Changing geothermal GHG emissions and impact on future low carbon power systems
The case of New Zealand's decarbonisation plan

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Overview

Geothermal power generation is seen as a renewable, sustainable solution in a low-carbon future for New Zealand (and global) electricity generation. NZ has 60+ years of experience in geothermal generation and significant, strategically located resources. Hence, new geothermal generation is expected to be a significant part of future, low-carbon electricity generation in NZ, and its future deployment and impact on total emission can be studied in energy systems models such as the TIMES-NZ model.

However, geothermal is not free from GHG-emissions (although generally significantly lower than ~1,000 g/kWh for coal or ~500 g/kWh for gas-fired generation). Geothermal power plants typically emit both CO_2 and CH_4 when they extract hot steam/fluid from the ground and before the cold waste fluids get reinjected. Actually, geothermal fields emit theses GHG naturally and there can be large differences between geothermal fields, power plants, and over time. Power plant technology and reinjection management can also make substantial difference, and even carbon sequestration could be included in the future. Hence GHG emissions from geothermal power plants are riddled with uncertainties and little, consistent data is available worldwide. NZ has had an Emissions Trading Scheme (ETS) since 2008, under which all, large GHG emitting installations (including geothermal) had to submit annual emissions data, following strict guidelines. This research uses such 2008-2019 emissions data to analyse trends, patterns and differences.

TIMES-NZ is an integrated energy systems assessment model recently developed for New Zealand using the TIMES modelling framework. It is a bottom-up techno-economic tool, which characterises the energy resources and transformation technologies in detail, and optimises investment to meet energy service demands across the economy, including residential, commercial, transport, industrial and agricultural sectors. Initial TIMES-NZ scenarios have used a standard emission rate/intensity of 91 gr CO_2/kWh (net) based on emissions from geothermal reported to the UNFCCC and geothermal energy supply as reported by MBIE. However, recent review of NZ ETS data shows GHG emissions intensities varying between 21 and 341 gr CO_2eq/kWh (net), with a general downward trend over time. The present paper explores scenarios for different assumptions on emissions intensities for geothermal generation, and their effect on geothermal deployment under a decarbonisation target.

Methods

- Brief literature review of geothermal GHG emissions and driving factors
- Review of historic/international emission rates vs fossil and non-NZ geothermal power plants
- Review and analysis of 2008-2019 GHG emission data for NZ geothermal plants to establish average, trends, etc
- Inclusion of a range of emission profile scenarios for geothermal generation in TIMES-NZ modelling, and
- Investigating the effects of the above on both geothermal deployment and total emissions under energy system decarbonisation.

Results

- Preliminary results show emissions from NZ geothermal power plants vary from 21 – 341 gr CO2eq/kWh(net) with a MW-capacity-weighted average of 76 gr CO2eq/kWh (vs ~950 g/kWh from NZ-coal, and ~400 g/kWh for NZ-CCGT);
- Some of the highest emitting plants (Ohaaki – 341 g/kWh; Ngawha – 304 g/kWh) are small and unlikely to be expanded much in the future, while some of the fields with considerable additional resource potential

have low emissions (e.g. Wairakei-Tauhara @21-45 g/kWh), others have higher emissions (e.g. Kawerau @ 104 g/kWh);

- The overall trend is for emission intensity (in g CO_2eq/kWh) to lower over time, although initial figures from the period 2008-2012 are likely to have been influenced by changes/improvements in emission measurement (initially default factors were used). The lowering trend is due to degassing of geothermal fields and can be further influenced by reinjection management and even carbon sequestration. Considerable debate exists whether 'produced emissions' actually simply replace 'natural emissions' that reduce as the carbon content of the fields' fluids diminishes over time;

- CH_4 makes up around $1/6^{th}$ of the CO_2eq emissions for NZ geothermal fields. This has changed slightly over time as the Greenhouse Warming Potential (GWP) of CH4 was increased by IPCC from 21 to 25 (2014/15) to 28 (2018/19?). This has put upward pressure on emissions intensity and CH4's share.

- Using different geothermal emissions scenarios), we investigate the impact of the assumed CO2 emissions on optimal investment pathways to a low-carbon energy system. Our preliminary results indicate that the emissions factor assigned for geothermal has a direct impact on the investment in future geothermal development under high decarbonisation targets; for example, a doubling of the initial emissions target leads to a 30% decrease in new geothermal capacity, whereas halving the emission intensity increases deployment by 10%. This paper investigates this sensitivity around emissions assumptions in further detail.

Conclusions

Geothermal energy is seen as a renewable, sustainable source of power generation, especially for future low-carbon electricity generation in NZ. However, geothermal energy is not free from GHG-emissions, and considerable variation exists between fields and over time. Hence, under different future (carbon price) scenarios, different geothermal fields/power plants might be developed. Emissions can also be further managed by reinjection management, carbon sequestration and closed-loop, binary cycles.

Simulating such variation under different TIMES-NZ scenarios shows a direct impact of geothermal emissions assumptions on the deployment of geothermal in a low-carbon future. Such variation in geothermal emissions and management is also likely for other geothermal-rich (Asian) countries (e.g. Indonesia, Philippines, Japan). This indicates that particular care must be taken when assuming emissions factors for geothermal generation, and separating new developments in detail according to their specific emissions profiles will be necessary for planning effective decarbonisation pathways in energy systems with significant amounts of geothermal potential.