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CREATING A FRAMEWORK FOR ASSESSING THE SUSTAINABILITY OF GEOTHERMAL ENERGY DEVELOPMENTS

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ABSTRACT

Geothermal projects have significant socio-economic and environmental impacts, both positive and negative. In order for energy developments to contribute to sustainable developments they must result in positive impacts in all dimensions. Sustainability assessments are valuable tools for policy- or decision-makers for making informed conclusions regarding policy effectiveness and progress toward sustainable development. Currently available assessment frameworks are not suited to assessing geothermal projects, thus a new, specialized framework is required. The methodology for developing a geothermal sustainability assessment framework is described in this paper.

1. INTRODUCTION

1.1 Geothermal Energy and Sustainable Development

Energy usage worldwide is increasing. Global energy demand is predicted to grow by more than one-third by 2035, with China, India and the Middle East accounting for 60% of the increase (International Energy Agency, 2012). The use of alternatives such as geothermal energy is set to increase, since the world has only a finite supply of fossil fuels. As well as this, in order to combat climate change and fulfill international agreements, low carbon energy sources such as geothermal energy are now being tapped on a larger scale. In 2008, geothermal energy represented around 0.1% of the global primary energy supply, but estimates predict that it could fulfill around 3% of global electricity demand, as well as 5% of global heating demand by 2050 (Intergovernmental Panel on Climate Change, 2012).

Whilst energy is necessary for economic growth and is also vital for sustainable development, energy development also has environmental and social impacts. Like any other energy source, geothermal energy developments can result in positive as well as negative socio-economic and environmental impacts (UNDP, 2002). For example, geothermal projects can result in socio-economic benefits particularly in developing countries and rural communities by improving infrastructure, or stimulating local economies. Such projects may also act as a good source of baseload power for a region's energy system. However, certain issues need to be addressed as many geothermal energy developments have negative environmental impacts, including air and water pollution, impacts on wildlife or landscapes.

The wide variety of available sustainability assessment frameworks highlights the ambiguity of the meaning of sustainable development for different user groups, cultures and regions (Pinter, Hardi , & Bartelmus, 2005). Given the unique issues associated with geothermal energy projects, a specialized assessment tool is required to ensure that geothermal projects will be properly guided into following best practices and result in positive impacts in all sustainability dimensions: environmental, social and economic.

1.2 Objective

The purpose of this paper is firstly to analyze the literature on means of developing sustainability indicators for energy developments. Secondly, the steps for developing an assessment framework for geothermal energy projects are described. The paper will illustrate the methods used in establishing an indicator framework in the Icelandic context and reflect on the learning process therein.

2. BACKGROUND

Sustainability assessment is a means of showing the progress of development projects towards or away from sustainability. Sustainability assessments are used for many different types of projects, including energy developments. Various assessment tools, many of which involve the use of sustainability indicators, exist from the national level, to the local level (Pinter, Hardi , & Bartelmus, 2005).

Such indicators must provide a holistic view of sustainability. Furthermore, as well as indicators, sustainability criteria or goals are also important for sustainability measurement. Such criteria and indicators should not be rigid but

take account of the local context as well as changes in opinions over time (Lim & Yang, 2009). In order to ensure this, broad stakeholder engagement is an essential part of the indicator development process (Fraser et al., 2006).

Assessment frameworks range from overarching guidelines, such as the BellagioSTAMP principles to specific sustainability indicator development approaches, such as the Pressure-State-Response (PSR)/ Driving Force-State-Response (DSR) framework or thematic approach (Shortall, Davidsdottir, & Axelsson, 2014). The International Institute of Sustainable Development's BellagioSTAMP principles identify desirable common patterns in sustainable development-related assessments.

The most widely used frameworks, especially for national indicator sets, are theme-based. In such frameworks, indicators are grouped according to sustainability issue-areas or themes, which are chosen based on their policy-relevance. Theme-based indicator sets allow decision-makers to link indicators to policies or targets (United Nations, 2007).

2.1 Sustainability Indicators and Energy

Several indicator frameworks exist to measure sustainable development in the context of energy developments. In 2005 the International Atomic Energy Agency (IAEA) in collaboration with several other bodies published guidelines and methodologies for a set of energy indicators for sustainable development (EISDs), emphasizing national self-examination (International Atomic Energy Agency (IAEA), 2005). The EISDs were created to provide policy-makers with information about their country´s energy sustainability. They are intended to provide an overall picture of the effects of energy use on human health, society and the environment and thus help in making decisions relating to choices of energy sources, fuels and energy policies and plans.

Athough not based on indicators as such, the International Hydropower Association published an assessment tool for hydropower projects in 2006 (International Hydropower Association, 2006). The IHA-SAP assesses the strategic basis for a proposed hydropower project including demonstrated need, options assessment and conformity with regional and national policies and plans; the preparation stage of a new hydropower project during which investigations, planning and design are undertaken; the implementation stage of the new hydropower project during which preparations, construction, and other management plans and commitments are undertaken and the operation of a hydropower facility with focus on continuous improvement (International Hydropower Association, 2008).

The Gold Standard Foundation provides a sustainability assessment framework for new renewable energy or end-use efficiency improvement projects. Projects must go through a number of steps, including a sustainability assessment, to become accredited with the Gold Standard. These steps include a Stakeholder Consultation Process and development of a Sustainability Monitoring Plan, which uses indicators of sustainable development relevant to the project. The aim of the Gold Standard is to promote investments in energy technologies and energy management techniques that mitigate climate change, promote (local) sustainable development and are directed towards a transition to non-fossil energy systems (The Gold Standard Foundation, 2012).

The Commission for Sustainable Development (CSD) has produced guidelines for the creation of general sustainability indicators, including energy indicators, at the national level (United Nations, 2007). In the EU, these indicators have been used in creating an indicator framework, which includes the theme of Climate Change and Energy, to monitor implementation of the main EU directives and other policy documents targeting sustainable energy development (European Commission, 2005).

The World Energy Council has also developed the Energy Sustainability Index, which looks at the impact of energy policies of different countries and ranks them in terms energy sustainability based on three core dimensions—energy security, social equity, and environmental impact mitigation. The index uses two types of indicator, energy performance indicators, covering supply and demand, energy affordability and access; and contextual indicators, covering broader issues such as living standards and the economic and political conditions (World Energy Council, 2011).

Other renewable energy associations have attempted to improve sustainability assessment for energy projects. The World Wind Energy Association (WWEA) have developed Sustainability and Due Diligence Guidelines (WWEA, 2005), for the assessment of new wind projects, similar to those developed by the International Hydropower Association in their Sustainability Assessment Protocol. These guidelines do not cover the operation stage of a wind energy project and do not provide a set of comprehensive indicators. The WWF Sustainability Standards for Bioenergy (WWF, 2006) does not provide any indicators but does highlight sustainability issues in bioenergy and offer recommendations for its sustainable use. UN-Energy has also published a report with a similar focus entitled Sustainable Bioenergy: A Framework for Decision-Makers (UN-Energy, 2007). However no indicators exist for assessing the sustainability of geothermal power.

3. DEVELOPMENT METHOD

3.1 Overview

A sustainability assessment framework consists of a set of sustainability goals and indicators that allow monitoring of geothermal projects during their entire life cycle. This section describes the methods used to carry out the first iteration of the indicator development process in the Icelandic context.

The goals and indicators in this framework were developed using an iterative process for thematic indicator development (Davidsdottir, 2007), with the intention of carrying out further iterations in a number of different countries. One iteration consists of choosing sustainability goals and indicators guided by stakeholder input; calculating the indicators in a trial assessment of an operational geothermal project and finally evaluating the indicators for suitability. The purpose of the iterative approach is to allow the progressive refinement of the indicators following each iteration.

Guiding principles known as the Bellagio STAMP were incorporated into the entire development process. A literature review of the impacts of geothermal energy projects on sustainable development (Shortall, Davidsdottir, & Axelsson, 2014) was carried out in order to determine the boundaries of the system that the assessment framework was intended for. Following the literature review, an initial, small group of stakeholders was gathered to critically review and a set of possible sustainability goals and indicators that were derived from the literature review. This set of goals and indicators provided a starting point for which further stakeholder input would be sought later in the process.

Stakeholder engagement methods were used at various points in the first iteration of the development process, from setting sustainability goals to the choosing of sustainability indicators (Figure 1). The Icelandic stakeholder engagement process consisted of a pre-engagement "World Café" workshop and a Delphi survey. Each component of the development process is described in detail below.

3.2 Iterative Process

3.2.1 General Description of Method

An iterative approach (Davidsdottir et al, 2007) to indicator development was chosen because it lends itself well to the trialing of the indicator set in several countries, allowing refinement of the indicators after each iteration. This was also intended to reduce country or stakeholder biases, which could arise if stakeholders in only one country were consulted. The method (Figure 1) consists of the following steps, which may be repeated as necessary, in an iterative fashion.

1. Definition of sustainability goals
2. Specification of dimensions
3. Selection of themes and sub-themes
4. Selection of indicators
5. Selection of aggregation function
6. Selection and calculation of weights (if needed)
7. Calculation of indicators
8. Reporting of indicators

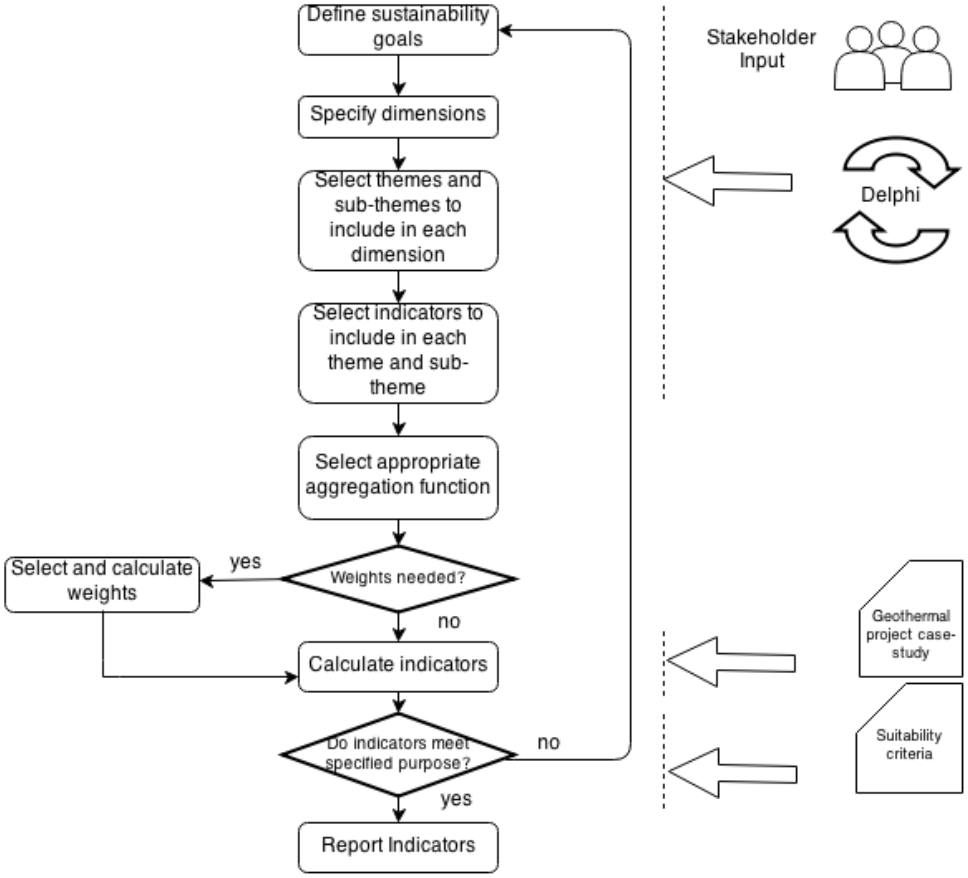

Figure 1: Iterative Method of Indicator Development modified from Davidsdottir et al., 2007

3.2.2 Implementation of Method

The first four steps of the iterative process (Figure 1) required stakeholder input, which in this case was obtained through pre-engagement "World Café" workshops (Section 3.4.1) and the Delphi technique (Section 3.4.2). These methods are explained in detail in the sections below.

During the first four steps, the facilitators used personal expert judgment and stakeholder input to determine best and most suitable indicators, using as a guidance of the suitability criteria shown below. Once indicators were chosen, they were then calculated in a trial assessment on an existing geothermal energy project. By carrying out trial calculations, issues such as lack of data, the suitability of reference values or responsiveness of the indicator were identified. The indicators were again evaluated for their suitability to their purpose against the following suitability criteria:

- Clear and unambiguous and able to show trends over time;
- Responsive to changes in the environment and related human activities;
- Relevant to assessing sustainable development progress;
- Provide a basis for international comparisons;
- Have a threshold or reference value against which to compare it so that users are able to assess the significance of the values associated with it.
- Theoretically well founded in technical and scientific terms
- Based on international standards and international consensus about its validity to the extent possible
- Lend itself to being linked to economic models, forecasting and information systems
- Use data which is readily available or made available at a reasonable cost/benefit ratio;
- Use data which is updated regularly or adequately documented and of known quality

3.3 Overarching Guidelines

3.3.1 General Description of Method

To guide the process of developing a sustainability assessment framework, the principles of the Bellagio group, known as the Bellagio STAMP (Box 1) were used as overarching guidelines. The International Institute of Sustainable Development's Bellagio STAMP principles are a set of guiding principles designed to be applied when improving sustainability assessment systems and have been widely adopted (IISD, 1997).

The principles are intended to serve as guidelines for the entire assessment process including the choice and design of indicators, their interpretation and communication of the result. While the Bellagio STAMP principles identify desirable common patterns in sustainable development-related assessments, they do not offer a detailed methodological approach required for the development of an indicator set.

1. Guiding Vision
Assessing progress towards sustainable development is guided by the goal to deliver well– being within the capacity of the biosphere to sustain it for future generations.

2. Essential Considerations
Sustainability Assessments consider:
- The underlying social, economic and environmental system as a whole and the interactions among its components.
- The adequacy of governance mechanisms.
- Dynamics of current trends and drivers of change and their interactions.
- Risks, uncertainties, and activities that can have an impact across boundaries.
- Implications for decision-making, including trade–offs and synergies.

3. Adequate Scope
Sustainability Assessments adopt:
- Appropriate time horizon to capture both short and long–term effects of current policy decisions and human activities.
- Geographical scope ranging from local to global.

4. Framework and Indicators
Sustainability Assessments are based on:
- A conceptual framework that identifies the domains that core indicators have to cover.
- The most recent and reliable data, projections and models to infer trends and build scenarios.
- Standardized measurement methods, wherever possible, in the interest of comparability.
- Comparison of indicator values with targets and benchmarks, where possible.

5. Transparency
The assessment of progress towards sustainable development:
- Ensures the data, indicators and results of the assessment are accessible to the public.
- Explains the choices, assumptions and uncertainties determining the results of the assessment.
- Discloses data sources and methods.
- Discloses all sources of funding and potential conflicts of interest.

6. Effective Communication
In the interest of effective communication, to attract the broadest possible audience and to minimize the risk of misuse, Sustainability Assessments:
- Use clear and plain language.
- Present information in a fair and objective way, that helps to build trust.
- Use innovative visual tools and graphics to aid interpretation and tell a story.
- Make data available in as much detail as reliable and practical.

7. Broad Participation
To strengthen their legitimacy and relevance, sustainability assessments should:
- Find appropriate ways to reflect the views of the public, while providing active leadership.
- Engage early on with users of the assessment so that it best fits their needs.

8. Continuity and Capacity
Assessments of progress towards sustainable development require:
- Repeated measurement.
- Responsiveness to change.
- Investment to develop and maintain adequate capacity.
- Continuous learning and improvement.

Box 1: List of Bellagio STAMP principles

3.3.2 Implementation of Method

Below is an explanation of the development process' adherence to the Bellagio principles (Box 1).

1. Guiding Vision

A set of sustainability goals were defined by the stakeholder group. The goals are intended to serve as an overall set of guiding principles for the assessment of geothermal projects.

2. Essential Considerations

All sustainability dimensions (social, economic, environmental) were covered by the chosen goals and indicators, following an extensive literature review and interviews with experts regarding the social, economic and environmental impacts of geothermal projects. Detailed studies of individual power projects provided a good insight into the underlying systems and interactions within them. The governance of monitoring bodies is considered, in that the quality of environmental monitoring is assessed. Further assessment of the monitoring bodies would be necessary to provide greater insight into governance mechanisms, but this is somewhat outside of the scope of the assessment framework and would also be time consuming and costly.

An extensive literature review and the input of experts regarding the social, economic and environmental impacts of geothermal projects helped to identify the dynamics of current trends and drivers of change and their interactions as well as risks and uncertainties. Furthermore, the detailed studies of individual power projects provide a good insight into the underlying systems and interactions within them.

3. Adequate Scope

The assessment framework is intended to be used in such a way as to build up time series data for the set of indicators. Qualitative information alongside the indicators can provide answers to questions regarding the short term implications of policy decisions. The indicators that were developed cover issues at local and national level. For instance, indicators could measure greenhouse gas emissions, which have a global impact, or resettlement of communities, which is a local issue.

4. Framework and Indicators

The sustainability goals in this framework provide a clear picture of the key issues that must be covered by the sustainability indicators. Indicators that were chosen by the stakeholders were evaluated for suitability against a set of criteria outlined in Section 3.2.2. According to these criteria, only indicators for which recognized measurement standards exist are deemed suitable for use. Each indicator has a corresponding reference value, where it is available.

5. Transparency

It is intended that the results of any sustainability assessment carried out using the framework would be made available to the public online. Each sustainability assessment carried out in this study is reported along with supplementary information for each indicator, which explains any assumptions or uncertainties. All data sources and methods are disclosed alongside any indicators that are reported.

6. Effective Communication

During the indicator development process, stakeholders with varied backgrounds were consulted. Any indicators that were unclear to the majority of people were removed, to ensure that the broadest audience would understand them.

Each indicator has a benchmark that is, as much as possible, international recognized, which means that subjective opinions of assessors are not required when calculating indicators. Indicators are reported alongside supplementary information, giving a background story for each issue. This allows the assessor to report on positive steps that may be underway to improve on indicators that are currently scoring negatively. Indicators are presented in graphic format where possible and supplementary information in the form of photos or graphs is also provided where appropriate.

7. Broad Participation

The World Café and Delphi technique were chosen as stakeholder engagement methods. Stakeholders have been consulted since the very beginning of the process. Stakeholders include both experts and grassroots representatives with local knowledge.

8. Continuity and Capacity

The assessment framework is intended for repeated use in assessing projects, in order to build up time series data to show progress towards or away from sustainability over time. Indicators have been chosen based on their responsiveness. The iterative indicator development process (Section 3.2) implicitly requires regular reassessment of the suitability of the framework to its purpose, due to the dynamic nature of sustainable development. To this end, further ongoing work will be required to continuously assess the relevant sustainability issues, consult with stakeholders and update the framework when necessary.

3.4 Stakeholder Engagement

Stakeholder engagement is the process used by an organization to engage relevant parties for a clear purpose to achieve accepted outcomes. It is now also seen as a type of accountability mechanism. Good stakeholder engagement should clearly define the scope, have an agreed decision making process, focus on issues material to the stakeholders, create opportunities for dialogue, be transparent, have a process appropriate to the stakeholders engaged, be timely, flexible and responsive (UK Institute of Social and Ethical Accountability, 2011). Stakeholder engagement techniques have been used to address sustainability issues in diverse sectors, including mining (Azapagic, 2004), forestry (Sharma & Henriques, 2005), transportation (Mihyeon Jeon & Amekudzi, 2005), aviation (Amaeshi & Crane, 2006) and environmental management (Reed M. S., 2008).

Stakeholders are generally defined as persons or groups who are directly or indirectly affected by a development project, as well as those who may have interests in a project and/or the ability to influence its outcome, either positively or negatively (International Finance Corporation, 2007). Another definition of stakeholders is as follows:

"Stakeholders are not just members of communities or non-governmental organisations. They are those individuals, groups of individuals or organisations that affect and/or could be affected by an organisation's activities, products or services and associated performance with regard to the issues to be addressed by the engagement." (UK Institute of Social and Ethical Accountability, 2011)

Sustainability is an interdisciplinary field, which requires knowledge of the social, economic and environmental impacts of a development. Yet often stakeholders from different fields have little interaction with each other, or little knowledge of other fields. In geothermal energy development, this is also the case and no framework for the assessment of geothermal projects in the context of sustainability has been developed to date. The wide-ranging topic of geothermal sustainability therefore requires the combined expert input of a varied group of experts, obtained by using an appropriate stakeholder engagement technique.

For a geothermal project, stakeholders may include locally affected communities or individuals and their formal and informal representatives, the geothermal industry, national or local government authorities, politicians, religious leaders, civil society organizations and groups with special interests, the academic community, or other businesses, such as suppliers or those that may use the geothermal power. For example, the risk of induced seismicity can become a real issue. In this regard, the concerned or affected members of the public would need to be included when gathering a group of stakeholders.

The interest that each of these different individuals or groups has in a geothermal project tends to vary. For example, some people would be directly affected by the potential environmental or social impacts of a project. Others may live far away or in another country altogether, but may still wish to communicate their concerns or suggestions regarding the project. Some may have great influence over the project, such as government regulators, political or religious leader or community activists. Some may have specialized knowledge that can be helpful to the project. Others may represent "voiceless" things or groups, such as ecosystems, future generations or indigenous peoples (International Finance Corporation, 2007).

A stakeholder mapping exercise was carried out before the engagement process to identify individuals or organizations that would potentially be impacted by or have an interest or impact in the sustainable operation of geothermal projects. Stakeholders were chosen based on a number of characteristics, as recommended by the Australian government stakeholder engagement practitioner handbook (Australian Government, 2008)**:**

Responsibility: people to whom a hypothetical geothermal development would have responsibility to, such as the local community or general public, community representatives or NGOs, environmental organisations, local businesses, future generations.

Proximity: those people who would have most interaction with a hypothetical geothermal project, such as: the geothermal industry itself, researchers, governments, local communities.

Dependency: those who depend directly or indirectly on a geothermal project, such as: power companies, financiers, potential users of the energy, the local community, local businesses.

Representation: those people that represent a constituency impacted by geothermal projects, such as: NGOs representing the environment or "voiceless" things such as landscape, geothermal features, delicate ecosystems, forests and so on; indigenous peoples representatives, other community group representatives such as local authorities, trade unions, or local leaders.

Policy and Strategic intent: those people to whom geothermal projects (or companies) address their policy or value statements, such as: NGOs, activists, community groups, financiers.

3.4.1 World Café Technique

The World Café is described as a powerful social technology for engaging people in conversations that matter. The World Café approach is based on the understanding that conversation is the core process that drives personal, business, and organizational life (Brown & Isaacs, 2005).

The World Café method has the advantage of being flexible and easily adapted to suit the needs of the group. Generally, participants meet in a Café style setting, seated at tables where they hold conversations exploring a particular question, moving between tables at prescribed time intervals (Brown & Isaacs, 2005). In this way, the method allows diverse information to be gathered as well as the sharing of ideas and insight. Participants learn collectively, allowing the group to find solutions to the given question, based on their new insights (Brown & Isaacs, 2005).

The disadvantages of using the World Café technique, as for any type of stakeholder group meeting (Thompson, 2007), include the potential for conflict in a group setting, due to differences in opinion of stakeholders. The success of the World Café will depend on the participants present. Furthermore, the cost of organizing and facilitating the workshop may be prohibitive and participants may need to travel long distances to reach the location.

Few studies using the World Café method exist in the literature, however the method has, for example, been applied in social science research in order to help develop a culture of enquiry among practitioners in social service (Fouché & Light, 2011). Further examples of its use appear in fields such as nursing (Brooma, Brady, Kecskes, & Kildea, 2013).

3.4.2 Delphi Technique

The Delphi technique is used for policy, decision, and goal setting, when consensus is required from a group of stakeholders with widely divergent opinions or backgrounds (Lim & Yang, 2009). The technique uses a structured format to elicit opinions and potential consensus among a group of stakeholders or experts in their field. As a result, the method has become increasingly popular and widely used in technology, education and other fields (Lim & Yang, 2009).

The Delphi technique also suits applications with the characteristics listed below (Thompson, 2007).

- The problem does not lend itself to precise analytical techniques but can benefit from subjective judgments on a collective basis.
- The individuals needed to contribute to the examination of a broad or complex problem have no history of adequate communication and may come from diverse backgrounds and have diverse experience or expertise.
- More participants are needed than can effectively interact in a face-to-face exchange.
- Time and cost make frequent group meetings impossible.
- Face-to-face meetings can be made more effective by using a supplementary group communication technique.
- Serious disagreements exist among individuals or the issues are so politically sensitive that the communication process must be refereed and/or anonymity assured.
- The diversity of the participants must be preserved to assure validity of the results, i.e., avoid domination of the process by high numbers of people or by strong personalities (the "bandwagon effect").

The Delphi technique has been used successfully in developing indicators of sustainability in diverse fields such as road infrastructure projects (Lim & Yang, 2009), ecotourism (Barzekar, 2011) and communities (Hai, Hai, Khoa, & Hens, 2009). The main steps taken by the facilitators in the Delphi technique (Linstone & Turoff, 2002; Barzekar, 2011; Lim & Yang, 2009) are as follows:

1. Assemble/choose participants.

2. Present list of goals and indicators to be rated and added to by the group.

3. Rate and comment on each item.

4. Record each participant's ratings and modify the list based on ratings or comments.

5. Return the statistics to all participants.

6. Rate and comment on items again.

7. Repeat the process (step 3-6)

8. Select the highest rated goals and indicators (those with the highest mean score) to use in final assessment framework

3.4.3 Implementation of Methods

As per the recommendations of the Bellagio STAMP (IISD, 2012), a diverse group of stakeholders was selected to contribute to the process of developing the sustainability assessment framework. The group consisted of participants from diverse backgrounds, from government to industry to NGOs.

Stakeholder engagement is an integral part of the iterative indicator development process. Stakeholders have an influence through their comments during the pre-engagement "World Café" workshop and the Delphi process, from the choice of sustainability goals and indicators (Figure 1). Their input also defines the scope of the assessment itself by identifying the most important sustainability issues that will be considered.

The World Café workshop technique was used as a starting point or pre-engagement method in Iceland, in order to gather stakeholder input on potential sustainability goals and indicators for geothermal energy projects, before holding a full-fledged Delphi process. Following the World Café in Iceland, the following steps were taken to refine the indicator set:

- Discard indicators that were voted to have low or no relevance (attempt to have less indicators overall)
- Discard indicators that are hard to understand, even with supplementary information
- Include new indicator suggestions, if they fulfill the criteria for good indicators.

The Delphi technique was chosen as the main stakeholder engagement method as it was considered the best technique to use given the circumstances. Firstly, around 70 stakeholders were invited to take part in the Icelandic Delphi. This would have been too large a group to facilitate the effective extraction of opinions in a short time frame.

It would also have been difficult and costly to arrange repeated face-to-face meetings with the number of people involved. Even though a pre-engagement World Café workshop was organized, it was not possible to arrange similar meetings for all three Delphi rounds. However the Delphi technique was presented and explained in the pre-engagement workshop, leading to a great understanding of the process by participants.

Furthermore, the Icelandic stakeholder group consisted of members of government and other institutions with differing views. Since Iceland is a small community, the Delphi technique was chosen as a way to circumvent political differences that could arise in a group setting. Twenty-three stakeholders attended the pre-engagement "World Café" workshop in Reykjavik and the Delphi had a good response (see Table 1 below).

	Invited	**Response Rate**	**Responded (Partial / Complete)**
Round 1	70	47%	33 (11/22)
Round 2	70	23%	16 (3/13)
Round 3	70	16%	11 (2/9)

Table 1: Response rates for Delphi rounds in Iceland

The list of goals and indicators from the pre-engagement workshop were presented to participants using online survey tools. Scores were allocated by participants on a scale of 1-5, according to the perceived relevance of the sustainability goal or indicator. Levels of agreement and consensus among stakeholders for individual goals and indicators differed, however participants agreed on a final list of ten sustainability goals (Table 2) and twenty-four sustainability indicators. This is not intended to be a detailed description of the results, but serves to illustrate how the method was used.

Goal	**Score after Round 2**	**Score after Round 3**
GOAL 1 - Renewability	4.72	4.55
GOAL 2 - Water Resource Usage	4.68	4.09
GOAL 3- Environmental Management	4.65	4.45
GOAL 4 – Efficiency	4.18	3.64
GOAL 5 - Economic Management & Profitability	4.12	4.09

GOAL 6 - Energy Equity	4.04	3.64
GOAL 7 - Energy Security & Reliability	4.12	4.00
GOAL 8 - Community Responsibility	4.5	4.00
GOAL 9 - Research and Innovation	4.4	4.18
GOAL 10 - Dissemination of Knowledge	4.4	4.27

Table 2: Sustainability Goals

The five highest scoring indicators after three Delphi rounds are shown in Table 3. These are the indicators that participants considered most relevant to geothermal sustainability.

Indicator	**Mean Score**
Resource reserve capacity ratio of the geothermal resource	4.22
Utilization efficiency	4.22
Estimated productive lifetime of geothermal resource	4.56
Water quality	4.67
Air quality	4.78

Table 3: Highest scoring indicators after three Delphi rounds

The five lowest scoring indicators are shown in Table 4 below. These are the indicators that participants considered least relevant to geothermal sustainability. These five indicators all received the same low score of 3.33.

Indicator	**Mean Score**
Average Income Levels in Project-Affected Communities	3.33
EBITA ratio per project	3.33
Expenditure on heat and electricity as a percentage of household income	3.33
Percentage of energy company expenditure given to R&D per year	3.33
Percentage of renewables in total energy supply nationally	3.33

Table 4: Lowest scoring indicators after three Delphi rounds

4. DISCUSSION AND CONCLUSIONS

The meaning of sustainable development depends on a group or society's opinions and values regarding issues that are important to them. These opinions and values will determine which goals should be pursued and what should be measured (Meadows, 1998; Shields, Šolar, & Martin, 2002). Sustainability is also a shifting, evolving and subjective concept (Mog, 2004). This means we must constantly reassess the definition of sustainable development for a given context and adjust how we measure it when necessary.

Indicators of sustainability are only likely to be effective if they provide users and the public with meaningful information they can relate to. Users like policy- and decision-makers will be in a better position to set attainable policy goals if they understand environment-society interactions well, and this is all the more likely to happen if indicators are derived from a participatory process, as they will reflect the objectives and values of the public (Shields, Šolar, & Martin, 2002). Whilst developing a sustainability assessment framework for geothermal energy projects, the goals and most important sustainability issues measured by the indicators chosen reflect the subjective opinions of the group of stakeholders, even though precise, analytical techniques may be used to calculate the indicators once they are chosen. The very act of choosing sustainability goals and indicators can be an adaptive learning process for all parties involved (Reed, Fraser, & Dougill , 2006).

In order to be influential, consensus must exist among policy actors that the indicators are legitimate, credible and salient (Cash et al., 2003). This means that the indicators must answer questions that are relevant to the policy actor, as well as providing a scientifically plausible and technically sound assessment. To be legitimate, the indicators must be perceived to be developed through a politicaly, socially and ethically acceptable procedure. The list of indicators produced in this first iteration has been critically evaluated through a stakeholder engagement process in Iceland and also against a set of theoretical criteria to determine their suitability to their purpose. The results of the Delphi show

the highest priority goals among Icelandic stakeholders to be resource renewability and environmental management, whereas the goals with lowest priority are those of energy efficiency and energy equity.

Based on this first iteration of the indicator development process in Iceland, it is clear that inevitably, each geothermal energy project will face unique sustainability challenges, due to the differing environmental and socio-economic setting in which it is found. By carrying out further iterations of the indicator development process, we suggest that the final assessment framework produced will be more likely to take into account the diverse and unique circumstances surrounding geothermal developments. Further iterations of the indicator development process will also produce better, more refined indicators and further study may reveal issues that may have been neglected previously.

4.1 Conclusion

This paper describes the development of a sustainability assessment framework for geothermal energy projects, using the input of stakeholder groups and internationally recognized methods. The lessons learned from this iteration in the Icelandic context will be applied to further iterations in New Zealand and Kenya. Following these iterations, more insights on the assessment framework will become apparent and allow for a more comprehensive evaluation of its suitability. We suggest that these indicators have the potential to inform policy decisions through either conceptual or instrumental use.

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