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Carbon dioxide emissions from Icelandic geothermal areas

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Abstract

The origin of CO_2 in fluids from Icelandic high-temperature geothermal systems is predominantly magmatic. Emissions from producing areas have risen with increased production. Abnormal rises have been recorded due to magmatic activity and the onset of boiling due to increase in production. Natural flow is predominantly through soil but to a small extent via steam vents and steam heated pools. The extent of natural steam flow varies considerably between areas apparently due to the formation of carbonate deposits (mainly calcite) in relatively cool liquid dominated aquifers at shallow depths where these are present. The CO_2 concentration of fluids from aquifers at higher temperatures apparently decreases with temperature and is for instance very low (<1000 ppm) in fluid from IDDP-1, Krafla where the source temperature is 450°C.

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Keywords: CO_2; Icelandic; high temperature geothermal area; natural steam flow; steam vent; steam heated pool; calcite

1. Introduction

The International Geothermal Association[1] carried out a survey of CO_2 emissions from geothermal power plants in order to demonstrate the environmental advantage of geothermal energy in mitigating global warming. The results were presented in terms of emitted CO_2 per energy unit (g kWh^{-1}) in relation to production in MW_e. The total range for all plants was 4-740 g kWh^{-1} with a weighted average of 122 g kWh^{-1}. It was suggested that the natural emission rate pre-development be subtracted from that released from the geothermal operation, citing Larderello as an example of a field where a decrease in natural release of CO_2 has been recorded and suggested to be due to development.

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2. Origin of gas in Icelandic high-temperature geothermal fluids

The gas in fourteen of the fifteen areas in which the carbon-13 isotope ratio has been studied is apparently magmatic in origin ($\delta^{13}C$ in CO_2 approx. -2 – -6‰) whereas that in the Öxarfjördur area could originate in organic sediments ($\delta^{13}C$ in CO_2 approx. -9‰)[2].

3. Gas emissions from geothermal activity in Iceland

The CO_2 emissions from Icelandic geothermal plants have been recorded since about 1970 (Figure 1). Gas concentrations in steam in Krafla were relatively high during the late 70s and 80s due to magmatic activity but later stabilised. The increase seen around 2000 is due to increased production. The gas concentrations in Svartsengi rose in the early 90s due to the formation of a steam cap and the resulting increased production. A steady value has been reached which may be expected to decrease if production is not increased. As is expected the gas emissions from Hellisheidi and Reykjanes increased during the first years of production.

The emissions from Nesjavellir are low and relatively constant. A comparison between the CO_2 emissions per kWh from the major geothermal plants in Iceland shows that they can be divided into two groups, i.e. Krafla and Svartsengi on the one hand but Hellisheidi, Reykjanes and Nesjavellir on the other (Table 1). The table also shows that the emissions per kWh in Krafla and Svartsengi have decreased since the year 2000. The effect of cascaded use, i.e. simultaneous production of heat and electricity in 2000 in Svartsengi and Nesjavellir is shown.

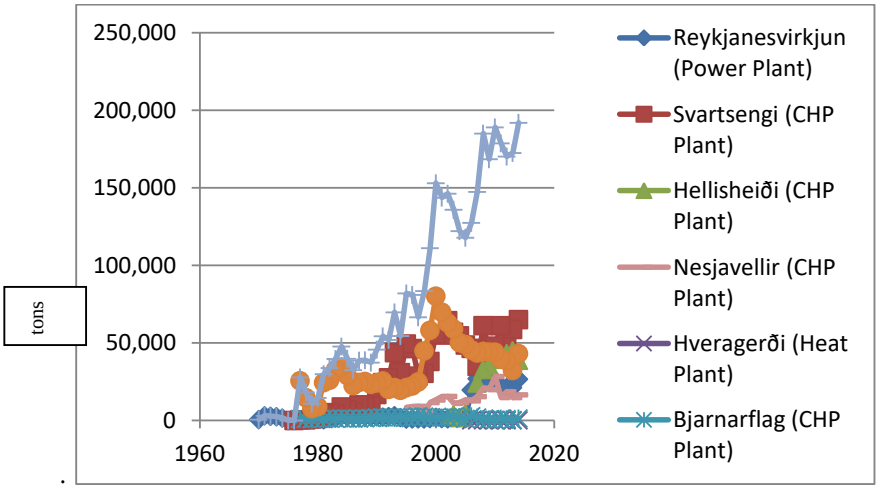

Figure 1. Gas emissions from geothermal activity in Iceland 1970-2014 (From http://www.os.is/orkustofnun/gagnasofn/talnaefni)

Table 1. CO_2 emissions per kWh from major geothermal power plants in Iceland[9] (http://www.os.is/orkustofnun/gagnasofn/talnaefni)

Power plant	Electricity generation only		Heat and electricity production
	CO_2 ($gkWh^{-1}$) 2012	CO_2 ($gkWh^{-1}$) 2000	CO_2 ($gkWh^{-1}$) 2000
Krafla	100	152	
Svartsengi	150	181	74
Reykjanes	18		
Hellisheidi	19		
Nesjavellir	25	26	10

Reykjanes: Several authors[3] studied the natural gas flow from the Reykjanes geothermal area prior to the commissioning of the Reykjanes power plant and their findings are summarized below.

Total discharge of CO_2 to the atmosphere at Reykjanes. Natural atmospheric emissions of CO_2 at Reykjanes take