2016 Working Group 1 Report – Environmental Impacts

Chris Bromley

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GNS Science, Wairakei Research Centre, Private Bag 2000, Taupo, New Zealand
Email: c.bromley@gns.cri.nz

1. Introduction

The goals of Working Group 1 (Environmental Impacts) are to: a) encourage the sustainable development of geothermal energy resources in an economic and environmentally responsible manner; b) quantify and seek ways to balance any adverse impacts that geothermal energy development may have on the environment; and c) identify ways of avoiding, remedying or mitigating any adverse effects.

These collaboration activities commenced in 1997 (as Annex 1) when the Geothermal Implementing Agreement was first initiated. The various tasks under this Annex have changed over time, as different environmental and social issues were identified and discussed by participants at meetings and during workshops. To date, outputs have mostly consisted of published papers (including three Geothermics Journal Special Issues), protocols and environmental workshops or conference sessions.

In 2016 there were four ongoing tasks for Working Group (WG) 1. They are listed and briefly described below:

A) Impacts on natural features: monitoring surface thermal feature and ecosystem changes and devising techniques to avoid or mitigate adverse impacts, while encouraging beneficial effects.

B) Discharge and reinjection problems: gas emissions (CO_2 & H_2S); chemical contamination of water, subsidence, scaling and corrosion, and treatment options (e.g. injection).

C) Methods of impact mitigation and environmental procedures: analysis of issues, procedures, efficient policies, protocols, effective compliance, and successful mitigation strategies to address social and environmental effects.

D) Sustainable utilisation strategies: long-term reservoir simulations, optimized future operational strategies, recharge factors, recovery times, improved reservoir performance, and sustainability protocol indicators.

Official participating countries in the Working Group are Australia, Iceland, Italy, Japan, New Zealand, Norway, Switzerland and the United States.

2. Progress in 2016

During 2016, progress reports on WG 1 activities were presented at the Executive Committee meetings held in Cuernavaca (Mexico) on 15/4/16, and in Munich (Germany) on 13/9/2016. The recent emphasis has been on networking and connecting researchers, policy makers and operators from different countries in order to increase awareness of environmental improvements and successful strategies to mitigate adverse effects.

Regarding tasks A to D, several ongoing projects within participating countries were reported in 2016. Gas emissions, reinjection of non-condensable gases (CO_2) and H_2S abatement technology remain important topics of research, especially within Europe and the USA. Improvements in shallow/surface feature and ecosystem monitoring, using drones, ground penetrating radar, thermal imaging and satellite imagery are also continuing. Subsidence

monitoring and improved modelling of reservoir deformation processes is ongoing, particularly in USA, Europe and New Zealand. Researchers looking into policy initiatives, and sustainability, in Mexico, USA, New Zealand, Italy, Switzerland and Germany, have all contributed their study results.

In addition to these existing work-streams, there has been a noticeable increase in studies into mitigation and avoidance of the effects of vibration on buildings and residents. For example, social pre-awareness campaigns were undertaken by operators in Japan (e.g. vibroseis contractor). These were discussed at a joint GNS (NZ) and JOGMEC Japan collaboration meeting in May 2016. Also, papers on social impacts of drilling-induced vibration in France were presented at the European Geothermal Congress in September (see section 6.4). Studies of impacts on society and social considerations have also increased in 2016 (see section 6.6). For example, local social benefits (e.g. free steam cooking facilities at Otake, Japan, and Ribeira Grande, Azores) were highlighted.

3. Outputs

2016 publications by geothermal environmental researchers from participating countries are shown in the list given in section 6 below. They are grouped according to the most popular environmental themes that were addressed: 6.1 General presentations (all tasks), 6.2 Surface thermal features & ecosystems (Task A), 6.3 Gas emissions (Task B), 6.4 Subsidence & Vibration (Task B), 6.5 Environmental Policy (Task C), 6.6 Society (Task C), and 6.7 Sustainability (Task D).

Many of these papers were presented and discussed at the following 2016 conferences (all attended by WG 1 participants): Stanford Geothermal Reservoir Engineering Workshop (Palo Alto, USA), Geothermal Resources Council Meeting (California), New Zealand Geothermal Workshop (Auckland, NZ), and European Geothermal Congress (Strasbourg, France). Papers from these conferences may be downloaded through the www.geothermal-energy.org conference database.

Invited presentations with an environmental component were also given in Bali, Indonesia (as outreach at the Bali Clean Energy Forum) and at a GNS-JOGMEC Japan/New Zealand collaborative workshop held in Tokyo, Japan (see 6.1).

4. Highlights

Selected highlights for the year include:

- A Bali Clean Energy Forum invited presentation on South-east Asia geothermal potential. This identified and highlighted the intermingling, in the decision-making process, of social and religious issues with environmental issues, with an example from Bedugal, Bali, Indonesia (see section 6.1).
- An IEA Geothermal, WG1-promoted, Virtual Special Issue of Geothermics Journal, focussing on the topic: 'Environmental Aspects and Social Acceptability of Geothermal Developments' was initiated. Invitations were sent out in June 2016, and 25 positive responses were received from prospective authors.
- As evidenced by the papers listed in section 6, networking and cooperation amongst numerous researchers, operators, policy-makers and funding-agencies within the participating countries has contributed to an increasing number of publications on environmental or social topics, and helped, through cross-referencing, to raise

international awareness of successful mitigation schemes and beneficial environmental or social outcomes (Figure 1).

Figure 1. At a meeting of collaborating research scientists from Japan (JOGMEC) and New Zealand (GNS), the benefits of social improvements and awareness campaigns for geothermal energy developments are discussed. This example is a communal cooking facility at Otake, Japan.

5. Future Activities

Plans for the future include continuing work on the four existing tasks with additional initiatives as listed in more detail in the 2013-2018 IEA Geothermal strategic plan and in the 2015 Annual Report for Annex 1. They include:

a) compilation of an Environmental and Social Special Issue (VSI) of Geothermics Journal,

b) preparation of an international geothermal environmental code-of-practice, and an article on 'effective protocols and policies for environmental management of geothermal projects'.

c) running focussed workshops on, for example, sustainability modelling and surface feature protection,

d) collating results of field trials for: targeted shallow reinjection of hot fluids to remedy adverse effects; gas sequestration by injection; and water treatment to remove toxic chemicals.

Task A Impacts on Natural Features

- Establish protocols and methods of drilling/producing/injecting deep beneath protected areas with negligible surface impact.

- Improve modelling of groundwater changes arising from deep pressure changes.
- Classify vulnerability of thermal features to reservoir pressure changes.

Task B Discharge and Reinjection Problems

- Mitigate corrosion and scale deposition.
- Document results of subsidence mitigation by injection.
- Monitor casing integrity to protect groundwater.

Task C Polices, Protocols, Procedures and Impact Mitigation

- Streamline environmental impact assessment timeframes.
- Itemize experience and best practice options for EGS water resource issues.
- Test the use of targeted injection to rejuvenate failed geysers/springs or halt subsidence.

Task D Sustainability

- Publish case studies on sustainable utilisation.
- Investigate permeability changes with time and interference effects.
- Design guidelines for optimum make-up production and injection strategies.
- Improve the use of dual tracers (volume and area) for predictive modelling

6. References

6.1 General presentations (all Tasks)

Bromley, C.J. (2016) 'Annex 1 Update Geothermal Environmental Tasks', IEA-GIA meeting, Cuernavaca, Mexico, 15th April 2016, www.iea-gia.org (16 slides).

Bromley, C.J (2016) Working Group (Annex) 1 'Geothermal Environmental Tasks', IEA-Geothermal ExCo meeting, Munich, Germany, 13th September 2016, www.iea-gia.org (14 slides).

Bromley, C.J. (2016) 'Geothermal Energy: opportunities in South East Asia'; Invited presentation on behalf of IEA-Geothermal, sponsored by Indonesian Govt., "Bali Clean Energy Forum and Ministerial Meeting"; Geothermal Session convened by NZMFAT; February 11-12, 2016, Nusa Dua, Bali, Indonesia, published in http://bceforum.org page 2625. (32 slides).

Bromley, C.J. & Bignall G., (2016) "Ngawha Geothermal Field: Geology, Geophysics, Conceptual Model, Geochemical Monitoring Trends & Environmental Issues", GNS-JOGMEC Joint Geothermal Workshop, Tokyo 2nd June 2016, presentation published by JOGMEC for participants (26 slides).

6.2 Surface thermal features & ecosystems (Task A)

Harvey, Mark. (2016) Geothermal Field Work Using a Drone with Thermal Camera: Aerial Photos, Digital Elevation Models and Heat Flow, Geothermal Resources Council Transactions, (2016), v.40, Geothermal Resources Council, Davis, California. GRC ID #1032355.

Sanders, F., A. Seward, A. Mazot (2016) Crown Park Thermal Area, Taupō: Taking a Pulse, Proc. 38th New Zealand Geothermal Workshop, University of Auckland paper 133, 8p.

Lynne, B.Y., I.J. Smith, G.J. Smith, K. Luketina (2016) Imaging the Shallow Subsurface of Armstrong Reserve, Taupo, New Zealand, Using Ground Penetrating Radar, Proc. 38th New Zealand Geothermal Workshop, University of Auckland, Paper 144

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6.3 Gas emissions (Task B)

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6.4 Subsidence & Vibration (Task B)

Koros, W., J. O'Sullivan, J. Pogacnik, M. O'Sullivan (2016) Modelling of Subsidence at the Wairakei Geothermal Field, New Zealand, Proc. 38th New Zealand Geothermal Workshop, University of Auckland, Paper 20.

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BARBOUR, Andrew, Eileen EVANS, Stephen HICKMAN, and Mariana ENEVA (2016) Sources of Subsidence at the Salton Sea Geothermal Field, Proc. 41st Stanford Workshop on Geothermal Reservoir Engineering, SGP-TR-209.

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Richard, A; Maurer, V; Lehujeur, M., (2016) Induced vibrations during a geothermal project and acceptability, how to avoid divorce? Proc. European Geothermal Congress 2016, T-El-134.

Heimlich, C; Masson, F; Schmittbuhl, J; Ferhat, G., (2016) Geodetic measurements for geothermal site monitoring at Soultz-sous-Forêts and Rittershoffen deep geothermal sites. Proc. European Geothermal Congress 2016, T-El-125.

6.5 Environmental Policy (Task C)

Ramirez Bueno, Michell Alejandra; Rocha Ruiz, David Alejandro. (2016) Geothermal Energy Reform in Mexico, Legal Framework, Tools and Outcome, Geothermal Resources Council Transactions, (2016), v.40, Geothermal Resources Council, Davis, California. GRC ID #1032351.

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Fedeli, M; Mannari, M; Sansone, F., BAGNORE 4: a benchmark for geothermal power plant environmental compliance, Proc. European Geothermal Congress 2016, T-El-169.

Menberg, K; Blum, P; Pfister, S; Rybach, L; Bayer, P., (2016) Life cycle assessment of geothermal power generation, Proc. European Geothermal Congress 2016, T-El-242.

Ravier, G; Baujard, C; Dalmais, E; Maurer, V; Cuenot, N., (2016) Towards a comprehensive environmental monitoring of a geothermal power plant in the Rhine graben, Proc. European Geothermal Congress 2016, T-El-282.

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6.6 Society (Task C)

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Climo, M., B. Carey, S. Bendall, A. Seward (2016) Developing a Geoheat Strategy to Increase Geothermal Direct Use in New Zealand: Stakeholder Consultation, Proc. 38th New Zealand Geothermal Workshop, University of Auckland, Paper 10.

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Martins Carvalho, J; Nunes, J C; do Rosário Carvalho, M. (2016) Direct uses as environmental mitigation measure in Ribeira Grande Geothermal Field (S. Miguel, Azores Islands, Portugal). Proc. European Geothermal Congress 2016.

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6.7 Sustainability (Task D)

Enedy, Steve (2016) Update of Injection Benefit Model for the Geysers, Geothermal Resources Council Transactions, (2016), v.40, Geothermal Resources Council, Davis, California. GRC ID #1032409. Burnell, J, van Campen, B., Kortright, N. Lawless, J. V., McLeod, J. Luketina, K. Robson, B.; Sustainability of TVZ Geothermal Systems: the Regulatory Perspective; Geothermics Special Issue on TVZ January 2016.

IEA Geothermal

Executive Secretary
IEA Geothermal
C/ - GNS Science
Wairakei Research Centre
Ph: +64 7 374 8211
E: iea-giasec@gns.cri.nz