Available online at www.sciencedirect.com
SCIENCE DIRECT®
PERGAMON
Geothermics 32 (2003) 451–461
GEOTHERMICS
www.elsevier.com/locate/geothermics

Environmental aspects of geothermal energy utilization

Hrefna Kristmannsdóttir*[,a], Halldór Ármannsson[b]

[a]*University of Akureyri, Faculty of Natural Resource Sciences, Solborg, 600 Akureyri, Iceland*
[b]*Iceland Geosurvey, Grensásvegus 9, 108 Reykjavík, Iceland*

Received 2 April 2003; accepted 19 May 2003

Abstract

Geothermal energy is a clean and sustainable energy source, but its development still has some impact on the environment. The positive and negative aspects of this environmental impact have to be considered prior to any decision to develop a geothermal field, as well as possible mitigation measures. The main environmental effects of geothermal development are related to surface disturbances, the physical effects of fluid withdrawal, heat effects and discharge of chemicals. All these factors will affect the biological environment as well. As with all industrial activities, there are also some social and economic effects. In Iceland an enforcement program was launched in the early 1990s to study the environmental impact of developing geothermal resources. Work began on tackling the environmental issues relative to the high-temperature geothermal fields under development in Iceland. Research was conducted on microearthquake activity in geothermal areas and a methodology developed for mapping steam caps. The foundations were laid of networks for monitoring land elevation and gravity changes. Baseline values were defined for the concentrations of mercury and sulfur gases. Groundwater monitoring studies were enforced. Atmospheric dispersion and reaction of geothermally-emitted sulfur gases and mercury were studied. Aerial thermographic survey methods were refined and tested and their capacity to detect and map changes in surface manifestations with time was demonstrated. To further the use of geothermal energy worldwide the International Energy Association set up a Geothermal Implement Agreement (GIA) in 1997; its environmental Annex has been actively implemented, with several projects still under way.

Keywords: Environment; Geothermal development; Natural changes; Mitigation; Gas emissions

* Corresponding author. Fax: +354-568-8896.
E-mail address: hk@os.is (H. Kristmannsdóttir).

0375-6505/03/$30.00
doi:10.1016/S0375-6505(03)00052-X

1. Introduction

All energy production causes some changes to the environment and requires some kind of engineering and building activity, which induces environmental effects of some kind. Although geothermal energy is considered to be a clean energy source, its development will lead to some emission of gases and effluent water that require disposal. Compared to nuclear and fossil fuels, geothermal is a benign energy source. The relative amounts of greenhouse gas emissions from electricity of geothermal origin are only a fraction of the amounts coming from fossil fuel, and are of the same magnitude as most other renewable energy sources, such as hydro and solar energy (Fig. 1). The geothermal electricity produced in the world in a year is estimated to be the equivalent to savings of 12.5 million tons (Mt) of fuel oil per year, whereas the savings due to direct geothermal heat use (and geothermal heat pumps) is equivalent to about 13.1 Mt per year (Hunt, 2001; Lund and Freeston, 2001). The corresponding savings in CO_2 emissions per year exceed 80 Mt. About 53% of the total energy consumed in Iceland is from geothermal energy whereas only 5% of the greenhouse gas emissions (in CO_2 equivalents) are from the production of geothermal energy (Ragnarsson, 2001; Hallsdóttir, 2001). For a long time now the effects of geothermal production on the environment have been studied, evaluated and compared with the effects of other forms of energy (Axtman, 1975; Ellis, 1975). The first Environmental Impact Assessment (EIA) was compiled in the USA in 1970 and since then many countries have set up their own procedures, usually referring to the 1987 report from the World Commission on Environment and Development and the 1992 United Nations Conference on Environment and

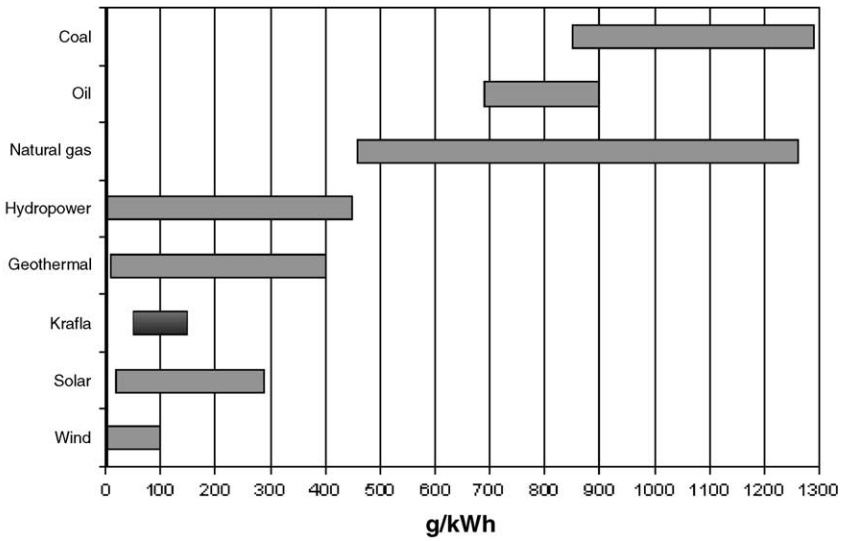

Fig. 1. Greenhouse gas emissions from various types of energy sources during generation of electricity. The emissions are expressed as CO_2 equivalents (Hunt, 2001; Ármannsson et al., 2001). Krafla has one of the highest CO_2 emissions of the Icelandic geothermal fields.