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GEORG Geothermal Energy Research Cluster Initiative – Bridging the Community Gap

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ABSTRACT

The Geothermal Research Cluster (GEORG) is a sustainable geothermal research cluster initiative which brings together players in the geothermal field to form a strong force for rapid progress and value creation in the geothermal research, engineering and design for the benefit of the society. It consists of 22 partners, combining all the main educational and research organizations, energy companies, engineering firms and start-ups in Iceland as well as their key international collaborators in the geothermal science and utilization. The GEORG project portfolio is based on enhancing the capabilities of the cluster members in developing their geothermal competencies. The largest project is the Horizon 2020 project, DEEPEGS, coordinated by HS Orka, which has already successfully drilled the deepest well in Iceland on the Reykjanes Peninsula. GEORG is leading the development of the Krafla Magma Testbed (KMT) project, with a large international group of experts and stakeholders, where the objective is to establish an international in-situ magma laboratory at Krafla volcano in Northern Iceland. GEORG is managing the project office of the HORIZON 2020 ERA NET Co-fund GEOTHERMICA, coordinated by Orkustofnun Iceland, and more recently, GEORG took part of the H2020 largely funded Geothermal Emission Control (GECO) Project, coordinated by Orkuveita Reykjavikur (Reykjavik Energy), both at the project office and at the dissemination levels. It is also undertaking a new project related to public acceptance of geothermal, carrying a socio-economic study. Moreover, GEORG is participating in several influential committees on geothermal issues, including the European Technology and Innovation Platform on Deep Geothermal (ETIP-DG) and the HORIZON 2020 Energy Committee. By adopting a sustainable business model, GEORG cluster has evolved to become a valuable platform helping foster geothermal cooperation around the World, creating opportunities in the geothermal field by investing and valorizing the geothermal research, knowledge and expertise, and it has benefited the cluster members with a special focus on building bridges not only between the research community and industry, but also with policy makers and the public.

1. INTRODUCTION

GEORG was founded in 2009 on the bases of “Clusters and Centers of Excellence” grant by the Science and Technology Policy Council of Iceland (Rannis). Today GEORG is operated as an independent and sustainable non-profit association.

The selection of GEORG by the Science and Technology Policy Council of Iceland was twofold. Firstly, it acknowledges the important role the geothermal sector has played in the progress of the Icelandic society, which is e.g. evident by the energy transition from oil and coal-based society to renewable energies as shown in Figure 1. Secondly, the decision was also influenced by the great challenges triggered by climate change that imply an urgent need for further development in the geothermal field, so that geothermal energy can continue to contribute to the solution to this global issue. The objectives of GEORG are to:

- Reduce worldwide GHG emission worldwide by contributing to significant increase in sustainable energy production/utilization from geothermal sources.
- Make Iceland a case study for near energy independent and carbon neutral society.
- Create a platform for entrepreneurship and export of geothermal energy resources and education, both for partners in the group and in the ensuing creative environment established through its national and international operations
- Contribute to the Sustainable Development Goals (SGD7, SDG9 and SDG13 – respectively related to Affordable and clean energy, Industry, innovation and infrastructure, and Climate action.

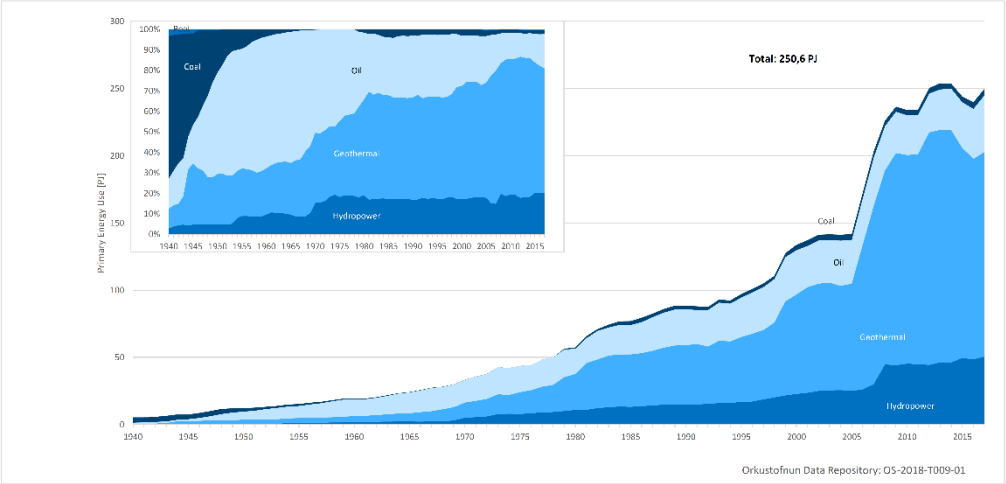

Figure 1: Energy Use in Iceland by Source (Orkustofnun, 2018).

GEORG is an entry point for those who have interests in the geothermal sector in Iceland and it has made an early progress in establishing a Knowledge Hub around its structure. Within GEORG, there are close interactions between academia and industry, which have contributed to better collaborations within and between the two sectors. The GEORG cooperation focuses on furthering interdisciplinary collaborations, notably with partners from socio-economic disciplines. On the international level, many renowned foreign partners have been involved in GEORG projects, which have resulted in closer and more comprehensive collaborations.

GEORG's business model allows it to play a diversified yet targeted forum to stimulate R&D in the geothermal sector. It brings together key researchers from academia and members from the industry sector. GEORG has supported and initiated many industry driven projects which provided support for 79 graduate students. Many GEORG's supported students are now influential leaders in their fields of expertise and contribute actively to the development of geothermal energy sector. In addition, GEORG has provided several conference travel grants for graduate students, including for the annual European Geothermal PhD day.

One of GEORG's goals is to create a platform for entrepreneurship. In that spirit GEORG is a proud founder of the business accelerator program Startup Energy Reykjavik (SER), together with Landsvirkjun (National Power Company of Iceland), Arion Bank and Innovation Centre Iceland. Startup Energy Reykjavik is a mentorship-driven seed stage investment program with a focus on energy related business ideas. In the program, selected teams receive up to USD 40,000 in seed funding, outstanding working facility, ten weeks of intensive top-notch mentorship and the chance to pitch to angel investors and venture capitalists at the end of the program.

The partnership of GEORG creates a critical mass of joint resources and efforts to break through existing scientific and technical barriers to innovation in the field of geothermal. GEORG aims to significantly increase the number of qualified experts in geothermal research, engineering, design and technical exploitation of the resource. This is done by emphasizing strongly on supporting young scientists, and by that, bridging the emerging generational gap in this area. GEORG creates synergy effects by combining different research aims of academic and industry partners and by joining relevant activities where operational effectiveness is enhanced.

Through its partnership in the European Commission's Energy Committees and other policy related activities, GEORG strongly supports international research collaboration by taking active part in promoting geothermal research within the European research agenda.

The GEORG group conducts research actions and projects, linking them in a managed manner with international or national groups capable of exploiting results through innovation and business development, to maximize possible return on investment in research in joint programmes of the partners.

1.1. Organization and Operational Structures

GEORG's organizational structure is composed three groups: Board of Directors, Operational Team and a Science Academy. The Board of Directors (BoD) comprises 9 representatives of GEORG members, i.e., a Chairperson and 8 directors, 4 directors represent the universities and research organizations and 4 directors represent the energy companies and the private sector. Members of the Board are elected for a term of 2 years. The general assembly takes place on March of every year. The GEORG office employs seven people. The experience and educational background of the team enhance the further growth of the GEORG in the international market by solving challenging problems and making a real impact to build the geothermal platform. The team has diverse background including geosciences, engineering, regulatory affairs, politics and graphic design.

GEORG operations are based on four key focus areas as shown in Figure 2. These four key areas are further defined as:

Figure 2: Operational Structure of GEORG.

The Science Academy's (SA) initial role was to act as a high-level advisory function for the overall research policy and priority setting, during GEORG's research projects funding, approving project funding policy and selection procedures. The SA acts now as a reviewing panel for scientific contributions received through GEORG's biennial event: The GEORG Geothermal Workshop (GGW).

1.2. Support for Geothermal Research Projects

GEORG assigned most of its initial funding budget to support and foster cooperation on research projects related to geothermal energy (Ingolfsson 2015). These include:

- Service to Cluster Participants: The most important service of GEORG is to provide a platform to link different disciplines and between academia and industry. This is done through matchmaking, contact sharing, knowledge sharing among partners, training organizations, organizing seminars and workshops.
- Grant Application Support for Participants: GEORG offers expertise in applying for grants at the European and international level. This grows the potential and significantly improves the success rate for research grant applications, it also influences the impact of the geothermal cluster for the benefits of the participants.
- Promotion and Dissemination: GEORG operations form a platform to promote knowledge on the geothermal energy resource, its utilization potential, sustainability and environmental issues. This is accomplished through training and information sharing through courses, workshops, seminars and conferences. Promotion of the geothermal energy resource at the European and international level increases the awareness of the opportunities the renewable energy sector offers.

1.3 GEORG Members

The group behind GEORG is highly multidisciplinary and consists of all the main educational and research organizations, energy companies, engineering firms, and start-ups in Iceland, as well as their key international collaborators in the geothermal sciences and energy resources utilization. Figure 3 shows the members of GEORG grouped by their role. The figure clearly illustrates that the members span nicely all the roles needed to form a solid research cluster that puts in its core goals the bridging between academia and industry. The main University and research institutes in Iceland are all members, the three largest energy companies as well as the main players in the engineering consulting field.

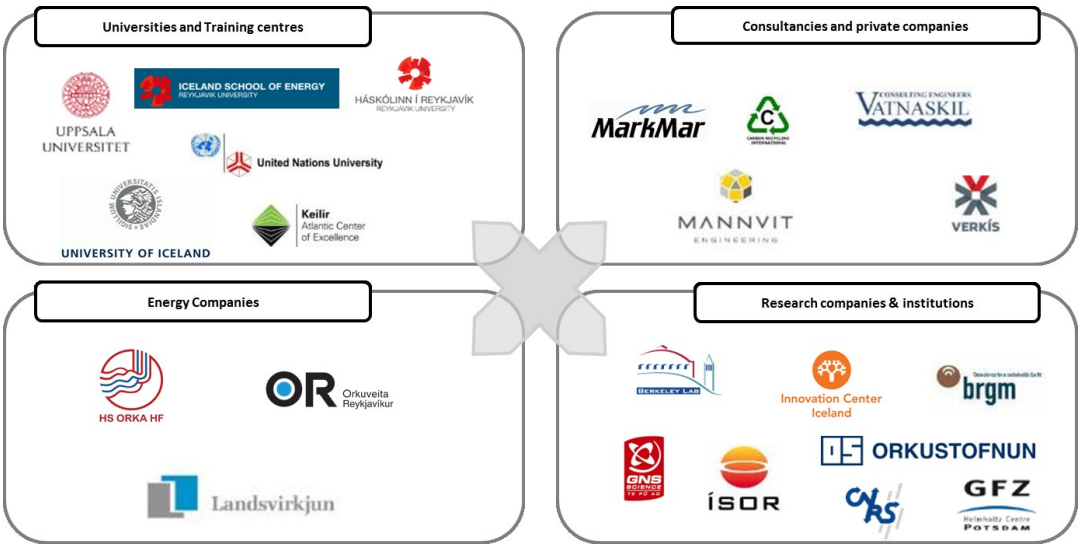

Figure 3: Members of GEORG Grouped by Operational Field.

2. MAIN ACTIVITIES

The GEORG projects portfolio is based on enhancing the capabilities of the cluster members in developing their geothermal competencies.

The largest project to-date is the Horizon 2020 project, DEEPEGS, coordinated by HS Orka, which has already successfully drilled the deepest well in Iceland on the Reykjanes Peninsula. GEORG is leading the development of the Krafla Magma Testbed (KMT) project, with a large international group of renowned experts and stakeholders, where the objective is to establish an international in-situ magma laboratory at Krafla volcano in North-Iceland. GEORG is managing the project office of the HORIZON 2020 ERA NET Co-fund GEOTHERMICA, coordinated by Orkustofnun Iceland (Figure 4). GEORG is also participating in several influential committees on geothermal issues, including the European Technology and Innovation Platform on Deep Geothermal (ETIP-DG) and the HORIZON 2020 Energy Committee.

Figure 4: Portfolio of GEORG's Ongoing Project (GEORG Annual Report - 2018).

2.1 Research projects by Cluster Members

GEORG supported over 30 research projects that were coordinated by the cluster members. The projects range from the geothermal reservoir upstream, the midstream technology, including borehole construction and equipment, downstream waste streams, environmental impacts, and geothermal management and data. Many of these research projects took place in collaboration with members within the cluster and in some cases with additional partners from outside the formal cluster cooperation. The collaboration net is shown in Figure 5, where the dotted circle indicates the division between cluster members and additional partners (Ingolfsson 2015). The figure also shows the strong connections that were established through the projects between universities, research institutes and the industry, both energy companies and consulting companies.

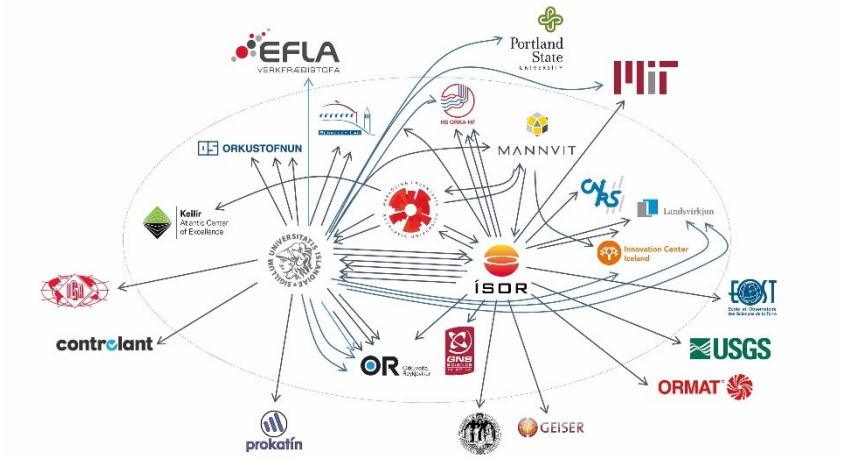

Figure 5: Cooperation Net of GEORG Research Projects. GEORG Members are inside the dotted circle and additional partners recruited for individual research projects are shown outside of the circle.

2.2 Excellence in communicating deep geothermal drilling through "DEEPEGS"

One of the greatest challenges for GEORG so far was its participation in the deep geothermal drilling 'DEEPEGS' project. GEORG´s main role in the project is to run the Project Office (PRO) and lead dissemination and communication activities. The total cost of the venture is 44M€ including 20M€ from the H2020. Three and a half years have passed since the kick-off meeting in December 2015 in Paris and consortium reached over 2/3 of its operation. Since the beginning, numerous plenaries, technical and executive board meetings were held in Iceland, France, Norway, Italy, Germany and Belgium. The first drilling was completed on January 25th, 2017 at 4,659 meters depth. The targets were achieved including drill depth, drill cores extraction, measured temperature and exanimated permeability. The temperature at the bottom of the well was measured at 427°C, with fluid pressure of 340 bars, drill cores were retrieved, and the rocks appear to be permeable at depth.

The work of the PRO is focused on communication and coordination to keep the consortium up to date and be able to react to the issues in a timely manner. Various workshops and meetings were held not only between the partners but also in collaboration with other H2020 deep geothermal projects, exchanging knowledge and expertise of researchers, students and industry fellows. The outreach to stakeholders was held continuously with over 15 successfully run workshops and meetings.

Communication activities ensured maximum visibility and accessibility of the project. The dissemination activities were tailored to make the project outcome visible and available for different stakeholders. This led to publications and documentaries on renowned media such as the BBC. Online presence gave the project notable exposure and the consortium an important channel to share the project information and materials with interested stakeholders.

2.3 Conquering the Extreme through "Krafla Magma Testbed (KMT)"

Driven by the needs to understand magmatic systems, to improve volcano monitoring strategy, and to develop next-generation, high-enthalpy, geothermal energy, we introduce the Krafla Magma Testbed (KMT) – located in Northeast Iceland.

The Krafla Magma Testbed (KMT) is one of the most ambitious projects that GEORG is coordinating. KMT aims to establish the first magma observatory – an international, open access, scientific platform to advance ductile zone to magma research via drilling. This frontier undertaking will enable direct, in situ sampling, instrumentation and manipulation, and monitoring of magma and its interface with solid Earth's crust, vastly advancing models of high-temperature crustal processes. Creating the world's first magma research facility will provide unparalleled opportunities for both basic and applied research in a number of fields, such as volcanology, basic science, geothermal energy, technology and innovation. KMT will develop a long-term infrastructure (>25 years) for the conduct of interdisciplinary scientific, engineering, technological, and educational activities.

This initiative is enabled by recent geothermal drilling at Krafla volcano that serendipitously intersected and thus determined the exact location of magma for the first time. The Krafla volcano has therefore the advantage of a long history of geological study, volcano monitoring, and drilling as well as supporting surface facilities to produce the safest and most efficient base from which to explore Earth beyond the solidus. KMT will be the place to develop (1) our science of hot Earth; (2) new ways of understanding and monitoring volcanoes; (3) our ability to extract and exploit geothermal energy sources; and (4) new technology and materials that function in the most extreme conditions in Earth's crust.

GEORG is leading the way for project and business management together with World-class organizations like the famous geoscience research centre - the British Geological Survey (BGS), and the Italian National Institute of Geophysics and Volcanology (INGV) which deals with some of the most dangerous volcanoes in the world. Moreover, the project involves some of the leading scientists of this field like John Eichelberger (University of Alaska) and Yan Lavallee (University of Liverpool). In October 2018, 13 Icelandic institutions, universities and companies signed a "Letter of Intent" for establishing an international centre for geothermal- and volcanological testbed at the Krafla area in North East Iceland. In late 2018 and early 2019 the KMT consortium received formal letters from Icelandic and UK governments and funds concerning financial and scientific support to the KMT project.

2.4 Supporting Energy Transition in Europe through "Horizon 2020 ERA NET Co-fund - GEOTHERMICA"

GEOTHERMICA's objective is to combine the financial resources and know-how of 18 geothermal energy research and innovation programmes owners and managers from 14 countries and their regions.

Together with financial support from the European Commission GEOTHERMICA launched a first call in 2017 with a budget of €32 million for joint transnational projects that demonstrate and validate novel concepts of geothermal energy deployment within the energy system, and that identify paths to commercial large-scale implementation. A second €19 million transnational call was launched in 2019 within the same scope inviting several new partners to join and contribute to expanding and further bettering the research and innovation space dedicated to geothermal energy.

GEOTHERMICA Projects cover a broad range of topics such as heat storage, managing induced seismicity, EGS drilling and completion, production operations, composite casing and integrated applications of geothermal heat. They have participants from the Netherlands, Switzerland, Iceland, Ireland, France, Flanders, Denmark, Slovenia, Germany, Spain, Italy and Azores Portugal. Through the second call, Norway and the USA joined the consortium.

GEORG is leading the GEOTHERMICA Office supporting the coordinator and consortium management team in implementing the co-fund calls and ensure an optimal, flexible and smooth operation of all activities. GEORG organizes and develops GEOTHERMICA's external and internal communication, operates the secretariat and supports the implementation of additional activities within the work package seven.

The good number of pre-proposals received shows the interest in accelerating geothermal energy across Europe and features technological and cross-cutting innovation themes. GEOTHERMICA is an important step in funding demonstration and technology development through a Member State and EU cooperative budget.

The GEOTHERMICA consortium is looking forward to proceeding with the projects and to accelerate the deployment of geothermal energy in Europe, reducing the time to market for novel geothermal energy concepts, and require industrial involvement in research, innovation and demonstration activities.

2.5. Tackling Environmental Challenges through "GEOENVI"

GEORG is participating in the GEOENVI project which was launched in November 2018. The objective of the project is to make sure that deep geothermal energy can play its role in Europe's future energy supply in an increasingly sustainable way, and to create a robust strategy to answer environmental concerns. The GEOENVI project will start by assessing environmental risks and impacts of geothermal energy. The GEOENVI project focuses on six key countries with varying deep geothermal potential, markets maturity and geological settings: France, Italy, Belgium, Iceland, Turkey and Hungary.

2.6 Supporting Entrepreneurship through "Startup Energy Reykjavik Business accelerator"

One of GEORG's goals is to create a platform for entrepreneurship, which aims at supporting innovation in the geothermal field and encourage the creation of start-up companies in order to transform geothermal research outputs into marketable products and concepts. This was accomplished by partnering with Arion Bank, Landsvirkjun and the Innovation Centre of Iceland through the Start-up Energy Reykjavik business accelerator in 2014—2016 (Figure 6).

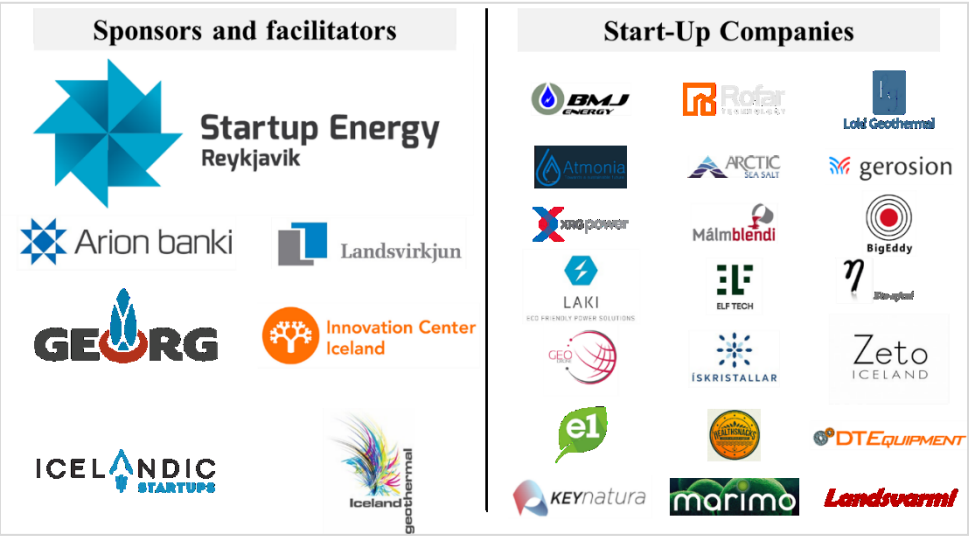

Figure 6: The Sponsors, Facilitators and the 21 Startup Companies Selected for participation in Startup Energy Reykjavik Business Accelerator.

Start-up Energy Reykjavik is a mentorship-driven seed stage investment programme with a focus on energy-related business ideas. The programme selected twenty-one energy start-ups, which took part in mentor-driven 10-week business accelerator activities. Start-ups got a cash infusion from the four partners, in exchange for an equity position and access to expert mentors during the programme, as well as a follow-up advice. Selected teams receive up to USD 40,000 in seed funding. GEORG is a shareholder in the start-ups, through the holding company "SER eignarhaldsfélag ehf".

2.7. Reducing Geothermal Production Emissions through "GECO"

The Geothermal Emission Control (GECO) Project is one of the latest projects GECO has joined as a partner. Launched in October 2018, GECO is a largely funded geothermal EU innovation action (EUR 16 Million grant from the Horizon 2020 Research and Innovation programme). It aims to capture, and store geothermal gases emitted during energy production and provide a cleaner and more cost-efficient power. GEORG is leading the dissemination work package and is partner in other work packages, including the project management office along with the coordinator 'Reykjavik Energy'. GECO builds on the success of the recently CARBFIX Project in Iceland, which proved that it is possible to capture and store CO_2 back in the ground, both onshore and offshore.

The novelty of GECO's concept is to demonstrate the feasibility of carbon capture and storage from geothermal power plants back into the ground, in different geological reservoir contexts, and on different stages of development of the 4 selected demo sites. The demonstration process will take place in: 1) a high temperature basaltic reservoir in Iceland; 2) a high temperature gneiss reservoir in Italy; 3) a high temperature volcano-clastic reservoir in Turkey, and 4) a low temperature sedimentary reservoir in Germany.

With a total of 18 partners involved, GECO aims to increase public acceptance and generalize this novel approach. To that end, the re-injection method will be applied in four distinct geothermal systems in four European countries

2.8. Contributing to European Strategy Work

GEORG staff has taken active part in strategy work for renewable energy within Europe. GEORG operational manager has been Iceland representative in the energy committee of FP7 and now Horizon 2020 since the establishment of GEORG. He also has a seat in the Steering Committee of The European Technology & Innovation Platform on Deep Geothermal (ETIP-DG). ETIP is an open stakeholder group, endorsed by the European Commission under the Strategic Energy Technology Plan (SET-Plan), with the overarching objective to enable deep geothermal technology to proliferate and reach its full potential everywhere in Europe.

In the past years through the operation of the GEOTHERMICA Office, partners of fourteen EU member states had an opportunity and a strong influence on the activities of the SET-Plan Temporary Working Group (TWG). The TWG, composed of Member states-Associated countries, stakeholders and the European Commission, kicked off in February 2017. The TWG was meeting regularly to draft the Implementation Plan, that contains concrete R&I activities and proposes relevant funding opportunities for their realization, which are considered essential for achieving the agreed set of targets. The TWG is chaired by national representatives from Italy and Iceland and co-chaired by the European Technology & Innovation Platform on Deep Geothermal (ETIP-DG). GEORG is currently also managing the project office of the Support Unit of the Deep Geothermal Implementation Working Group (SU-DG-IWG).

3. GEORG'S BUSINESS MODEL AND STRATEGY

The formal grant period for "Centres of Excellence and Research Clusters" program which was supporting GEORG during 7 years, took end at the end of March 2016. The operation of GEORG has therefore been formalized into a non-profit association and will be operated as such in the future. Nonprofits have generally distinctive organizational goals than businesses or governmental agencies, and often revolve around improving social well-being (Milne et al., 1996). GEORG currently operates through a sustainable business model (Stubbs and Cocklin, 2008; Bocken et al., 2013; Wells, 2013; Geissdoerfer et al., 2016), based on value creation through different aspects related to the geothermal sector. Sustainable business models have the benefit of higher risk mitigation and resilience (Choi and Wang, 2009) and yield the additional diversification and value co-creation opportunities (Nidumolu et al., 2009; Porter and Kramer, 2011; Tukker and Tischner, 2006; Geissdoerfer et al., 2018) (Figure 7) that GEORG aims for as a change agent in the sector. The collaborative outputs GEORG's activities and endeavors have generated over the years – overcoming the „outsider" status obstacle most non-profit organizations struggle with when building cooperation with other sectors – prove that GEORG is on steady steps to influence positively the geothermal sector dynamics at different levels.

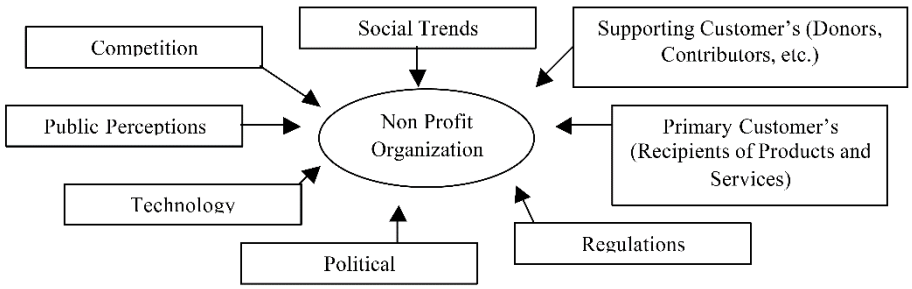

Figure 7: The Framework for Value Based Non-Profit Organizations (Matt H. Evans, Course).

The main focus will therefore continue following the structure in Figure 2, with an emphasis on grant application support at the European level, service for the cluster participants and promotion of the geothermal issues, especially on the European and international stage. Funding for the operations of the cluster for the next four years has been secured and further development of the cluster initiative is under way. GEORG's motto will remain service the society through bridging gaps in the geothermal sector and promoting its growth.

3.1. GEORG Outreach Initiatives

Public acceptance and stakeholder management are becoming increasingly important issues for successful geothermal development (Wallkist and Hollstein 2015). Geothermal energy triggers a wide range of responses among the public and in decision-making systems ranging from outright opposition to strongest possible support and acceptance (Siddiqi et al., 2016). Awareness and knowledge of the geothermal prospects of energy innovations, exploitations, research, challenges and benefits accrued from use of geothermal energy is still very limited to public domain (Okaka 2016).

With its ten years history of promoting geothermal energy research and industry efforts, and also participation in various geothermal projects, notably at the European level, GEORG realizes that geothermal energy's image as a "green" and economically feasible energy source is much weaker than for most other "alternative" energy sources, and therefore requires a thorough investment in building political and public acceptance to develop new geothermal projects.

Figure 8: Selection of #GeothermalFriday Posts with the Concept's Logo.

With this mindset, GEORG developed in 2018 a marketing strategy putting forward outreach initiatives to raise the profile of geothermal energy among a diverse set of audiences. In 2018, GEORG launched two geothermal communication concepts/initiatives; The first is "#GeothermalFriday" (Figure 8), a weekly series on social media to promote geothermal concepts, efforts and outputs, and the second is #LetsTalkGeothermal, a series of video interviews on YouTube with geothermal actors who are shaping the future of the geothermal energy.

These endeavors are carried out while staying abreast with geothermal energy development trends and diversified applications, increasing therefore interest in those and visibility to the limitless potential of this energy source and its place among renewable energy which will insure an efficient energy transition of our fossil-fuels energy-dependent world.

3.2. GEORG Geothermal Workshop (GGW)

Since 2016, GEORG sets a Rendez-vous to the community every two years to meet around a theme of interest. After the first GGW in 2016, revolving around the culmination of Startup Energy Reykjavik results and Research Projects outcomes supported by GEORG, GEORG organized the second edition GGW2018 themed "New Geothermal Generation" (Figure 10), which successfully took place in Reykjavik, in conjunction with a KMT high-level meeting and DEEPEGS executive meeting. The core theme of the GGW2018 was about sustainable food and geothermal, with fruitful discussion during the plenary session.

3. CONCLUSIONS

The geothermal cluster initiative GEORG has operated for the last 10 years bringing together different players in the geothermal field, both nationally and internationally. The members of the cluster have accomplished significant research goals and the cluster has been able to use the synergy of the projects for further research development. The innovation focus of GEORG has resulted in small equity stake fourteen startups which have promising future. The European connection is strong, reflected in participation in several European commission funded projects. From supporting research, to startups, to managing project offices, developing communication, marketing and business strategies, to conducting social studies, GEORG has proved to be a model for successful nonprofit organizations in the geothermal sector. Its open and neutral position and adopting a sustainable business model has shaped GEORG's values and ethics, making it a key agent of change in the community, creating opportunities and fostering consequently collaboration between multiple actors in the field, and ultimately generating impact by bridging the gap in the geothermal community for the benefit of the society.

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