two main Tasks, 7.1 and 7.2, are addressing different target groups. While Task 7.1. "Information, Knowledge and strategy" aim on enhanced cooperation between the various funding bodies in the participating countries, Task 7.2 "Development and Implementation of support joint activities" creates additional benefit for the whole geothermal community in Europe (Berg, 2019).

In task 7.1, a straightforward approach was used to collect the status of geothermal energy in the partner countries. The collection of national barriers, opportunities and RD&D needs in the geothermal sectors helps the funding agencies to identify common ground for transnational collaboration on a project scale. Also, the team of the task created an internal database of geothermal funding projects from the last five years until now. This move helps to identify cooperation potential on a thematic level and leads to more efficient use of funding budgets. A web-based showcase of these nationally and jointly funded geothermal innovation projects has been developed and made available to the public on the GEOTHERMICA website www.geothermica.eu under the name JoProShow (Joint Projects Showcase).

Building upon the results of the first task, Task 7.2. organises different platforms for knowledge and information exchange as well as strategic discussions within the community. So far, a round table with relevant stakeholders from the European Commission, national funding agencies, the SET-Plan IWG Deep Geothermal and industry and research organisations is planned (Johannesson et al., 2018). Additionally, a technical workshop on a specific issue in geothermal operations will be organised, bringing together researchers and operators of geothermal installations. The third task aims at providing a web-based platform for knowledge exchange on operational issues of geothermal plants.

The planned additional activities aim at an enhanced transnational communication within the European geothermal community to support the further development of geothermal energy in Europe.

8 CONCLUSIONS

GEOTHERMICA has exceeded our expectations in bringing together an extensive range of national and regional geothermal energy research program owners and managers. Importantly, joint calls have produced exciting research and innovation projects whose objectives and expected outcomes contribute to national and regional ambitions for geothermal energy. Not only that, GEOTHERMICA proves to be an essential instrument for translating Europe's Strategic Energy Technology Plan (SET-Plan) into actions that are well aligned with the SET-Plan's Deep Geothermal Implementation Plan. Furthermore, GEOTHERMICA is

essential in coordinating national and regional research and innovation agendas for geothermal energy. Coordination is expected to lead to harmonisation along with joint and shared interests and thus will lead to optimisation and high grading of public investments into deep geothermal energy's research and innovation space.

It is essential to recognise that GEOTHERMICA's strength also lies in the highly diversified approach of its national and regional constituency. Single voices are heard and are free to contribute according to their needs and capabilities to this pan-European effort. In effect, GEOTHERMICA is a highly complementary, yet independent approach to the European Commission's efforts in the framework research programs such as Horizon 2020 or, as expected Horizon Europe.

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