



ANNEX I

Project Plan

H₂S sequestration into geothermal systems

Project ID: 11-04-003

Coordinator: Andri Stefánsson, University of Iceland

Start date: April 2012

Duration: 3 years / 36 months

Partners: Ingvi Gunnarsson, Reykjavik Energy
Sigurður H. Markússon, Landsvirkjun
Shuhei Ono, MIT, Bandaríkin

1 Project description

Hydrogen sulphide (H_2S) is among the major components in geothermal fluids, with concentrations ranging from a few ppb to levels of hundreds of ppm. Hydrogen sulphide is volatile and is commonly emitted into the atmosphere from geothermal power plants, causing potential environmental problems.

Several methods are employed in cleaning H_2S emissions including oxidation to form elemental sulphur or sulphuric acid. One method includes injection of H_2S into geothermal systems where it may be mineralized into sulphides including pyrite. Reykjavík Energy and Landsvirkjun, Iceland, are currently considering such an injection into the geothermal system at Hellisheidi, Námafjall and Krafla, where geothermal gas (CO_2 , H_2S , N_2 and H_2) will be separated in a gas abatement station and the H_2S ($+CO_2$) stream mixed at the surface with water prior to injection into the geothermal aquifer.

The focus of the project will be twofold. Firstly, laboratory experiments will be conducted to study the interaction of H_2S -rich water with basalt. Based on this, the reaction path, H_2S mineralization rate and possible H_2S oxidation rate will be studied. Secondly, using data obtained in the first part, data on fluid composition and secondary mineralogy from selected geothermal systems and geochemical modelling, the optimal conditions for H_2S sequestration into geothermal systems will be studied.

The project is divided into three major tasks: (1) H_2S oxidation under geothermal conditions, (2) H_2S -water-rock interaction and H_2S mineralization rate and (3) H_2S geochemistry and sequestration into geothermal systems. All project tasks are within WP 6.3 of the Georg project. In subtasks (1) and (2) experimental work will be carried out on H_2S oxidation rates and H_2S -water-rock interaction and in subtask (3) the data obtained together with data on fluid composition and alteration mineralogy at Hellisheidi and Krafla geothermal systems will be used to assess the feasibility of H_2S sequestration into geothermal systems. The subtasks are described below.

The work will be carried out by a graduate student at the M.Sc. level and a postdoctoral researcher at the University of Iceland. The student is Jóhann Gunnarsson Robin (M.Sc student, University of Iceland) and Nicole S. Keller (Postdoctoral Researcher, University of Iceland).

2 Work plan and time schedule:

The project involves three major tasks. These are

WP 6.3 – H_2S oxidation under geothermal conditions

This subtask will involve experimental work on the oxidation rate of H_2S during water-rock interaction under geothermal conditions (150-300°C) as a function of pH_2S and pH_2 . It is intended to perform experiments using a mixed-flow reactor on the interaction of H_2S -rich fluids with basalts. From the results, the stability and possible oxidation rates of H_2S may be assessed

WP 6.3 H_2S -water-rock interaction and H_2S mineralization rate

This subtask will involve experimental work on the interaction of H_2S -rich fluids with basalts as a function of pH_2S and pH_2 and under geothermal conditions (150-300°C). The experiments will be carried out in batch type reactors and the secondary mineralogy and fluid chemistry studied as a

function of time. From the results, the reaction path of H₂S-water-rock interaction and H₂S mineralization rates may be assessed. The experimental work will be complemented with geochemical simulations.

WP6.3 – H₂S geochemistry and sequestration into geothermal systems

This subtask aims at gathering data on fluid composition and secondary mineralogy in selected geothermal systems in Iceland, Krafla and Hellisheidi. Combined with the results on H₂S-water-rock interaction and H₂S oxidation rates obtained in the first two tasks of this study the geochemical behaviour and feasibility of H₂S sequestration into geothermal systems will be evaluated and assessed as possible.

Subtask	Start	Finish	Deliverable/Milestone
H ₂ S oxidation under geothermal conditions	01/04/12	01/04/14	Rate of H ₂ S oxidation
H ₂ S-water-rock interaction and H ₂ S mineralization rate	01/04/12	01/04/14	Rate of H ₂ S mineralization
H ₂ S geochemistry and sequestration into geothermal systems	01/04/12	01/04/15	Geochemical feasibility of H ₂ S sequestration into geothermal systems
Writing and introduction of the results	01/04/13	01/04/15	Introduction and publication of the results

3 Project Management

The participating group of institutions comprises University of Iceland (UI), MIT, USA (MIT), Reykjavik Energy (OR), and Landsvirkjun (LV). Access to sampling and instrumental facilities (UI, MIT), data on fluid composition (UI, OR, LV) and access to geothermal power plants and sites (OR, LV) is guaranteed. The research group consists of highly experienced scientists within the field of geothermal fluid geochemistry that is currently working on H₂S sequestration into geothermal systems at Hellisheidi and Námafjall. The Science Institute, University of Iceland (UI) head office will be responsible for the financial management of the project.

The main leaders of the research project are: from UI: Andri Stefansson, professor in geothermal geochemistry; from MIT: Shuhei Ono, professor of isotope and sulphur geochemistry; from OR: Ingvi Gunnarsson, scientist; from LV: Sigurdur H. Markússon, project manager. The group will have access to other scientists and technical help within their institutions. The students and postdoctoral scientists involved in the project include Jóhann Gunnarsson Robin (UI) and Nicole Keller (UI).

4 Budget overview

An over view of the budget for 2013 to 2015 is shown in Table 1.

Table 1. Budget overview

Cost item		Georg	Other financing	Total
2013	Salaries			7350
	Operational expenses			1500
	Travel expenses			0
	Total 2012/2013:	3125	5725	8850
2014	Salaries			7350
	Operational expenses			1500
	Travel expenses			350
	Total 2013/2014:	3280	5920	9200
2015	Salaries			7350
	Operational expenses			1500
	Travel expenses			350
	Total 2014/2015:	3275	5925	9200
Grand Total		9680	17570	27250

The project will involve one full time PhD student for 3 years (Georg Funding ca 75% of total cost) in addition to salary cost of applicants and a postdoctoral scientist at the University of Iceland. Other funding is mostly secure and includes Landsvirkjun and Rannis.