GEORG

GEOTHERMAL RESEARCH GROUP

FINAL REPORT

Sustainability Assessment Protocol for Geothermal Utilization

Project ID:	**10-03-012**
Coordinator:	Brynhildur Davíðsdóttir/University of Iceland
Start date:	4 / 2011
Duration:	4 years
Partners:	University of Iceland, ISOR, Orkustofnun, Reykjavik Energy

1 Project summary

Sustainable development calls for the use of sustainable energy systems. However the way in which a geothermal resource is utilized will ultimately determine whether or not it is sustainable. Sustainable utilization of geothermal energy means that it is produced and used in such a way that it is compatible with the well-being of current and future generations.

The objective of this project was to develop a Sustainability Assessment Protocol for Geothermal Utilization (GSAP), tailored especially for geothermal energy development projects. This protocol will be tested and implemented for projects in countries at various stages of development.

The project involved the following general steps:

A) Index pre-development; (1) defining the purpose of the index (2) specifying index dimensions (3) selecting subindices for the index (3) selecting the aggregation function (4) selecting weights.

B) Index development in iterative sessions; in 3 case studies the index was developed in Iceland, New Zealand and Kenya, in addition to an international session with fellows from the United Nations Geothermal Training programme. **Table 1, below, reviews the main milestones and deliverables of the project.**

Table 1. Subtasks, milestones and deliverables

Subtask	**Milestone**	**Deliverable (articles in thesis – other publications were also developed – see list below).**
Review of sustainability impacts of geothermal power	Identification of sustainability implications relevant for sustainability assessment	Journal article 1 in Renewable and Sustainable Energy Reviews
Choice of preliminary indicators and trial assessment at Krafla energy project	Krafla trial assessment	Internal document
Indicator framework development in a developed country	Development iterations in Iceland	
Review of indicators for suitability – derived from Delphi survey	First iteration of indicators; appropriate indicators chosen	Journal article 2 in Energy for Sustainable development
Indicator framework development in a developed country;	Development iterations in New Zealand	
Review of indicators for suitability – derived from Delphi survey	Second iteration of indicators; appropriate indicators chosen	Journal article 3 in Renewable and Sustainable Energy Reviews
Indicator framework development and trial assessment of energy project in a developing country	Development iterations in Kenya	
Review of indicators for suitability – derived from Delphi survey	Third iteration of indicators; Appropriate indicators chosen for a	Journal article 3 in Renewable and

	core and satellite indicators	Sustainable Energy Reviews
Indicator framework development with a multi-country stakeholder group	Development iterations with UNU Geothermal training programme fellows	
Review of indicators for suitability	Fourth iteration of indicators; Appropriate indicators chosen	Journal article 3 in Renewable and Sustainable Energy Reviews
Final Indicator set produced	Final set of goals and indicators delivered	Journal article 3 in Renewable and Sustainable Energy Reviews; Book chapter 1 delivered.
Identifying usefulness of sustainability indicators in a policy context – with a focus on geothermal power		Journal article 4 in Energy Policy.
Development of thesis	Thesis written	Thesis submitted.

Complications:

Originally the aim of the project was to have a development iteration in an emerging economy. However this proved to be beyond the budget available. In an attempt to make up for this, an indicator development session was organized with fellows of the United Nations Geothermal Training Programme.

In addition, the aim was to develop software based on project results. This effort is still on-going, and will take more time, effort an funds than originally realized which perhaps is a testament to how naïve us academics are to the effort required to develop commercial applications out of our research. To facilitate the continuation of this effort, the core-investigator will e.g. participate in Startup-energy workshops and apply for innovator grants in order to fund additional programmers to work on the software development which is beyond the scope of just one programmer.

Overall the main aim of the project, to develop a sustainability protocol for assessing the sustainability of the development of geothermal resources has been achieved and described in several academic publications.

The main achievements of the project are:

1. The development of a full set of sustainability goals and indicators to be used for assessing geothermal developments at different stages and in different situations (e.g. countries at different levels of economic development).
2. The development of a method that has been generalized (and already applied in different contexts), for developing sustainability indicators with stakeholder participation.
3. Five high-impact publications as well as numerous presentations at international conferences.

4. The development of a website illustrating the ever evolving indicators derived from this effort.

5. The delivery of a PhD thesis.

Interdisciplinary research as was conducted in this project tends to be very difficult to get funded, and it is clear that without support from GEORG, this research would not have been realized. We gratefully thank for the support received.

2 Project Management

The project was supervised by Icelandic sustainability and geothermal experts, in particular:
Dr. Brynhildur Davidsdóttir (University of Iceland), who was the principal supervisor of the project , responsible for coordination and financial management.
Dr. Guðni Axelsson (ÍSOR)
Dr. Kristin Vala Ragnarsdottur (University of Iceland)

Liasons with Orkustofnun and projects abroad:
Mr. Jónas Ketilsson (National Energy Authority), who facilitated project development abroad.
Dr. Sadiq Zarrouk (facilitator of geothermal certificate course, University of Auckland)
Katherine Luketina (liason from Waikato Regional Council)
Pacifica Ogola (liason to KenGen power company)

Liasons with Reykjavik Energy:
Dr. Einar Gunnlaugsson and Holmfridur Sigurðardóttir who facilitated indicator assessment in Iceland.

Project management and scientific excellence

Day to day management of the project was overseen by B. Davidsdottir, but R. Shortall was responsible for project implementation. Davidsdottir and Shortall met at a minimum 1x per month, but in most cases every two weeks to go over progress and address any issues.

To ensure scientific excellence, the core scientists involved in the project formally met twice every year, discussed project progress, challenges and how to deal with them. As the project progressed closer to completion meetings were held more frequently. Decisions regarding project development were made during these meetings.

In addition, meetings were held with e.g. stakeholders at Orkustofnun, Reykjavik Energy, KenGen and Contact Energy, to get stakeholder view on project development. Valuable input was received at these meetings and project participants got the opportunity to explain rationale for project development and direction.

No unforeseen issues were encountered in project management. The project largely progressed according to plan, with the exception that has already been explained above.

3 Student involvement

This research involved several students, but one in particular, **Ruth Shortall** who has handed in her PhD thesis for evaluation within the Department of Life and Environmental Sciences; Environment and Natural Resources at University of Iceland. Other students involved were masters and PhD students within Environment and Natural Resources that helped with pre-engagement workshops

and the Delphi surveys. They were: Eydís Mary Jónsdóttir, Maria Maack, Thorri Dagsson and Auður Ingimarsdóttir.

4 Publications and disseminations

Doctoral Dissertation

Shortall, R., 2015, *A Sustainability Assessment Framework for Geothermal Energy Developments*, PhD dissertation, University of Iceland, 316 pp.

Conference Papers

Shortall, R., Davidsdottir , B. & Axelsson, G. (2014). Creating a framework for assessing the sustainability of geothermal energy developments. 14th IAEE European Energy Conference. Rome: IAEE. http://www.iaee.org/en/publications/proceedingssearch.aspx

Book Chapters

Shortall, R., Axelsson, G. Davidsdottir, B. (In Press) Assessing the Sustainability of Geothermal Utilization. In J. Dewulf, S. De Meester, R. Alvarenga (Eds.) Sustainability Assessment of Renewables-Based Products: Methods and Case Studies. Wiley.

Peer-Reviewed Articles

Shortall, R., Davidsdottir, B. & Axelsson, G. (2015). Geothermal Energy for Sustainable Development: A Review of Sustainability Impacts and Assessment Frameworks. Renewable and Sustainable Energy Reviews, 44, 391–406.

Shortall, R., Davidsdottir, B. & Axelsson, G. (2015). A Sustainability Assessment Framework for Geothermal Energy Projects. Energy for Sustainable Developement, 27: 28–45.

Shortall, R., Davidsdottir, B. & Axelsson, G. A Sustainability Assessment Framework for Geothermal Energy Projects: Development in Iceland, New Zealand and Kenya. Renewable and Sustainable Energy Reviews. (Accepted – will be available soon online)

Shortall, R., Davidsdottir, B. & Axelsson, G. (In review). The Use of Indicators of Sustainable Development in Policy-Making Relating to Geothermal Energy Developments. Energy Policy.

Selected Conference Presentations

Presentation: Sustainability Assessment Framework for Geothermal Utilization
Presented (session chair) at International Association for Energy Economics Conference, LUISS University, Rome, Oct 2014. www.iaee2014europe.it/pages/Programme.html

Presentation: Sustainability Assessment Framework for Geothermal Utilization
Presented at International Society for Ecological Economics Conference Iceland, University of Iceland, Reykjavik, Aug 2014. http://isee2014.yourhost.is/programme/full-programme

Presentation: Geothermal Sustainability Assessment Framework
Presented at European Geosciences Union General Assembly 2014, International Conference Center Vienna, April 2014. http://www.egu2014.eu/programme/how_to_access_the_programme.html

Poster: A Sustainability Assessment Protocol for Geothermal Utilization
Presented at the 7th International Society for Industrial Ecology Biennial Conference, University of Ulsan, Korea, July 2013 http://isie2013.ulsan.ac.kr/sub/sub03_01.asp

5 Cost statement

Total direct project cost was 19 781 thousand ISK. Total funding from GEORG that has been received is ISK 15150 thousand, and the remainder ISK 3350 thousand is expected. The direct project costs not covered by GEORG were funded by the University of Iceland. In addition salaries of all participating professors/experts was funded by applicable institutions; University of Iceland, ISOR, Reykjavik Energy, Energy Authority, KenGen and University of Auckland. These costs are what we call indirect costs as they do not appear as direct cost statements.

The following costs constitute what we call direct costs.

1. Funding of a PhD student for the duration of the project (salary and salary related payments) in the amount of ISK: 14.781.340

2. Funding of indicator development workshops (assistants, housing and refreshments) in the amount of ISK: 100.971

3. Funding of website and Delphi survey (survey monkey software and domain) in the amount of ISK: 77.211

4. Funding of travels (airfare and accommodation – room and board for several months) for field work in Kenya and New Zealand and participation in conferences in the amount of ISK: 3.994.959

5. Funding of registration fees for conference participation and PhD student registration in the amount of ISK: 507.746

Total direct project cost ISK: 19.462.227

Total funding received: -15.150.000

Remaining funding from GEORG requested: 3.350.000

Please see the attached cost statement excel sheet for breakdown of each cost item per year.