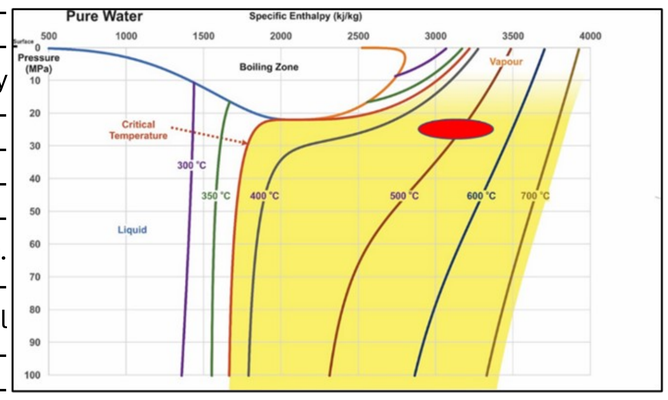
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Outcomes of International Collaboration within IEA Geothermal on Research into Deep and Superhot Geothermal Resources

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INTRODUCTION

The International Energy Agency Geothermal Technology Collaboration Program (IEA-Geothermal, WG12, Bromley & Carey, 2023) has members collaborating on the topic of deep, high-temperature roots of geothermal systems. These roots may host either supercritical or superhot geothermal fluids. Supercritical fluids have both temperatures and pressures above the critical point of water (374°C and 22.1 MPa). Superhot fluids share the high temperatures of supercritical fluids but occur at subcritical pressures, for example as superheated vapor (see Figure above).



WG12 'Deep Roots' was first established in 2014, although it evolved from earlier deep resources work in Annex 4, (1997-2006). Joint leaders (Operating Agents) were Iceland and New Zealand. The purpose of WG12 is sharing information and research results from deep drilling, conceptual models, geoscientific experiments, and simulation modelling of the anticipated extraction and reinjection of resource fluids at high temperatures and pressures.

MEMBER CONTRIBUTIONS

Joint Seminars and Workshops on Superhot Fluids and Deep Roots were held in:
Gran Canaria, (Spain, April 2019), Taupo (N.Z., Jan. 2020), Reykjavik (Iceland, July 2021), Rotorua (NZ, Nov. 2022), Beijing (China, Sept. 2023), Paris (France, April 2025), and online (Feb.2022, March 2023) (see www.iea-gia.org, for details).

Countries and research/demonstration projects most actively contributing include:
USA - CATF (2025), FORGE, DOE-GTO, Newberry EGS, FERVO, DEEPEN
Iceland - IDDP1, IDDP2, IDDP3, HORIZON-COMPASS
Japan - NEDO, AIST, JBB
Italy - DESCRAMBLE, HORIZON2020
New Zealand - GNS, GNG
Norway - IFE, IMAGE, GEMex, GECO



Collaborative laboratory studies (see photo) have included mineral-fluid saturation-stability, chemical deposition/dissolution effects, and tracer stability at supercritical static or flowing conditions (e.g. Rendel et al., 2021).
Collaboration outcomes have included joint conference presentations and targeted seminars (www.iea-gia.org)

COLLABORATION RESULTS

The main topics for consideration by the working group when assessing the potential for exploration and development of the 'deep roots' of geothermal systems are listed below:

a) Reservoir properties: the temperatures, permeability range (linked to seismicity & ductility), recovery factors, production cut-off (minimum) temperature and pressure, and tolerable fluid chemical properties (e.g., gas content, acidity, mineral saturation) appropriate for a superhot resource capacity assessment

b) Geophysics: interpretation of geophysical data to establish resource volumes and conceptual models using: MT (resistivity), magnetics (Curie Point depth), gravity (density and topographic stress), seismic (reflections, P and S wave velocity tomography and attenuation), and geodetics (creep, inflation & deflation)

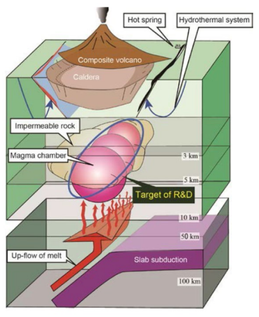
c) Resource modelling: conceptual & simulations, to establish the knowledge required for sizing and planning sustainable operations; to quantify the heat input needed into the base of the reservoir and relate it to the heat output from the wells; to investigate the parameters that most strongly affect sustainability, including heat in place per unit volume, acceptable temperature changes over the project life, and appropriate recovery factor

d) Development strategies: to provide optimized choices for production and reinjection wells to sustainably utilize the available resources

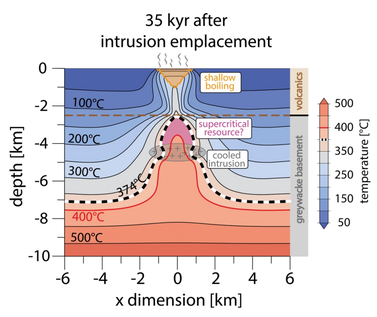
e) Engineering challenges: investigate drilling rate improvements, select appropriate materials for pressure containment that achieve adequate well and plant longevity, improve procedures for cementing well casings, manage casing expansion/contraction with temperature changes, initiate and maintain well flow, control well bore scaling and corrosion, and choose the appropriate process for energy transformation

f) Regulatory issues: assist regulators to adjust policies, without inadvertently imposing excessive compliance costs, to address the following topics: imprecise 3D resource boundaries, the need for flexibility so learnings through time can lead to adaptation, effective environmental management, land access over the most desirable resource volumes, and management of possible resource interference between users (proving cause and effect when there are multiple resource tappers).









References: Asanuma (2022), CATF (2025), Cladouhos et al (2024), IEA (2024) 'The Future of Geothermal Energy' IEA publications, www.iea.org

Useful websites
www.geothermalnextgeneration.com,
www.iea-gia.org, www.catf.us/superhot-rock/
www.superhotrock.org/library/

Images : 1) IDDP2, Iceland ; 2) Concept, Japan; 3) Lab experiments, NZ; 4) Simulation, ETH, CH.



NEW SUPERHOT TASK

The focus of a new IEA-Geothermal Superhot Task Group, initiated in 2025, is to establish a pathway to commercialization of superhot geothermal energy by addressing key challenges. Details can be found in www.iea-gia.org/superhot and www.superhotrock.org/. The task focuses on geothermal technology advancements at temperatures > 400˚C, but also includes studies collecting relevant learnings from any projects > 300˚C, with an emphasis on findings relevant to geothermal energy extraction from deep, hard-rock, high-temperature settings. The goal is to achieve the lowest possible cost and highest possible market penetration of geothermal energy production in these challenging, but potentially widely applicable, geological settings. Conventional hydrothermal and oil/gas exploration researchers are encouraged to participate, as many of their advancing technologies can be applied to improved development of deep superhot resources in relatively low-permeability rock. Participants will be asked to share learnings relevant to superhot geothermal, particularly in low-permeability settings, so that the work remains useful to a broad number of countries across diverse geological environments.

Objectives: a) To facilitate cross-border information-sharing and ensure shared learnings between pilot projects, so that groups can build from each others successes and failures

b) To leverage knowledge from global technology leaders on multiple projects

c) To build from a shared understanding of technological development needs

d) To coordinate global activities to reduce cost, de-risk development, and standardize tools

e) To support SHR testbed and pilot projects

f) To lay the groundwork for joint resource commitment toward the commercialization of Superhot resources globally. This could include shared : data repository, venue for information exchange, global testbeds, financial resources, and more.

CONCLUSIONS

It is undisputed that there is a large amount of energy in place in the 'deep roots' of high temperature geothermal systems and beneath areas of relatively high heat flow across the globe (IEA, 'The Future of Geothermal Energy', 2024). In places, these potentially contain superhot fluids.

To accelerate development of these superhot resources, an active, collaborative, collegial group is hosted by IEA-Geothermal to share relevant ideas, outputs and proposed investigative activities. We review work ongoing in several countries, and discuss the results of collaboration between members of the IEA-Geothermal Working Group focusing on 'Deep Roots' of geothermal systems. We also introduce the proposed forward work program for a new collaborative task with broader objectives on 'Superhot' geothermal energy.

The work is focused on collaboration to assist: a) delineation and identification of locations of supercritical geothermal resources that might be prospective and accessible by drilling, b) evaluation of the energy that might be available long term, c) advancing technology to enable reliable drilling and energy production from the high temperature prospects, and d) developing appropriate regulatory regimes and economic frameworks that will provide adequate certainty to support the needed investment in superhot geothermal.

The work discussed here reflects foundational research by members of the IEA Geothermal Working Group on 'Deep Roots'. The new Task Group builds on this by facilitating test-bed collaboration, standardizing key performance indicators, and creating shared technical infrastructure to advance technology readiness and deployment across countries.

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