Proceedings World Geothermal Congress 2026, Calgary, Canada, June 8—11, 2026

IEA-Geothermal Collaboration on Environmental and Social Awareness and Summary of Best-Practices

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INTRODUCTION

The 'IEA-Geothermal' Implementing Agreement commenced its first joint activities in 1997 with 'Annex 1' ('Working Group 1' or WG1), on the 'Environmental Impacts of Geothermal Energy Development'. The initial group included representatives from New Zealand, USA, Japan, UK, Switzerland, Australia and Mexico. Over the following decades, several other countries and supporting sponsors joined the group, and the tasks within the overall 'environmental' theme adjusted to changing interests and needs. This poster provides an historical overview of these environmental activities, with the aim of identifying common messages, and lessons learnt. The objective is to assist with guiding environmental and social aspects of future geothermal projects and providing a sound basis for regulators to develop appropriate policy .

The initial objective of WG1 was to determine the environmental effects of geothermal development and provide methods to avoid or minimize their impacts. Progress made with collaborative research in various environmental and social aspects of geothermal was summarised in World Geothermal Congress Events (Bromley et al, (2005, 2010, 2015, 2021). Outputs can be tracked through the IEA-Geothermal annual reports and presentation summaries (iea-gia.org). Special Issues of environmental articles inspired by collaborative WG1 work were published in the Journal 'Geothermics' (2005, 2010, 2014, 2021). More historical details are documented in an IEA-Geothermal 25th anniversary report :

SUBTASKS

Initial WG1 Tasks included studying the impacts on natural features, the problems associated with discharge and reinjection of geothermal fluids and gas emissions, and methods of impact mitigation. WG1 then addressed issues concerning 'Geothermal Resource Sustainability' and 'Renewability' as a subtask (Axelsson et al 2010). The outcomes from assessments of resource sustainability and capacity were incorporated into 2010 international efforts to address climate change mitigation for the IPCC, then address development progress challenges to inform a geothermal road-map, with forward projections, for the IEA .

From 2004, another subtask of WG1 addressed the effects of 'Induced Seismicity' as an environmental and social concern. A series of three international workshops were organized in USA between 2005 and 2009 to discuss the issues related to fracture creation for EGS. The subtask transferred to a full Annex task (WG 11) in 2010, and then a subtask of WG13 in 2015. A summary of the results from this 'Induced Seismicity' collaboration within IEA-Geothermal is described in a companion article for WGC2026 (Bromley et al. 2026)

Scientific contributions have been shared on topics as diverse as: a) mitigating ground subsidence, b) treating atmospheric emissions to remove H_2S gas, c) monitoring tools for assessing risks of hydrothermal steam eruptions, d) improving 'traffic-light' protocols for managing induced seismicity risk, and e) enhancing long-term aquifer sustainability through applying seasonal cycles of hot water extraction, balanced by periods of natural fluid recharge.

SUMMARY OF BEST PRACTICES

- Protect natural geothermal surface features through appropriate land-use protocols and reinjection strategies to manage near-surface aquifer pressures and temperatures.
- Manage the discharge and reinjection of fluids, with flexible strategies, to minimize adverse environmental impacts and maximize local community social benefits.
- Monitor and treat atmospheric gas emissions (CO_2, H_2S, Hg), aiming to reinject by dissolving these gases into separated brine or condensate, where feasible.
- Mitigate ground deformation (subsidence, uplift), through reinjection strategy adjustments, and reparations where needed.
- Address local concerns, if any, through robust community engagement throughout the project life, and provide community benefits to mitigate identified adverse effects.
- Enable sustainable resource utilization, through many generations, by updating reservoir simulation models, informed by monitoring, to help adjust production/reinjection strategies

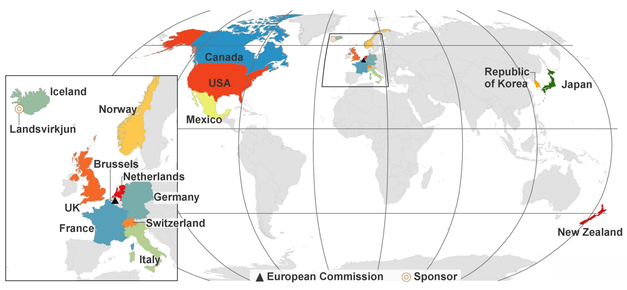
SUMMARY OF ACHIEVEMENTS

Publication of *Geothermics Special Issues*: 2005 Environmental Aspects, 2010 Sustainable Utilization, 2014: Analysis of Induced Seismicity, 2021 Environmental Aspects and Social Acceptability

Proceedings of Geothermal Conferences : World Geothermal Congress, European Geothermal Congress, New Zealand Geothermal Workshop, Stanford Geothermal Workshop, *Transactions* of Geothermal Resources Council, Asian Geothermal Symposia, Australian Geothermal Energy Conference.

IEA-Geothermal Annual Reports (WG1 Chapter), which are hosted at www.iea-gia.org

Participating member countries



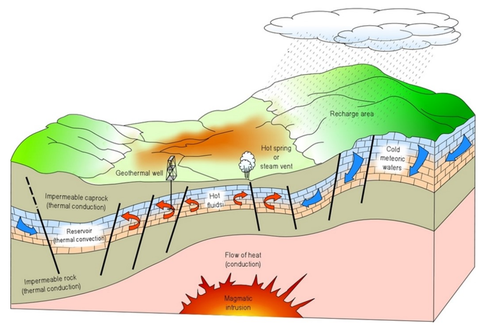
Geyser recovery (Rotorua, NZ)



Protection of outstanding natural features



Sustainable resource management

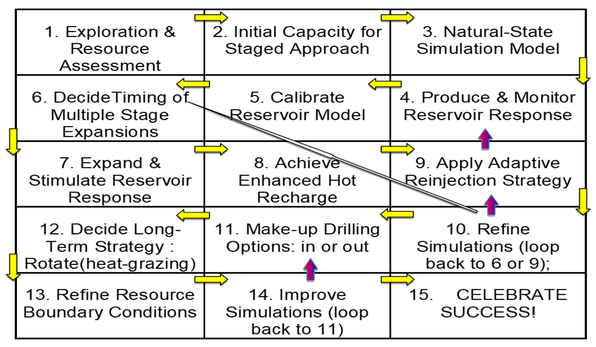


Hot Spring enjoyment



SUSTAINABILITY– ADAPTIVE FLOWCHART STRATEGY

Stages of development: Start at #1, work towards #15 (yellow) with loop backs (purple) as required to adapt to new monitoring data and improved simulation models



Larderello, 113 yrs old, ExCo visit 2012



Wairakei, 68 yrs old, ExCo visit 2015



THREE DECADES OF COLLABORATION

Collaboration between participating countries within the IEA Geothermal TCP (WG1) over the past 29 years has resulted in many studies into geothermal environmental and social awareness issues. Solving these issues has helped advance development of new geothermal resources and sustain production from existing projects through scenario modelling of appropriate development strategies. Together we have consolidated the learnings from sharing of advanced monitoring technology and best-practice procedures for mitigation or avoidance of identified adverse effects. The goals of the group undertaking this collaboration were: a) to encourage the sustainable development of geothermal energy resources in an economic and environmentally responsible manner; b) to quantify and balance any adverse and beneficial impacts that geothermal energy development may have on the environment; and c) to identify ways of avoiding, remedying or mitigating adverse effects. Tasks have included: a) address impacts on natural features by monitoring surface thermal feature and ecosystem changes and devising techniques to avoid or mitigate adverse impacts, while encouraging beneficial effects; b) rectify discharge and reinjection problems, including: induced seismicity, gas emissions (CO_2 & H_2S), chemical contamination of water, subsidence, scaling and corrosion, by adjustment of treatment options and reinjection strategies; c) develop methods of impact mitigation and environmental procedures through analysis of issues, procedures, efficient policies, protocols, and effective compliance; d) develop successful strategies to address social and environmental effects; eand e) sustain utilisation by undertaking long-term reservoir simulations, optimizing future operational strategies, improving recharge factors and recovery times, improving reservoir performance, and applying sustainability indicators that holistically integrate all these environmental factors.

The authors acknowledge 29 years of enthusiastic support from all IEA-GIA ExCo members.

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Technology Collaboration Program
by iea