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Development of a sustainability assessment framework for geothermal energy projects

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ABSTRACT

With the increasing global energy consumption, geothermal energy usage is set to increase in the future. Geothermal developments may result in both positive and negative environmental and socio-economic impacts. Sustainability assessment tools are useful to decision-makers in showing the progress of energy developments towards sustainability. Due to the unique characteristics of geothermal energy projects, a customized framework for assessing their sustainability is required. This paper presents the development of an appropriate indicator assessment framework, through a case-study in Iceland. The results reveal Icelandic stakeholder views on sustainability issues relating to geothermal energy projects. Environmental and economic indicators were regarded as more relevant than social or institutional indicators. A Delphi survey revealed that the priority sustainability goals for stakeholders were related to renewability, water resource usage and environmental management. The top five indicator choices were related to resource reserve capacity, utilization efficiency, estimated productive lifetime of the geothermal resource and air and water quality.

Introduction

Geothermal energy and sustainable development

Energy usage worldwide is increasing. It has been predicted that global energy will increase by over one-third by 2035 and fossil fuels are still dominating the global energy mix (International Energy Agency, 2012), but the use of alternatives such as geothermal energy is set to increase, since the world has only a finite supply of fossil fuels. Furthermore, 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).

While energy is needed for economic growth and 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. They can also act as a good source of base-load power for a region's energy system. However, certain issues need to be addressed as many geothermal energy developments result in negative social or environmental impacts (Shortall et al., 2015).

The wide variety of available sustainability assessment frameworks in existence today highlights the ambiguity surrounding the meaning of sustainability for different user groups, cultures and regions or organizations. As shown by the county pilot studies undertaken using the CSD indicator set, for example, customized indicator sets were often developed to suit local conditions (Pinter et al., 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.

Objective

The purpose of this paper is to

1. Review the literature on means of developing sustainability indicators for energy developments.
2. Describe the steps needed to develop an assessment framework for geothermal energy projects, with highly organized participatory processes, through a case-study in Iceland.

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The paper will illustrate the methods used in establishing a stakeholder-qualified indicator framework in the Icelandic context and reflect on the learning process therein. The framework may then be applied in Iceland and elsewhere. The paper concludes with recommendations for the development process of the assessment framework. The Icelandic case study presented in this paper represents the first iteration of the indicator development process. Further iterations are to be carried out in Kenya and New Zealand to further refine the indicator set and reveal its suitability in these regions.

Background

Many international organizations, such as the United Nations Commission for Sustainable Development (CSD) (Pinfield, 1996), have made case that indicators are needed to guide countries or regions towards sustainable energy development and the necessity of developing sustainability indicators is clearly set out in Agenda 21. There have also been further calls in the literature for the use of sustainability indicators as a means to measure sustainability (Bell and Morse, 2008). Sustainability assessment is a means of showing if development projects contribute to a progress 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 et al., 2005). Such indicators must provide a holistic view of sustainability, and thereby include all sustainability dimensions. 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 and 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 Bellagio STAMP principles to specific sustainability indicator development approaches, such as the Pressure-State-Response (PSR)/Driving Force-State-Response (DSR) framework or the theme based approach (Shortall et al., 2015). The most widely used development approach, especially for national indicator sets, is 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). While the various impacts of geothermal projects have been discussed in depth by the authors (Shortall et al., 2015), some examples of unsustainably management of geothermal clearly illustrate the need for better sustainability monitoring systems.

The Hellisheidi geothermal power plant is the largest combined heat and power plant in Iceland. Turbines were brought online in a series of phases between 2006 and 2011. Decisions on how large the Hellisheidi Power Plant should be were made before enough steam had been proved by drilling. No production data was available and therefore the decisions were based on the initial state of the reservoir alone. By 2040, the draw down and cooling of the geothermal field will most likely render production uneconomic, leaving the resource with a total productive lifetime of only 34 years. A total of 66 production wells will need to be brought online by the end of 2040 (Gunnarsson et al., 2011). In the Icelandic context, this is at odds with the acceptable resource lifetime of at least 100–300 years (National Energy Authority, 2010). It is predicted that pressure will return in 60–80 years if all production is terminated by 2040, but temperature could take up to 1000 years to recover. This could have been avoided by using more appropriate resource management strategies (Gunnarsson et al., 2011).

A further example of unsustainable management can be seen with the Wairakei power plant in New Zealand where separated geothermal water and cooling water are discharged into the section of the Waikato river between Lake Taupo and Ohaaki Bridge (Ray, 2001). The arsenic level in the Waikato River has more than doubled since the station opened in the 1950s and now exceeds drinking water standards (Waikato Regional Council, 2012).

In Iceland, assessment of the impacts of geothermal projects on sustainable development is mainly limited to the pre-development phase. An energy Master Plan has been proposed in Iceland that ranks the desirability of potential energy projects according to a number of environmental, social and economic criteria. Environmental impact assessments are done for proposed geothermal projects, as for any major development, yet the outcome of these assessments can vary significantly. While routine environmental monitoring is carried out by various agencies nationally, no specific requirements to monitor the environmental, social and economic impacts of geothermal projects are currently specified in legislation for the sustainable management of geothermal projects.

Sustainability indicators and energy

As has been illustrated (Shortall et al., 2015), the impacts of geothermal energy developments have significant implications for sustainable development, and require specific monitoring tools to ensure the impacts are managed in a sustainable manner. Several indicator frameworks exist to measure sustainable development in the context of energy developments. While they are not all suited to assessing geothermal projects in themselves, they can be used as guidelines to further the development of a framework to assess geothermal energy developments. These frameworks and the methods used to create them are described below. For a more in-depth discussion of such frameworks, please refer to the author's previous work.

International atomic energy agency energy indicators of sustainable development

In 2005 the International Atomic Energy Agency (IAEA) created a set of energy indicators for sustainable development (EISDs) (International Atomic Energy Agency (IAEA), 2005) 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.

The EISD indicators are intended for use at a national level and cover many different types of energy usage. For this reason, they are unsuited to assessing individual geothermal projects, but their conceptual framework provides some basis for the design of a framework for geothermal energy assessment in particular.

International hydropower association sustainability assessment protocol

The International Hydropower Association has developed a sustainability assessment tool for hydropower projects (IHA-SAP) (International Hydropower Association, 2006). Although not based on indicators as such, the IHA-SAP assesses various strategic and managerial aspects of proposed or operational hydropower projects (International Hydropower Association, 2008).

Gold Standard foundation indicators for carbon projects and credits

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 (The Gold Standard Foundation, 2012). The Gold Standard is an accreditation system for greenhouse gas (carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) only) reduction projects, whose eligibility is evaluated under a number of criteria such as the project scale or location (The Gold Standard Foundation, 2012). The Gold Standard indicators are general and therefore not specifically tailored to geothermal projects. As a result,