GEORG

GEOthermal Research Group

Annual Report
RAN090326-1303

Centres of Excellence and Research Clusters
Strategic Research Programme

Year 5, 2013-2014
May 20th 2014

rannís

Geothermal Research Group

Grensásvegur 9,

108 Reykjavík

Iceland

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May 2014

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GEOTHERMAL RESEARCH GROUP

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GEORG is a research-driven Geothermal Cluster-cooperation aiming at joint effort in geothermal research and innovations.

GEORG is supported by the Science and Technology Policy Council in Iceland through their Centers of Excellence and Research Clusters - program.

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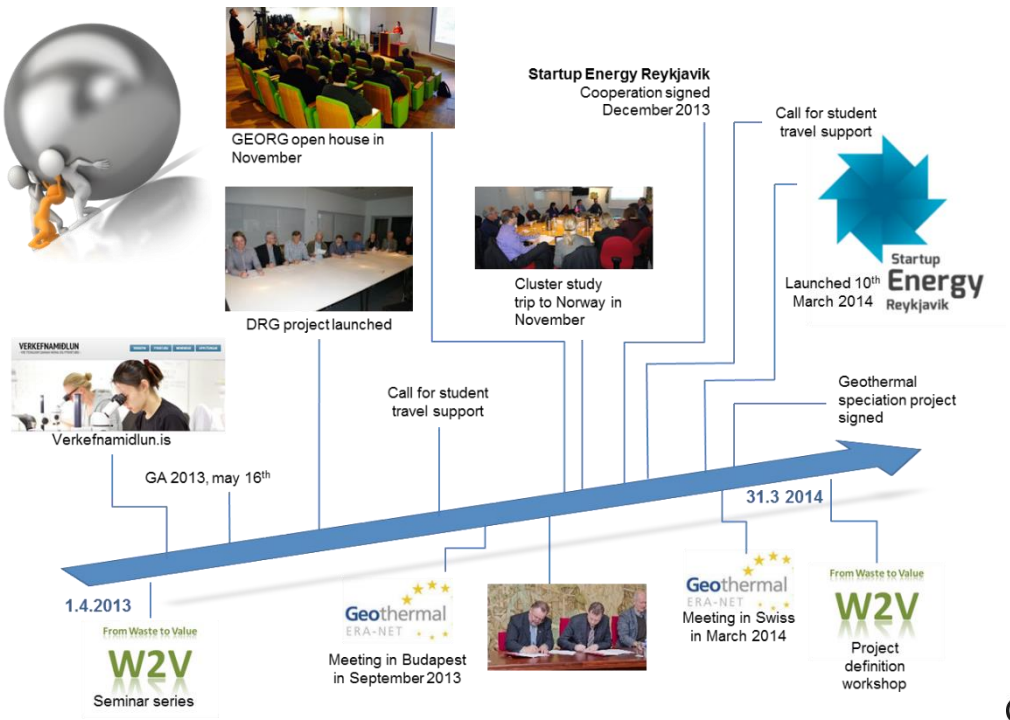
EXCECUTIVE SUMMARY

GEORG has now been operating for five successful years. During this time the cooperation has matured and developed further towards the ideology of cluster cooperation. Following are highlights of activities that took place during the operational year April 1st, 2013 till March 31, 2014:

- The **Fifth General Assembly** (GA) was held on May 16th, 2013.
- The **DRG project** was launched with the support of GEORG, HS Orka, Orkuveita Reykjavíkur, Landsvirkjun, Orkustofnun and the IDDP project. The DRG project is a collaborative project on the Deep Roots of Geothermal systems. The supporters will contribute nearly 100MISK directly to the project.
- GEORG, in cooperation with Arion banki, Landsvirkjun, Innovation Centre Iceland, Klak Innovit and Iceland Geothermal launched the innovation effort **Startup Energy Reykjavik** in January 2014. This is a mentorship-driven seed stage investment program with focus on energy related business ideas. Seven carefully selected teams got 5 MISK in seed funding, combined with mentorship and training from more than 60+ mentors and workspace at Reykjavik University.
- GEORG continued to **support students** during the year. Two calls were publishes and 17 grants were awarded in Y5.
- GEORG organized an **Open House, November 6nd 2013**, where five projects that are supported by GEORG were presented.
- GEORG took part in two **cluster study trips** last year, one to Lithuania in October, in connection the GeoDirect project, and another to Norway in November.
- The **Geothermal ERA NET** is well under way. The next steps are to analyse the research need of the countries and search for cooperation opportunities for joint activities in favour of geothermal energy in Europe.
- GEORG negotiated with the energy companies (LV, OR and HS) and Orkustofnun to continue supporting Jon Örn Bjarnason and Stefán Arnórsson work on the **rewriting of the WATCH program**.
- **Waste to Value, W2V** work continues and joint actions are in preparation.



GEORG GENERAL ASSEMBLY

GEORG 5th General Assembly (GA) took place at Orkugarður on May 16th, 2013. The GA agenda was traditional with a presentation of the 4th year annual report and discussions, as well as the presentation and approval of the annual accounts for year 4. The management and committees of the cluster cooperation was elected and other issues discussed, such as the entry of new partners

One new GEORG member was inauguration at the 2013 GA. This was the Uppsala University in Sweden. The geophysics section at the dept. of Earth Sciences, Uppsala University (UU), has been involved in many projects in Iceland in the last 20 years. The projects have ranged from structural studies based on local seismicity, seismicity studies, earthquake induced stress fields, reflection seismic to electromagnetic studies. Some of these have been of direct relevance for geothermal research, though some have had other objectives. UU is involved in several projects of direct relevance for geothermal research in cooperation with other research institutes on Iceland and the US.

The following ***Board of Directors (BoD)*** was elected at the GA:

Sigurður Magnús Garðarsson
Chairman
University of Iceland

Magnús Tumi Guðmundsson
University of Iceland

Auður Andrésdóttir
Mannvit

Guðmundur Ómar Friðleifsson
HS Orka

Ernst Huenges
GFZ, Potsdam, Germany

Einar Jón Ásbjörnsson
Reykjavík University

Rúnar Unnþórsson
University of Iceland

Steinunn Hauksdóttir
ISOR

Further information on the management of GEORG can be found at the GEORG website.

STARTUP ENERGY REYKJAVIK

The two Icelandic geothermal cluster cooperation's GEORG and Iceland Geothermal (IG) in cooperation with Arion banki, Landsvirkjun, Innovation Centre Iceland, and Klak Innovit signed an agreement on innovation effort focusing on energy and technology. The project is based on the well-known methodology of business accelerators which have turned out to be quite successful in creating increased values and stimulate innovation and growth.

The effort is based on the experience from Startup Reykjavik (www.startupreykjavik.com) and is called Startup Energy Reykjavik or SER. Arion banki, Landsvirkjun, GEORG and Innovation Centre Iceland will allocate up to 60MISK in total to the effort, of which more than half will be devoted direct to investment in the selected projects and business ideas. Arion banki and Landsvirkjun will allocate 20MISK each and GEORG and Innovation Centre Iceland 10MISK each. Klak Innovit and Iceland Geothermal will facilitate the effort and the funding partners will take active part in providing mentors and making sure that the projects get the full support they need.

Startup Energy Reykjavik is a mentorship-driven seed stage investment program with focus on energy related business ideas. Startup Energy Reykjavik founders also get a great place to work at Reykjavik University, ten weeks of intensive top-notch mentorship, and the chance to pitch to angel investors and venture capitalists at the end of the program.

There is immeasurable value in the mentorship-driven connections and advice that the teams receive when starting their company with Startup Energy Reykjavik. The opportunity to pitch to angel investors and venture capitalists at the end of the program is provided during the Investor and Demo Day.

The Startup Energy Reykjavik formally started with an introduction meeting at Arion banki headquarters on January 16th 2014. At that event the call for application were published and the application deadline was February 16th.

More than 70 applications were submitted of which 25 were invited for a special presentation before the final selection of 7 ideas.

The 7 carefully selected teams got 5 MISK in seed funding, combined with mentorship and training from more than 60+ mentors and workspace at Reykjavik University. In return for program participation, each team gave 10% of their equity.

The selected teams are:

- **The HTPM Gerosion Center**
  - HTPM GEROSION Center will provide consultation, material testing & specialized R&D work for entities in the geothermal/petroleum industries.
- **BMJ Energy**
  - We offer total solutions for hydro with focus on micro scale. Designed and built from scratch by BMJ both generator sets and control units.
- **Sodium Chorate Plant**
  - Small scale Sodium Chlorate production for export and more efficient use of energy.
- **Landsvarmi**
  - Organization that finances, sets up and operates heat pumps for central heating of houses.
- **BigEddie**
  - A novel approach to wind resource assessment using a combination of observations, Large Eddie Simulations (LES) and CFD modeling techniques.
- **PEA Aluminum**
  - Portable Element Analyzer for real-time data in potrooms
- **GeoDrone**
  - GeoDrone is providing services for the geothermal industry. We combine modern technology in UAV with advanced remote sensing (e.g. LIDAR).

GEORG OPEN HOUSE 2013

GEORG open house was held for the third time at National Museum of Iceland on the 6th of November 2013 with great success. About 50 persons attended the event and enjoyed an introduction to GEORG operation and plans, presentation of five GEORG supported projects and an interesting poster session.

The following projects were introduced at the event:

The GSAP project, Geothermal Sustainability Assessment Protocol, introduced by Brynhildur Davíðsdóttir;

The HYDORIFT project, introduced by Sigríður Kristjánsdóttir;

GEISER project, Geothermal Engineering Integrating Mitigation of Induced Seismicity in Reservoirs, introduced by Kristján Ágústsson;

H_2S sequestration into geothermal systems, introduced by Andri Stefánsson and

Green Geothermal Growth, introduced by Atli Arnarsson

The slides and videos from the event can be found at the GEORG website

DEEP ROOTS OF GEOTHERMAL (DRG) PROJECT IN GOOD PROGRESS

The science community, energy companies and Orkustofnun agreed last summer to devote about ISK 100 million to research on the interaction of water and magma in volcanic roots. To learn how this interaction occurs and how heat is transferred from the magma into the geothermal systems is key to acquiring a deeper understanding of the rational utilization of geothermal energy.

The cooperative project, titled "DEEP ROOTS OF GEOTHERMAL SYSTEMS" (DRG), is managed within the cluster cooperation of GEORG and is financially supported by GEORG, Orkustofnun, Reykjavik Energy, HS Orka, Landsvirkjun and the Iceland Deep Drilling Project (IDDP).

The aim of the project is to understand the relationship of water and magma in the roots of volcanoes and how heat is transferred into geothermal systems to maintain their energy. Furthermore, the design of wells and well heads for high temperatures will be a focus of the project, as will methods for utilizing superheated steam from greater depths.

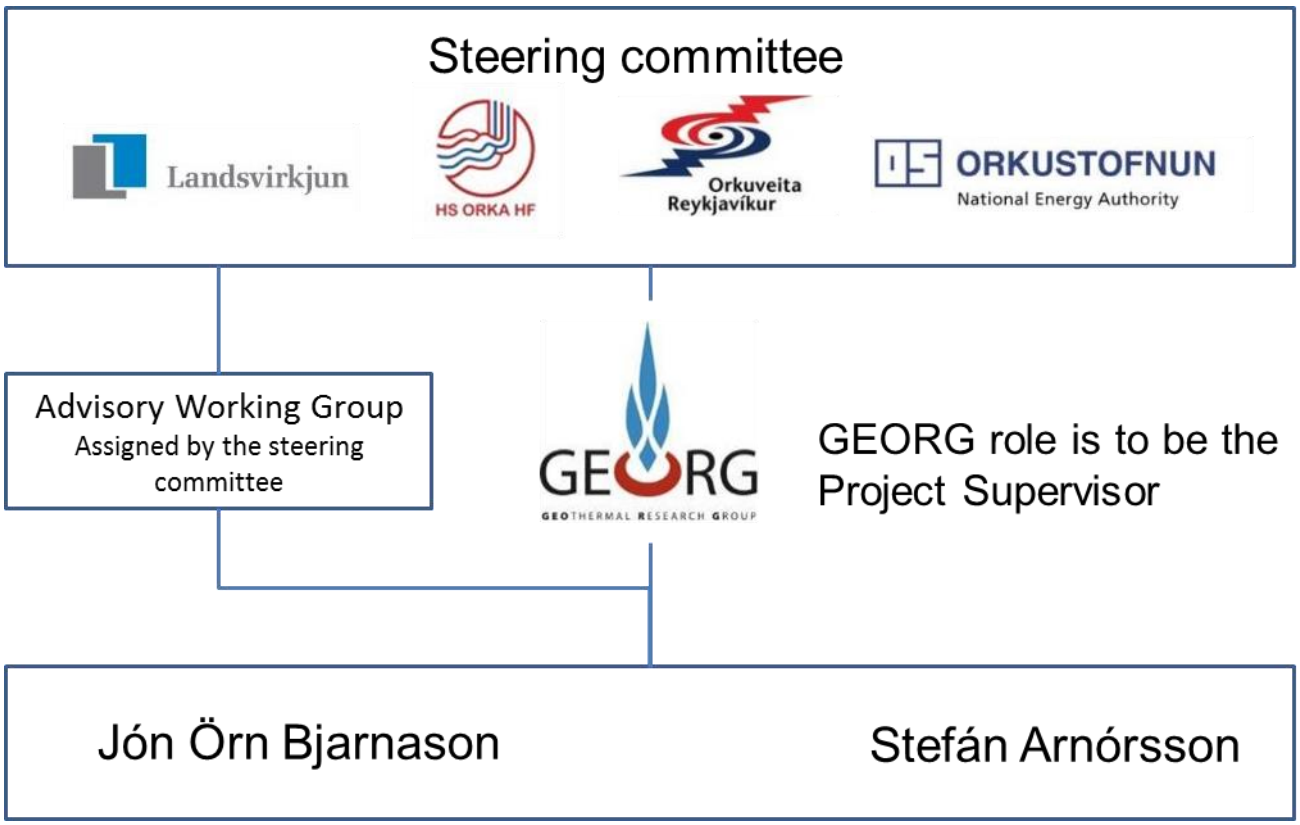
The research will be performed by three groups made up of representatives from universities, research institutes, engineering companies and energy companies. The latest technology will be applied in surveying, resistance measurements and seismic measurements, petrology and geochemistry. In addition, new simulation models will be developed. These models will be used to simulate heat transfer and operation of geothermal boreholes for high temperature steam. Training young scientists to work in this field will be an area of heavy focus for this project.

One of the key aspects of the DRG project is to foster and encourage cooperation with other international project in the same field such as the Swiss/IPGT-COTHERM project and EU-IMAGE project. As a starting point of that work GEORG organized a workshop on September 10th 2013, with the aim of introducing the DRG, COTHERM and IMAGE projects and stimulate discussions on synergy and cooperation between these projects. The first half of the workshop was devoted to introductions on the respective projects while two hours at the end of the workshop were devoted to a group discussion (see presentations and discussion points at the GEORG DGR website).

GEOCHEMICAL SPECIATION AND REACTION PROGRESS SOFTWARE FOR GEOTHERMAL APPLICATIONS

Together with Stefán Arnórsson and Jón Örn Bjarnason, GEORG negotiated with the energy companies (LV, OR and HS) and Orkustofnun to continue supporting Jón Örn and Stefán work on the rewriting of the WATCH program. The project has 4 major milestones due every six months, and a support agreement for the first milestone was signed in February 28th 2014 (see Annex I).

GEORG is responsible for the supervision of the project. This includes arranging all contracts and agreements related to the project as well as receiving funds from the Sponsors and transferring these to ISOR – Iceland GeoSurvey in accordance with grant agreements and project progress. GEORG also keeps the Steering Committee informed about the status of the project and follows up on the Steering Committee's decisions. GEORG assists in organizing meetings as needed in cooperation with Jón Örn Bjarnason, Stefán Arnórsson, the Advisory Working Group and the Steering Committee.



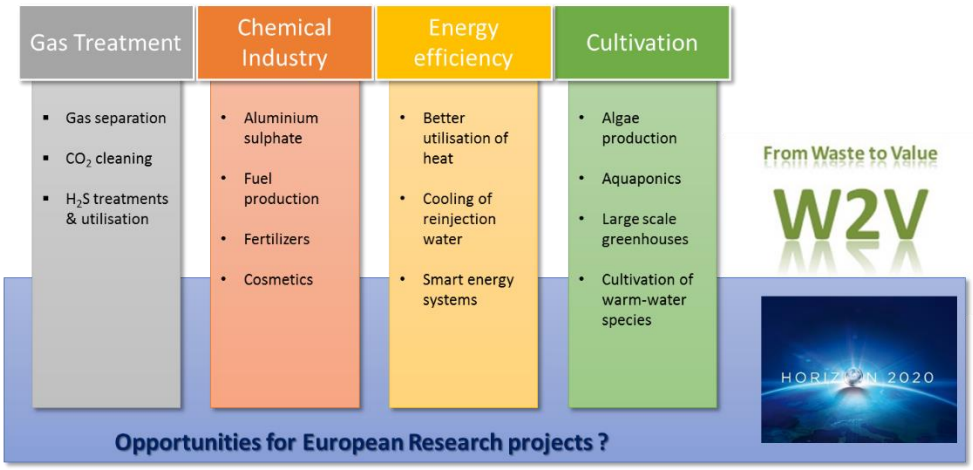
FROM WASTE TO VALUE

Last spring GEORG organized a seminar series of five seminars under the headline: "From Waste to Value, Treatment and utilization of discharge from Geothermal Power Plant. How can GEORG help?"

The idea of this seminar series is to start the communication within the partnership of GEORG to form a research project on this topic, somewhat in the same spirit as the DRG project.

As a follow up of this work GEORG organized a workshop this spring where the status of treatment and utilization of discharge from geothermal Power Plants were discussed further and possible opportunities of cooperation on research projects within GEORG explored. GEORG is willing to lubricate cooperation in this field with up to 20 MISK, given that sufficient co-funding is provided and the projects are scientifically and/or technically viable. Slides from the workshops can be found at GEORG W2V website

Following the introductory talks the workshop was divided into groups according to the scheme below, where the aim is to define possible cooperation projects.



Thirteen ideas were listed at this brainstorming session and after the prioritization of the preparation committee, where some project ideas were merged, five project ideas remain and will be explored further. The project ideas are listed below and further description (in Icelandic) is in Annex II

Methane gas production from geothermal gases
Mapping of opportunities in utilizing geothermal energy and chemicals in chemical industry
Continues monitoring of chemical properties of geothermal waste gas from geothermal power plants
Utilization of geothermal heat in aquaponics
Capturing and utilizing of silica from geothermal power plants streams.

STUDENT TRAVEL GRANTS

GEORG had two calls for travel grants for graduate students, working on the topics of geothermal energy, to participate in International Conferences on Geothermal. The support was up to 100.000 ISK for each student as a contribution to travel cost. The first application deadline was on August 19th 2013, and the second one was on January 31st 2014. 17 grants were awarded and the students can claim it upon return of travelling documents (airline ticket/boarding pass or similar).

Grants awarded August 2013

Name	Degree	University, faculty/department/Institute	Supervisor	Conference attended
Thecla Munanie Mutia	Doctoral	University of Iceland	1. Ingibjörg Svala Jónsdóttir (University of Iceland) 2. Þráinn Friðriksson (Iceland Geosurvey)	The Geothermal Resource Council 37th Annual meeting and US Geothermal Energy Association Geothermal Energy Expo 2013 in Las Vegas Nevada, USA
Santosh Narshima Prathap Moola	Doctoral	University of Iceland, Department of Earth sciences	Bergur Sigfusson and Andri Stefansson	Goldschmidt workshops (Thermodynamics of Geothermal Fluids) that is held from 23-31 August 2013 in Florence, Italy
Reynir Smári Atlason	Doctoral	University of Iceland / Dept. of Engineering and natural sciences	Rúnar Unnþórsson, Ph.D	ASME Power 2013 conference, to be held in Boston between the 29th of July and 1st of August.
Manuel Plasencia Gutierrez	Doctoral	University of Iceland, Faculty of Science	Hannes Jónsson	The German Geothermal Energy Congress 2013, taking place in Essen, Germany this November
Jan Přikryl	doctoral	University of Iceland/School of Engineering and Natural Sciences /Faculty of Earth Sciences /Institute of Earth Sciences	Andri Stefánsson	Goldschmidt Conference on 25-30.8.13 in Florence, Italy,
María Sigríður Guðjónsdóttir	doctoral	University of Iceland School of Engineering and Natural Science Reykjavik University School og Science and Engineering	Dr. Guðrún Sævarsdóttir, gudrunsa@ru.is	*The 5th European Geothermal PhD day 2014*
Sigríður Kristjánsdóttir	Doctoral (starting fall 2013)	Uppsala University, Departement of Earth Sciences	Ólafur Guðmundsson, Ari Tryggvason and Kristján Ágústsson	Stanford Geothermal Workshop, February 24-26, 2014

Grants awarded January 2014

Name	Degree	University, faculty/department/Institute	Supervisor	Conference attended
STEPHEN ODHIAMBO ONYANGO	Doctoral	UNIVERSITY OF ICELAND, SCHOOL OF ENGINEERING AND NATURAL SCIENCES	Professor Magnus Thor Johnson. University of Iceland	*World Geothermal Congress to be held in Australia in April 2015.*
Esteban José Rodríguez Pineda	Master	University of Reykjavík, School of Science and Engineering, Iceland School of Energy	Einar Jón Ásbjörnsson and William Scott Harvey (Professors at Reykjavík University)	*Stanford Geothermal Conference 2014*
Ruth Mary Shortall	doctoral	University of Iceland / Faculty of Engineering & Natural Science / Department of Life and Environmental Science	Brynhildur Davidsdottir	*The European Geosciences Union (EGU) General Assembly 2014 – Energy, Resources and Environment Group and The International Association for Energy Economics (IAEE)*
Sandra Ósk Snæbjörnsdóttir	doctoral	University of Iceland, Faculty of Earth Science/Geochemistry/Institute of Earth Science	Sigurður Reynir Gíslason, Eric Oelkers	*GHGT-12, International conference on Greenhouse Gas Technologies*
Thecla Munanie Mutia	Doctoral	University of Iceland	1. Ingibjörg Svala Jónsdóttir (University of Iceland) 2. Þráinn Friðriksson (Iceland Geosurvey)	*5th European Geothermal PhD Day*
Manuel Plasencia Gutierrez	Doctoral	University of Iceland, Faculty of Science	Hannes Jónsson	*The 5th European Geothermal PhD day 2014*
María Sigríður Guðjónsdóttir	doctoral	University of Iceland School of Engineering and Natural Science Reykjavik University School og Science and Engineering	Dr. Guðrún Sævarsdóttir, gudrunsa@ru.is	*2015 World Geothermal Congress"*
Gaetan SAKINDI	Master	University of Iceland, Earth Sciences/Geophysics	Gylfi Páll Hersir& Knútur Árnason	*World Geothermal Congress 2015.*
Massimiliano CIACCI	Doctoral	Università degli Studi di Bari, dipartimento di Scienze della Terra e Geoambientali, Italy	Prof. Domenico Liotta	*European Geothermal PhD day 2014.*
Andrew Peter George Fowler	doctoral	Department of Earth and Planetary Sciences/ University of California, Davis.	Robert Zierenberg, Professor of Geology, University of California, Davis Additional Reference: Guðmundur Ómar Friðleifsson, HS Orka hf.	*World Geothermal Congress (WGC)*

COURSE ON INVERSE MODELING AND OPTIMIZATION

GEORG will hold a course in inverse modelling and optimization in June 2014. The course is organized by Magnús Þór Jónsson in cooperation with Stefan Finsterle and Yingqi Zhang (LBNL) which will be instructors at the course. Following an application from GEORG, IGA (International Geothermal Association) supports the course with a grant amounting to USD 5.000.

The proposed course is connected to the supported project "Evaluation and Improvements of Geothermal Models using Inverse Analysis", coordinated by Magnús Þór Jónsson. The main objective of that project is to develop improved models by using inverse analysis as a basis for providing tools for designers and decision makers in the fields of optimal geothermal power production.

The purpose of the course is to share the findings of this project to both geothermal graduate students as well as scientists working on modelling and exploration of geothermal fields. The course will introducing the fundamentals of inverse modelling of geothermal systems as well as train the attendees in how to utilize the improved models.

CLUSTER NETWORKING/STUDY-TRIPS AUTUMN 2013

GEODIRECT – CONNECTION TO LITHUANIA

Iceland Geothermal took part in the call BSR Innovation Express last spring, which is a part of a call named "BSR Stars" a cooperation carried out in collaboration with the Nordic Council of Ministers. Iceland Geothermal applied in cooperation with Klaipedia Science in Lithuania on a project called GeoDirect and was granted a support through Iceland Innovation Center. The goal of this project is to stimulate and encourage new business opportunities in new markets and build new business relationships.

The GeoDirect project is twofold, on the one hand, to support a study trip of Icelandic Geothermal delegation to Klaipeda in Lithuania in October 2013 and on the other hand to receive a Lithuanian delegation in Iceland in April 2014.

GEORG among other partners of the Iceland Geothermal cluster cooperation went to Klaipeda last October to examine, first hand, the geothermal utilization potential and research capabilities in Lithuanian. Among companies visited was **Geotrema** heat plant**,** the oil drilling company **JSC Lotos Geonafta,** the **University of Klaipeda** and **Klaipeda Free Economic Zone**.

Hjalti Pall Ingólfsson, on behalf of GEORG, signed a memorandum of understanding on research collaboration with the University of Klaipeda on possible cooperation in research on health science and balneology. The MoU can be found on the GEORGs website.

CLUSTER-TRIP TO NORWAY

Hjalti Páll Ingólfsson, on behalf of GEORG, was invited to take part in a helpful and interesting cluster study trip to Norway 18th -20th of November 2013. The trip was organized by Rannis as a part of the CDCM (Capacity Development for Cluster Managers Project), supported by the EU Competitiveness and Innovation Framework Programme (CIP). In addition to GEORG cluster managers of 7 other clusters in Iceland where invited and experts from the Innovation Centre Iceland and the University of Iceland.

The objective of the Norway tour was to learn from the experience of Norway in terms of cluster support and policy as well as hearing from few cluster managers which have shown excellent success in cluster management. It's obvious that Norway has developed a very comprehensive public cluster support schema which fits a broad range of clusters cooperation platforms both in regards to size and maturity. The Norwegian

support is both in terms of capital lubrication and consulting which is essential in the early steps of cluster cooperation development.

It was also interesting to hear from cluster managers themselves and it will be interesting to continue such cluster to cluster cooperation and knowledge sharing.

For further information on Norwegian cluster programs please visit the arena website.

WGC2020 Iceland Application

GEORG supported, both professionally and financially the Iceland Application preparation for holding the World Geothermal Congress 2020 in Iceland. The application is carried and supported by all members of the Iceland Geothermal Cluster Initiative and the associations of SAMORKA, GEORG the reasearch cluster and the Geothermal Associaion of Iceland.

Bjarni Pálsson and Rósbjörg Jónsdóttir presented the application in Manila in March 21st at IGA's 59th Board meeting. The competition is hard as the bidding countries include Chile, Iceland, Kenya, The Netherlands & Germany, Philippines and the USA. In the coming weeks the IGA WGC2020 Selection Committee will further evaluate the bids. Subsequently, the 30 members of the IGA Board will vote on the best candidate to host the WGC2020. Results are expected June or July 2014.

DISSEMINATION

GEORG maintains an overview of all dissemination and publication outputs as a part of the objectives managed under WP8 Dissemination and outreach. The objectives are the following:

• To make available to a wider audience information about the work and the outcome of the GEORG project with the aim of enhancing the uptake of its results.

• To strengthen the networking relationships between R&D Centres, Energy Authorities, Energy Companies, Geothermal Industry SMEs, NGOs and other stakeholders in the sustainable geothermal resources utilisation.

• To promote and encourage the uptake and use of the results by policy makers, energy and environmental managers in Europe, and prepare the basis for maximum impacts of the results.

A list of publications from the projects as reported by the project coordinators in April 2014 can be found in Annex III.

In addition GEORG members have also disseminated results in seminars organized by the cluster. The seminars include:

- Open Conferences at GEORG General Assemblies 2009 and 2010
- Support for PhD students to present results at European PhD days 2010 (Germany), 2011 (Iceland), 2012 (Italy), 2013 (Hungary) and 2014 (Germany)
- Roots of Geothermal Systems: 6 seminars in Year 3
- Series of five seminars under the headline: "From Waste to Value, W2V"
- Deep Root seminar at Hotel Hengill, August 27th, 2011
- GEORG Open House, Oct. 20th, 2011, Nov. 22nd, 2012 and Nov. 6th 2013.
- Four seminars on the four main Icelandic geothermal areas: Hengill, Krýsuvík, Krafla, and Reykjanes
- From Steam to Currency: Six seminars from February to May 2011, on the theme of generating value from the geothermal resource, other than for district heating and electrical power generation.
- Project defining workshop W2V in April 2014

GEORG web address is www.georg.hi.is. All relevant information on the cluster is gathered at this website as well as all application documents and evaluation guidelines for the call of GEORG. The website is maintained and updated by the Operational Manager.

GEORG is also active on Facebook. The site can be found at http://www.facebook.com/pages/GEORG-GEOthermal-Research-Group/203518776344624 or simply by looking up GEORG – GEOthermal Research Group.

PROJECT SHARING WEBSITE

GEORG and Iceland Geothermal have signed a contract with the Iceland Ocean Cluster cooperating on a project sharing website, called Verkefnamiðlun.

Verkefnamiðlun is a platform for project sharing which was initiated by the Iceland Ocean Cluster and members of the Ocean Cluster education group. The aim of Verkefnamiðlun is to enhance the connection between students and companies. Initially, the focus was on connections between students and companies in ocean related fields but due to high demand there are now projects from all sectors of the economy. Over 60 projects have been registered on the site, dozen of which are already active with students working together with companies.

If you as a company have any projects that you need working on, do not hesitate to contact us. We encourage students as well, to be in touch and register for possible projects. **Visit www.verkefnamidlun.is for more information.**

GEOTHERMAL ERA NET NEWS

GEORG initiated the Geothermal ERA NET, together with Orkustofnun, in May 2012. The project is supported by the EU Seventh Framework and the participants of the project, together with Orkustofnun, are Rannís and administrative bodies of eight other European countries, namely from the Netherlands, France, Switzerland, Germany, Italy, Hungary, Turkey and Slovakia.

The collaboration has been very successful and already analyses on the research programs of the participating countries have been done and a considerable work has been put into preparation work for synchronisation of geothermal information in Europe, through geothermal information platform. Already four meetings have been held and two special workshops on the preparation work for European Geothermal Information Platform. The next steps are to analyse the research need of the countries and search for cooperation opportunities for joint activities in favour of geothermal energy in Europe. The latest ERA NET newsletter is annexed to the report in Annex IV

EU HORIZON 2020 WORK PROGRAMME

Hjalti Páll Ingólfsson, GEORG operational manager, participates in the energy committee of Horizon 2020 where the Secure, clean and efficient energy WP is prepared. This program is planned for two year 2014 and 2015 and there are quite a few topics there that are directly or indirectly related to geothermal energy.

The preperation for WP2016-2017 is now starting and GEORG in cooperation with Rannis will follow that development closely and report to stakeholders as frequent as possible

5TH EUROPEAN PHD DAY

The European Geothermal PhD Day (EGPD) is a student organized conference for PhD students working in all fields of science related to geothermal research (geosciences, engineering, chemistry, business, law, etc.). Attendees will have the opportunity to present their research projects both with an oral and a poster presentation, to receive feedback and to engage an open debate with peer doctoral students. The conference offers a great platform for international networking to aspiring academic researchers.

The 5th EGPD conference was hosted by the Chair of Geothermal Science and Technology of the Technical University of Darmstadt in cooperation with the Young Geothermal Chapter (Junge Geothermie) of the German Geothermal Association.

When : 31st March Icebreaker Party **Where:** Institute of Applied Geosciences
1st April EGPD Conference Schnittspahnstraße 9 2nd April Field Trip 64287 Darmstadt, Germany

Visit http://www.egpd.tu-darmstadt.de/ for more information.

ANNUAL ACCOUNTS

In April 2012 the association of GEORG was established and this is its second year of operation. On the bases of a service agreement between UNI, on behalf of the GEORG Project, and GEORG the new association handled all the operational cost of the GEORG office except for the cost of staff. Therefore there are two accounts presented in the annual report, the accounts of the GEORG Project and accounts for the GEORG Association. In both cases the operating year is April 1st, 2013 –March 31th, 2014. All amounts are in thousand ISK. The accounts were approved by Sveinbjörn Sveinbjörnsson at Íslenskir Endurskoðendur slf.

ANNUAL ACCOUNTS-GEORG PROJECT

GEORG Project- Cost and financing account

		Year 5		
Cost	**Note**	**GEORG**	**Partners**	**Total**
Grants	1	68.638	308.299	376.937
Contracted services	2	171		171
Travel expenses		130		130
Conferences, dissem. & outreach	3	0	0	0
Overhead total	4	11.096	2.000	13.096
Total operation cost		**80.035**	**310.299**	**390.335**
Financing				
Partner Co-financing		0	310.299	310.299
Funding from Rannis	5	126.000		126.000
Total financing		**126.000**	**310.299**	**436.299**
Results of operational activities		**45.965**	**0**	**45.965**
Transferred between years				
Unpaid funding from Rannís		14.000		
Acquired funding from last year		-70.000		
Other receivables		0		
Allocated but unpaid grants to R&D projects		-117.610		
Allocated grants to R&D projects last year		89.185		
Other short term liabilities from last year		0		
Final results of the year		**-38.460**	**0**	**-38.460**

GEORG Project - Balance sheet

Assets	Note	Year 5 31. March 2014
Cash and cash equivalents	6	85.909
Unpaid funding from Rannís	5	14.000
Other receivables	7	0
Total assets		**99.909**
Debts and liabilities		
Unpaid grants for projects	8	117.610
Other short term liabilities	1	0
Total debts and liabilities		**117.610**
Balance at beginning of period		20.792
Final results of the year		-38.493
Total assets		**-17.701**

ANNUAL ACCOUNTS GEORG PROJECT- NOTES

1. Grants

GEORG has supported over 20 research projects as well as supporting students and other activites. The partners co-financing is estimated according to the projects status.

	Year 4 April 2012- April 2013			Year 5 April 2013- April 2014		
Grants	**GEORG**	**Partners**	**Total**	**GEORG**	**Partners**	**Total**
RTD Projects first call						
09-01-003	*0*	*0*	*0*	*4.080*	*2.895*	*6.975*
09-01-005	*0*	*0*	*0*	*0*	*0*	*0*
09-01-007	*0*	*0*	*0*	*6.900*	*36.900*	*43.800*
09-01-011	*0*	*0*	*0*	*3.600*	*24.826*	*28.426*
09-01-012	*4.000*	*9.425*	*13.425*	*0*	*0*	*0*
09-01-013	*0*	*0*	*0*	*0*	*0*	*0*
09-01-016	*0*	*0*	*0*	*2.475*	*3.038*	*5.513*
09-01-017	*0*	*0*	*0*	*0*	*0*	*0*
09-01-028	*5.420*	*11.561*	*16.981*	*0*	*0*	*0*
09-01-029	*0*	*0*	*0*	*0*	*0*	*0*
				0	*0*	
RTD Projects second call						*0*
09-02-001	*8.000*	*21.780*	*29.780*	*0*	*0*	*0*
09-02-003	*0*	*0*	*0*	*12.500*	*193.020*	*205.520*
09-01-005	*1.125*	*8.338*	*9.463*	*0*	*0*	*0*
09-02-010	*0*	*0*	*0*	*520*	*1.969*	*2.489*
09-02-017	*1.000*	*1.432*	*2.432*	*1.005*	*1.439*	*2.444*
09-02-017	*1.000*	*0*	*1.000*	*0*	*0*	*0*
				0	*0*	
RTD Projects third call						*0*
10-03-004	*3.000*	*4.748*	*7.748*	*7.300*	*31.299*	*38.599*
10-03-005	*0*	*0*	*0*	*3.350*	*3.482*	*6.832*
10-03-012	*3.000*	*3.118*	*6.118*	*2.600*	*2.604*	*5.204*
10-03-013	*2.500*	*2.504*	*5.004*	*0*	*0*	*0*
				0	*0*	
RTD Projects fourth call						*0*
11-04-002	*1.500*	*1.826*	*3.326*	*0*	*0*	*0*
11-04-003	*2.000*	*2.330*	*4.330*	*0*	*6.827*	*6.827*
11-04-005	*2.725*	*3.038*	*5.763*	*6.125*	*0*	*6.125*
PhD day travel grants	*480*	*0*	*0* *0*	*960*	*0*	*960*
BEST Reykjavik		*250*		*0*		*0*
Startup Energy Reykjavik				*4.167*		*4.167*
WGC2020				*2.000*		*2.000*
DRG				*11.056*		*11.056*
Grants Total	**35.520**	**70.099**	**105.369**	**68.638**	**308.299**	**363.881**

2. Contracted services

Contracted services	Year 4 April 2012- April 2013 GEORG	Partners	Total	Year 5 April 2013- April 2014 GEORG	Partners	Total
Printing & publishing etc.						
Advertisements	*0*		*0*	*0*		*0*
Website	*80*		*80*	*80*		*80*
Legal & audits	*0*		*0*			*0*
Account audit	*212*		*212*	*171*		*171*
Subcontracted other	*0*					
MarkMar-consult.	*0*	*0*	*0*	*171*		*171*
Contracted services Total	**292**	**0**	**428**	**171**	**0**	**171**

3. Other costs

All activites on conferneces and dissemination has been moved over to the assosiation of GEORG.

Conferences, dissem. & outreach	Year 4 April 2012- April 2013 GEORG	Partners	Total	Year 5 April 2013- April 2014 GEORG	Partners	Total
GEORG - Open Conferences	*0*		*0*	*0*		*0*
Conference participation	*105*			*0*		
Workshops	*0*	*2.000*	*2.105*	*0*	*0*	*0*
DRG	*0*	*4.020*	*4.020*	*0*	*0*	*0*
Dissimination Total	**105**	**6.020**	**6.125**	**0**	**0**	**0**

4. Overhead

The largest part of GEORG overhead goes into operating the office and paying the salaries of the Operational Manager. A large part is also involved in the participation of partners in committees as BoD, SA and other. The cost of these participations is paid by the partners themselves and is accounted as partner co-financing.

Overhead for GEORG	Year 4 April 2012- April 2013 GEORG	Partners	Total	Year 5 April 2013- April 2014 GEORG	Partners	Total
Operational Manager & secretariat	*7.987*		*7.987*	*9.024*		*9.024*
Office operation	*2.418*		*2.418*	*73*		*73*
Other general operational costs	*0*	*3.900*	*3.900*	*0*	*2.000*	*2.000*
Travel expenses				*2.000*		*2.000*
	10.405	**3.900**	**14.305**	**11.226**	**2.000**	**13.226**

5. Funding from Rannís

Due to how long it took to finalize the mid term evaluation GEORG had no contract with Rannís for larger part of that operating year and the payment of the grants for Y4 was delayed the payment was received in June and July 2013. The grant for the fifth year is divided in three payments, one by singing of the contract (28MISK), the second one (28MISK) by the submission of progress report in December and the last one (14MISK) at the delivery and acceptance of this annual report, see table below.

Payments upon:	*Date*	*Amounts in ISK thousand*
Signature of the contract		28.000
By submission of progress report	Des 2013	28.000
An Annual report	June 2013	14.000
Total amount for the 5th year		70.000

6. Cash and cash equivalents

On the 31st of March 2014 the status of GEORG accounts was **82.409 thousand ISK**.

7. Other receivables

GEORG Project had no outstanding claim at the end of Y5.

8. Unpaid grants to R&D projects

ID #	Allocated grants 31.3.2013	Committed grants 31.3.2013	Unpaid grants 31.3.2013
09-01-003	6.660	6.660	0
09-01-005	5.400	13.400	8.000
09-01-007	11.400	11.400	0
09-01-011	4.600	4.600	0
09-01-012	16.000	21.800	5.800
09-01-013	7.452	7.452	0
09-01-016	7.425	7.425	0
09-01-016-2	2.475	18.825	16.350
09-01-017	2.500	2.500	0
09-01-028	15.410	16.910	1.500
09-01-029	1.000	1.350	350
	80.322	**112.322**	**32.000**

ID #	Allocated grants 31.3.2013	Committed grants 31.3.2013	Unpaid grants 31.3.2013
09-02-001	19.500	19.500	0
09-02-003	20.000	30.000	10.000
09-02-005	4.500	4.500	0
09-02-010	3.020	3.020	0
09-02-017	5.535	8.540	3.005
	52.555	**65.560**	**13.005**

ID #	Allocated grants 31.3.2013	Committed grants 31.3.2013	Unpaid grants 31.3.2013
10-03-004	9.000	9.000	0
10-03-005	10.200	15.300	5.100
10-03-012	12.150	18.500	6.350
10-03-013	8.309	10.309	2.000
	39.659	**53.109**	**13.450**

ID #	Allocated grants 31.3.2013	Committed grants 31.3.2013	Unpaid grants 31.3.2013
11-04-002	1.500	18.450	16.950
11-04-003	2.000	9.680	7.680
11-04-005	8.850	17.875	9.025
	12.350	**46.005**	**33.655**

ID #	Allocated grants 31.3.2013	Committed grants 31.3.2013	Unpaid grants 31.3.2013
13-05-xxx	11.056	33.056	22.000
	11.056	**330.56**	**22.000**
Total	**195.942**	**310.052**	**114.110**

ANNUAL ACCOUNTS-GEORG ASSOCIATION

REPORT OF THE BOARD OF DIRECTORS AND THE CEO

GEORG-Rannsóknarklasi í jarðhita was founded in the year 2012 as an International Geothermal Cluster Cooperation. GEORG is a non-for-profit organisation with the purpose of bringing together players in the geothermal field and creating a strong force for rapid progress and added value in geothermal research, engineering and design. GEORG achieves its purpose by: 1) Supporting and promoting projects among the Cluster members, in the field of geothermal research and development. 2) Service its members by organizing workshops and seminars addressing the most urgent issues and challenges of each time. The members will also maintain a strong contact network among the members. 3.) Systematically promote geothermal energy and geothermal research, both domestically and abroad. The fiscal year is from 1st April to 31st March.

These financial statements are compiled in accordance with Icelandinc laws and regulations regarding preparing and presenting financial statements and in accordance with other applicable laws and regulations.

Total Revenues for the fiscal year March 31, 2013 - April 1, 2014 amounted to ISK 21.325.865 and deferred revenues amounted to ISK 19.608.767. Total revenues over expenditures for the financial year were none. Assets total were ISK 23.775.443 at financial year end.

We, the board of directors and CEO, of GEORG-Rannsóknarklasi í jarðhita hereby confirm that we are responsible for the preparation and presentation of these financial statements and we hereby ratify these financial statements for the financial year of 1.4.2013-1.3.2014 with our signatures.

Reykjavík, May 14, 2014

AUDITOR'S COMPILATION REPORT

To the board of directors of GEORG-Rannsóknarklasi í jarðhita.

We have compiled, on the basis of the information provided by management, in accordance with the International Standard ISRS 4410, these financial statements of GEORG-Rannsóknarklasi í jarðhita as of March 31, 2014 and statement of income and cash flows for the year then ended.

We have not performed an audited or reviewed these financial statements and accordingly we express no assurance thereon.

Reykjavík, May 14, 2014

Sveinbjörn Sveinbjörnsson
löggiltur endurskoðandi

Íslenskir endurskoðendur Bíldshöfða slf
Bíldshöfða 14, 110 Reykjavík

STATEMENT OF ACTIVITIES 1.4.2013-31.3.2014

	Note	1.4.2013-31.3.2014	1.4.2012 31.3.2013
Revenues			
Operational grants		21.325.865	1.981.443
		21.325.865	1.981.443
Expenses			
Grants awarded		19.957.375	670.000
Other expenses		1.646.849	1.293.573
		21.604.224	1.963.573
Financial income and (expenses)			
Interest revenues and exchange differences		373.264	1.243
Financial income taxes		(74.652)	(248)
Bank related service fees		(20.253)	(18.865)
		278.359	(17.870)
Excess of revenues over expenditures		0	0

STATEMENT OF FINANCIAL POSITION

Assets

	Note	31.3.2014	31.3.2013
Current assets			
Receivables:			
Accounts receivable		6.411.965	0
Cash and cash equivalents		17.363.478	1.886.417
Current assets		23.775.443	1.886.417
Total assets		23.775.443	1.886.417

31 MARCH 2013

Equity and Liabilities

	Note	31.3.2014	31.3.2013
Net assets			
Permanently restricted		0	0
Temporarily restricted		0	0
Unrestricted		0	0
Total net assets	3	0	0
Current liabilities			
Deferred income		21.147.734	1.538.967
Accounts payable		2.627.709	347.450
Total liabilities		23.775.443	1.886.417
Total net assets and liabilities		23.775.443	1.886.417

STATEMENT OF CASH FLOWS

	Note	1.4.2013-31.3.2014	1.4.2012-31.3.2013
Operating activities			
Net income (loss)		0	0
Changes in operating assets and liabilities:			
Short term receivables, change		(6.411.965)	0
Short term payables, change		2.280.259	347.450
Changes in operating assets and liabilities		(4.131.706)	347.450
Net cash from operating activities		(4.131.706)	347.450
Financing activities			
Other payables, change		19.608.767	1.538.967
Net cash flow from financing activities		19.608.767	1.538.967
Increase in cash		15.477.061	1.886.417
Cash at beginning of year		1.886.417	0
Cash at year end		17.363.478	1.886.417

NOTES

Accounting principles

1. These Financial Statements of GEORG-Rannsóknarklasi í jarðhita for the fiscal year 1.4.2013-31.3.2014 have been prepared in accordance with applicable Icelandic laws and regulations and in accordance with generally accepted accounting principles pertaining to non-for-profit organizations.

2. Revenues are recorded at the time of grant decisions made.

Net assets

3. Changes in Net Assets:

	Permanently restricted net assets	Temporarily restricted net assets	Unrestricted net assets	Total
Increase in Net Assets	0	0	0	0
Net Assets 31.3.2014	0	0	0	0

ITEMIZATIONS

	1.4.2013-31.3.2014	1.4.2012-31.3.2013
Operating revenues		
Income contributed to meet office expense	0	2.000.000
Háskóli Íslands	19.222.667	0
HS-Orka	6.125.000	0
IDDP	1.000.000	0
Landsvirkjun	6.125.000	0
Orkustofnun	7.336.965	0
Orkuveita Reykjavíkur	1.125.000	0
Styrkir	0	1.520.410
Deferred income	(19.608.767)	(1.538.967)
	21.325.865	1.981.443
Grants awarded		
Ísor, Íslenskar orkurannsóknir	9.425.000	0
Klak Innovit	2.500.000	0
Iceland Geothermal	3.250.000	0
Háskóli Íslands	3.000.000	0
Raunvísindastofnun HÍ	1.500.000	0
Íslenski Sjávarklasinn ehf	282.375	0
MarkMar	0	280.000
Gekon ehf	0	140.000
Víðfari Best á Íslandi	0	250.000
	19.957.375	670.000
Other expenses		
Rent	794.197	697.628
Tools and equipment, charged	314.932	0
Accounting services	161.406	0
Other services purchased	0	148.592
Computerized IT systems	9.140	12.235
Paper, printing and other office supplies	13.365	56.964
Meetings and conferences	353.809	322.762
Advertising and marketing costs	0	50.392
Founding & related expenses	0	5.000
	1.646.849	1.293.573

ANNEX I-IV

Samkomulag milli Landsvirkjunar, kt. 420269-1299, HS Orku, kt. 680475-0169, Orkuveitu Reykjavíkur, kt. 551298-3029, Orkustofnunar, kt. 500269-5379, Raunvísindastofnunar Háskólans, kt. 530269-2219 og GEORG, kt. 430412-0350,

UM STUÐNING VIÐ SAMSTARFSVERKEFNIÐ
„Geochemical speciation and reaction progress software for geothermal applications“

1. gr. Saga verkefnisins og aðdragandi umsóknar

Haustið 2000 hófst vinna við gerð nýs forrits, sem ætlað var til reikninga á jafnvægi milli uppleystra efna í vatni, steinda í bergi og gasa í jarðgufu. Forriti þessu skyldi fylgja varmafræðilegur gagnagrunnur. Vinna við forritið var studd frá byrjun og fram á mitt ár 2006 af Hitaveitu Suðurnesja, Landsvirkjun og Orkuveitu Reykjavíkur, og framan af einnig af Orkustofnun. Síðari helming árs 2006 fékkst styrkur frá Raunvísindastofnun Háskólans. Vinnu við forritið var fram haldið á árunum 2007 til 2012, þótt ekki fengist til þess stuðningur, en þó af nokkru minni þunga en áður. Raunvísindastofnun Háskólans styrkti vinnu við forritið árið 2013, en hún hafði einnig styrkt vinnu við gagnagrunninn á árunum 2008 og 2009 og á síðari hluta árs 2012. Þá hefur Raunvísindastofnun einnig látið í té skrifstofuaðstöðu allan tímann og gerir enn. Íslenskar orkurannsóknir hafa góðfúslega veitt Jóni Erni Bjarnasyni leyfi frá öðrum störfum þennan tíma, og látið honum í té ýmsa aðstöðu.

Haustið 2013 var sótt um styrk frá HS Orku, Landsvirkjun, Orkustofnun og Orkuveitu Reykjavíkur (hér eftir nefndir stuðningsaðilar) fyrir árin 2014 og 2015 í því augnamiði að ljúka gerð forritsins og gagnagrunnsins. Fallist hefur verið á þennan stuðning með þeim skilyrðum sem greint er frá í 2. gr.

2. gr. Skipulag samstarfsins og fjármögnun

Verkefnið er þróunarverkefni, sem unnið er undir umsjá GEORG og stutt af fjárframlögum frá HS Orku, Landsvirkjun, Orkustofnun og Orkuveitu Reykjavíkur (hér eftir nefndir stuðningsaðilar). Verkefninu og verkáætlun er lýst í viðauka við samning þennan (Annex I). Verkefnið skiptist í fjóra áfanga og lýkur hverjum þeirra með mælanlegri vörðu (e."Milestone", sjá kafla 5 í Annex I). Samningur þessi gildir aðeins um fyrsta áfanga. Heildarstuðningur við þennan fyrsta áfanga verkefnisins er kr. 4.500.000 og skiptist jafnt milli stuðningsaðila. Yfir verkefninu er sérstök stýrinefnd (Steering Committee), sem skipuð er einum fulltrúa frá hverjum stuðningsaðila og einum frá Raunvísindastofnun Háskólans. Stýrinefnd metur framgang verksins út frá framvinduskýrslum og kynningu.

3. gr. Hlutverk og skyldur GEORG

GEORG er vörsluaðili fjárframlaga stuðningsaðila og kemur þeim til þátttakenda skv. sérstökum samningi við Íslenskar orkurannsóknir. GEORG heldur utan um vinnu stýrinefndar, sér til þess að hún sé upplýst um framgang verkefnisins og að framvinduskýrslur skili sér til stýrinefndar.

4. gr. Vinna við verkefnið

Verkefnið er tvíþætt. Annars vegar gerð sjálfs forritsins og hins vegar gerð varmafræðilegs gagnagrunns sem forritið nýtir til allra reikninga. Jón Örn Bjarnason, eðlisefnafræðingur mun annast alla forritun en Stefán Arnórsson, prófessor emeritus, vinnu við gagnagrunninn.

5. gr. Hlutverk Raunvísindastofnunar Háskólans

Raunvísindastofnun Háskólans veitir Stefáni Arnórssyni og Jón Erni Bjarnasyni skrifstofuaðstöðu. Á móti skuldbindur Stefán Arnórsson sig til að ljúka vinnu við gagnagrunninn af hálfu Raunvísindastofnunar án þess að sérstakar greiðslur komi til.

6. gr. Faghópur

Stofna skal sérstakan faghóp til að fylgjast með fylgjast með framvindu verksins. Hópinn mynda alls sex einstaklingar, þeir Jón Örn Bjarnason og Stefán Arnórsson auk fjögurra annarra þar sem einn skal tilnefndur af hverjum stuðningsaðila. Hlutverki hópsins er lýst í Annex I, kafla 6.4.

7. gr. Greiðslur, samningstími og gildissvið

Samningur þessi skal ná yfir tímabilið 1. Janúar til 30. Júní, 2014.
Vegna fyrsta áfanga verkefnisins greiðir hver stuðningsaðili samtals **1.125.000 kr**. til GEORG. GEORG leggur fram reikninga fyrir greiðslum samkvæmt eftirfarandi greiðslufyrirkomulagi:

Greiðsla:	**Dags**	**Upphæð í kr.**
Fyrir fyrsta áfanga	01.03.2014	1.125.000

8. gr. Úrlausn ágreiningsefna

Komi upp ágreiningur milli aðila er varðar framkvæmd eða túlkun samnings þessa, skulu aðilar leitast við að leysa ágreining sinn með samningum. Gangi það ekki skal vísa ágreiningnum til dómstóla og skal málið rekið fyrir Héraðsdómi Reykjavíkur.

Samningur þessi er tvær blaðsíður auk viðauka (Annex I) uppá 11 síður. Hann er gerður í sex eintökum, eitt til handa hverjum aðila.

Reykjavík, 28. febrúar 2014

f.h. Landsvirkjunar
Bjarni Pálsson

f.h. HS Orku
Albert Albertsson

f.h. Orkuveitu Reykjavíkur
Hildigunnur H. Thorsteinsson

f.h. Orkustofnunar
Jónas Ketilsson

f.h. GEORG
Hjalti Páll Ingólfsson

f.h. Raunvísindastofnunar Háskólans
Sigurður Guðnason

ANNEX I
Project Plan

Geochemical speciation and reaction progress software for geothermal applications

Project ID: 14-06-001

Coordinator: Jón Örn Bjarnason / Stefán Arnórsson

Start date: February 2014

Duration: 2 years

Partners and supporters: Orkustofnun, Landsvirkjun, Orkuveita Reykjavíkur and HS Orka
University of Iceland and ISOR

Table of Contents

1 Project abstract

A software package for the calculation of multicomponent heterogeneous chemical equilibrium in geothermal systems is outlined. This code, which has been under development for some years, is designed to simulate reactions between aqueous species, rock minerals, and gases in steam. The program will compute activities and concentrations of species in a liquid phase and partial pressures of gases in vapour. It will simulate the heating, cooling, boiling, and condensing of a fluid; the dissolution and precipitation of minerals; and the mixing of fluids. Provisions are made to allow users to select redox reactions into their models. A thermodynamic database to use with the program is being developed in parallel. The database will be open so that data may be added or deleted without changing or recompiling the program itself.

2 Project Background and History

Many processes in the Earth's crust are governed by chemical reactions between dissolved aqueous species, solid minerals, and gases in vapor. Examples of such processes include metasomatism on mid-ocean ridges, metamorphism, chemical weathering of soil and rocks, and, pertinently, hydrothermal alteration in geothermal systems.

Processes such as these may be elegantly described by the methods of classical thermodynamics, which allow the state of a model system to be determined by solving equations for heterogeneous multicomponent chemical equilibria. With calculations of this kind, it is possible to simulate the chemical properties and evolution of a geothermal system in some detail. One may, in particular, compute the activities and concentrations of aqueous species in the fluid, the partial pressures of gases, and the saturation state of minerals, for a given temperature, pressure, and bulk chemical composition. The formation of secondary alteration minerals from primary minerals in the host rock may thus, in turn, be explained or predicted. For the operators of geothermal power plants and heating utilities, it is no less important that these properties can be calculated for fluids in wellbores, pipelines, separators, and heat exchangers. In this way, important engineering design parameters, such as the potential for mineral scale formation, the gas content of steam, and bubble point pressures, may be estimated.

Computations of this kind are much too complicated to do by hand except in trivial cases. For this reason, numerous computer programs have been written for this purpose over the years, beginning around 1970. These programs fall, broadly speaking, into two classes: a) chemical speciation and saturation state codes, and b) so-called reaction progress or reaction path programs.

Programs of the first type allow one to calculate aqueous species activities and concentrations, and gas fugacities. They also permit the evaluation of saturation indices, showing which minerals are likely to be precipitated or dissolved under some given conditions, as well as the calculation of bubble point pressures of gases.

In addition to the above, the reaction progress codes permit the computation of the amount of the various minerals that must be dissolved or precipitated for equilibrium to be reached between the fluid and the rock. Reaction progress programs can also simulate reactions that occur upon the

mixing of different fluids, and upon the addition of rock minerals to, or the removal of alteration product from, the system.

These computer codes do not exist in a vacuum, to be sure. They must be backed by chemical thermodynamic data on the solubilities of minerals and gases and by data on the dissociation of aqueous species at the temperatures and pressures of interest. Such data are available for a wide variety of aqueous species and minerals at atmospheric pressure and 25°C. Fairly good data may also be found for many species and minerals up to 100°C, but the data becomes more sparse and often less reliable at high temperatures and pressures. At temperatures above 300°C, one may need to rely on extrapolations and predictive models for some species.

Numerous computer programs for geochemical equilibrium calculations have been written over the years. Most of these, by far, are speciation and saturation state codes. Only a handful are intended for reaction progress calculations. Many of the older programs have not been maintained and must now be considered obsolete. Some programs are specialized or somehow limited in scope, and others are backed only by room-temperature thermodynamic data. As a result, there are really only a few programs that are suitable for geothermal applications. And only a few of these can handle steam-water mixtures properly.

One of the older programs that has been maintained and still finds wide use is called WATCH. Originally developed in Iceland in the late 1970's by Stefán Arnórsson, Sven Sigurdsson, and Hördur Svavarsson, it was rewritten from scratch in the early 1990's by Jón Örn Bjarnason, who has maintained it since. WATCH is a primarily a chemical speciation and saturation state code, but it can handle steam-water mixtures and boiling processes along constant-enthalpy paths as well.

By the turn of the century, Arnórsson and Bjarnason had decided that the time had come for the development of an entirely new program to supersede WATCH, one that would include reaction progress capabilities and a modern graphical user interface, among other features. A new thermodynamic database to go with the program would be built simultaneously. To this end, they received support for a few years to work on this project from Hitaveita Suðurnesja, now HS Orka, (Sudurnes Regional Heating), Landsvirkjun (National Power Company of Iceland), Orkuveita Reykjavíkur (Reykjavík Energy), and Orkustofnun (National Energy Authority of Iceland). When the grant was exhausted, development continued anyway, albeit at a somewhat slower pace. Support has been secured from the Science Institute of the University of Iceland to cover the salary of Jón Örn Bjarnason for the year 2013.

3 Project description

The project comprises two separate parts, both of which are essential to the success of the enterprise. One of these is the computer program itself, with its thermodynamic approach, mathematical formalism, numerical algorithms, and implementation in code. The other part is the compilation and construction of an internally consistent thermodynamic database holding the dissociation constants of aqueous species and the solubilities of minerals and gases, as functions of temperature and of pressure, density, or dielectric constant, as the case may be. These parts will be outlined in turn below.

3.1 Program code

The program will read a data file containing specifications of all components, aqueous species, minerals, and gases used by the program. The specifications will include the requisite thermodynamic data for aqueous species dissociation and mineral and gas solubilities. The file will include some oxidation-reduction reactions and their equilibrium constants.

The program will also read the chemical component composition of water samples, steam samples, and rocks or rock-forming minerals included in the system, as desired. By "component composition" is meant, approximately, the elemental composition. The mole numbers, concentrations, and activities of species in the system are then computed using the thermodynamic data previously read. Once these are known, all other quantities of interest may be readily computed.

With this program it will be possible to:

1) Compute the activities and concentrations of species in a system comprising a liquid water phase, and optionally a vapour phase and one or more solid phases.
2) Simulate the result of mixing two or more different liquids, whether natural waters or laboratory reagents such as hydrochloric acid.
3) Simulate the result of injecting steam and gas into a fluid.
4) Simulate the results of heating, cooling, boiling, or condensing a fluid.
5) Simulate the dissolution of rock-forming minerals.
6) Simulate the precipitation of secondary minerals from a fluid. It will, in particular, be possible to compute the amount of each individual mineral that is deposited. This will be a particularly useful feature, since minerals often precipitate when a fluid is cooled, heated, or boiled, and also when different fluids are mixed.
7) Include oxidation-reduction reactions of the user's choice in the model. These will be selected at runtime.
8) Simulate reactions where the mole numbers of one or more chemical components are governed by mineral equilibrium instead of being strictly conserved in the system.
9) Add new components or species to the computational model. This will be done simply by adding information about these to the external thermodynamic database without changing or recompiling the program. There will be no particular limit on the number of aqueous species or minerals that may be added.

The program will permit the state of the system to be determined by specifying:

1) Temperature and pressure directly.
2) Temperature and one of the following: enthalpy, entropy, density, or volume.
3) Pressure and one of the following: enthalpy, entropy, density, or volume.

In this way it will be possible to simulate reaction processes along paths that may be isothermal, isobaric, isenthalpic, isentropic, or isochoric.

The program will be able to parse rather general functions of one or more independent variables. Functions for dissociation constants, solubilities of minerals and gases, and activity coefficients can thus be specified in the database, and their form need not be explicitly defined in the program code.

The program is being written in the Java language.

3.2 Thermodynamic database

The thermodynamic database will be external to the program. It will be open so that users will be able to include new components, aqueous species, minerals, and gases, by specifying the appropriate data. They will also be able to modify existing data at will. This database will be constructed in a spreadsheet, but a small program module will be provided to read the data from the spreadsheet and write it to an XML-file that constitutes an input to the main program.

The database will contain specifications of all components, aqueous species, minerals, gases, and oxidation-reduction reactions available to the program. These specifications will include the component formulas and molar masses, and the names and formulas of all aqueous species, gases, and minerals. Reactions of dissociation or dissolution of these will also be included, as will their dissociation and solubility constants as functions of temperature, pressure, or other variables. Provisions will be made for activity coefficients in the file, so that their functional form need not be hardcoded into the program. Equilibrium constants for selected redox reactions will also be included.

The thermodynamic database consists of three parts, one for minerals and two for aqueous species and gases, including oxidation-reduction reactions. The mineralogical database is for the most part based on Holland and Powell (2011) and on Robie and Hemingway (1995). For the first of these data sets the thermodynamic properties of minerals can be calculated over a wide range of temperature and pressure, but for the latter the effect of pressure is included by assuming that the molar volume is independent of T and P. One of the aqueous species databases is based on the HKF model (**H**elgeson-**K**irkham-**F**lowers) using published values for thermodynamic data at 25°C and 1 bar and equation of state parameters, largely from Helgeson and co-workers. The other aqueous species database is being specifically compiled as a part of the present project. It is largely based on the density model initially proposed by Franck (1956) to describe the temperature and pressure dependence of the equilibrium constants of aqueous species dissociation reactions. If good quality experimental data are available over a considerable range of temperature, the density model is used to extrapolate the equilibrium constant values to higher T and P. If data are inadequate, equilibrium constant values are predicted from thermodynamic data at 25°C as described by Anderson (2005).

4 Current project status

4.1 Program code

The program is written in Java, as stated above. Programs in this language are composed of so-called classes, one or more, depending on the size and type of program. Each class contains methods, which are subprograms. Both classes and methods may vary greatly in size, from a few lines to hundreds or even several thousand. Larger programs often consist of many classes, which are generally arranged into packages. A stand-alone program frequently constitutes a single package, but often more are required.

The classes comprising the geochemical equilibrium program under consideration are lodged in four packages. Three of these are complete, or nearly so.

The first package contains codes for steam tables, which return values for many properties of water and steam over a wide range of temperature and pressure. It is based on the so-called IAPWS-IF97 formulation. Much effort has been put into making this package as solid as possible. This is felt to be important, since one of the more significant features of the program will be the capability of handling steam-water mixtures. Very few of the existing speciation or reaction progress programs possess such a feature. This package, which is complete, comprises a total of 265 methods in 14 classes.

The steam table package, which now includes a graphical user interface, may be used on a stand-alone basis. For convenience, it has been wrapped into a Java archive file (jar-file). This file may be copied unchanged to a computer with almost any operating system and used there directly, provided only that the Java Runtime Environment (Java 7 RTE), which is freely available on the Web (java.com or oracle.com), has been installed. There has been some interest in including with this package a VBA macro that would allow the user to call functions directly from an Excel spreadsheet. This is under study and should be useful, but would, strictly speaking, fall outside the scope of the main project.

The second package contains methods used to parse and evaluate rather general functions of one or more independent variables. This permits one to express dissociation constants, mineral or gas solubilities, or activity coefficients stored in the database in almost any functional form desired, and it will not be necessary to choose the same form for different species or minerals. This package is also essentially complete, although minor modifications may be made later if necessary. The package contains 14 methods in three classes.

The third package contains codes for carrying out various matrix calculations and manipulations. These methods constitute a support module for the fourth, main package, but they may well find applications in other calculations at some later time. This package is considered complete, at least in the current context, but additional methods could easily be included later, if desired. This package contains 47 methods in two classes.

The fourth package is the centerpiece and workhorse of the program. It holds classes with methods to read thermodynamic data and sample analyses, and to define chemical components, species, redox reactions, and chains of redox reactions. It also contains classes with methods to sort species and reactions in various ways. The package furthermore includes classes with methods to build matrices for the nonlinear set of equations to be solved. The largest class, by far, comprises methods to solve this set.

This package is still far from completion. Still to be written are classes for a graphical user interface, among others. The classes mentioned above have not been debugged yet. Once they have, test runs of the program core classes can be made. This will, no doubt, reveal many bugs that must be corrected and many problems that must be addressed and solved. The package currently contains 181 methods in 18 classes.

A fifth package, external to the main geochemical equilibrium program, has been written. This package contains a program that reads the Excel spreadsheet containing the database and converts it to an XML-file. This package is nearly complete, but the remaining work will be deferred until the structure of the Excel file has been finalized. This package contains 33 methods in five classes.

At this time, a total of 42 classes containing 540 methods have been written. They are lodged in five packages.

4.2 Thermodynamic database

A total of 279 minerals are included in the mineral database. The HKF-database for aqueous species comprises a total of 265 dissociation constants, in addition to gas solubility reactions. The density model database already contains 271 reactions. This number is likely to reach 300, in addition to gas solubility and redox reactions. The mineral database is largely complete.

The HKF database is also almost complete. A review of published experimental data has been completed for just over 100 reactions for the density model database and the results evaluated. The variation of logK with T and P is expressed as a polynomial consistent with the density model. Further experimental data have been collected for another 40 reactions. These data are presently being evaluated.

Since chemical thermodynamic data are limited for many dissociation reactions, especially at elevated temperatures and pressures, it will often be necessary to extrapolate logK data from relatively low to high T and P. When data at ~25°C only are available, prediction of logK at high T and P will be attempted. The density model appears to describe pressure effects accurately, and the present study indicates that the effects of temperature are well represented by a simple heat capacity expression, CP = a + bT.

Thermodynamic data in the density model database will be ranked by quality into four groups based on the following criteria:

1) Good experimental data on heat capacity, enthalpy, and logK are available from ~25°C to at least 200°C.
2) Good experimental data on heat capacity, enthalpy, and logK are available from ~25°C to 80-100°C.
3) Good data are available at ~25°C for logK only and these data allow reasonable estimates of enthalpy and heat capacity at 25°C and 1 bar.
4) Data at 25°C only are available and heat capacity values are based on estimates using correlation algorithms or other methods.

Evaluation of experimental data indicate that logK can be quite accurately described to ~300°C, if good data on logK, enthalpy, and heat capacity are available at 25°C. The problem of having good data at 25°C generally lies with the heat capacity.

In many publications that describe thermodynamic experiments, the experimental data are not reported. Instead, the data are fitted to various types of polynomials that appear to describe the experimental results well. The choice of polynomials often seems to be arbitrary. Fitting of data presented in this manner by a density model expression is thus constrained by the published polynomials and this may influence extrapolation to temperatures above the experimentally determined values.

4.3 References

Anderson, G. (2005) Thermodynamics of natural systems, 2nd edition. Cambridge University Press, Cambridge, UK, 648 pp. ISBN-13 978-0-521-84772-8.

Franck, E.U. (1956) Hochverdichterer Wasserdampf II. Ionendissociation von KCl in H2O bis 750°C. Z. Phys. Chem., 8, 107-126.

Holland, T.J.B. and Powell R. (2011) An improved and extended internally consistent thermodynamic dataset for phases of petrologic interest, involving a new equation of state for solids. J. metamorphic Geol., 29, 333-383.

Robie, R. A. and Hemingway, B.S. (1995) Thermodynamic properties of minerals and related substances at 298.15 K and 1 bar (105 pascals) pressure and higher temperatures. U.S. Geol. Surv. Bull., 2131, 461 pp.

5 Work plan and time schedule for 2014-2015:

5.1 Milestone A: June 30, 2014

A partial version of the new computer program will be delivered to the Advisory Working Group. This program version will read two files: a file containing the requisite thermodynamic database, and another one containing analyses of the chemical composition of fluid samples. The version will be able to compute the activities and concentrations of chemical species in a single-phase water sample at a specified temperature and pressure, and return said activities and concentrations. Equilibrium with solid minerals and a vapor phase will not be included in this version, nor will equilibrium involving oxidation-reduction reactions. The database and sample files read by the program are based on the open XML file format.

A file in the Excel format containing a substantially complete version of the thermodynamic database will be delivered to the Advisory Working Group at the same time. A program for converting data in the Excel file to the XML-format will be delivered with it.

A software package for computing the thermodynamic properties of water and steam will also be delivered at this time. This package, which can be used on a stand-alone basis, comes complete with a graphical user interface. Those who use "steam tables" on a regular basis should find this package helpful in its own right, without any reference to the main chemical speciation and reaction progress program.

By the completion of this Milestone, a decision on the long-term ownership of the rights to the software must have been made. At the same time, the protocol and responsibility for future upgrades, distribution, and maintenance of the program and associated database must have been clarified. This will be done in consultation and cooperation with all the stakeholders involved, including the Sponsors, ISOR - Iceland GeoSurvey, the Science Institute of the University of Iceland, Stefán Arnórsson, and Jón Örn Bjarnason.

5.2 Milestone B: December 31, 2014

The second partial version of the computer program will be delivered to the Advisory Working Group. This program version will include, in addition to the features described in Milestone A, the ability to compute equilibrium between aqueous species, solid minerals, and gases in a vapor phase, but oxidation-reduction reactions will not be included at this time.

5.3 Milestone C: June 30, 2015

The third partial version of the computer program will be delivered to the Advisory Working Group. This program version will include, in addition to the features described in Milestones A and B, the ability to simulate processes where enthalpy, entropy, or volume is specified instead of either temperature or pressure. Computation of oxidation-reduction equilibrium will have become functional at this point.

5.4 Milestone D: December 31, 2015

A version of the computer program ready for beta testing by selected users will be delivered to the Advisory Working Group. A graphical user interface will be included at this time.

6 Management structure

6.1 Project management

Jón Örn Bjarnason and Stefán Arnórsson are responsible for the professional management of the project, in particular that it be carried out according to the project description and that Milestones are reached.

Jón Örn Bjarnason is a theoretical physical chemist who received his PhD from Stanford University. Stefán Arnórsson is a geochemist who worked on the chemistry of geothermal fluids for his PhD at Imperial College in London. Both have worked for decades on natural water chemistry, in particular the chemistry of geothermal fluids. Jón Örn has extensive experience in scientific programming. Stefán has spent most of his career on aqueous speciation and the thermodynamics of mineral-solution reactions. Both have been involved with the development of aqueous speciation programs and have long experience in using such programs. Thus, both have an understanding of their theoretical and practical aspects. As a team they complement and support each other with their respective backgrounds and experiences.

6.2 Project supervision

GEORG is responsible for the supervision of the project. This includes arranging all contracts and agreements related to the project as well as receiving funds from the Sponsors and transferring these to ISOR – Iceland GeoSurvey in accordance with grant agreements and project progress. GEORG also keeps the Steering Committee informed about the status of the project and follows up on the Steering Committee's decisions. GEORG also assists in organizing meetings as needed in cooperation with Jón Örn Bjarnason, Stefán Arnórsson, the Advisory Working Group and the Steering Committee.

6.3 Steering committee

The Steering Committee comprises representatives of the Sponsors, one from each. The members of the Steering Committee evaluate the progress of the project based on progress statements and reports. The members are:

Jónas Ketilsson	Orkustofnun
Hildigunnur H Thorsteinsson	Orkuveita Reykjavíkur
Bjarni Pálsson	Landsvirkjun
Albert Albertsson	HS Orka
Sveinbjörn Björnsson	GEORG SA chair

6.4 Advisory Working Group

The Steering Committee, in consultation and cooperation with Jón Örn Bjarnason and Stefán Arnórsson, shall appoint an Advisory Working Group.

This Advisory Working Group shall be charged with the following tasks:

1) Verify that each of the Milestones in this Contract are, in turn, reached, and report this to the Steering Committee.
2) Identify a person who will work with Stefán Arnórsson on issues involving the thermodynamic database. Ideally, this person should be able and willing to continue occasional work on the maintenance and upkeep of the database for many years to come. It is imperative that this person have a solid background in chemical thermodynamics.
3) Provide suggestions and feedback to Jón Örn Bjarnason on user interface functionality and design, and on other issues pertinent to the project.
4) Identify persons that might carry out beta testing of the program.

The partial program versions that will be delivered at Milestones A, B, and C, as described above, will not include a graphical user interface. They will be provided with a command-line (text-based) interface instead. The person(s) verifying the Milestones must therefore have some familiarity with the use of such interfaces. It will also be very helpful if said person(s) have at least a passing acquaintance with speciation and reaction progress programs and some knowledge of how they are used.

Under no circumstances shall any program versions or related software packages be distributed to any outside party until a formal decision is reached as to how the program will be distributed in the future. In this context, "outside party" is understood to mean any person(s) other than:

(a) the developers (JÖB and SA),
(b) those on the Steering Committee,
(c) those in the Advisory Working Group, and
(d) other persons specifically designated by the Sponsors.

Hugarflug v/vinnu við skilgreiningu á W2V verkefni

Niðurstöður vinnustofu 8. apríl 2014

Heiti	Skilgreining og umfang	Markmið	Lýsing á afurðum	Aðföng	Hagsmunaaðilar
Metangasframleiðsla úr jarðhitagasi	Kanna möguleika þess að framleiða metangas úr H2S snauðum gasstraumi með hjálp hitakærra örvera. Með tilkomu SulFix II gasskiljustöðvar við Hellisheiðarvirkjun skapast tækifæri á að prófa iðnaðarferil sem verið er að þróa í Dannmörku og Austurríki til að nýta gasið	Finna hagkvæma aðferð til að geyma umframorku í formi eldsneytis	Könnun á fýsileika þess að framleiða Metnagas úr jarðhitagösum, greina mögulega notendur og stærð markaðar	Sérfærðiþekking NMÍ, verkfræðistofur, okrufyrirtæki, olíufélug ofl.	Orkufyrirtæki, vísindasamfélagið, olíufélög Nýsköpunarmiðstöð
Kortlagning tækifæra í nýtingu jarðhita til efnaiðnaðar	Samantekt og kortlagning á efnaferlum og framleiðsluferlum sem geta nýtt þá orkustrauma sem í boði eru á jarðhitasvæðum (varmaorka, gufa, gas) og henta sem samliggjandi iðnaður við jarðvarmaorkuver. Ekki verður kafað djúpt í eintaka ferla heldur er um heildaryfirlit að ræða. Hlutir eins og hvar er trendið í framleiðslu á efnum, hvar er verið að framleiða þau, hvar er líklegasti markaðurinn og hvar er mestur vöxtur. Einnig þarf að ráðast í samantekt á því sem áður hefur verið gert og byggja á þeirri vinnu. Verkefnið verður unnið í samvinnu við NMÍ, Íslandsstofu, verkfræðistofur, orkufyrirtækin ásamt atvinnuþróunarfélögum Sérstök áhersla lögð á að greina möguleika á nýtingu CO2 Eins kæmi til greina að skoða hvernig bæta megi hönnun jarðvarmavera með tilliti til fjölnýtingar innan veranna eða í næsta nágrenni. Sem og skoða skipulagsmál og hvort hægt sé að gera ráð fyrir fjölnýtingu strax við upphafa skipulags framkvæmda. Er hægt að auðvelda framgang iðnaðar með því að gera víðari landnýtingaráætlun í upphafi?	Heildaryfirlit yfir líkleg framleiðsluefni og efnaferla - Möguleg niðurstaða gæti verið t.d. Einsskonar efnafræðilegt lindal diagram þar sem efnastraumar og hiti er sett upp á móti mögulegum ferlum. Einnig þarf samhliða þessu að vinna markaðsgreiningu og úttekt á efnaiðnaði t.d. í evrópu.	Skýrsla, markaðsgreining og tækilegar útfærslur.	Þverfaglegur hópur sem liggur yfir þessu í sumar, sumarstörf fyrir 3-4 aðila með aðstöðu í NMI/HI/HR eða hjá fyrirtækjunum. Vettvangsferðir, t.d. Í Kröflu.	Orkufyrirtæki, verkfræðifyrirtæki, rannsóknastofnanir, framleiðslufyrirtæki.
Síritun á efnainnihaldi afgass jarðvarmavera	Skoða leiðir til að síritunar á efnasamsetningu gass frá jarðhitaorkuverum. Kostnaðargreining og "reality check" á slíkri hugmynd. Samræma aðferðafræði við efnainnihaldsmælingar milli orkufyrirtækja.	Fá betri mynd af gassamsetningu og flæði, umfram það sem nauðsynlegt er fyrir rekstur orkuvera. Ætlað til að styðja við mögulega notendur á gasstraum	Tæknibúnaður, tillaga að uppsetningu og útfærslu á slíkum búnað eða greining á hvort slíkur búnaður sem til.	Hugmyndavinna og greining markaðar á fyrstu stigum verkefni. Möguleg þróunarvinna í síðari stigum.	Orkufyrirtækin, fjölnýtingarfyrirtæki og rannsóknarhópar.
Nýting jarðvarma í aquaponics (samræktun)	Samræktun á fiski og grænmeti - tengsl við ferðamennsku - stigvaxandi framleiðsla - hægt að byrja í smáu - fasaskipt. Svinna-verkfræði og Háskóli Íslands eru þátttakendur í Evrópuverkefnum á þessu sviði með það að markmiði að koma upp Aquaponics fyrirtæki á Íslandi. 3-4 háskólanemendur munu vinna að verkefninu í sumar, en leitað er að heppilegu húsnæði á höfuðborgarsvæðinu þar sem hægt væri að setja upp einingar (heppilegra að vera í upplýstu húsnæði heldur en gróðurhúsi á þessu svæði) og bjóða gestum og gangandi að koma inn og skoða. Hugmyndin er að þetta yrði eitt skref í átt að stærra fyrirtæki sem myndi tengja saman jarðvarma, ferðamennsku og matvælaframleiðslu.	Markmiðið er að fullnýta alla framleiðsluþætti - "zero waste - þannig að ekkert frárennsli komi frá kerfinu. Íslenski jarðvarminn yrði markaðssettur og tengdur við heilnæma og umhverfisvæna matvælaframleiðslu. Hægt væri að tengja veitingarekstur við þetta. Jafnframt yrði þetta markaðssett í sögubúningi um hvernig jarðvarminn hefur verið nýttur í Reykjavík í gegnum tíðina. Hugmyndin er að setja upp einingu í miðbænum og framleiðslueiningu fyrir austan eða í Reykjanesbæ. Afar brýnt er að koma upp einingu í Reykjavík í fyrstu ekki einungis vegna fjölda ferðamanna heldur einnig til að aðstandendur verkefnisins og nemendur sem vinna í því á fyrstu mánuðum geti haft það nálægt sér.	Ferskur fiskur, grænmeti, ávextir, tropical umhverfi, upplifun fyrir ferðamenn og Íslendinga, kennsla og frekari nýsköpun, tenging við þörungaframleiðslu og nýsköpun um nýtingu affalls frá landeldisstöðvum, aukin framleiðsla í gróðurhúsum, markaðssetning á jarðvarma, veitingarekstur, gestastofa, fundarherbergi - skilja á milli framleiðsluhluta og gestastofu.	3-4 stúdentar munu verða ráðnir til að vinna í verkefninu í sumar - Erum að leita að ódýru og heppilegu húsnæði í Reykjavik til að starta upp pilot sem myndi opna sem gestastofa strax í sumar - áhugasama aðila á framleiðslustaðnum sem taka málin í fangið og drífa þau áfram. Erum í sterkum tengslum við fjölmörg lönd í Evrópu, USA og Kanada sem vinna á þessu sviði, bæði fyrirtæki og rannsóknaraðila. Það sem vantar helst aðstoð með er ódýrt og heppilegt húsnæði.	Orkufyrirtækið, framleiðslufyrirtækin, sveitarfélag, háskólaumhverfið
Föngun og nýting á kísil	Finna leiðir til að fanga kísil úr jarðhitavökva í nýtanlegu magni og á réttu formi þannig að hann sé nýtanlegur í annan iðnað.+	Þróa aðferð til að fanga kísl í jarðhitavökva á hagkvæman hátt og þróa aðferðir við að framleiða afurðir úr kísil í miklu magni.	Heilsudrykkur, krem,chips, byggingarefni, lím, umhverfisvæn og endingargóð steypa, vegagerð, styttur og fleira - afar áhugavert er að kanna með samstarf við aðila sem hafa verið að vinna að þróun GEOPOLYMERS í þessu sambandi	Fjármuni - áhugasama aðila, stofna fyrirtæki í kringum þetta - hugmyndasamkeppni -	Orkufyrirtækið, framleiðslufyrirtækin, sveitarfélag, náttúruverndarsamtök, NMÍ

Annex III

International Journals

'Multidimensional reactive transport modeling of CO2 mineral sequestration in basalts at the Hellisheidi geothermal field, Iceland', E.S.P. Aradóttir, E.L. Sonnenthal, G. Björnsson and H. Jónsson, Int. J. Greenhouse Gas Control (in press, 2012)

'Development and evaluation of a thermodynamic dataset for phases of interest in CO2 mineral sequestration in basaltic rocks', E.S.P. Aradóttir, E.L. Sonnenthal and H. Jónsson, Chemical Geology (in press, 2012),

'Global Optimization of Reservoir Models by Mapping Out Object Function Minima and Saddle Points', M. Plasencia, A. Pedersen, A. Arnaldsson and H. Jónsson, Proceedings of the Thirty-Seventh Workshop on Geothermal Reservoir Engineering at Stanford University, Jan. 30 - Feb. 1 (2012).

'Dynamics of basaltic glass dissolution - Capturing microscopic effects in continuum scale models', E.S.P. Aradottir, E.L. Sonnenthal and H. Jonsson, Geochimica et Cosmochimica Acta (submitted, 2011).

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www.geothermaleranet.eu

EDITORIAL

by Guðni A Jóhannesson, Coordinator

How can Geothermal contribute to increase energy security and savings in Europe?

Geothermal resources have been used successfully and economically in some locations in Europe where geological conditions are exceptionally favourable (e.g. Italy and Iceland), but they can play a much more important role at the European scale, if they can be made accessible in other places.

Numerous projects in several countries (e.g., in France, Germany, Switzerland) have started to make use of this source of energy applying new approaches.

On top of the long term climatic challenges Europe is now looking at instability and limited security of the gas market and the countries are now feeling the urge to limit the dependency on gas and fossil fuels. Since a substantial part of the gas consumption is used for direct heating of homes and domestic hot water the obvious choice is to develop methods to use renewable, carbon free sources for this purpose.

For regions with known access to geothermal energy such as the Pannonian basin and the Molassen stretching from Switzerland into Germany we have the possibility to tap the geothermal sources for energy that with good economy can replace gas use and be a game changer in improving the energy security, cost savings and mitigating climate change.

District heating can play a key role in this aspect. In the Nordic countries we have good examples where district heating provides means and the flexibility to utilise various sources of renewable energy from surplus wind power, biomass, waste heat from industries, heat pumps and geothermal. In Sweden we can follow how this has paved the way from 100% fossil fuel dependency to more than 80% renewable energy delivered by the district heating networks.

In many regions in Eastern Europe we have district heating networks that have wide coverage but have severe technical problems due to inferior technology from the start and lack of maintenance. Individual customers have found it more economical and secure to provide heating and hot water from their own gas boilers which in turn has led to deteriorating economy for the district heating plant operation.

It is of high importance that necessary financing is provided to break this negative spiral. District heating systems are without comparison our most effective instrument to provide heating and even cooling with lowest possible CO_2 emission regardless of if we have access to geothermal energy or not.

The feed in tariffs system that has been the dominating instrument for enhancing use of renewable energy sources such as the sun or the wind have specified cost frame for certain technologies. We now see emerging subsidy systems that are technology neutral in such a way that they give premium for delivered energy based on saved CO_2 emissions regardless of the technology used. Bidding rounds in competition in the Netherlands have shown that the use of geothermal energy can be very cost efficient compared to other conversion technologies when it comes to CO_2 savings per cost unit including capital cost and operation.

It is therefore important for policymakers and others to recognise the great opportunity regarding geothermal heating for savings for countries, as it is estimated that geothermal heating in Iceland is saving equal to 7% of GDP or 3000 US$ per capita or close to 1 billion US$ for the economy only for 2012. It has also been estimated that renewables for heating and cooling could save EUR 11.5 billion per year within EU, improve the energy security and mitigate climate change.

Geothermal ERA NET

VISION

- *Minimize the fragmentation of geothermal research in Europe*
- *Build on European know-how and know-who to utilize geothermal energy*
- *Contribute to a framework to realise large opportunities in the utilization of geothermal energy through joint activities*

RENEWABLE NEWS

Renewables for heating and cooling could save EUR 11.5 billion per year within EU

AEBIOM, EGEC and ESTIF representing the biomass, geothermal and solar thermal sectors respectively, addressed an open letter to the Heads of State and Government, ahead of their spring meeting in Brussels 19th of March 2014.

The letter is stating among others that *"...Investing in renewables for heating and cooling will bring security of supply and more competitiveness, and could save EUR 11.5 billion per year, announces the industry.*

Over recent years, the lack of awareness and political support to renewables for heating and cooling has meant only modest market development in the sector. However, in view of the upcoming discussion of the European Council on EU climate and energy policies beyond 2020, there is a great opportunity to invert this trend.

Decarbonising our energy sector should not be regarded as a burden, but rather as an opportunity for Europe's industrial renaissance. Clear pledges on renewables for heating and cooling and energy efficiency will increase EU's energy independence, while improving our balance of trade, creating a substantial amount of new local jobs and ensure stable and affordable energy prices to our consumers and industries". http://egec.info/

Renewables for heating in Iceland is already saving 7% of GDP or equivalent 3000 US $ per capita every year

In a cold country like Iceland, space heating needs are greater than in most countries. In Reykjavik, extensive distribution of hot water for heating homes began in 1930. Already in the 1940s, the State Electricity Authority promoted geothermal development and carried out a regional survey of geothermal areas suitable for space heating and explored promising fields with exploratory drilling.

When the oil crisis struck in the early 1970s, fuelled by the Arab-Israeli War, the world market price for crude oil rose by 70%. The oil crises in 1973 and 1979 caused Iceland to change its energy policy, reducing oil use and turning to domestic energy resources, hydropower and geothermal heat.

Throughout most of the period 1970–2012, oil heating was 2-6 times more expensive than geothermal heating but peaks to 16 times more expensive in the period 1973 to 1985 and has risen again since 2007 to a present ratio of 10.

In comparison to the cost of heating with oil, the annual savings in Iceland have been in the range of 1–2% of the GDP for most years from 1970–2012, but rose to 7% in the period 1973 to 1985 and are reaching that peak again in recent years.

The 7% of GDP are equivalent to 3000 US$ per capita or total close to 1 billion US$ for the economy, or about 80% of the state budget cost of health care at the same year 2012.

The Geothermal heating in Iceland have therefore approved that it can contribute to huge savings for the economy and citizens, as well to cleaner environment every year. There are therefore great possibilities of savings based on geothermal heating, in other countries with geothermal potential, which depends on policy, research and possibilities in each area.

Geothermal District Heating has the potential to alleviate Europe's energy *security crisis*

"Geothermal district heating has the potential to alleviate Europe's energy security crisis" – is stated in a press release from Geothermal District Heating (GeoDH) in Brussels, 15th May 2014.

In the release it is stating among others that

"*Over 25% of the EU population lives in areas directly suitable for Geothermal District Heating (GeoDH)[1]. There is a large potential in Central and Eastern Europe, with GeoDH systems in operation in 22 European countries including Hungary, Poland, Slovakia, Slovenia, the Czech Republic, and Romania, where existing heat networks are well developed.*

Geothermal district heating is a valuable and immediate option for the alleviation of Central and Eastern Europe's dependency on Russian gas.

The main benefits of geothermal heating and cooling are provision of local, baseload and flexible renewable energy, diversification of the energy mix, and protection against volatile and rising fossil fuels prices. Using geothermal resources can provide economic development opportunities for countries in the form of taxes, royalties, technology export, and jobs.

In order to increase awareness, GEODH, an IEE project co-financed by the EU - has assessed and presented for the first time the potential in Europe on an interactive map.

From the map we can note that:

- *GeoDH can be developed in all 28 EU countries;*
- *Geothermal can be installed with existing DH systems during extension or renovation, replacing fossil fuels;*
- *New GeoDH systems can be built in many regions of Europe at competitive costs;*
- *The Pannonian basin is of particular interest when looking at potential development in Central and Easter Europe.*

According to Eurostat, about one third of the EU's total crude oil (34.5%) and natural gas (31.5%) imports in 2010 originated from Russia. Of this, 75% of the gas is used for heating (2/3 in households and 1/3 in the industry). Geothermal DH technology has the potential to replace a significant part of that fuel. In order to enable such a development the specific proposals from the GeoDH consortium are to:

- *Simplify the administrative procedures in order to create market conditions which would facilitate development;*
- *Develop innovative financial models for GeoDH, including a risk insurance scheme, and the intensive use of structural funds;*
- *Establish a level playing field, by liberalising the gas price and taxing GHG emissions in the heat sector appropriately;*
- *Train technicians and decision-makers from regional and local authorities in order to provide the technical background necessary to approve and support projects."* www.geodh.eu

PROGRAM NEWS

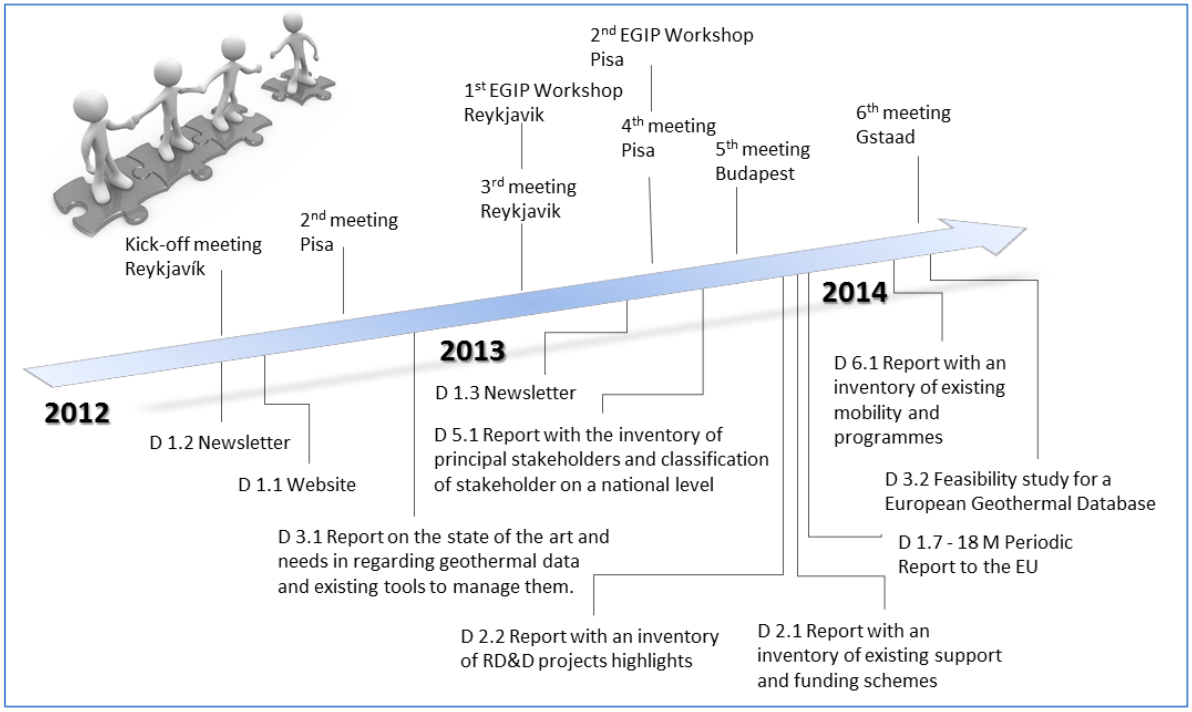
What has been achieved?

During the first 24 months of the Geothermal ERA NET the focus has been put on exchanging information on the status of geothermal energy utilization, including national support schemes and research, development and deployment (RD&D) activities and the creation of an inventory report on these activities.

Emphasis has also been put on gaining an understanding of the principal stakeholders, including key industry players for a successful, Europe-wide coordination of publicly funded national research, development, deployment and innovation geothermal energy programmes. Great efforts have also been put on the preparation for a Joint European Data/Information platform called EGIP or European Geothermal Information Platform.

In order to identify areas of collaboration the Geothermal ERA NET mapped existing mobility and training programmes at national and European level. Special attention was given to the trans-national aspects of the programmes, i.e. if they are open to researchers of all nationalities. The results of the mapping is demonstrated on an interactive map which can be found under this link.

https://mapsengine.google.com/map/viewer?mid=zxd60TZthCCU.ktuAqcSJZv8I



The **Geothermal** ERA NET program is split into 7 Work Package:

1. Coordination and Management
2. Information exchange on National incentives and status on Geothermal energy
3. Towards a European Geothermal Database
4. Development of Joint Activities
5. Coordination with Stakeholders
6. Transnational Mobility and Training
7. Implementation of Joint Activities

More information regarding the program and progress can be seen at the website,
http://www.geothermaleranet.is/

Interactive map to indicate Transnational Research Agenda and Programs

WP 6 addresses transnational researchers' mobility and a common approach in training of research talents as adequate human resources and capacity have to be in place to achieve targets in geothermal research. A coordinated approach to research has to be supplemented by idea exchange and the development of a trans-national approach to research training.

Feasibility Study for a European Geothermal Information Platform (EGIP)

GEO ERA-NET partner countries have proposed to set up European Geothermal Information Platform (EGIP), as organization and sharing of geothermal data play an important role, as was specifically mentioned in recent EU Commission Call.

The mission is to increase the share of potential geothermal energy users - primarily international operators, and surveyors - primarily European bodies.

Creating an EGIP now that the INSPIRE directive are being implemented has several benefits:

- Guaranteed data interoperability: retrieval, viewing and access of information from partners/providers.
- Harmonized geothermal domain at a European level.
- Efficiency, data linked directly to national databases.
- Guaranteed ownership: data belong to and stay in the country they are related to. Each country decides what to share and what to keep private.
- Durability and maintainability, since this is information is directly related to national data sources.
- Economically viable, requiring only coordination with what each country would need to develop.
- Productivity, by covering all published data, long term.

Geothermal energy status & policy review

The Geothermal ERA NET focuses on direct use and higher enthalpy uses of geothermal energy. The consortium does not consider shallow geothermal energy for geothermal heat pumps, which is a different market with its own characteristics and challenges.

Geothermal energy utilisation accounts for 68% of energy utilisation in Iceland, and one could say that the potential that this energy source holds for this country is largely deployed. Italy also has a significant geothermal production. It ranks as fifth country in the world for geothermal electricity production. After Turkey, Iceland and Italy, Hungary is ranked at 4th place regarding installed geothermal direct use in Europe. For all other participating countries, geothermal energy is an energy source with potential.

With the exception of Iceland, all countries have an ambitious agenda for an increase of the market for geothermal energy. In all countries except for the Netherlands and Slovenia, this includes a significant growth in electricity production with geothermal energy. Up to 2020, the Netherlands will focus on direct use. In all participating countries, there are policy instruments in place to forward geothermal energy utilisation. This includes R&D efforts, but in some countries also soft loans or guarantee funds.

The Geothermal ERA NET group met for the sixth time in March this year, now in Gstaad in Switzerland. The topic of the meeting was the development of possible joint activities and actions. The meeting was well attended by partners and was very productive

Stakeholder Analysis on a National Level

The **Stakeholder Analysis** aims at identifying and listing the main stakeholders and assessing their interest and attitude and how they are likely to impact / be impacted by the work of funding agencies and geothermal program owners. It is important to highlight the fact that the partners of the ERA-NET project, are affected by other national stakeholders. The collection of data of national stakeholders and the related analysis can be summarized as follows:

- The stakeholder lists and analysis differ strongly between countries. This is mostly related to the local availability of resources and energy demand.
- Depending on the local situation, the national RD&D has developed in different directions.
- Concerning the proposed actions there are some general findings which are valid for all partners.

The next step will be to extend the stakeholder listing and analysis to regional and European level.

ERA NET PARTNERS

The Consortium represents National and Regional programmes from 10 European countries, giving the Geothermal ERA-NET the critical mass required for successful operations. All members have assigned senior staff to this ERA-NET and most of the representatives from the different partners have beyond their responsibilities for the home front programmes experience in international cooperation and ERA-NET's in particular.

List of partners:

Iceland - OS (Orkustofnun) (Coordinator)
http://www.nea.is/

Iceland - RANNIS (Icelandic Centre for Research)
http://www.rannis.is/

The Netherlands - Rijksdienst voor Ondernemend Nederland
http://english.rvo.nl/

Switzerland – SFOE (Swiss Federal Office of Energy)
http://www.bfe.admin.ch

Italy – CNR (The National Research Council of Italy)
http://www.cnr.it

Germany – Jülich (Project Management Jülich)
http://www.ptj.de

France - ADEME (French Agency for Environment and Energy Management), BRGM as third party of ADEME
http://www.ademe.fr

Turkey - TUBITAK (Scientific and Technological Research Council of Turkey)
http://www.tubitak.gov.tr

Slovakia MESRS (Ministry of Education, Science, Research and Sport of the Slovak Republic)
https://www.minedu.sk/about-the-ministry/

Hungary – HGGI (The Energy Efficiency, Environment and Energy Information Agency)
http://www.mfgi.hu

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