# 2019 Annual Report

IEA Geothermal

July 2020

IEA Geothermal

# Contents

# Message from the Chair

Dear Reader,

Welcome to the 2019 IEA Geothermal Annual Report. The document describes the work of IEA Geothermal and our Working Groups, providing you with comprehensive information about geothermal sector activities in our participating nations, as well as market, technology, research, and statistical information.

2019 was the 22$^{nd}$ year for the IEA Geothermal Technical Collaboration Programme. It included activity associated with meetings in Germany, Gran Canaria (Spain) and Costa Rica, including three excellent workshops; a Baltic Sea nations Symposium held in collaboration with the International Geothermal Association as an adjunct to the 2019 GeoTHERM Expo and Congress, and two day workshops in, Pozo Izquierdo, Gran Canaria (8$^{th}$ / 9$^{th}$ April) and San Jose, Costa Rica (11$^{th}$ / 12$^{th}$ November).

In April, the 41$^{st}$ Committee (ExCo) meeting was convened in Pozo Izquierdo, Gran Canaria and during November the 42$^{nd}$ ExCo meeting was held in San Jose, Costa Rica.

It is pleasing to see geothermal energy utilisation continuing to grow and the interest being shown in this source of energy. In particular, it is terrific to see the growth in direct use applications, where annual global growth rates of 10% have been seen in recent years.

I would like to thank contributors to our work, those who have provided material and assisted in preparing this report, the Working Groups and the Working Group leaders.

Please enjoy the read.

Dr Lothar Wissing

Chair IEA Geothermal

# Executive Summary

The work of IEA Geothermal, and highlights from 2019, are presented in this report. IEA Geothermal had 16 contributing members in 2019; 13 country members; the European Commission; and two industry organization/company sponsors. The group foster the sustainable use of geothermal energy through international collaboration, collating and distributing quality information, supporting the development and uptake of geothermal technologies, and communicating geothermal energy's strategic, economic and environmental benefits. Please visit our website, participate in our Working Groups, join one of our workshops, or become a member of IEA Geothermal.

Geothermal energy is used around the world in direct use applications: space heating and cooling, greenhouse heating, aquaculture, bathing, thermal city networks, and industrial uses. In certain parts of the world, where appropriate conditions are found, geothermal energy is also used to generate electricity.

The interest in geothermal heat is booming as value from this renewable energy source is being realised. It is not only heat in the traditional sense but also cooling. The interest is right across sectors from residential to city scale. Large integrated smart city energy systems are being proposed with the potential for significant reductions in city $CO_2$ emission footprints. Volcanic geothermal systems that are superheated or supercritical are the focus of studies seeking to release usable energy from them. The Enhanced Geothermal System (EGS) environment offers enormous potential that is yet to be realised on a large scale and significant investment in EGS technology and development is occurring. It is an exciting emerging technology.

The Executive summary is structured with the achievements of our Working Groups summarised first, followed by the achievements and highlights from our participating nations.

## Working Group Activities

**Working Group 1 (WG1)**

Four tasks were active through 2019 focussing on:

- Impacts on natural features;
- Discharge and reinjection issues;
- Environmental mitigation methods and procedures; and
- Sustainable utilisation strategies.

Networking and cooperation amongst participating countries' researchers, operators, policy-makers and funding-agencies continues, contributing to a number of publications on environmental and social topics, that have raised awareness internationally of successful mitigation schemes and beneficial environmental and social outcomes.

Three joint WG1 papers on "Environmental and Social Impacts" were prepared for the proceedings of the WGC2020.

A number of refereed papers by scientists from member countries were presented at international conferences and workshops during 2019, with references for those in Section 2.4 of the WG 1 Chapter. The papers can be downloaded through the IGA conference database web page.

Future plans include presentation of papers in 2021 on environmental topics for the World Geothermal Congress (WGC 2020), continuing work on the four active tasks and work on preparing a book on geothermal environmental codes-of-practice, protocols and policies for environmental management of geothermal projects.

**Working Group 8 (WG8) (2018)**

Direct use of geothermal energy is growing worldwide and has many applications from heating and cooling buildings, to bathing, to fish farming. Working Group 8 focuses on providing quality information, communicating and transferring knowledge to mitigate the barriers to direct use in order to increase uptake. In 2018, there were 4 continuing tasks and one new task:

- New and Innovative Geothermal Direct Use Applications
- Communication
- Statistics for Geothermal Heat Pump Applications
- Design Configuration and Engineering Standards
- Costs of Geothermal Heat Pump Applications (2018)

WG 8 spans the range from large innovative thermal grids and heat pump applications that are being designed and progressively installed in a number of European cities as a way to significantly reduce the $CO_2$ emission footprint from inter-connected facilities through to innovative fruit dehydrators that have been developed in Mexico, with patents pending.

The questionnaire and guidelines developed in 2017 for the collection of statistical data on geothermal heat pump applications were recommended for use by the IEA Geothermal member countries in 2018. The approach seeks to capture Geothermal Heat Pump heating and cooling data, along with free cooling data.

**Working Group 10 (WG10)**

Internationally, there is a growing demand for reliable information on renewable energy capacity and energy production. Working Group 10 is seeking to fulfil some of that demand for geothermal data. The work in association with the International Geothermal Association has been ongoing during 2019 seeking to better harmonise statistical information across several organisational formats.

The IEA Geothermal Power Report 2017 was released at the 2019 GeoTHERM Expo and Congress in Offenburg, Germany (February 2019).

In October 2019 the geothermal trend reports for 2016 and 2017 were released, with two years data reviewed in one report. This report used data from the more detailed questionnaire for geothermal (ground source) heat pumps prepared in 2018 in conjunction with Working Group 8 Task D. This questionnaire facilitates data for cooling with ground source heat pumps as well as free cooling to be collected if it is available.

Reports can be accessed from the IEA Geothermal web site.

**Working Group 12 (WG12)**

Led by Gudni Axelsson (Iceland) with support from Chris Bromley (New Zealand), this WG focuses on the deep roots of volcanic systems and has enthusiastic participation from Iceland, Japan, USA, Switzerland, New Zealand and Italy. The work in very high temperature geothermal systems is actively being shared, accelerating deployment in supercritical and superheated geothermal resource utilisation. This is reducing duplication of effort, focusing technical expertise, and leading to more rapid sector advancement.

Energy utilisation from very high temperature geothermal conditions requires improved modelling methods, measurement tools, and advancing the understanding of water-rock-gas interaction at high temperatures and pressures. These activities are being undertaken and shared by participants in WG12, with collaboration and project involvement continuing to strengthen through 2019.

2019 saw a number of peer reviewed papers and presentations by scientists from member countries at international conferences and workshops. Three conferences where a number of papers were presented 2019 were the Geothermal Resources Council Meeting, the Stanford Geothermal Workshop and the European Geothermal Congress. A comprehensive reference list at the end of the Working Group 12 chapter provides the details.

**Working Group 13 (WG13)**

Working Group 13 covers a broad spectrum of geothermal activity including exploration, drilling, reservoir creation and enhancement, corrosion, scaling, tracers, and the mitigation of induced seismicity. The goal is to provide quality information to facilitate the utilization of geothermal energy worldwide. The development of innovative technologies is being pushed by expert collaboration between countries and the results made available in documents and presentations at conferences and workshops.

Work is carried out in six tasks:

- Exploration (A1), Measurement and Logging (A2),
- Drilling Technology (B),
- Reservoir Creation and Enhancement (C),
- Induced Seismicity (D),
- Surface Technology (E) - Heat and Electricity Production, Corrosion, Scaling, Tracer Technology.

Task A1 held two playtype definition workshops during 2019, one in Gran Canaria on the 5th April and the second in San Jose, Costa Rica on the 7th November. The latter focussed on better defining volcanic geothermal playtypes. Task A2 continued to collect information on high temperature and pressure logging tools and services.

Task B produced a video during 2019. The content of the film seeks to inform on innovative geothermal drilling. The Drilling Technology video and can be accessed from: https://www.youtube.com/watch?v=I4IXeY7JyH0&t=5s.

The Induced Seismicity task (Task D) is focussed on encouraging collaboration and result sharing between interested countries and participants, this continued through 2019. Papers on induced seismicity by participating country authors were presented at major international geothermal workshops, including papers at the 44th Stanford Geothermal Workshop (February, California), the 3rd Induced Seismicity Workshop, Davos (March Switzerland), European Geothermal Congress (June, The Hague), Geothermal Resource Council Meeting (October, Reno, Nevada) and 41st New Zealand Geothermal Workshop (November, Auckland, New Zealand). The section at the end of the WG 13 Task D chapter contains the references.

The Surface Technology task (Task E) has a focus on developments in above ground geothermal production operations, corrosion, scaling and tracer technologies. The EU GECO project is a project with many important aspects relevant to Task E work. Participants are working to collaborate, collating, and disseminating material seeking to increase awareness and knowledge transfer across the international community.

Task E presented in several international forums including:
- Presentation at "The 8th International Conference on Tracers and Tracing Methods", Da Nang (TRACER 8)
- Presentation at EAGE geothermal workshop in London, June 2019
- ETIP (European Technology & Innovation Platform for Deep Geothermal) meeting, Brussels, January 2018

## National Activities

The material immediately below is a summary of 2019 activity from each of our member countries. Each participant's geothermal programme provides the basis for IEA Geothermal cooperative activity. The country material is written up in more detail in chapters 7-20. Not all participants have been able to complete the 2019 material for this report and where 2018 material is used it is recorded in the section heading.

**Australia**

The transition of Australia's electricity sector to renewables is proceeding rapidly with renewable generation exceeding 40,000 GWh in 2019 and with more capacity per capita being installed in 2018 than in any other country. Investment in renewables is strong with enough capacity built or under construction to exceed the 2020 20% Renewable Energy Target for Australia. A record 3455MW of renewable generation was accredited in 2018 and the forecast for 2019 is for 4000MW to be accredited. Commercial factors are now a stronger driver for ongoing investment than incentives under the Renewable Energy Target.

Construction and commissioning of the 310 kW ORC geothermal power plant in the remote community of Winton, Queensland, was completed in 2019, with plant operation commencing in December 2019. The town's water supply is sourced from the Great Artesian Basin with 77 l/s of water emerging from a network of 1330m deep bores at 86°C. Water was originally cooled in ponds before being reticulated through the town for community consumption and now the two 155kW ORC modules generate electricity using the heat that was once lost to the atmosphere from the cooling ponds. Generation from the plant is automatically modulated to match water consumption. The project is a prototype and a test case for a number of other potential small scale geothermal developments throughout outback Australia, particularly in regional Queensland.

The results of the Australian Geothermal Association (AGA) 2018 census cataloguing and mapping the type, size and distribution of geothermal energy installations and projects across Australia were published in 2019.

Increased interest and investment in Ground Source Heat Pumps (GSHP) and Direct Use geothermal applications has continued, with some significant developments being funded by organisations across all tiers of government in recent years. This success occurs largely in the absence of supporting policy incentives for direct geothermal use technologies. A number of geothermal aquatic centre projects have been constructed by local councils in Western Australia and Victoria, encouraged by rising domestic gas prices. An example is the geothermal direct use project in Victoria where at the Traralgon Gippsland Regional Aquatic Centre (GRAC) the natural gas fired heating is being replaced by geothermal heat supplied from 65°C water taken from wells drilled into the Traralgon aquifer. The water is to be returned to the aquifer at 40 °C. This geothermal project is due for completion early in 2021.

A three-year study on the performance of 'deep well direct exchange' (DWDX) ground source heat pumps installed in a residential community in Western Sydney is underway with the study due for completion in 2022.

**European Commission**

In late 2018 the European Parliament adopted the revised Renewable Energy Directive, the Energy Efficiency Directive and the Governance of the Energy Union Regulation which lay out the European climate and energy regulatory framework from 2020.

The EU Clean Energy Package sets a 32% binding target for renewables by 2030.

The European Commission is supporting the development of the geothermal sector through funding from the Horizon 2020 and the European Regional Development Fund programs, and policy initiatives with a particular focus in the SET-Plan.

The finalised Deep Geothermal Implementation Plan is now in the implementation phase with the Deep Geothermal Implementation Working Group advancing the plan.

With Horizon 2020 drawing to conclusion there are many outputs being delivered. Please refer to Chapter 8 for a short description of these outputs.

The programme replacing Horizon 2020 is Horizon Europe which runs from 2021 to 2027.

The 2019 geothermal electricity production in the EU amounted to some 6.64 TWh which is ~0.2% of the total EU electricity consumption.

The European district heating market has seen 3% annual growth in geothermal based systems in the last five years. In the EU, there are currently about 200 geothermal district heating plants in operation, with a total capacity of 1.8 $GW_{th}$

**France**

The Geothermal Market Update in France (AFGP 2019) documents the installed capacity for geothermal heating and cooling reaching ~2600 $MW_{th}$ with about 600 $MW_{th}$ of this being associated with the deep reservoirs in the Paris area, and the balance linked to the recent and strong development in using shallow geothermal resources occurring across France.

The number of geothermal installations feeding collective housing and residential blocks, including office buildings, is growing significantly, whilst less than 2500 geothermal probes are annually being installed in the individual residential housing market. This is well down on the peak in this market with more than 20,000 installations annually in 2010.

Geothermal electricity capacity is some 16.7 $MW_e$ producing some 98 GWh per annum. During 2019 two small capacity Organic Rankine Cycle plants (20-40 kW) have been installed; one at Soultz-sous-Forêts on the existing EGS plant and one in Chaunoy, Ile de France, using old oil wells. Two geothermal doublets have been drilled near Strasbourg with the facilities expected to co-generate electricity (10 $MW_e$) and heat (20 $MW_{th}$) once these are developed.

Total geothermal heat pump capacity is some 2015 MW producing some 10.9 Pj/yr of energy. Over the last 4 years ~2500 geothermal heat pumps have been installed each year. This market is facing strong competition from air/water and air/air heat pump systems. In 2020, a differentiated tax credit is expected to be implemented, between geothermal and air heat pumps, that should encourage more geothermal installations in the individual housing market.

Several schemes have been implemented to assist geothermal sector development;

- A geological risk mitigation tool providing for failure in locating geothermal resources, insufficient temperature, insufficient flow rates or highly aggressive fluid chemistry.
- EGS Geothermal Electricity Fund. GEODEEP in cooperation with ADEME and Caisse des Dépôts et Consignations, is building a fund to primarily support EGS and then volcanic projects producing electricity from geothermal.
- The SAF Environment guarantee for deep aquifer heat production has a proven track record over 40 years. It covers the geological risk for the first well drilled, up to 200m depth for open loop systems, and then the geothermal production during the first 10 years of operation.
- The Renewable Heat Fund (Fonds Chaleur Renouvelable) created in 2009, to subsidise geothermal installations in collective housing, tertiary, industry and agriculture.

Géodénergies, an Institute of Excellence, created in July 2015 supports development of underground activities in: CO2 storage, energy storage, and geothermal energy production (heat and electricity).

**Germany**

A shift in emphasis is occurring in Germany with geothermal energy increasing being considered as heat for city and district heating networks rather than for electricity generation. At the beginning of 2018 there were 37 geothermal production operations across Germany with an associated thermal energy delivery capacity of 337 megawatts (thermal). Nine of these facilities generate electricity (capacity of around 37 MWe) either exclusively or supplementary to the heat supply. The feed-in-tariff for geothermal electricity continues to be 25.2 Euro-cents per KWh.

Stadtwerke München (SWM) is working to provide the entire district heating for Munich from renewable energy by 2040, with the majority being geothermal energy. Project GeoMARE initiated in 2018 provides both conceptual and comprehensive design of the district heating system with the project overall i targeting adaption of citywide heating infrastructure supported from a 400 MW sustainable geothermal heat supply. By the end of 2019 six geothermal wells had been drilled at the Schäftlarnstraße geothermal project site.

The Market Incentive Programme of the Federal Government promotes renewable energy systems that provide energy for space heating, hot water, cooling and process heat. It covers smaller buildings administered by the Federal Office of Economics and Export Control (BAFA), and larger buildings and commercial uses being a component of the KfW Banking Group renewable energies program. MAP subsidizes the installation of efficient heat pump systems in residential buildings through a repayment bonus, depending of the installation size.

The Federal Government has a strategic approach for technology and innovation transfer using living labs to bring new, promising technological solutions to market through exploring and mastering the challenges under real-life conditions, and then later implementing the tested technologies on a large scale.

The Federal Government supports international collaboration and cooperation through, for instance, the implementation of the EU SET-Plan and by participation in transnational funding instruments such as GEOTHERMICA.

For deep geothermal research in 2019, the BMWi approved funding of around 24.1 million euros. At the same time, around 13.2 million euros were invested in 94 ongoing research projects.

**Iceland**

Iceland has developed expertise and experience in harnessing geothermal resources for both space heating and for electricity generation.

Over 90% of Icelandic households are heated with geothermal energy. An Energy fund, operated by Orkustofnun, supports geothermal development in areas where geothermal energy is not yet used for heating. The financial support comprises a lump sum of 16 years-worth of subsidies to assist in establishing either geothermal heating or a more efficient heating system, such as using heat pumps. No market incentives apply to geothermal electricity development.

Preparation for the fourth Icelandic Master Plan for Nature Protection and Energy utilization due for completion in 2021 has begun. The third plan, presented to the Minister for Industry in September 2016 remains under consideration by parliament.

At the end of 2019 the installed capacity was 755 $MW_e$. In 2018 6000 GWh of geothermal electricity and 33 PJ of geothermal heat were produced in Iceland.

The main purpose of the IDDP work is to find out if it is economically feasible to extract energy and chemicals from hydrothermal systems at supercritical and above conditions. Planning for an IDDP-3 well in the Hengill area (near the Hellisheiði power plant) is underway.

**Italy**

At the end of 2018 the italian Installed geothermal capacity was 915,5 MWe. The gross electricity generation for 2018 was 6,105 GWh.

No new geothermal electricity generation plants were commissioned in 2019.

At the end of 2017 direct geothermal use capacity was more than 1400 MWt, with corresponding total energy use for 2017 of 10.9 Pj/yr. The geothermal energy use is broken down with the main sector use as follows: space heating 42%, thermal balneology 32% and fish farming 18%. Agricultural applications, industrial processes and other minor uses amount to less than 8% of the total annual energy use.

Installed ground-source heat pump (GSHPs) capacity is some 532 $MW_{th}$ delivering ~3.3 Pj/yr of energy. District heating systems with a total installed capacity of ~150MWt annually supply 863 Tj/yr of energy, ~8% of the total geothermal heat. The district heating systems are mainly in the Tuscany Region and District heating is the only sector growing significantly.

Recent official Italian documents forecasting renewable energy production in Italy envisage limited growth in geothermal energy applications. The 2017 Italian Energy Strategy (MISE, 2017) predicts a rather limited increase in geothermal electricity production whilst proposing to establish a support scheme for innovative geothermal technologies demonstrating power production with zero emissions. In July 2019 geothermal power was excluded from participating in the incentive schemes offered for electrical energy produced from renewables.  At the end of 2019 the support scheme for zero emission or other innovative geothermal technologies had not been established.

Recent Italian research projects focussing on sustainable development, and reducing and mitigating environmental impacts have achieved good results:

- In 2019 the EU H2020 program Matching concluded. The Matching project achieved the target of an up to 15% reduction in evaporative losses from geothermal cooling towers, through the replacement of wet cooling towers with hybrid towers.
- The Spirulina cultivation project successfully demonstrated use of geothermal $CO_2$ and heat to grow spirulina algae. This integrated geothermal and algae production process reduces $CO_2$ emissions from a geothermal facility.

The H2020 Geoenvi project was established in 2019. Scheduled for completion by April 2021 the project aims to define Guidelines for Life Cycle Analysis (LCA) and environmental impact assessments of geothermal energy facilities.

**Japan**

By the end of 2019 Japanese geothermal electricity capacity had grown to 550 $MW_e$ with the 46 $MW_e$ Wasabizawa and the 7 $MW_e$ Matsuo-Hachimantai facilities coming on line during 2019. Geothermal energy production was some 2400 GWh over the 12 month period ending March 2018.

Direct geothermal use capacity is ~2400 MWth producing ~30 PJ/year of energy.

The installation of GSHP has been increasing exponentially in recent years, with a total of 2,662 geothermal heat pump installated, with a capacity of ~160 MWth delivering about 770 TJ/year of energy.

Promotional measures in play since 2011 to intensify deployment of Renewable Energy have brought renewed interest in geothermal energy development.  in 2019 ~6 billion JPY in total grant subsidy was paid to 24 projects from JOGMEC.

Social acceptance of geothermal development remains difficult, especially amongst hot spring resort owners. METI began a program in 2013 to improve social acceptance of geothermal power generation. It is a subsidy scheme for general public educational activities undertaken by local governments and/or the private sector. Thirteen projects were adopted in 2019. In 2016 JOGMEC established a third-party expert organization the “Advisory Committee for Geothermal Resources Development” seeking to support municipality consultation to improve the understanding of specific geothermal energy projects and their social acceptance.

Since 2013 JOGMEC has been undertaking airborne helicopter geophysical surveys and by the end of 2018 16 areas in Hokkaido, Honshu and Kyushu had been surveyed. Heat flow drilling to ascertain temperatures and geological structure to a depth of ~1,000 m has been completed at 11 sites in Hokkaido and northern Honshu.

NEDO began research in 2017 on subduction-origin supercritical geothermal resources, which has potential for 10's of giga-watts of power generation for Japan, with a pilot plant targeted to be in place by 2040. Fundamental studies are being conducted by the National Institute of Advanced Industrial Science and Technology (AIST) and Kyoto University looking to utilise 500°C super critical fluids at up to 5km depths.

The Japan International Cooperation Agency is organizing training courses for geothermal specialists from developing countries. In 2019 a course was held from 11th June to 21st December at Kyushu University. The course was attended by 14 people from 6 countries (Bolivia, Djibouti, Ethiopia, Nicaragua and Philippines).

**Mexico**

The installed geothermal electricity capacity in 2019 was ~1000 MW, of that 948 MW was operational. This operational capacity represents ~1.3% of the country's total installed electricity capacity. During 2018, 5,375 GWh of electricity was produced from geothermal energy (1.7% of Mexico's electricity).

A new 26.5 $MW_e$ gross capacity condensing steam turbine generator set was commissioned in the Los Azufres geothermal field in late 2019

In 2018 23.2% of the total electricity generated in Mexico was from clean energy sources. Set by the Energy Transition Law the national target is to produce 35% of the total electrical energy from clean sources by 2024.

There were 225 production wells and 41 injection wells (2018 data) operational in five geothermal fields; Cerro Prieto, Los Azufres, Los Humeros, Las Tres Vírgenes and Domo San Pedro.

No changes or new policies regulating geothermal energy use were introduced in Mexico. Public auctions to buy electric power produced by clean energy sources, clean energy certificates and power capacity have been suspended.

The GEMex bilateral initiative between Mexico (SENER-CONACyT Energetic Sustainability Fund) and the European Community under Horizon 2020 is investigating two unconventional geothermal concepts; an EGS system in Acoculco, Pue., and a superheated system at Los Humeros. The European workgroups finished their tasks in February 2020, and the Mexican groups are scheduled to finish in July 2021. Public information is available from http://www.gemex-h2020.eu/index.php?lang=en

Direct use of geothermal energy in Mexico is largely undeveloped but recent demonstration projects from CeMIEGeo include the first geothermal heat pumps (GHP) in Mexico and a food dehydrator capable of producing up to 200 kg of dry fruit per day developed from a CeMIEGeo initiative that is operating in the Domo San Pedro geothermal field.

At the end of 2019, 32 projects sponsored by SENER-CONACyT through the CeMIEGeo consortium concluded. After five years of work, the projects conducted by this consortium produced significant results in four strategic areas:

- Evaluation of national geothermal resources
- Development and innovation of exploration techniques
- Technological developments for exploitation
- Direct uses of geothermal heat

CeMIEGeo's initiative allowed Mexico to set-up world-class geothermal laboratory infrastructure. Capacity building in geothermal disciplines was promoted and developed as never before. CeMIEGeo's digital collection contains references to technical papers and thesis generated by CeMIEGeo's projects. CeMIEGeo's Digital Collection includes papers in refereed international journals, thesis, and conference posters, most of which are accessible through https://colecciondigital.cemiegeo.org/xmlui/?locale-attribute=en.

In April 2019 the Mexican Geothermal Association held its 26th Annual Congress in Morelia City, Michoacán.

**New Zealand**

Electricity generated from geothermal energy contributed 17.4% to national electricity production in 2019. Geothermal capacity is ~1030 MWe.

Preparations commenced in late 2019 for a staged expansion of the Tauhara II project using resource consents that have previously been granted. Construction of the 31.5 MWe Top Energy Ngawha, unit 3, is on track, with injection well drilling (3 wells) completed in January 2019 and commissioning expected later in 2020. The Te Ahi O Maui ~25 MW binary power plant at Kawerau completed its 1st year of operation.

There is increased interest from policy makers and investors in direct geothermal heat use in New Zealand. The Bay of Plenty Region and the Taupo District (Bay of Connections) are promoting geothermal seeking to increase the direct use of geothermal energy and associated jobs. A Geothermal Business Development Lead was funded for 2018 and 2019 by the Bay of Connections, industry partners, the Government and the New Zealand Geothermal Association.

Implementation of a nation-wide geothermal direct use strategy initiative continued. Several operators and investors are working on commercial projects that would benefit economically from a supply of geothermal fluids. The New Zealand Geothermal Association direct use initiative is well underway. This Geoheat Strategy for Aotearoa NZ, 2017 – 2030, has goals out to 2030 of increasing the direct use of geothermal energy by 7.5 PJ per annum (primary energy) and fostering an additional 500 jobs in those enterprises that use it. An Action Plan 2020 – 2021 has been prepared through 2019, for launch in January 2020.

Direct use development at Kawerau has seen process steam produced from geothermal steam supplied to the Waiū Dairy factory and to Oji Fibre Solutions. At Tauhara a 20 $MW_{th}$ geothermal energy supply to Nature's Flame, a word pellet producer, was commissioned in November, replacing an undersized aging biomass boiler enabling wood pellet production to more than double.

A collaborative development at Ohaaki, by Geo40, Contact Energy, and Ngati Tahu Trust, has seen expansion of a demonstration silica removal plant into a successful commercial operation.

Through 2019 GNS Science management reduced core funding available for geothermal research to about NZ$2.5M/year. The research themes, under the umbrella "New Zealand's Geothermal Future", were restructured to:

- Shallow resources and direct use,
- Taupo Volcanic Zone - Structure and Dynamics;
- Taupo Volcanic Zone – Source models; and
- Reservoir Chemistry.

The "Endeavour Fund" has supported research into "Empowering Geothermal Energy; Increased Utilisation of Geothermal Energy Through New Integrated Geoscience Methods". This project addresses the geoscientific uncertainties of accessing underground resources. The project is funded at NZ$1.3M / yr until 2022.

A 5-year Endeavour fund research program, Geothermal the Next Generation, funded at a level of about NZ$2M / yr, commenced in October 2019 studying supercritical (high temperature and high pressure) fluid resources that are likely to occur in the deep roots of volcanic-hosted geothermal systems of New Zealand. This research project has a high degree of international collaboration and will also investigate technologies to capture and reinject gas emissions.

A 2- year "Marsden" research project commenced in 2019 addressing the topic of improved understanding of natural $CO_2$ flux passing through Taupo Volcanic Zone geothermal systems.

During 2019 the University of Auckland ran the PGCert geothermal diploma course with ~30 participants. The NZ Government-sponsored scholarships (up to 25 students) target the training needs of countries such as Indonesia, Philippines, Mexico, Kenya and the Caribbean. The University of Canterbury ran geothermal graduate programs: a Geothermal Energy Systems Engineering Group within the Department of Mechanical Engineering, and Geothermal Resource Research Group within the Department of Geological Sciences.

A one-day seminar was organised by the New Zealand Geothermal Association (NZGA website) in Taupo (11 July 2019). Presentations covered a range of topics including innovative mineral extraction technology, brewing using geothermal and documenting changes in green-house gas emissions from geothermal facilities in New Zealand. An NZGA mini-seminar was held in Wellington on the 26th of September, 2019. Presentations were "Direct use Opportunities" and the "Geothermal Operations Carbon Footprint".

The 41st New Zealand Geothermal Workshop was organised by the Geothermal Institute and was held at the University of Auckland on 25-27th November. Themed: "Innovation and the Future of Geothermal in a Low Carbon World". International keynotes speakers were invited from NREL (Colorado), Ormat Technologies Inc., ENEL Green Power and PT Supreme Energy. Papers can be accessed through the IGA website.

### Norway

Geothermal energy use in Norway is dominated by the widespread deployment of geothermal heat pumps. Statistics from the Norwegian heat pump organization (NOVAP) identifies a peak of 3600 GHP installations in 2011. Recent annual installations number about 2500. Total capacity installed is some 900 MWth (2017 data).

Rock Energy has finished a project constructing two geothermal wells to 1500 meters drilled for Avinor at the Oslo airport to de-ice the engine test area during the winter season. The heat from the wells is used directly. There is no electricity production from geothermal resources in Norway and no geothermal energy installations with wells deeper than 1500m in operation.

Increasing the use of geothermal energy in Norway is aligned with the country´s energy policy of increasing the use of renewable energy resources.

Norwegian industrial and academic expertise in off-shore technologies is anticipated to be readily utilised in an emerging geothermal industry with an emphasis on deep drilling, well technology, reservoir management, corrosion and scaling mitigation, and tracer technology.

**Republic of Korea**

The total installed capacity of geothermal heat pumps in Korea at the end of 2019 exceeded 1,430 MWth. Over recent years capacity has been growing at a rate of about 100 MWth per year.

Korean geothermal research expenditure was of the order of 1.6 million USD in 2019, with contributions from both government and industry.

Work at the Pohang EGS site and Ulleung Island exploration have ceased following the release of the findings from the Official Pohang investigation.

A GHP system installed at the KIGAM Daejeon office designed to quantify the benefits of GHP compared to air-source heat pumps has been operational during 2019. Two separate heat pumps each with a capacity of ~25 kW are installed. The system is equipped with a borehole which can be used as a closed-loop heat exchanger or an open-loop pumped well, or both at the same time. Performance monitoring commenced in early 2019. No analysis of the collected monitoring data has been undertaken.

**Switzerland (2018)**

Geothermal use in Switzerland is dominated by shallow lower temperature use with ~2200 $MW_{th}$ of geothermal heat pump capacity installed. The use of this technology will continue to grow as the push for renewable heat intensifies over the coming years. Additionally, large infrastructure projects, such as rail and road tunnels, are being used as sources of geothermal energy (~11 $MW_{th}$). In Western Switzerland an investigative programme is being advanced by the Canton of Geneva working to decarbonise the heating sector. With time smart thermal grids are expected to become a focus in a number of cities and research is underway on low temperature energy storage.

Direct geothermal use is dominated by Spa use, with an estimated capacity of ~25 MWth. There are no geothermal power facilities operational in Switzerland. Five EGS power projects and six hydrothermal heat / combined heat and power / energy storage projects are in the planning phases.

In January 2018 Switzerland enacted an entirely revised Energy Act and a partially revised $CO_2$-Act. These Acts contain measures supporting Switzerland's Energy Strategy 2050, some of the measures pertain to direct geothermal use and geothermal power generation.

During 2018 several financial measures supporting geothermal energy were revised and some introduced:

- Increasing the guarantee scheme for geothermal power projects to a maximum of 60% and extending the cover to include prospecting expenses. The scheme runs until the end of 2030.
- Financial support for geothermal prospecting and exploration to a maximum of 60% of the eligible cost, capped at CHF 50 million (1 CHF ~ 1 US$) per year. The scheme runs until the end of 2030.
- Financial support for direct use geothermal energy projects, maximum 60% of the eligible costs, capped at CHF 30 million per year. The scheme runs until the end of 2025.

- Feed-in tariffs for power production from hydrothermal and EGS plants have been re-calculated on the basis of a cost of capital of 5.44% for a period of 15 years. Projects admitted till November 2023.

Switzerland's geothermal research expenditure for 2017 was some 20 million USD (No data available for 2018).

Research highlights for 2018:

- Hydraulic stimulation / fracturing tests at the Grimsel Test Site
- Construction of the Bedretto Underground Laboratory
- ThermoDrill (International) – fast track innovative drilling system for deep geothermal
- GEOTHERMICA
    - ZoDrEx – zonal isolation
    - Heatstore
    - COSEISMIQ
- DESTRESS (International) – Demonstration of Soft Stimulation treatments
- DG-WOW – Deep Geothermal Well Optimisation Workflow
- RT-RAMSIS – Real-Time Risk Assessment and Mitigation System for Induced Seismicity
- Shallow geothermal applications:
    - smart thermal grids (including geothermal heat storage),
    - quality assurance and control, and
    - enhancing efficiency.

The Swiss Federal Office of Energy actively participates in:

- GEOTHERMICA,
- the International Partnership for Geothermal Technology, and
- the IEA Geothermal Technology Collaboration Program.

Geothermal conferences or conferences with significant geothermal content in 2018:

- Journées romandes de la géothermie 2018, Geneva (GE), 28-29 January 2018
- Geothermie Forum 2018, Zurich (ZH), 26 June 2018
- SCCER-SoE Annual Conference in Horw (LU) from 13-14 September 2018.

**Spain**

During 2019 the Spanish government sent the European Commission the draft National Integrated Energy and Climate Plan 2021-2030. This plan lays the foundation for modernising the Spanish economy; for Spain to take a leading position on renewable energies, for the development of the rural environment, and for improving the health of citizens, the environment and social justice. The document proposes greenhouse gas emission reduction to ~20% of the 1990 levels, targeting 42% renewable energy use by 2030, with renewable electricity at 74%. The energy efficiency improvement of 39.6% by 2030.

Geothermal exchange systems for heating and cooling in city environments are positioned as the best available technology to assist in decarbonization and in renewable energy supply as part of the energy transition.

In 2019, geothermal energy in Spain continued to advance in supplying thermal energy in the domestic, commercial and industrial sectors. The installation of geothermal exchange systems for heating and cooling public administration facilities has increased as new public buildings conform to the Near zero-energy buildings (NZEB) approach promoted by the European Union.

The potential for geothermal energy to be extracted from abandoned mines is actively under investigation in Spain. A demonstration center has been built at the mining facilities of the Santa Barbara Foundation in La Ribera del Folgoso. GEOPLAT collaborated with the Fundación Santa Bárbara and the Regional Energy Body of Castilla (EREN) to organise a geothermal conference in November 2019.

GEOPLAT and IEA Geothermal organized an International Workshop on Geothermal Energy in Gran Canaria, Spain. The event was supported by the Government of the Canary Islands and Instituto Tecnológico de Canarias (ITC) with the to promote the internationalisation of the Spanish geothermal sector, to share learnings on efficient and cost-effective geothermal energy use technologies, to gain knowledge about innovation and emerging geothermal energy technologies and not least to strengthen international cooperation and information exchange.

In 2019 the Spanish Association of Heating and Cooling Networks (ADHAC) identified 7 geothermal district heating & cooling systems in operation, with GeoDH systems 2 planned.

Spain is active in several Horizon 2020 funded projects, these are listed in main body of the report in Chapter 17.

Geoplat was involved in five workshop events during 2019:

- The European Meeting on Science, Technology and Innovation round table, Málaga, 13th February 2019. R&D&I in the energy technologies of the transition – TRANSFIERE 2019.
- The 8th and 9th April 2019 International Workshop on Geothermal Energy in Gran Canaria, Spain.
- The 10th Anniversary GEOPLAT Annual Assembly, 19th June 2019, Madrid.
- 14th November 2019 geothermal mine energy workshop on 'Shallow Geothermal: approach to geothermal, current situation and unique experiences' organized by Fundación Santa Bárbara, in collaboration with Junta de Castilla y León, Regional Energy Body of Castilla (EREN) and GEOPLAT.
- United Nations Climate Change Conference - COP 25, Madrid, 5 and 7th December 2019. GEOPLAT facilitated two sessions: "Emerging energy technologies" and "Technologies for the empowerment of the energy consumer".

There is great potential for geothermal energy to contribute to future Spanish climate change mitigation activity, as well as to generate employment associated with renewable energy technology production and manufacturing.

**United Kingdom**

The most significant use of geothermal energy in the United Kingdom is through geothermal heat pump installations with a total capacity of ~700 MWth (2019 data).

The United Downs Deep Geothermal Power project (UDDGPP) made significant progress during 2019, with two wells completed. This project is led by Geothermal Engineering Ltd. and is the first commercial project in the UK to develop deep geothermal for power generation. The project is established to utilise the natural permeability of the Porthtowan Fault in the Carnmenellis granite in Cornwall. The production well, UD1, has a drilled length of 5275 m (5057 m total vertical depth) and the injection well, UD2, has a drilled length of 2393 m (2214 m total vertical depth). Water injected at shallower depth is to migrate downward to be extracted as heated water from the deeper well.

The British Geological Survey are developing a geothermal energy research site over former coal workings in Glasgow. This Glasgow Geothermal Energy Research Field Site (GGERFS) is being established to study the low temperature mine water geothermal environment at shallow depth. The installation is nearing completion with 12 wells equipped for monitoring at a high resolution enabling the UK science community to study the low temperature mine water geothermal environment at shallow depth. The site will be operational and available to third party researchers from April 2020.

**United States of America**

The United States leads the world in installed geothermal electricity capacity, with ~3.7 GW installed. 95% of this is in the western USA, in California and Nevada.

The Geothermal Technologies Office (GTO) of the USDOE funds geothermal research and development (R&D) to stimulate growth in the geothermal industry and encourage adoption of geothermal technologies by the public and private sectors. There are four program areas:

- Enhanced geothermal systems (EGS),
- Hydrothermal resources,
- Low temperature and coproduced resources, and
- Systems analysis.

The GeoVISION study was released in May 2019. The work is a geothermal roadmap out to 2050. Three significant findings point to:

- Geothermally powered district heating schemes growing to ~18,000 (from 21 currently).
- Geothermal heat pumps (GSHP) growing to 28 million installs.
- Geothermal electricity growing to 60 GW contributing 8% of US capacity.

The Frontier Observatory for Research in Geothermal Energy Utah site at Milford has been selected as the location where this work will continue to 2024. During 2019 planning for the Phase 3 drilling occurred along with the preparation of competitive research solicitations for public release in early 2020. Funds have been appropriated by Congress to conduct this cutting-edge geothermal research and development through 2024. A video of the FORGE Utah work can be viewed through the url link.

The EGS Collab work launched in 2017 continued through 2019. The work is focussed on controlled, small-scale, in-situ experiments and on improving the understanding of rock fracture behaviour and permeability enhancement. It serves as an intermediate-scale field site where the geothermal reservoir modelling and research community is validating against controlled, small-scale, in-situ experiments focused on rock fracture behavior and permeability enhancement. During 2019 Experiment 1 work built on what had been undertaken in 2018 with continuing work on fracture stimulations, monitoring stimulation in high resolution, performing flow tests and using tracers to map fracture networks.

Play Fairway Analysis (PFA) entered Phase 3 in 2018 with the goal of validating the conceptual models by drilling temperature gradient wells into identified resources. Phase 3 drilling and assessments continued through to completion in 2019. Drilling sites included two in Nevada, one in Idaho, two in Washington, and one in Hawaii. Initial data is favourable for validation of the PFA methodology.

In 2018 six Deep Direct-Use (DDU) projects were initiated to conduct feasibility studies of large-scale, low-temperature deep-well geothermal systems coupled with advanced direct-use applications and cascaded surface technologies. The studies completed in 2019 show great potential for geothermal deep direct-use district heating and cooling (GDHC) technology beyond the western U.S., especially where very low-temperature geothermal resources are combined with temperature-boosting technologies such as heat pumps and (where still higher temperatures are required) natural gas fired boilers as a secondary heat source, integrated with the geothermal system. The feasibility studies have collectively demonstrated the economic viability of DDU. With these studies now concluded the next phase of DDU development has a focus on Advanced Energy Storage Initiatives.

Geothermal drilling research focused on three areas:

- Drilling efficiency improvements
- Waterless stimulation techniques, and
- Zonal isolation

There were two geothermal conferences in the USA in 2019, the 44th Annual Stanford Geothermal Workshop, and the GRC 2019 Annual Meeting. At the American Geophysical Union (AGU) 2019 GTO Director Susan Hamm presented the *GeoVision* study

# 1. Introduction

Progress reducing and mitigating greenhouse gas emissions along with the increasing use of renewable energy sources is occurring in many nations with geothermal energy utilisation providing a valuable contribution.

Geothermal energy is a renewable energy resource, available independent of the time of day or weather. Energy can also be stored in the ground for later retrieval and use, such as in borehole energy storage or aquifer energy storage systems. Geothermal resource use and investigations continued to grow through 2019 with a number of nations making significant investments in the direct use of geothermal energy and in geothermal heat pump technology. Growth rates in these sectors are globally running at 10% or more per annum. Globally direct geothermal energy use uptake rates are out pacing the growth rates in geothermal electricity generation.

To develop non-traditional (ultra-high temperature, supercritical and EGS) geothermal resources, technology development is vital. Research in EGS is needed to release vast geothermal energy potential contained within the earth. Supercritical research is being undertaken in Japan, Iceland, Italy and New Zealand. EGS research is a particular focus in countries in Europe and the USA. Reliable technology needs to be developed to be able to release the energy potential from these sources of earth energy.

## 1.1 IEA Geothermal

The International Energy Agency (IEA) Technology Collaboration Programmes look for solutions to long-term energy challenges through government and industry collaboration. IEA Geothermal seeks to:

> Promote the sustainable use of geothermal energy through collaboration, facilitating knowledge transfer, providing high quality information, and communicating geothermal's strategic, economic and environmental value.

IEA Geothermal has 16 members, 13 countries (Australia, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Norway, the Republic of Korea, Switzerland, the United Kingdom and the United States of America), Ormat Technologies Ltd (industrial company), the Spanish Geothermal Technology Platform (GEOPLAT) and the European Commission.

IEA Geothermal members focus activities into the Working Groups. Working Group activity is further subdivided into tasks. Task Involvement is determined by members' current interests and their research and development programmes.

IEA Geothermal collects and collates geothermal energy data annually as part of Working Group 10. The data is assembled into annual trend and power statistics reports. These can be found under Working Group Publications tab on the IEA Geothermal website.

The activities of IEA Geothermal are managed by an Executive Committee. Committee meetings were held in Gran Canaria (April 2019 Figure 1-1), and San Jose, Costa Rica, in November 2019 (Figure 1-2). Working Group meetings were held in conjunction with these meetings.

Figure 1-1 Participants attending the 41st Executive Committee meeting in Gran Canaria (Photo 4th April 2019)

Figure 1-2 Participants attending the 42nd Executive Committee meeting in San Jose, Costa Rica (Photo, 7th November 2019).

IEA Geothermal influences beyond participant member nations, with members participating in international meetings, conferences and workshops. In 2019, IEA Geothermal, in conjunction with the International Geothermal Association (IGA), ran the Baltic Sea Symposium in Offenburg, Germany on the 13h February 2019, a day before the 2019 GeoTHERM Expo and Congress. The presentations from the Symposium can be viewed and downloaded from the IEA Geothermal website.


Figure 1-3 IEA Geothermal and IGA Baltic Sea Symposium –13th February 2019

A presentation delivered on the 14 March 2019 to the 2019 Geotherm event by the Executive Secretary entitled 'Research, Development and Deployment. Advancing Deep Geothermal Energy Utilisation and Geothermal Technology' can be viewed and downloaded.

A two day International Geothermal Workshop was organised and run on the 8th and 9th April 2019 in conjunction with Geoplat, the Instituto Tecnologico de Canarias (ITC), and the Consejeria de Economia, Idustria, Comercio y Conocimeiento, Gobierno de Canarias. A photo of attendees is shown in Figure 1-4 and the presentations can be viewed and downloaded from the IEA Geothermal website.


Figure 1-4 International Geothermal Workshop at ITC, Pozo Izquierdo, Gran Canaria –April 2019

A two day International Workshop on Geothermal Energy – Central America was organised by IEA Geothermal, Instituto Costarricense de Electricidad (ICE), Sistema de la Integración Centroamericana (SICA) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on 11th / 12th November 2019. The presentations can be viewed and downloaded from the IEA Geothermal website.

This report provides details on the activities carried out by the Working Groups and The geothermal activities in member countries. The status, activities and 2019 achievements of the Working Groups are described in Chapters 2 to 6. Information on member activity is found in Chapters 7 to 21. There are many references to up-to-date information contained within the report and they can found at the end of each chapter.

Appendix 1 details the IEA Geothermal Executive Officers at the end of December 2019, and Appendix 2 the IEA Geothermal Executive Committee Members and Alternates.

For more information on IEA Geothermal please visit our website iea-gia.org or email iea-giasec@gns.cri.nz.

# 2. Working Group 1 – Environmental Impacts

Chris Bromley

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

## 2.1 Introduction

Working Group 1 (Environmental Impacts) has several goals. They 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 adverse effects.

The Working Group 1 (WG 1) web page on the IEA Geothermal web site can be accessed through this hyperlink.

Collaboration activity commenced in 1997 and at that time the group was referred to as Annex 1 (now Working Group 1). The tasks have changed over time, as different environmental and social issues have been identified and discussed by participants at meetings and workshops. Outputs have mostly consisted of published papers (including three Geothermics Journal Special Issues), protocols and environmental workshops or conference sessions.

In 2019 there were four active tasks - 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: 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 simulation, optimized operational strategies, recharge factors, recovery times, improved reservoir performance, and sustainability protocol indicators.

The countries officially participating in WG 1 are Australia, Iceland, Italy, Japan, New Zealand, Norway, Switzerland and the United States.

## 2.2 Highlights

Highlights for the year include:

- Completion of environmental and society collaboration papers for WGC2020.
- Presentations made at workshops held in Gran Canaria, Costa Rica and Kunming (China).

- Networking and cooperation amongst researchers, operators, policy-makers and funding-agencies within the participating countries
- Raising international awareness of successful mitigation schemes and beneficial environmental or social outcomes.
- Presentations and refereed papers by scientists from member countries at international conferences and workshops.

## 2.3 Task Progress and Outputs

### 2.3.1 Progress in 2019

A compilation of relevant references is included in the References section. Below is a review of the most significant activities.

WG1 focusses on networking and connecting researchers, policy makers and operators from different countries to increase awareness of environmental improvement opportunities and successful strategies mitigating adverse effects.

Cooperation between WG1 participating countries continues, and members are involved in a range of national and international research projects. An interesting project that commenced in 2019 is the European Horizon 2020 funded "GEOENVI" project https://www.geoenvi.eu/ with collaboration between France, Italy, Iceland, Turkey, Belgium and Hungary, and peer review support from other WG1 participating countries. The objective is exchange best practices across the group, establish an environmental database and develop a life-cycle assessment methodology to calculate net environmental impacts and benefits for geothermal facilities.

During 2019, progress reports on WG 1 activities were presented at the Executive Committee meetings (4/4/2019 in Gran Canaria, Canary Islands, Spain and 7/11/2019 in San Jose, Costa Rica).

At the IEA-Geothermal sponsored international workshop in Gran Canaria (8th April 2019) Kasumi Yasukawa gave a comprehensive presentation on "Geothermal Development and Environmental Protection" with examples from six countries. This presentation is available for download at http://iea-gia.org/workshop-presentations/2019-gran-canaria-geothermal-energy-workshop/

During the "East Asia Summit – New Energy Forum" held on 21-22 August 2019, at Kunming, China, Chris Bromley gave an invited presentation, and participated in a "Think Tank Dialogue" panel discussion. This focussed on novel examples, relative benefits and environmental aspects of increased geothermal energy deployment, especially across East Asia.

At the IEA-Geothermal sponsored international (Central America) workshop held in Costa Rica (11-12 November 2019), a special session on "Environmental Aspects" included an overview of WG1 activities (Chris Bromley), followed by presentations on individual country experience in environmental regulations: New Zealand (Chris Bromley), Japan (Kasumi Yasukawa), USA (Lauren Boyd), Iceland (Hjalti Ingolfson) and Costa Rica (Johan Valerio Perz). These presentations are also available for download from the IEA-Geothermal website. http://iea-gia.org/workshop-presentations/2019-costa-rica-geothermal-workshop/

Gas emissions, reinjection of non-condensable gases ($CO_2$), and $H_2S$ abatement technology remain important topics of research. Improvements in shallow/surface feature and ecosystem monitoring using drones, thermal imaging and satellite imagery are also continuing. Subsidence monitoring and improved modelling of reservoir deformation processes is ongoing. Researchers have contributed their study results to policy initiatives and sustainability discussions in several countries.

WG 1 participants were also encouraged to address the following issues:

a) shallow thermal 'pollution' extent (heating or cooling);
b) insurance industry outreach (communication of risks & solutions);
c) power-plant visibility (acceptable design for a given landscape environment);
d) casing integrity (monitoring corrosion rates); and
e) sustainability protocols in practical applications.

Selected publications during 2019 by geothermal environmental researchers from participating countries are listed below. A number of these papers were presented and discussed at the following 2019 conferences: Stanford Geothermal Workshop (Palo Alto, USA), New Zealand Geothermal Workshop (NZGW) (Auckland, NZ) and the European Geothermal Congress (The Hague). Papers may be downloaded through the www.geothermal-energy.org conference database or http://europeangeothermalcongress.eu/proceedings-egc-2019/ .

### 2.3.2 Outputs

The 2019 environmental outputs are linked with task activities, through member country participation or cooperation. These include presentations at several workshops and publications in conference proceedings, including Stanford, NZGW, and EGC (Refer the References section).

Joint WG1 papers on "Environmental and Social Impacts" were prepared for WGC2020 (see list of collaborative articles in the References section).

WG1 presentations given at IEA-Geothermal sponsored workshops in Gran Canaria, (Canary Islands) and San Jose, (Costa Rica), are published on the IEA-Geothermal website.

### 2.3.3 Future Activities

Future work includes presentation of collaborative papers on environmental topics at the World Geothermal Congress (WGC2020, postponed from April 2020 to May 2021), and continuing work on the existing tasks (as described in previous annual reports).

Ongoing efforts include:

a) Preparation of a book describing international geothermal environmental codes-of-practice, and effective protocols and policies for environmental management of geothermal projects.

Sub topics include: construction and drilling environmental effects; induced seismicity; production & injection effects (noise, effluents, emissions); social impacts; promotion of beneficial effects and mitigation of adverse effects; methods of drilling/producing/injecting deep beneath protected areas with negligible surface impact; subsidence mitigation by injection; avoiding groundwater contamination; Biochemical remediation/treatment of condensates; Monitoring of casing integrity to protect groundwater; Appropriately allocating geothermal systems for protection or development using categories and criteria; Streamlining EIA by standardising common issues and good practice procedures; cooling, stimulation and make-up water issues; tools to monitor, model and manage sustainable reservoir performance and long term reinjection; communication with local and indigenous stakeholders.

b) Organising workshops or special sessions on, for example, sustainability and surface feature monitoring.

c) Collating results of trials; using targeted shallow reinjection of hot fluids to remedy adverse effects; on gas injection; and on water treatment to remove potentially harmful species.

## 2.4 References


**Journal papers:**

Marnel Arnold Ratio, Jillian Aira Gabo-Ratio, Yasuhiro Fujimitsu "Exploring public engagement and social acceptability of geothermal energy in the Philippines: A case study on the Makiling-Banahaw Geothermal Complex", Article 101774, V85. Geothermics 2019.

**Conference papers:**

**WGC2020: (postponed from April 2020 to May 2021), Reykjavik, Iceland (in press)**

Jonas KETILSSON, Chris BROMLEY : Adaptive Leadership Roles and Tools of Government to Assist Geothermal Developers in Overcoming Barriers. Paper #03037

Chris BROMLEY, Lauren BOYD, Adele MANZELLA, Kasumi YASUKAWA : Review of Environmental & Social Aspects and Best-Practice Mitigation Measures from an IEA-Geothermal Perspective. Paper #02007.

Abdul NISHAR, Chris BROMLEY, Fabian SEPULVEDA, Kerin BROCKBANK : Review of Subsidence at Ohaaki geothermal field, New Zealand. Paper #13061

**Proc. 41st New Zealand Geothermal Workshop, Auckland, New Zealand:**

Chris Bromley, F. Sepulveda, W. Mannington, S. Currie, M. Abele: "NOVEL APPLICATION OF CONTINUOUS GRAVITY AND GNSS TO UNDERSTAND EFFECTS OF LIQUID SATURATION CHANGES ON YIELDING DEFORMATION"

M. Krieger: "GEOTHERMAL ENERGY AND ETHICAL RISK ASSESSMENT"

Katie McLean, I. Richardson: "GREENHOUSE GAS EMISSIONS FROM NEW ZEALAND GEOTHERMAL POWER GENERATION IN CONTEXT"

**Proc. European Geothermal Congress, 11-14 June 2019, The Hague:**

Anna Pellizzone, Adele Manzell , Agnes Allansdottir: "Geothermal energy and public engagement: a comparative analysis"

Spyridon Karytsas , Olympia Polyzou , Dimitrios Mendrinos, Constantine Karytsas : "Towards social acceptance of geothermal energy power plants"

Philippe Dumas, Abigaelle Peterschmitt Thomas Garabetian, Giampaolo Manfrida, Annick Loschette , Guillaume Ravier, Isabelle Blanc, Adele Manzella, Loredana Torsello, Sandra Scalari, Fausto Batini, Arni Ragnarsson1, Hjalti Páll Ingólfsso, Gudni Johannesson, Ben Laenen, Cannur Bozkurt, Ozge Solak, Annamaria Nador: "GEOENVI Project: Tackling the environmental concerns for deploying geothermal energy in Europe"

Virginie Schmidle-Bloch, Patrice Heintz, Michel Moullet: “How to win social acceptibility : the French geothermal industry approach”

Pierfranco Lattanzi, Marc W. Beutel, Pilario Costagliola , Cesare Fagotti, Valentina Rimondi: “Tracing the impact of geothermal plants in the Monte Amiata area, Tuscany, Italy: evidence from Hg contents in stream sediments and tree barks”

**44th Stanford Geothermal Workshop, February 2019**

Grimur BJORNSSON, Gunnar GRIMSSON, Ari SIGURDSSON, Valdimar Steinar LAENEN “Thermal Mapping of Icelandic Geothermal Surface Manifestations with a Drone”

# 3. Working Group 8 – Direct Use of Geothermal Energy

Katharina Link

Rebstrasse 3, 8500 Frauenfeld, Switzerland. Email: info@geo-future.expert

## 3.1 Introduction

Figure 3-1: The thermal spas of d'Ovronnaz in the Western Swiss Alps ("Les bains d'Ovronnaz")

Geothermal water has been used for millennia in various heating and bathing applications. During the last few decades the use of geothermal energy for a range of heating purposes has become more important worldwide, and this has resulted in steadily increasing uptake and use. Applications using geothermal energy include; heating buildings, raising crops and flowers in greenhouses, crop drying, aquaculture, snow melting, spas such as shown in Figure 3-1, bathing, therapeutic use, and industrial processes. Over the last decade, cooling using geothermal energy has become more important.

In 2013, Working Group 8 ("Direct Use of Geothermal Energy") was restructured. The Working Group members defined four new Tasks and continued with one from earlier work: A) New and Innovative Geothermal Direct Use Applications, B) Communication, C) Guidelines on Geothermal Energy Statistics, D) Guidelines on Statistics for Geothermal Heat Pump Applications and E) Design Configuration and Engineering Standards (continued). In 2018, a new Task F) "Costs of Geothermal Heat Pump Systems" was launched.

The Geothermal Direct Use Working Group also includes large innovative heat pump applications including smart thermal low temperature grids combined with underground storage.

The Working Group's mission is to provide unbiased quality information, communication and knowledge transfer to mitigate the barriers to geothermal direct use in order to enhance deployment. The main objectives are to collaborate, cooperate, share knowledge, and boost awareness thereby increasing the use of existing technologies.

Current participants of Working Group 8 (WG 8) are France, Germany, Iceland, Japan, Mexico, New Zealand, Republic of Korea, Switzerland, United Kingdom, and United States of America. Observing guests are Australia, Norway and the European Commission.

Geothermie-Schweiz, the Swiss Geothermal Association, is the Operating Agent for WG 8. Katharina Link, CEO and owner of Geo-Future GmbH, Switzerland, is the leader of the Working Group.

### 3.1.1 Highlights

Working Group 8 was very active in 2018 with highlights including:

An international Asia Symposium focusing on Geothermal Energy development in Asian countries conducted as a side event to the GeoTHERM Expo and Congress in Offenburg (Germany) on 28 February 2018. Experts and representatives from many Asian countries participated highlighting the potential, the opportunities and benefits from geothermal direct use and heat pump applications.

An IEA Geothermal Workshop in Vienna, Austria, highlighted potential, discussed market and project examples of geothermal direct use and heat pump applications in Austria and neighbouring countries. The event was held on the 3rd May 2018 as part of the IEA Geothermal Vienna Meetings.

An IEA Geothermal workshop was organised in conjunction with the 12th Asian Geothermal Symposium in Daejeon (South Korea) promoting geothermal direct use and heat pump applications. Innovative case studies and market conditions necessary to establish the technology in a country were presented.

The IEA Geothermal questionnaires for collecting statistical data about geothermal direct use and the guidelines for reporting the data were finalized. It was first used in 2018 for the 2016 reporting year (Trend Report 2016).

Important progress was made in improving the IEA Geothermal questionnaire for geothermal heat pump applications. In addition, guidelines for collecting and reporting this kind of statistical data for were written. The results will be presented through a paper to be presented at the World Geothermal Congress in 2020.

A new Task focusing on cost data of geothermal heat pump applications was initiated with the initial meeting taking place in November 2018. The work is seeking to develop recommendations, derived from cost analysis and interpretation, that will help to emphasise the importance of geothermal heat pump applications in reducing $CO_2$ emissions and provide information on opportunities to reduce installation capital costs.

Four publications from WG8 are in preparation for the World Geothermal Congress 2020:

- Link, Katharina and Carey, Brian: Geothermal Direct Use - International Energy Agency Geothermal TCP.
- Song, Yoonho, Link, Katharina, Yasukawa, Kasumi and Weber, Josef: Proposal of New Data Collecting Spreadsheet for Geothermal Heat Pumps Statistics: An Outcome of IEA Geothermal Working Group Activities.

- Link, Katharina and Garcia-Gutierrez, Alfonso: Costs of Geothermal Heat Pumps – a worldwide study by IEA Geothermal.
- Farr, Gareth and Busby, Jon: The Thermal Resource of Mine Waters in Abandoned Coalfields; Opportunities and Challenges for the United Kingdom.

## 3.2 Task A – New and Innovative Geothermal Direct Use Applications

(Task Leader: Brian Carey, GNS Science, New Zealand)

Geothermal direct use technologies are, in general, mature and in many countries competitive. One aspect that is in focus is the development of innovative applications that open up new utilization possibilities, to enhance efficiency, and to reduce costs, such as "Smart cities" and "energy grids" which are being adopted in a number of European cities. There is a move towards larger geothermal heat pump systems (Ground Source Heat Pumps - GSHPs), sometimes combined with other energy sources (e.g., solar thermal energy) and usually incorporating underground energy storage. Geothermal in agriculture is increasing rapidly, such as in countries like the Netherlands where in the 10 years from 2007 to 2017 geothermal heat use in greenhouses has grown from nothing to 3PJ per annum (IRENA 2019). In many countries in the world, cooling using geothermal energy is becoming at least as important as heating. Mexico is actively working in fostering direct geothermal use. An innovative food dehydrator has been developed and patents applied for (Figure 3-2).

Figure 3-2 Food Dehydrator model DGA200 at the Domo San Pedro Field Mexico. Photo courtesy CeMIEGeo 2017 update report to the IEA Geothermal Daejeon Geothermal Workshop 9 November 2018.

### 3.2.1 Progress in 2018

Three events were organized during 2018;

1. The first was as part of the 2018 GeoTHERM Expo and Congress in Offenburg, Germany on 28 February 2018 focusing on Asian nations.
2. The second was conducted in Vienna, Austria, in May 2018 and focused on geothermal project development in Austria and neighbouring countries.
3. The third was a one-day workshop in Daejeon, South Korea, in November 2018, to share knowledge and information about innovative direct use applications, to boost the awareness and deployment of geothermal direct use and heat pump applications by highlighting the advantages and opportunities for these technologies in developing

green economies. The event was held on 9 November 2018, just prior to the 12th Asian Geothermal Symposium.

### 3.2.2 Outputs

All presentations from the workshops are available as PDF from the IEA Geothermal website.

### 3.2.3 Future Activities

At least one event is proposed to be planned each year. Additionally, fact sheets about innovative projects worldwide are proposed to be compiled and uploaded to the IEA Geothermal website.

Future work will be carried out in conjunction with Task B including:

A two-day workshop in the Canary Islands in April 2019 and a second event in Costa Rica in November 2019. Both events will promote geothermal direct use and heat pump applications by presenting case studies and highlighting the opportunities and benefits of geothermal energy use.

## 3.3 Task B – Communication

(Task Leader: Katharina Link, Geo-Future GmbH, Switzerland)

Although the worldwide technical and economic potential of geothermal direct use applications is enormous, knowledge amongst the general public, politicians and decision-makers is generally lacking. The level of awareness varies widely. In some countries, like many in Europe, the potential of GSHP systems for heating residential houses is well known, but the fact that there are many other applications much less so. Even in a country like New Zealand, which has obvious potential, the many direct uses for geothermal energy are poorly known compared to geothermal power generation. To boost geothermal direct use and to enhance deployment, communication is essential. Activities are concentrating on collecting available information from member countries and cooperating organizations and exchanging experiences through the IEA Geothermal workshops held at different locations around the globe.

### 3.3.1 Progress in 2018

The Communication Task of WG 8 organised several international events in cooperation with Task A (see Chapter 3.2). The events are intended to successively cover as many continents as possible.

### 3.3.2 Outputs

All presentations are available as PDF on the IEA Geothermal website.

### 3.3.3 Future Activities

For future activities see Task A, Chapter 3.2.3.

## 3.4 Task C – Guidelines for Geothermal Energy Statistics

(Task Leader: Jonas Ketilsson, Orkustofnun, Iceland;)

No work occurred on this task as it was closed at the Executive Committee Meeting in Hanoi, Vietnam, in November 2017 as the work had been completed.

## 3.5 Task D – Statistics for Geothermal Heat Pump Applications

(Task Leader: Yoonho Song, Korean Institute of Geoscience and Mineral Resources (KIGAM), Republic of Korea).

Different load factors are applicable to various types of direct utilization, such as heating a residential house, an office building, or a green house, but different load factors are not usually considered when estimating capacity factors of the different applications. In smaller applications, as opposed to large-scale district or other heating systems, flow rate monitoring is not often undertaken and the thermal loads for GSHPs are not determined. There is therefore significant uncertainty in the statistics for geothermal energy use in GSHPs, at both a national and global level. In addition, many countries do not separate the statistics for cooling with GSHPs from heating, which causes further uncertainty in the statistics. Consequently, Task D was initiated in 2013 to determine a method for estimating geothermal energy utilization with GSHPs as accurately as possible.

If the statistics and the standard load pattern of each application type could be determined, it might be possible to establish a recommended method, or develop a reference table for calculating GSHP statistics.

### 3.5.1 Progress in 2018

At the international workshop of IEA Geothermal in Florence (Italy) in 2017 on statistical data of geothermal direct use and heat pump applications, the challenges of collecting this data were highlighted. Marit Brommer, Executive Director of the International Geothermal Association (IGA) was present. Solutions were presented and developed into the revision of the IEA Geothermal questionnaire. Collecting statistical data on geothermal heat pump applications that incorporates the appropriate estimation of the utilisation in a specific country is difficult, especially if the (seasonal) cooling mode is considered. The overall objective is to achieve consistent and comparable statistics for geothermal heat pump energy data.

The work of Task D was finalised in 2018 with the new questionnaire used in 2018 for collecting IEA Geothermal member country data for 2017.

### 3.5.2 Outputs

The questionnaire and the guidelines for the collection of statistical data of geothermal heat pump applications were completed and first used in 2018 (Trend Report of Working Group 10).

### 3.5.3 Future Activities

The new questionnaire will be presented at the World Geothermal Congress 2020 in a written paper.

## 3.6 Task E – Design Configuration and Engineering Standards

(Task Leader: Kasumi Yasukawa, National Institute of Advanced Industrial Science and Technology, AIST)

The Scope of this Task is to collect, characterize and exchange standard design and practice information for applications, with the goal of minimizing the engineering related input. The main issues are quality, reliability of operation, long term efficiency, sustainability, and cost reduction achievable through standardized procedures. Examples of successful cooperation are the dissemination of experience using quality certificated ground source heat exchangers, and the results from long-term monitoring of direct use installations. Task E also includes the collection and distribution of a list of national and international standards, engineering practice and other relevant documents.

### 3.6.1 Progress in 2018

No work was carried out during 2018 due to the Task Leader position being open. Kasumi Yasukawa took on Task Leadership late in 2018.

### 3.6.2 Outputs

No output in 2018.

### 3.6.3 Future Activities

The listing of design and engineering standards will be updated and the compilation uploaded on the IEA Geothermal website.

## 3.7 Task F – Costs of Geothermal Heat Pump Applications

(Task Leader: Alfonso Garcia Gutierrez, CeMIEGeo and iiDEA Group, UNAM, Mexico)

Costs are the key issue in most countries worldwide: in industrial countries, but especially in emerging economies / developing countries. Knowledge about the costs of geothermal heat pump applications and the influencing factors are crucial for boosting deployment of such systems. Cost data from the Working Group member countries and some further selected countries especially from Europe will be collected and analysed and the influencing factors will be deduced. The results will allow conclusions to be drawn on how costs can be minimized efficiently and sustainably while maintaining high quality standards.

### 3.7.1 Progress in 2018

The kick-off meeting took place in Daejeon (South Korea) in November 2018. A comprehensive study on life cycle costs of geothermal heat pump systems is planned in Switzerland during 2019. it is intended to incorporate the results of this study into the work of Task F and to make the report available as a case study.

### 3.7.2 Outputs

No outputs were issued during 2018.

### 3.7.3 Future Activities

Information about the costs will be collected from the Working Group member countries. The results will be analysed and interpreted. Based on the results, the influencing factors on costs will be identified and recommendations will be developed for efficient and sustainable cost minimisation. The work will be published as a report and the main outcomes and recommendations summarized in a factsheet.

A publication for the proceedings of the WGC 2020 is planned work for 2019.

## 3.8 References

IRENA. Accelerating geothermal heat adoption in the agri-food sector. Key lessons and recommendations. International Renewable Energy Agency, Abu Dhabi. ISBN 978-92-9260-105-8 (2019)

# 4. Working Group 10 – Data Collection and Information

Dr. Josef Weber

Leibniz Institute for Applied Geophysics, Section 4 – Geothermics and Information Systems, Stilleweg 2, 30655 Hannover, Germany. Email: josef.weber@liag-hannover.de

## 4.1 Introduction

Working Group (WG) 10 was established at the end of 2010 with activity commencing in 2011. The focus is collecting geothermal energy use data, trends and developments in IEA Geothermal countries and publishing this material in Geothermal Trend Reports. The objectives are achieved by the member countries providing information to the Working Group Leader and sharing the work of the Working Group. All Contracting Parties are obliged to participate and Sponsors have also agreed to contribute.

The Operating Agent for Working Group 10 is the Leibniz Institute for Applied Geophysics (LIAG), Germany with the WG led Josef Weber.

The task of data collection and information is important in terms of a growing international demand for data on renewable energy use. Data collection activities commenced in 2011 with data collated for the 2010 year. To provide trends and allow a comparison with geothermal uses worldwide, additional data, from sources such as the publications associated with the World Geothermal Congress, have also been compiled and analyzed.

The Geothermal Trend Report provides a brief overview of key data on geothermal energy use and shows the development of geothermal energy in the member countries. Work is in progress collaborating with other institutions and organizations operating internationally in the field of geothermal energy to expand the database to include geothermal energy use data from a number of non-member countries

Data on geothermal power utilization is easier to obtain than for heat utilization and since 2018 IEA Geothermal have produced a Geothermal Power Report earlier in the year than the Trend Report, which is published separately later. This short report includes tables and figures on the development of geothermal power in IEA Geothermal member countries and an overview of the latest geothermal power plants commissioned.

## 4.2 Highlights

In February 2019, the IEA Geothermal Power Report 2017 was released at the 2019 GeoTHERM Expo and Congress in Offenburg, Germany.

In October 2019 the comprehensive geothermal trend reports for 2016 and 2017 were released. The two years were included in one report. This report used data from the more detailed questionnaire for ground source heat pumps prepared in 2018 in conjunction with Working Group 8 Task D. This questionnaire enables data for cooling with ground source heat pumps as well as free cooling to be collected.

## 4.3 Progress in 2019

- Publication of the Geothermal Power Report 2017.
- Publication of the Trend Report 2016 / 17.
- Data collection for 2018.
- Commenced preparation of the 2018 Power report and the 2018 Trend Report.

## 4.4 Outputs

See highlights section above.

## 4.5 Future Activities

- Preparation and publication of the IEA Geothermal Trend and Power Report
- Collaboration with other organizations and institutions to expand data collection and to extend the countries involved.

## 4.6 References

Weber, J. & IEA Geothermal (2019): Geothermal Power Statistics 2017. Publication of the IEA Geothermal, February 2019. (available at: http://iea-gia.org/publications-2/working-group-publications/#Annex-X).

Weber, J. (2019): Trends in Geothermal Applications 2016/17. IEA Geothermal Report. Published October 2019. (available at: http://iea-gia.org/publications-2/working-group-publications/#Annex-X).

# 5. Working Group 12 – Deep Roots of Volcanic Systems

Gudni Axelsson[1], Chris Bromley[2]

[1] Iceland GeoSurvey, Grensásvegur 9, IS-108, Reykjavik, Iceland.
Email: gax@isor.is
[2] GNS Science, Wairakei Research Centre, Private Bag 2000, Taupo, New Zealand.
Email: c.bromley@gns.cri.nz

## 5.1 Introduction

The transfer of heat from the deep roots of volcanic geothermal systems to shallow depths results from complex interactions involving the flow of magma, flow of single-phase, two-phase or supercritical fluids, heat transfer, and water-rock interactions with water, gases, and salts. These processes cannot be simulated using conventional geothermal simulation modelling methods. Developing a strategy for deep roots energy utilisation therefore requires improved modelling methods, innovation of measurement tools and better understanding of high temperature water-rock-gas-salt interaction. Advances are being accelerated by collaborative research, cooperation and coordination across international research groups. Many of those are represented by IEA-Geothermal participants in Working Group 12 (WG 12).

WG 12 strategies to address these challenges, are:

Task A: Compilation of conceptual models of the roots of volcanic geothermal systems and associated research methods, using open-source information from participating countries to provide background material for deep-roots research, including information on exploration and modelling methods and tools.

Task B: Advancement of methods for deep geothermal exploration to disseminate information on advances in exploration methods, facilitate cooperation amongst research-groups, and enhance the depth resolution of available methods by using the power of joint data-set interpretation.

Task C: Methods for modelling conditions and processes in deep geothermal resources, by advancement of methods applied in the modelling of physical processes, revealing the overall process of upwards heat transfer, improving geothermal reservoir modelling, and enhancing synergy by avoiding duplication of effort through improved sharing of open-source software and information.

## 5.2 Highlights

Key highlights for WG12 in 2019 are:

- Joint preparation of collaboration paper for WGC2020 (see the References section)
- Presentation on 'Deep Roots' at IEA-Geothermal Workshop in Gran Canaria (9th April 2019)
- Presentations by scientists from member countries at international conferences and workshops (GRC, NZGW, EGC and Stanford workshops).
- Peer reviewed papers by scientists from member countries.
- Internal cooperation between WG12 participating countries continues to be strengthened; along with their involvement in various national and international research projects.

## 5.3 Progress and Outputs

### 5.3.1 Progress in 2019

WG12 activities to date have been jointly coordinated by the WG leader, Gudni Axelsson (Iceland), and deputy leader Chris Bromley (New Zealand). Participation from other country representatives (especially Japan, USA, Switzerland and Italy) continues with enthusiasm.

The compilation of references from relevant 2019 conferences are listed in the References section.

Below is a review of the most significant 2019 activities.

A presentation titled "Deep Roots of Volcanic Systems" was given at the International Workshop on Geothermal Energy, held in collaboration with Canary Islands Institute of Technology, Gran Canaria, on 9th April 2019. The presentation covered summaries of supercritical projects and research in Iceland (IDDP2), Italy (DESCRAMBLE), Mexico (GEMex), Japan and New Zealand. The presentation is available on: http://iea-gia.org/workshop-presentations/2019-gran-canaria-geothermal-energy-workshop/.

Testing of the IDDP-2 well was undertaken in the Reykjanes geothermal field, SW-Iceland, following the earlier drilling and testing of the IDDP-1 well in Krafla, N-Iceland (www.iddp.is). The IDDP-2 well was drilled to 4.7 km depth where a bottom-hole temperature of ~550°C was inferred, indicating proximity to "deep roots". Some permeability was found near to the bottom of the well, even though it's believed that some of the permeability may have been stimulated/enhanced through the high pressure difference between the well and the conditions out beyond the well during drilling, and perhaps even more by the very large temperature contrast in place at depth during drilling. The well remains to be tested, while the option of using it as a deep reinjection well is still being considered.

Internal cooperation between WG 12 participating countries continued to be strengthened. The list below identifies WG 12 participant involvement in national and international research projects:

- COTHERM, Switzerland (exploration and modelling)
- IMAGE, EU funded (exploration) – Completed
- DESCRAMBLE, EU funded (Completed - deep drilling in Italy and research)
- DEEPEGS, EU funded (deep stimulation in Iceland and France, with international research cooperation)
- GEOWELL, EU funded (drilling technology)
- GEMEX, Funded by EU and Mexican Gov.
- JBBP, Super-critical research in Japan
- Supercritical ("Geothermal the Next Generation") and super-hot fluids research (funded by New Zealand government)
- IDDP, Iceland deep drilling project (4-5 km) – Two wells drilled and IDDP-3 to be drilled after 2020
- GEORG DRG, Deep roots exploration and utilization in Iceland – Completed, but deep roots research will continue through the GEORG cooperation, which has international participation
- FUTUREVOLC (volcanology and hazards)
- Krafla Magma Testbed (KMT)
- Work associated with the IPGT- cooperation, e.g. modelling

### 5.3.2 Outputs

The 2019 outputs that are linked with WG12, directly or indirectly through participation by member countries or their cooperation, are listed in the References section. These include various presentations at workshops, as well as papers in conference proceedings and peer-reviewed journals.

### 5.3.3 Future Activities

An important future activity will be the planned presentation of a joint paper at WCC2020, now postponed from April 2020 to May 2021 (see References section). Other 2020 activity will build on the achievements to date, by communicating and sharing research results amongst participating countries and organisations, thereby reducing duplication of effort and accelerating deployment opportunities for supercritical (deep roots) geothermal resource utilisation.

Ideas for future activities include;

- organising an IEA-Geothermal symposium on supercritical (deep roots) research and development, either in conjunction with other IEA-Geothermal activities or separately, and
- Publication of a special issue of a relevant peer-reviewed scientific journal, similar to the Geothermics 2010 IEA-GIA Special Issue on Sustainability.

## 5.4 References - 2019

**Journal publications:**

Biancamaria Farina, Flavio Poletto, Dimitrios Mendrinos, José M. Carcione, Constantine Karytsas, "Seismic properties in conductive and convective hot and super-hot geothermal systems" p16-33 V82. Geothermics 2019

Kyosuke Okamoto, Hiroshi Asanuma, Takuya Ishibashi, Yusuke Yamaya, … Kuniaki Shimada, "Geological and engineering features of developing ultra-high-temperature geothermal systems in the world" p267-281, V82. Geothermics 2019.

Matylda Heřmanská, Andri Stefánsson, Samuel Scott "Supercritical fluids around magmatic intrusions: IDDP-1 at Krafla, Iceland" p101-110, V79. Geothermics 2019

de Franco, R., Petracchini, L., Scrocca, D., Caielli, G., Montegrossi, G., Santilano, A., Manzella, A.: Synthetic seismic reflection modelling in a supercritical geothermal system: an image of the K-horizon in the Larderello field (Italy), Geofluids, 2019, Article ID 8492453, 21p. (2019).

**Workshops/meetings:**

**WGC2020 postponed from April 2020 to May 2021 (in press)**

Chris BROMLEY, Gudni AXELSSON, Hiroshi ASANUMA, Adele MANZELLA, Patrick DOBSON : Supercritical Fluids - Learning about the Deep Roots of Geothermal Systems from IEA Geothermal Collaboration. Paper # 37011.

**Proc. 44th Stanford Geothermal Workshop, February 2019**

James SHNELL, Wilfred A. ELDERS, John ORCUTT, William L. OSBORN "Exploration and Development of Supercritical Geothermal Reservoirs on the Ocean Floor"

Junzo KASAHARA, Yoko HASADA, Haruyasu KUZUME, Yoshihiro FUJISE, Takashi YAMAGUCHI, Hitoshi MIKADA "Seismic Time-lapse Approach to Monitor Temporal Changes in the Supercritical Water Reservoir"

Junzo KASAHARA, Yoko HASADA, Takashi YAGAGUCHI "Seismic Imaging of Supercritical Geothermal Reservoir Using Full-waveform Inversion Method"

Tobias B. WEISENBERGER, Björn S. HARÐARSON, Kiflom G. MESFIN, Gunnlaugur M. EINARSSON, Steinþór NÍELSSON, Robert A. ZIERENBERG, Guðmundur Ó. FRIÐLEIFSSON "The Iceland Deep Drilling Project at Reykjanes - 4.5 km Deep Drilling Into Supercritical Conditions"

Wilfred A. ELDERS, William L. OSBORN, Arun S.K. RAJU, and Alfredo MARTINEZ-MORALES "The Future Role of Geothermal Resources in Reducing Greenhouse Gas Emissions in California and Beyond"

**Proc. European Geothermal Congress, 11-14 June 2019, The Hague:**

Manzella, A., Botteghi, S., Flovenz, O., Gola, G., Hersir, G.P., Limberger, J., Liotta, L., Santilano, A., Trumpy, E., van Wees, J-D.: "Mapping super-critical geothermal resources in Europe".

Guðmundur Ómar Friðleifsson, Albert Albertsson, Ari Stefánsson , Geir Þórólfsson, Kiflom G. Mesfin, Kristján Sigurðsson, Ómar Sigurðsson, Þór Gíslason: "The Reykjanes DEEPEGS Demonstration Well – IDDP-2"

Serniotti Pallotta: "Drilling in supercritical condition: the DESCRAMBLE project"

Francesco Baccarin , Henrik Büsing , Stefan Buske , Andrea Dini , Adele Manzella, Wolfgang Rabbel, "Understanding supercritical resources in continental crust"

R. de Franco, L. Petracchini, D. Scrocca, G. Caielli, G. Montegrossi, A. Santilano, A. Manzella : "SYNTHETIC SEISMIC REFLECTION MODELLING IN THE SUPERCRITICAL GEOTHERMAL SYSTEM OF THE LARDERELLO FIELD (ITALY)"

M. DARNET, N. COPPO, P. WAWRZYNIAK, S. NIELSSON, G.O. FRIDLEIFSSON, E. SCHILL: "Imaging and monitoring the Reykjanes supercritical geothermal reservoir in Iceland with time-lapse CSEM and MT measurements"

**Trans. Geothermal Resources Council, Vol. 43, October (2019) Reno, Nevada**:

Asanuma, Hiroshi; Mogi, Toru; Tsuchiya, Noriyoshi; Watanabe, Noriaki; Naganawa, Shigemi; Ogawa, Yasuo; Fujimitsu, Yasuhiro; Kajiwara, Tatsuya; Osato, Kazumi; Shimeda, Kuniaki; Horimoto, Seiki; Sato, Takashi; Yamada, Shigeto; Watanabe, Kimio; Gotoh, Y "Status of Japanese Supercritical Geothermal Project in FY2018"

Schnell, J.; Elders, W.A.; Kostecki, R.; Osborn, W.L.; Tucker, M.C.; Urban, J.J.; Wachsman, E.D. "Supercritical Geothermal Cogeneration to Provide Long Run Solutions to Problems Facing the Salton Sea Area"

**Proc. 41st New Zealand Geothermal Workshop, Auckland, New Zealand:**

I. Chambefort, M. Rowe, A. Mazot, T.J. Yang and D. Farsky "SUPERHOT FLUIDS: THE ORIGIN AND FLUX OF NATURAL GREENHOUSE GASES IN VOLCANIC AREAS"

I. Chambefort, B. Mountain, A. Blair, G. Bignall "GEOTHERMAL: THE NEXT GENERATION"

# 6. Working Group 13 – Emerging Geothermal Technologies

Dr. Josef Weber[1], Christian Minning[2], Dr. Inga Moeck[3], Dr. Tae Jong Lee[4], Manuela Richter[5], Dr. Peter Meier[6], Dr. Katharina Link[6] Chris Bromley[7], Dr. Jiri Muller[8]

[1] Leader of WG 13, Leibniz Institute for Applied Geophysics, Section 4 – Geothermics and Information Systems, Stilleweg 2, 30655 Hannover, Germany. Email: josef.weber@liag-hannover.de

[2] Co-Leader of WG 13, Swisstopo, Swiss Geological Survey, Seftigenstrasse 264, 3084 Wabern, Switzerland. Email: christian.minnig@swisstopo.ch

[3] Task A.1 Head of section Geothermics and Information Systems, Leibniz Institute for Applied Geophysics (LIAG) Stilleweg 2, 30655 Hannover, Germany Email: inga.moeck@leibniz-liag.de

[4] Task A.2, Climate Change Mitigation and Sustainability Division, Korea Institute of Geosciences and Mineral Resources (KIGAM), Gwahang-no 124, Yuseong-gu, Daejeon 34132, Korea. Email: megi@kigam.re.kr

[5] Task B, Project Management Jülich, Division Energy System – Renewable Energies/Power Plant Technology, Geothermal Energy, Hydropower, Science Communication, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany. Email: ma.richter@fz-juelich.de

[6] Task C, Geo-Energie Suisse AG, Reitergasse 11, 8004 Zurich, Switzerland. Email: p.meier@geo-energie.ch; k.link@geo-energie.ch

[8] Task D, GNS Science, Wairakei Research Centre, Private Bag 2000, Taupo 3352, New Zealand. Email: c.bromley@gns.cri.nz

[7] Task E, Institute for Energy Technology (IFE), P.O. Box 40, 2027 Kjeller, Norway. Email: jiri.muller@ife.no

## 6.1 Introduction

Working Group (WG) 13, Emerging Geothermal Technologies, was established on 21st April 2015 and work commenced subsequent to a meeting in Hanover, Germany in September of that year. The working group covers a broad spectrum of geothermal activity including: exploration, drilling, reservoir creation and enhancement, corrosion and scaling in surface facilities, the use of tracers, and the mitigation of induced seismicity.

Work in WG 13 is carried out in six tasks:

| Task | Description | Task Leader |
|---|---|---|
| A-A1 | Exploration (Geothermal Play Types) | Inga Moeck |
| A-A2 | Measurement and Logging | Tae Jong Lee |
| B: | Drilling Technology | Manuela Richter |
| C: | Reservoir Creation and Enhancement | Peter Meier |
| D: | Induced Seismicity | Chris Bromley |
| E: | Surface Technology (Heat and Electricity Production, Corrosion, Scaling, Tracer Technology) | Jiri Muller |

The goal of WG 13 is to provide quality information to facilitate and promote the utilization of geothermal energy worldwide. The development of innovative technologies is being pushed by expert collaboration between countries with the results made available in documents and through presentations at conferences and workshops.

Participants are Germany (The Leibniz Institute for Applied Geophysics as the Operating Agent, with Josef Weber the WG leader), Switzerland (with Christian Minnig as WG co-leader), Norway (IFE), Korea (KIGAM), New Zealand (GNS Science), Japan, Australia, France, the United States and the European Commission.

## 6.2 Highlights

The release of the video produced in Task B, explaining the technology and advancements in geothermal drilling was received well. The Geothermal TCP intends to produce more such short information pieces to inform about geothermal energy. The video is publicly available for download.

## 6.3 Task A – Exploration, Measurement and Logging

Task A is targeted at sharing information on new and emerging technologies in exploration, measurement, geophysical and well logging, and sharing experiences from case studies in geothermal fields in different countries.

In 2017, it was decided to subdivide Task A into two subtasks: Task A1, Exploration (Geothermal Play Types) and Task A2, Measurement and Logging.

### 6.3.1 Progress in 2019

#### Subtask A1: Exploration

Refinement of the playtype concept and definitions occurred during 2019. A playtype workshop was held in Gran Canaria on the 5th April and a second in San Jose, Costa Rica on the 7th November. The latter focussed on better defining volcanic geothermal playtypes.

#### Subtask A2: Measurements and logging

Subtask A2 continued to collect and sharing information on high temperature and high pressure (HTHP) logging tools and services.

### 6.3.2 Outputs

#### Subtask A1: Exploration

No output to report in 2019

#### Subtask A2: Measurements and logging

The updated information about the high temperature and pressure logging technologies was published on the Journal of Geothermal resources Society of Japan in January (Lee, 2019).

### 6.3.3 Future Activities

#### Subtask A1: Exploration

Future activities yet to be defined.

#### Subtask A2: Measurements and logging

The list of organizations who provide downhole measurements and logging services for geothermal applications will be updated, as will the list of research projects developing HT/HP tools. Information about the standard processes or manuals will be added for quality control during data acquisition and processing for those HTHP logging.

## 6.4 Task B – Drilling Technology

Drilling can account for up to 50% of the total costs of a geothermal project. Task B seeks to address the question of reducing drilling costs and innovative drilling alternatives to rotary methods that are predominantly used. For this purpose, Task B includes the compilation of geothermal well drilling performance and cost information. The aim is to identify problem areas identifying suggested improvements.

### 6.4.1 Progress in 2019

A video was produced during 2019. The content of the film is of a quality to promote acceptance and inform the public about drilling for geothermal use.

Participants from business and science were:

- Baker Hughes, a GE Company
- Stadtwerke München GmbH
- Herrenknecht AG
- TU Dresden
- Geothermal Center Bochum

The video called "Innovative Geothermal Drilling Technology" and can be downloaded using the following link: https://www.youtube.com/watch?v=I4IXeY7JyH0&t=5s.

### 6.4.2 Outputs

A report summarising new global developments in geothermal drilling technologies was published (https://drive.google.com/open?id=1VJ2Di92erffd_xBuwXDcRZVGtfilg9zW) as part of Task B in 2017. Several examples of alternative drilling methods are described, for example drilling hard rocks with lightning, LaserJet Drilling and percussion drilling.

The video "Innovative Geothermal Drilling Technology" produced in 2019 can be downloaded using the following link: https://www.youtube.com/watch?v=I4IXeY7JyH0&t=5s.

### 6.4.3 Future Activities

Task B will continue collecting and summarising data related to geothermal drilling. The information will be collected mainly from published papers as industry data is more difficult to access. It is planned to use available information to prepare a geothermal well drilling learning curve.

## 6.5 Task C – Reservoir Creation and Enhancement

### 6.5.1 Progress in 2019

No activity to report in 2019

### 6.5.2 Outputs

No output to report in 2019

### 6.5.3 Future Activities

Future activities not planned yet

## 6.6 Task D – Induced Seismicity

### 6.6.1 Progress in 2019

Induced seismicity risk remains an issue for many geothermal projects, particularly those involving deep EGS fracture stimulations, and those located in densely-populated regions, near fragile buildings, or surrounded by people not familiar with natural earthquakes. Collaborative research into this topic commenced in 2004 as a task in Annex 1, this then switched to Annex 11, and in 2015 transferred to Task D under WG 13. The initial work focus was on developing a protocol to assist developers and regulators, as well as providing a forum for research collaboration and information exchange. Through collaboration with IPGT, efforts also focussed on establishing consistent data protocols, understanding mechanisms, and improving advanced forecasting methods using a modified "traffic-light" approach for adaptive response to observed levels of seismicity based on modifying injection and stimulation parameters. Aspects of this work are continuing under this task.

A new research focus is to better understand, through collaborative modelling and data sharing, the key mechanisms behind induced seismicity that may accompany long term injection.

### 6.6.2 Outputs

In 2019, the primary effort of this task was to further encourage collaboration of researchers and to share the results of the considerable amount of funded research undertaken by participants. Countries with a strong interest in this topic include: Germany, France, Switzerland, Iceland, Japan, USA and New Zealand.

Geothermal participants from IEA-Geothermal countries met at the 3rd Induced Seismicity Workshop held in Schatzalp, Davos , Switzerland, (http://www.seismo.ethz.ch/en/research-and-teaching/schatzalp-workshop/) on 5-8th March 2019. Countries represented at this event as keynote speakers or presenters with geothermal research interests, included: Switzerland, USA, France, UK, Korea, Japan, Norway and New Zealand. Topics addressed included: traffic light protocols, social impacts, induced/natural, automatic picking, predicting ground motion, b-value/stress-state, hydro-shearing, aseismic-slip. Case-studies included: Pohang (Korea), The Geysers, Fenton Hill, & Utah Frontier (USA), Espoo (Finland), Basel & St Gallen (Switzerland), TVZ (New Zealand), and Hellisheidi (Iceland).

A paper was prepared for the WGC2020 meeting (see reference section below). Papers were also published in 'Geothermics', 'Geothermal Energy', and 'Geochemistry Geophysics & Geosystems' journals. These are listed in the reference section.

Papers by authors from participating countries on the topic of induced seismicity were presented and published in the proceedings of several international geothermal workshops. They include: 44th Stanford Geothermal Workshop (February, California); European Geothermal Congress (June, The Hague), Geothermal Resource Council Meeting (October, Reno, Nevada) and 41st New Zealand Geothermal Workshop (November, Auckland, New Zealand).

Publications on the 2017 Pohang earthquake and nearby EGS stimulation project appeared in 'Nature' and 'Science', and were followed by a formal investigation to determine the cause of the earthquake, a special session at the 2019 Schatzalp workshop, and a series of articles (including at https://science.sciencemag.org/content/360/6392/1007) and papers for a virtual special issue of 'Geothermics'.

The main topics that were of interest to collaborating researchers during 2019 remained similar to previous years, that is: seismicity observations, network design, mechanisms and models, triggers, seismic tomography, risk governance and policy.

### 6.6.3 Future Activities

In addition to the task of keeping interested parties up-to-date on the latest research results and technology developments in this topic, further efforts to strengthen international collaboration will continue. Lessons learnt will be summarised to assist developers, policy makers and the general public to make informed opinions about the risks involved. Outcomes will include improved and informed decisions about protocols and recommended monitoring schemes required for new or expanded geothermal projects.

## 6.7 Task E – Surface Technology (Heat and Electricity Production, Corrosion, Scaling, Tracer Technology)

### 6.7.1 Progress in 2019

Task E has continued to focus on recent developments in surface technology for geothermal heat and electricity production, corrosion, scaling and tracer technologies. It is based on the following activities:

- Collecting and collating available information from IEA Geothermal members
- Technical presentations at international forums
- Increasing awareness of the work of IEA Geothermal and knowledge transfer to the international community
- Collaboration and joint activity with international organisations dealing with similar aspects and issues
- Launching new research projects
- Attracting new members from the results presented and the benefits derived
- Commencing cooperation between countries, research organizations and industry

### 6.7.2 Outputs

Task E presented, with aspects discussed in several international forums. These included:

- In connection with "IEA-Geothermal EXECO meeting", Las Palmas, April 2019
- In connection with "IEA-Geothermal EXECO meeting", San Jose, November 2019
- Presentation of Task E at "The 8th International Conference on Tracers and Tracing Methods", Da Nang (TRACER 8)
- Presentation of Task E at EAGE geothermal workshop in London, June 2019
- Preliminary preparation of the Workshop on Surface Technology organized by Task E in collaboration with ORMAT Technologies in spring 2021
- Dissemination event in connection with GeoTHERM-expo & congress, Offenburg, February 2019
- "ETIP" (European Technology & Innovation Platform for Deep Geothermal) meeting, Brussels, January 2018

### 6.7.3 Future Activities

We expect to collect and collate available information as identified in section 6.7.1 from technical presentations at international forums, increasing awareness of the work of IEA Geothermal, sharing knowledge with the international community, collaborating, initiating joint actions and research projects with international bodies dealing with similar aspects and issues, and attracting interested new members.

## 6.8 References

### 6.8.1 Task A


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Ana C. AGUIAR, Stephen C. MYER S.: “Microseismic Focal Mechanisms and Implications for Changes in Stress During the 2014 Newberry EGS Stimulation”

Bruce R. JULIAN, Gillian R. FOULGER, Najwa MHANA, Ceri NUNN, Andrew SABIN, David MEADE: “Time-dependence of Seismic Wave Speeds in Volcanic and Geothermal Systems”

David DEMPSEY, Jeremy RIFFAULT, Alberto ARDID, Ted BERTRAND, Rosalind ARCHER: “Integrating Magnetotelluric and Microseismic Data with Geothermal Reservoir Models”

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Emmanuel Gaucher, Tania Toledo, Malte Metz, Angel G. Figueroa-Soto and Marco Calò: "One year of passive seismic monitoring of the Los Humeros (Mexico) geothermal field"

Rike Koepke, Olivier Lengliné , Emmanuel Gaucher , Jean Schmittbuhl, Thomas Kohl: "Long term seismicity monitoring of the Rittershoffen deep geothermal reservoir"

**Trans. Geothermal Resources Council, October 2019, Reno, Nevada.**

Eneva, Mariana; Adams, David; Falorni, Giacomo; Shumski, Mark: "Surface Deformation and Seismicity at the North Brawley Geothermal Field in Southern California"

Pankow, Kristine; Mesimeri, Maria; Moore, Joe: "Seismic Monitoring at the Utah Frontier Observatory for Research in Geothermal Energy"

Zingg, Olivier; Meier, Peter: "Summary of the Investigations Conducted Following the November 2017 Earthquake in Pohang, South Korea, and Implications for the Haute-Sorne Multi-stage-stimulation EGS Project, Switzerland"

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# 7. Australia

Betina Bendall, Barry A. Goldstein

Department of State Development, Level 6, 101 Grenfell St, Adelaide, South Australia 5000.
Email: betina.bendall@sa.gov.au; barry.goldstein@sa.gov.au

## 7.1 Introduction

Activity in geothermal energy in Australia peaked in the 2009 to 2015 period with a focus on the development of electricity generation from Engineered Geothermal (EGS) and Hot Sedimentary Aquifer (HSA) Systems. At this time about 10 unconventional geothermal projects were under development and significant technical successes were achieved including the creation of EGS reservoirs by Geodynamics Ltd at the Habanero field in the Cooper Basin, South Australia and Petratherm Ltd at Paralana, South Australia and the first generation of electricity from an EGS resource in Australia also at Geodynamics Ltd.'s Habanero field in 2013.

The technical achievements made were tempered by a lack of commercial success, largely influenced by a combination of high drilling costs, poor market conditions leading to the retraction of private venture capital for speculative investments, and an uncertain policy environment for renewable technologies. This led to the contraction of the sector, with most projects either being abandoned or suspended. Succinct discussions of these issues and the current climate faced by the generation sector in Australia are provided by Budd and Gerner (2015) and a 2019 report by the Australian Geothermal Association (Ballesteros et al, 2019). Recently there has been renewed interest in developing small-scale geothermal generation in remote regional centres using heat from bore water infrastructure, cooling the water before it enters the town / community water supply. An example is the recently completed ORC plant at Winton, Queensland and two similar projects are in the design phase.

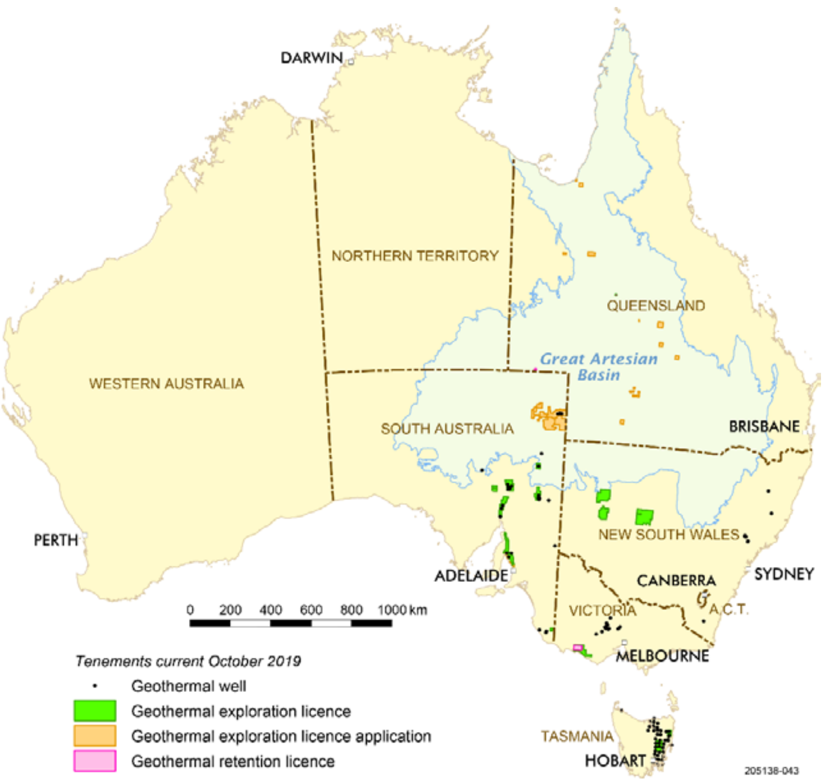


**Figure 7-1:** Geothermal licences, applications and gazettal areas as at 31 October 2019.

Increased interest and investment in Ground Source Heat Pumps (GSHP) and Direct Use geothermal applications has continued, with some significant developments being funded by organisations from all tiers of government in recent years. A number of geothermal aquatic centre projects have been constructed by local councils in Western Australia and Victoria, encouraged by rising domestic gas prices. These projects are largely funded directly from the councils' infrastructure budgets, driven by projected savings in operating costs compared to natural gas boiler systems (AGA, 2019).

These developments occur in the absence of supporting policy incentives since Direct Use geothermal technologies, including GSHPs, remain ineligible under the Australian Commonwealth Government's Small-Scale Renewable Energy Target program. Lack of supporting policy mechanisms and low community awareness of the potential of GSHP and direct use geothermal constitute major impediments to the wider deployment of these technologies.

The following table summarises geothermal energy usage in Australia for the calendar year 2019.

| Electricity | | Direct Use | |
|---|---|---|---|
| Total Installed Capacity ($MW_e$) | 0.3 | Total Installed Capacity ($MW_{th}$) | 60.8* |
| New Installed Capacity ($MW_e$) | 0.3 | New Installed Capacity ($MW_{th}$) | 4.3* |
| Total Running Capacity ($MW_e$) | N/A | Total Heat Used (PJ/yr) [GWh/yr] | 283.7* |
| Contribution to National Capacity (%) | NA | Total Installed Capacity Heat Pumps ($MW_{th}$) | 35* |
| Total Generation (GWh) | NA | Total Net Heat Pump Use [GWh/yr] | 30.9* |
| Contribution to National Generation (%) | 0 | Target (PJ/yr) | N/A |

(N/A = data not available)

(* indicates estimated values from 2018)

## 7.2 Changes to Policy Supporting Geothermal Development

At the international level, Australia's commitment under the 2015 Paris Agreement is to reduce emissions by 26–28% below 2005 levels by 2030, building on Australia's Kyoto Protocol commitment to reduce emissions by 5–25% per cent below 2000 levels by 2020. A revised Renewable Energy Target (RET) scheme in operation since 2011 has been the main incentive for delivering this target through the deployment target of 33000 GWh of renewable generation by 2020 (Clean Energy Regulator, 2019a; DAWE, 2019; DoEE, 2019b; Li et al, 2020).

The transition of Australia's electricity sector to renewables is proceeding rapidly with more capacity per capita being installed in 2018 than in any other country. Investment in renewables is strong and there is now enough capacity built or under construction to exceed the 2020 Renewable Energy Target, with a record 3455MW of new renewable generation accredited in 2018 and a forecast 4000MW expected to be accredited in 2019. This new capacity will overachieve on the 20% by 2020 target leaving no further legislated incentive for new renewables, however renewable generation exceeded 40,000 GWh in 2019, suggesting that commercial factors are now a stronger driver for ongoing investment than incentives from the RET (Clean Energy Regulator, 2019a; 2019b; DoEE, 2019).

At this stage no new policies have been foreshadowed by the current Commonwealth Government and in the absence of additional national level policy directives, many Australian states and territories have introduced their own renewable energy and emission reduction targets. South Australia, Tasmania and Queensland are developing significant renewable generation and storage capabilities. Tasmania already regularly achieves over 100% renewable generation and exports the excess to the mainland states. South Australia also regularly generates up to 50% of their supply from renewables and is on track to achieve 75% by 2030. The Australian Energy Market Operator (AEMO), foresees renewables offering the least-cost solution to replace aging fossil fuel (particularly coal) fired generators as they are retired in the coming decades (Clean Energy Regulator, 2019b; DoEE, 2019a; Li et al, 2020).

In the calendar year 2018, total electricity generation rose slightly in Australia by about 1% to 261,000 GWh. Renewable generation across all technologies accounted for 19% of total generation with an estimated generation of 49,00 GWh (DoEE 2019a). The steady increase in renewable generation has driven significant reductions in greenhouse gas emissions from the electricity generation sector since 2016. Emissions from the sector in 2019 were 180 MtCO2e and are projected to decline to 170 MtCO2e in 2020 and to 131 MtCO2e by 2030 (DoEE, 2019b). Australia will overachieve on the 2020 Kyoto target by an estimated 264 MtCO2e, largely as a result of the declining emissions trend in the generation sector. The latest cumulative emissions projections from all sectors suggest that Australia's abatement task to reach the 2030 target is between 395 – 462 MtCO2e. If the 2020 target overachievement is included in projections, the task is reduced to between -16 and 51 MtCO2e (DoEE, 2019b).

In Australia, jurisdiction for the legislation, permitting and regulation of geothermal exploration and development is a State and Territory government responsibility. Currently there are no national policies or grant structures which specifically target geothermal technologies. There has been some support for individual projects however by the Commonwealth and State Governments under general funding mechanisms for renewable technologies and infrastructure (e.g. ARENA, 2019).

## 7.3 Geothermal Project Development

### 7.3.1 Projects Commissioned

Construction is underway on the AU$57 million Gippsland Regional Aquatic Centre (GRAC) in Traralgon, a regional centre located in SE Victoria. This is the first geothermal direct use project of its kind to be constructed in Victoria and will feature a range of facilities for competitive swimming, leisure, general community use and major regional events. Heating for the pools and heating and cooling for the associated buildings and adjacent Latrobe Creative Arts Precinct will be provided from 2 x 650m deep bores into the 65°C Traralgon aquifer. The cooled water will be reinjected into the aquifer at about 40 °C. The original swimming complex used natural gas for heating and it is estimated that use of geothermal energy will lead to savings of about AU$370,000 per year plus an environmental benefit of 730 tonnes per year in greenhouse gas emission offsets. The project is due for completion early in 2021.

### 7.3.2 Projects Operational

Construction and commissioning of a 310 kW ORC geothermal power plant in the remote community of Winton, Queensland was completed in 2019, and the plant began operation in December 2019. Production statistics for the Winton plant are not yet available.

Winton township is located in central western Queensland with a population of about ~900 people. It is situated toward the end of the existing regional transmission grid and suffers from poor security of supply, relying on diesel backup generators when common brown outs and power interruptions occur. The local council's electricity usage is on the order of 1850MWh/y at a cost of ~AU$500,000/year however demand and costs are rising steadily, in 2019 alone there was an increase of 13.5% in electricity usage.

Figure 7-2 Winton Shire ORC geothermal plant.

The town's water supply is sourced the Great Artesian Basin. Water emerges from a networked bore system drilled to 1330m depth at 86°C with a flow rate of 77 l/s which was originally cooled in ponds before being reticulated throughout the town for use. The small modular ORC plant is comprised of two 155kW modules which generate electricity using the heat from the town water supply. Generation from the plant is automatically modulated to match water consumption and is distributed via a private underground network for the Council's use with any excess electricity being fed into the regional grid. This future proofs the Council against rising electricity costs, rising power demand and insecure supply, and also improves the efficiency of the water reticulation system, reducing its footprint and the need for additional cooling ponds. Conservative projections suggest the plant will deliver AU$12.1 million in electricity savings over 20 years with the potential for the plant to be expanded if the town's water allocation is increased in the future.

The Winton project is noteworthy as it serves as a prototype and test case for a number of other potential small scale geothermal developments throughout outback Australia, particularly in regional Queensland.

## 7.4 Research Highlights

Government funded geothermal research is largely conducted by government research institutions and universities, supported by both State and Commonwealth Government funding including the Australian Research Council (ARC) and the Australian Renewable Energy Agency (ARENA). As the principal agency for the funding and support of renewable energy technologies in Australia, ARENA's objectives are to increase the supply and competitiveness of renewable energy in Australia. ARENA are currently funding a three-year study on the performance of 'deep well direct exchange' (DWDX) ground source heat pumps installed in a residential community in Western Sydney, due for completion in 2022 (ARENA, 2019).

In July 2018 the Australian Geothermal Association (AGA) independently commenced a comprehensive national Census to map the type, size and distribution of Australian geothermal energy installations and projects. Results of the Census were published in 2019 (AGA, 2019).

## 7.5 Other National Activities

### 7.5.1 Geothermal Education

No new educational programmes commenced in 2019.

### 7.5.2 Conferences

No national geothermal conference program was held in 2019.

### 7.5.3 Publications

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## 7.6 Useful Websites

https://www.australiangeothermal.org.au/

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http://www.wearepeak.com.au/wintongeothermal

https://www.youtube.com/watch?v=ArML2QVbH08

https://www.uts.edu.au/sites/default/files/LNCLET_Winton_Fact_sheet_finalV3.pdf

https://www.bing.com/videos/search?q=winton+geothermal&docid=608050502521259273&mid=9138C7D7AD9E3E7D60E19138C7D7AD9E3E7D60E1&view=detail&FORM=VIRE

https://www.facebook.com/watch/?v=416280545936162

http://www.latrobe.vic.gov.au/Building_and_Planning/Major_Projects/Latrobe_Valley_Sports_and_Community_Initiative/Gippsland_Regional_Aquatic_Centre

## 7.7 Future Activity

Key activities scheduled for 2020 include completion of the Gippsland Aquatic Centre in Victoria and commencement of construction of another small-scale geothermal plant in Thargomindah (Queensland).

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# 8. European Union

Samuel Carrara and Matthijs Soede

European Commission:
Joint Research Centre, Netherlands and DG Research and Innovation, CDMA 03/046, B-1049 Brussels.
Email: Samuel.Carrara@ec.europa.eu matthijs.soede@ec.europa.eu

## 8.1 Introduction

The European Commission is supporting the development of the geothermal sector through an array of activities based on two major policy initiatives: the Energy Union and the SET-Plan.

The European Commission cooperates closely with its Member States to increase support for geothermal energy. The SET-plan steering group has adopted the deep geothermal implementation plan (DG-IP) and A Deep Geothermal Implementation Working Group (DG-IWG) is being established to advance the DG-IP.

The European Commission continued to support geothermal energy research and development via the Horizon 2020 and the European Regional Development Fund programs.

In November 2018, the European Parliament adopted the revised Renewable Energy Directive, the Energy Efficiency Directive and the Governance of the Energy Union Regulation which lay out the European climate and energy regulatory framework after 2020. The EU Clean Energy Package sets a 32% binding target for renewables by 2030.

The 2019 geothermal electricity production in the EU amounted to some 6.64 TWh which is approximately 0.2 % of the total electricity consumption of the EU. The European district heating market as a whole has seen a 3% annual growth rate in geothermal based systems in the last five years. In the EU, there are currently about 200 geothermal district heating plants in operation, with a total capacity of 1.8 $GW_{th}$.

## 8.2 Changes to Policy Supporting Geothermal Development

The European Commission is supporting the development of the geothermal sector through an array of activities based on two major policy initiatives: the Energy Union and the SET-Plan in particular. Geothermal energy is promoted through the Climate and Energy objectives of the European Union (EU). The regulatory and policy framework for geothermal energy is complex and national and regional frameworks may vary significantly from the European level, with more regionally specific policies in place in different locations.

The European Climate and Energy Framework is structured around two axes:

- Climate and energy targets (on renewable energy, energy efficiency and carbon emission reduction) and the related legislative text, such as the Renewable Energy Directive or the Energy Efficiency Directive;
- The Emission Trading Scheme (ETS): the largest existing carbon market and associated mechanisms.

The Renewable Energy Directive introduced key provisions for the development of innovative energy technologies. The directive requires a binding target for the share of renewables by 2020, hence countries have been obliged to specify sources of renewable energies to develop. Under the directive, priority of dispatch and priority access is given to geothermal electricity, which provides investors with certainty when supporting demonstration projects. Feed-in tariffs or premiums that incentivise investments in new deep geothermal projects were also established.

To meet the EU's energy and climate targets for 2030, EU Member States need to establish a 10-year integrated national energy and climate plan (NECP) from 2021 to 2030. The NECPs were introduced by the Regulation on the governance of the energy union and climate action (EU/2018/1999)[1]. The national plans outline how the EU Member States intend to address energy efficiency, renewables, emissions reductions, and research and innovation. This approach requires coordination across all governmental departments. It also provides a level of planning that will ease public and private investment. The fact that all EU Member States are using a similar template means that they can work together to make efficiency gains across borders. All the EU Member States were asked to submit their plans before the end of 2019. EU countries are required now to develop national long-term strategies by 1 January 2020 with consistency between the long-term-strategies and the NECPs

The new European Commission President Ursula von der Leyen said that she wants Europe to becomethe world's first climate-neutral continent by 2050, "It will be the greatest challenge and opportunity of our times". To achieve this, the European Commission presented the European Green Deal2. It will be the most ambitious package of measures that should enable European citizens and businesses to benefit from the sustainable green transition. Measures accompanied with an initial roadmap of key policies range from ambitiously cutting emissions, to investing in cutting-edge research and innovation, to preserving Europe's natural environment.

Supported by investments in green technologies, sustainable solutions and new businesses, the Green Deal is a new EU growth strategy with involvement and commitment of the public and all stakeholders crucial to its success.

The European Green Deal sets a transition path that is just and socially fair. It is designed in such a way as to leave no individual or region behind in the transformation ahead.

Geothermal developments have been shown to benefit from government support. Several member states (MS) of the EU have implemented support policy instruments that have resulted in an acceleration of geothermal development [Subir K. Sanyal et al. 2016]. Policy support instruments for geothermal energy include both push and pull mechanisms. These differ between member states and depend on the technology in question (power production, direct use, GSHP). For geothermal power, support schemes at EU or national level include feed-in tariffs, feed-in premiums, subsidies, loans, tenders, quota systems, net-metering and tax regulation. For geothermal heating and cooling (including GHSP), subsidies, loans, quota systems, tax regulation and price-based mechanisms are available. A forthcoming Joint Research Centre (JRC) report will show all policy instruments available for geothermal electricity, and heating and cooling [Shortall et al. 2019].

The geothermal energy sector is now supported at European level through the Cohesion Fund, the European Regional Development Fund, the European Social Fund and the European Agricultural Fund for Rural Development [ETIP-DG 2018a]. Financial Instruments provide technical assistance, soft loan schemes or revolving funding.

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[1] https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/national-energy-climate-plans
[2] https://ec.europa.eu/info/publications/communication-european-green-deal_en

Horizon 2020 is the main EU R&I programme with nearly EUR 80 billion of funding available over 7 years (2014 to 2020). H2020 has provided funding to geothermal R&D projects since its inception. The European Investment Bank (EIB) is owned by the Member States and works closely with other EU institutions to implement EU policy focussing on specific priorities such as climate action and strategic infrastructure. It supports projects through loans, technical assistance, guarantees or venture capital [ETIP-DG 2018a].

In 2019 the European Commission has presented the 2021-2027 Horizon Europe programme, which follows on from the Horizon 2020 programme.

## 8.3 Geothermal Project Development

### 8.3.1 Geothermal power

As of end 2018, there are 127 geothermal power plants in operation in Europe, with 3 $GW_{el}$ of installed capacity. Most of this capacity (about 2 $GW_{el}$) is located in two non-EU countries; Turkey and Iceland, with only about 1 $GW_{el}$ installed in the EU, almost entirely in Italy [EGEC 2019]. In order to put these numbers in perspective, the economic potential of geothermal power in the EU is estimated at 522 $GW_{el}$ in 2050 [Limberger et al. 2014].

Turkey and Iceland are also the countries that installed the most new geothermal capacity in 2018, amounting to 290 $MW_{el}$ and 45 $MW_{el}$, respectively. The only new power plant in the EU was installed in Croatia, with a capacity of 17.5 $MW_{el}$. On the other hand, about two thirds of the almost 200 geothermal power plants currently under development or investigation in Europe are located in the EU [EGEC 2019].

The yearly electricity production from the geothermal source in the EU amounts to 7 $TWh_{el}$ corresponding to 0.2 % of the total electricity consumption [IEA 2019].

Most geothermal energy in the EU is produced from hydrothermal resources. Only four Enhanced Geothermal Systems (EGS) plants exist within the EU. Three Hot Sedimentary Aquifers (HSA) EGS plants are in operation in Germany where work has gone into ensuring reservoir / wells connectivity, the lowering of drilling costs and mitigating induced seismicity [Shortall et al. 2019].

### 8.3.2 Geothermal direct use

The direct use of geothermal energy for heating and cooling purposes shows a growing trend in Europe. Geothermal heat can be used for a variety of applications, including district heating, the agri-food sectors, and process heat in industry. District heating for households remains the main application, but the number of businesses investing in geothermal energy supply have markedly grown in the past decade [EGEC 2019].

Iceland and Turkey are the main markets for geothermal district heating in Europe with an installed capacity of 2.2 $GW_{th}$ and 0.9 $GW_{th}$, respectively. An additional 1.9 $GW_{th}$ is distributed across the EU, mainly in France, Germany, and Hungary. However, new countries are emerging as important markets, notably the Netherlands, which accounted for about half of the installed capacity in the EU in 2018 (66 $MW_{th}$ out of 144 $MW_{th}$). Other countries with a number of geothermal heating plants under development or investigation are Italy, Poland, and the United Kingdom [EGEC 2019].

### 8.3.3 Geothermal heat pumps

Ground source heat pumps (GSHPs) represent the most common and widespread form of geothermal energy use in the EU: around 1.7 million systems are installed, corresponding to a capacity of 23.7 $GW_{th}$. An additional 0.2 million heat pumps, corresponding to 3.2 $GW_{th}$, in capacity are installed in non-EU European countries, mainly Switzerland and Norway [Sanner 2019] [EGEC 2019].

In the EU, installations are mostly found in Sweden and Germany (0.6 and 0.4 million GSHPs, respectively), but growing market trends are noted in Finland, Poland, the Netherlands, and Austria as well [Sanner 2019] [EGEC 2019].

## 8.4 Research Highlights

In 2014, the European Commission launched the eighth Framework Programme for Research and Technological Development for the years 2014-2020, known as Horizon 2020 (H2020).

The Horizon 2020 energy Work Programme for 2018-2020 [European Commission 2017] included six R&D topics specifically targeting geothermal energy, covering the range of technology development, from TRL (Technology Readiness Level) 3 (experimental proof of concept) to TRL 8 (system complete and qualified). The topics had the potential to provide geothermal players with an EU R&D funding of up to €58m over the three years.

Figure 8-1 shows the EU contribution to co-funded projects starting from 2004. The chart reports funds from the Framework Programmes which preceded H2020, i.e. FP6 (2002-2006) and FP7 (2007-2013), as well as from two other funding schemes called Intelligent Energy Europe (IEE) and NER300

In 2021, H2020 will be succeeded by a new seven-year R&D funding programme, named Horizon Europe.

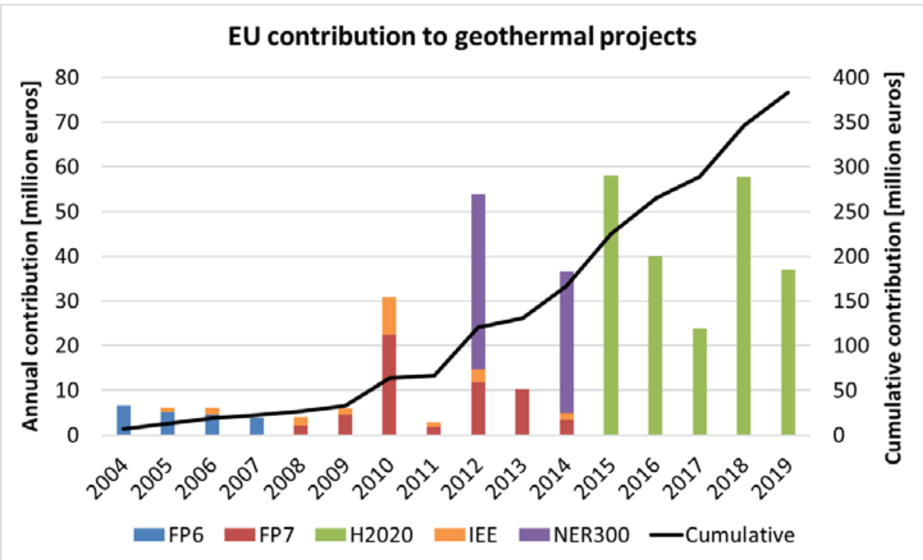


Figure 8-1 EU contribution to co-funded projects since 2004. Source: JRC elaboration based on CORDIS

### 8.4.1 H2020 Projects

The EU-funded H2020 projects are listed in the sections that follow: Projects are sorted into sections as to those that were;

- Finished in 2019
- Ongoing in 2019
- Started in 2019.

Each section lists the projects in descending order of EU funding.

More information about the projects and the outputs can be found via the CORDIS project database[3].

#### 8.4.1.1 H2020 Projects finished in 2019

**DEEPEGS – Deployment of deep enhanced geothermal systems for sustainable energy business[4]** (December 2015 – November 2019, EUR 19 million EU funding, topic: Demonstration of renewable electricity and heating/cooling technologies)

The goal of the project was to demonstrate the feasibility of enhanced geothermal systems (EGS) for delivering energy from renewable resources in Europe. Testing of stimulating technologies for EGS in deep wells in different geologies delivered new innovative solutions and models for wider deployments of EGS reservoirs with sufficient permeability for delivering significant amounts of geothermal power across Europe.

**GEOTeCH – Geothermal Technology for €conomic Cooling and Heating[5]** (May 2015 – April 2019, EUR 7.1 million EU funding, topic: Demonstration of renewable electricity and heating/cooling technologies)

The drilling technology that is currently used for installation of vertical borehole heat exchangers requires capital-intensive equipment that is expensive to mobilise, leads to deteriorated working conditions and requires experienced teams of specialist operatives. Drilling operations also often require significant quantities of drinking quality water and dispose of dirty water and mud. The project employed a different drilling concept that is based on dry auger methods that requires less capital-intensive equipment, enhances safety and avoids the environmental risks, complexity and costs of dealing with water supplies and contaminated waste.

**SURE – Novel Productivity Enhancement Concept for a Sustainable Utilization of a Geothermal Resource[6]** (March 2016 – August 2019, EUR 5.9 million EU funding, topic: Developing the next generation technologies of renewable electricity and heating/cooling)

Within the project, the radial water jet drilling (RJD) technology was investigated and tested as a method to increase inflow into insufficiently producing geothermal wells.

[3] https://cordis.europa.eu
[4] https://cordis.europa.eu/project/id/690771
[5] https://cordis.europa.eu/project/id/656889
[6] https://cordis.europa.eu/project/id/654662

**ThermoDrill – Fast track innovative drilling system for deep geothermal challenges in Europe**[7] (September 2015 – August 2019, EUR 5.4 million EU funding, topic: Developing the next generation technologies of renewable electricity and heating/cooling)

The overall goal of the project was the development of an innovative drilling system based on the combination of conventional rotary drilling with water jetting that allows at least 50% faster drilling in hard rock, a cost reduction of more than 30% for the subsurface construction and a minimised risk of induced seismic activity.

**Cheap-GSHPs – Cheap and efficient application of reliable ground source heat exchangers and pumps**[8] (June 2015 – May 2019, EUR 4.8 million EU funding, topic: Demonstration of renewable electricity and heating/cooling technologies)

The project improved actual drilling/installation technologies and designs of Ground Source Heat Exchangers (GSHE's) to reduce the total cost of low enthalpy geothermal systems by 20-30%. This was combined with a holistic approach for optimum selection, design and implementation of complete systems across different underground and climate conditions.

**Geowell – Innovative materials and designs for long-life high-temperature geothermal wells**[9] (February 2016 – January 2019, EUR 4.7 million EU funding, topic: Developing the next generation technologies of renewable electricity and heating/cooling)

New concepts for high-temperature geothermal well technologies are strongly needed to accelerate the development of geothermal resources for power generation in Europe and worldwide in a cost effective and environmentally friendly way: the project addressed the major bottlenecks like high investment and maintenance costs by developing innovative materials and designs that are superior to the state of the art concepts.

**TESSe2b – Thermal Energy Storage Systems for Energy Efficient Buildings. An integrated solution for residential building energy storage by solar and geothermal resources**[10] (October 2015 – September 2019, EUR 4.3 million EU funding, topic: Integrated solutions of thermal energy storage for building applications)

The target of the project was to design, develop, validate and demonstrate a modular and low cost thermal storage technology based on solar collectors and highly efficient heat pumps for heating, cooling and domestic hot water (DHW) production. This was done coupling storage tanks with borehole heat exchangers (BHEs) that take advantage of the increased underground thermal storage and maximise the efficiency of the ground-coupled heat pumps (GCHP).

**CHPM2030 – Combined Heat, Power and Metal extraction from ultra-deep ore bodies**[11] (January 2016 – June 2019, EUR 4.2 million EU funding, topic: Developing the next generation technologies of renewable electricity and heating/cooling)

The project aimed to develop a novel and potentially disruptive technology solution that can help satisfy the European needs for energy and strategic metals in a single interlinked process. Working at the frontiers of geothermal resources development, minerals extraction and electro-metallurgy, the project aimed at converting ultra-deep metallic mineral formations into an

[7] https://cordis.europa.eu/project/id/641202
[8] https://cordis.europa.eu/project/id/657982
[9] https://cordis.europa.eu/project/id/654497
[10] https://cordis.europa.eu/project/id/680555
[11] https://cordis.europa.eu/project/id/654100

"orebody-EGS" that served as a basis for the development of a new type of facility for "Combined Heat, Power and Metal extraction" (CHPM).

**TERRE – Training Engineers and Researchers to Rethink geotechnical Engineering for a low carbon future**[12] (November 2015 – October 2019, EUR 4 million EU funding, topic: Marie Skłodowska-Curie Innovative Training Networks (ITN-ETN))

The project aimed to develop novel geo-technologies to address the competitiveness challenge of the European construction industry in a low carbon agenda. It was delivered through an inter-sectoral and intra-European coordinated PhD programme focused on carbon-efficient design of geotechnical infrastructure.

**GeoCollector – Geothermal energy for cost-effective and sustainable heating and cooling**[13] (July 2017 – June 2019, EUR 2.1 million EU funding, topic: Stimulating the innovation potential of SMEs for a low carbon and efficient energy system)

"GeoCollector" is the name of a recently developed innovative geothermal heat absorber system. The project output was the ability to produce the Prototype GeoCollectors (TRL 6/7) in a way meeting the identified market requirements: use of renewable energy, low installation effort, low investment costs, high surface extraction rate of heat from the ground, low land usage, best value for money, low amortisation rate, high quality, no approval procedure necessary.

**STORM – Self-organising Thermal Operational Resource Management**[14] (March 2015 – March 2019, EUR 2 million EU funding, topic: Technology for district heating and cooling)

A generic district heating and cooling (DHC) network controller was developed and demonstrated, with the ambition to increase the use of waste heat and renewable energy sources in the DHC network.

**ITHERLAB – In-situ thermal rock properties lab**[15] (October 2016 – April 2019, EUR 0.2 million EU funding, topic: Individual Fellowships)

The project investigated the influence of in-situ (present state in the geological subsurface) pressure and temperature (p/T) on rock thermal properties (thermal conductivity and thermal diffusivity) as one of the essential thermal properties in the evaluation of the Earth thermal field. The project established mathematic formulations for p/T dependence of both parameters and demonstrated whether micro-structural effects affect these relations for different rock types. The focus was on conditions for depths (to approx. 7 km), which are of interest in the use of Earth resources (such as geothermal energy, hydro-carbons, storage of energy or waste).

**GeoElectricMixing – Geophysical Signature of Subsurface Reactive Mixing**[16] (April 2017 – March 2019, EUR 0.2 million EU funding, topic: Individual Fellowships)

The project developed a novel approach to investigate the temporal dynamics of reactive mixing processes from Complex Impedance and Self Potential signals. The coupling of reactive mixing and geoelectrics was quantified and up scaled by integrating charge transport and polarisation phenomena in a new modelling framework to predict the spatial distribution of chemical species

[12] https://cordis.europa.eu/project/id/675762
[13] https://cordis.europa.eu/project/id/768292
[14] https://cordis.europa.eu/project/id/649743
[15] https://cordis.europa.eu/project/id/703333
[16] https://cordis.europa.eu/project/id/752773

and reaction rates across mixing fronts. Dedicated experiments were then designed by integrating electrodes in a novel millifluidic setup to monitor jointly the temporal evolution of geoelectrical parameters and the spatial distribution of concentrations and reactions rate in a reactive mixing front progressing through the cell.

#### 8.4.1.2 H2020 projects ongoing in 2019

**GECO – Geothermal Emission Gas Control**[17] (October 2018 – September 2022, EUR 15.6 million EU funding, topic: Demonstrate solutions that significantly reduce the cost of renewable power generation)

The project applies an innovative technology, recently developed and proved successfully at pilot scale in Iceland, which can limit the production of emissions from geothermal plants by condensing and re-injecting gases or turning the emissions into commercial products. To both increase public acceptance and to generalise this approach, it is being applied in four distinct geothermal systems in four different European countries.

**DESTRESS – Demonstration of soft stimulation treatments of geothermal reservoirs**[18] (March 2016 – November 2020, EUR 10.7 million EU funding, topic: Demonstration of renewable electricity and heating/cooling technologies)

The project is aimed at creating EGS reservoirs with sufficient permeability, fracture orientation and spacing for economic use of underground heat. The concepts are based on experience in previous projects, on scientific progress and developments in other fields, mainly the oil & gas sector. Recently developed stimulation methods are adapted to geothermal needs, applied to new geothermal sites and prepared for the market uptake. Understanding of risks in each area (whether technological, in business processes, for particular business cases, or otherwise), risk ownership, and possible risk mitigation are the scope of specific work packages.

**GEMex – Cooperation in Geothermal energy research Europe-Mexico for development of Enhanced Geothermal Systems and Superhot Geothermal Systems**[19] (October 2016 – May 2020, EUR 10 million EU funding, topic: International Cooperation with Mexico on geothermal energy)

The GEMex project is a complementary effort of a European consortium with a corresponding consortium from Mexico, who submitted an equivalent proposal for cooperation. The joint effort is based on three pillars: (i) resource assessment at two unconventional geothermal sites, for EGS development at Acoculco and for a super-hot resource near Los Humeros; (ii) reservoir characterisation using techniques and approaches developed at conventional geothermal sites, including novel geophysical and geological methods to be tested and refined for their application at the two project sites; and (iii) concepts for site development.

**MEET – Multidisciplinary and multi-context demonstration of EGS exploration and Exploitation Techniques and potentials**[20] (May 2018 – October 2021, EUR 10 million EU funding, topic: EGS in different geological conditions)

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[17] https://cordis.europa.eu/project/id/818169
[18] https://cordis.europa.eu/project/id/691728
[19] https://cordis.europa.eu/project/id/727550
[20] https://cordis.europa.eu/project/id/792037

The project aims at demonstrating the viability and sustainability of EGS with electric and thermal power generation in all kinds of geological settings with four main types of rocks: granitic (igneous intrusive), volcanic, sedimentary and metamorphic with various degrees of tectonic overprint by faulting and folding.

**GeoFit – Deployment of novel GEOthermal systems, technologies and tools for energy efficient building retroFITting**[21] (May 2018 – April 2022, EUR 7.9 million EU funding, topic: Easier to install and more efficient geothermal systems for retrofitting buildings)

The project is an integrated industrially driven action aimed at deployment of cost effective EGS on energy efficient building retrofitting. This entails the technical development of innovative EGS and its components, namely, non-standard heat exchanger configurations, a novel hybrid heat pump and electrically driven compression heat pump systems and suite of heating and cooling components to be integrated with the novel GSHP concepts, all specially designed to be applied in energy efficient retrofitting projects.

**GEOTHERMICA – ERA NET Cofund Geothermal**[22] (January 2017 – December 2021, EUR 7 million EU funding, topic: Joint Actions towards the demonstration and validation of innovative energy solutions)

The objective of the project is to combine the financial resources and know-how of 16 geothermal energy research and innovation programme owners and managers from 13 countries, to launch joint actions that demonstrate and validate novel concepts of geothermal energy utilisation within the energy system and that identify paths to commerciality. Joint actions comprise joint calls and coordination activities, which will strengthen Europe's geothermal energy sector by building a tightly interconnected and well-coordinated network of European funding agents.

**GEO4CIVHIC – Most Easy, Efficient and Low Cost Geothermal Systems for Retrofitting Civil and Historical Buildings**[23] (April 2018 – March 2022, EUR 6.8 million EU funding, topic: Easier to install and more efficient geothermal systems for retrofitting buildings)

The project will identify and, where missing, develop building block solutions in drilling (machines and methods), GSHE types, heat pumps and other renewable energy/storage technologies, heating and cooling terminals with the focus on every type of built environment, civil and historical. It will also generate and demonstrate the easiest to install and most cost-effective geothermal energy solutions using and improving existing and new tools.

**EUROVOLC – European Network of Observatories and Research Infrastructures for Volcanology**[24] (February 2018 – January 2021, EUR 5 million EU funding, topic: Integrating Activities for Starting Communities)

The project will construct an integrated and harmonised European volcanological community able to fully support, exploit and build-upon existing and emerging national and pan-European research infrastructures, including e-Infrastructures of the European Supersite volcanoes. Among other outcomes, the project will open pathways for enterprise to better exploit georesources in volcanic areas such as geothermal energy.

[21] https://cordis.europa.eu/project/id/792210
[22] https://cordis.europa.eu/project/id/731117
[23] https://cordis.europa.eu/project/id/792355
[24] https://cordis.europa.eu/project/id/731070

**Geo-Coat – Development of novel and cost effective corrosion resistant coatings for high temperature geothermal applications**[25] (February 2018 – January 2021, EUR 4.7 million EU funding, topic: Developing the next generation technologies of renewable electricity and heating/cooling)

The project develops new resistant materials in the form of high performance coatings of novel targeted "High Entropy Alloys" and Cermets, thermally applied to the key specified vulnerable process stages (components in turbines, valves, pumps, heat exchangers and pipe bends) in response to the specific corrosion and erosion forces we find at each point. It also captures the underlying principles of the material resistance, to proactively design the equipment for performance while minimising overall capex costs from these expensive materials.

**TEMPO – TEMPerature Optimisation for Low Temperature District Heating across Europe**[26] (October 2017 – September 2021, EUR 4.1 million EU funding, topic: New heating and cooling solutions using low grade sources of thermal energy)

The technical and economic viability of today's district heating networks are undermined by transitions to highly efficient building stocks and ineffective business models which fail to benefit all stakeholders. The project tackles this by (i) innovations to create low temperature networks for increased network efficiency and integration options for renewable and residual heat sources, and (ii) new business models to boost network competitiveness and attractiveness for stakeholder investment.

**MPC-. GT – Model Predictive Control and Innovative System Integration of GEOTABS in Hybrid Low Grade Thermal Energy Systems**[27] (September 2016 – August 2020, EUR 4 million EU funding, topic: New heating and cooling solutions using low grade sources of thermal energy)

The MPC-. GT project brought together a transdisciplinary team of SMEs, large industry and research institutes, experienced in research and application of design and control systems in the combined building and energy world. Based on prior research, supported by (joint) EU and national projects, and practical experience the bottlenecks where identified that prevent at this moment a real breakthrough of geothermal heat pumps combined with thermally activated building systems - GEOTABS.

**GEOCOND – Advanced materials and processes to improve performance and cost-efficiency of Shallow Geothermal systems and Underground Thermal Storage**[28] (May 2017 – October 2020, EUR 4 million EU funding, topic: Developing the next generation technologies of renewable electricity and heating/cooling)

By a combination of different material solutions under the umbrella of sophisticated engineering, optimisation, testing and on-site validation, the project develops solutions to increase the thermal performance of the different subsystems configuring a Shallow Geothermal Energy Systems (SGES) and an Underground Thermal Energy Storage (UTES).

[25] https://cordis.europa.eu/project/id/764086
[26] https://cordis.europa.eu/project/id/768936
[27] https://cordis.europa.eu/project/id/723649
[28] https://cordis.europa.eu/project/id/727583

**ENIGMA – European training Network for In situ imaGing of dynaMic processes in heterogeneous subsurfAce environments**[29] (January 2017 – December 2020, EUR 3.9 million EU funding, topic: Innovative Training Networks)

The ENIGMA network has been training a new generation of young researchers in the development of innovative sensors, field survey techniques and inverse modelling approaches. This will enhance our ability to understand and monitor dynamic subsurface processes that are key to the protection and sustainable use of water resources. The project focuses mainly on critical zone observation, but the anticipated technological developments and scientific findings also contribute to monitor and model the environmental footprint of an increasing range of subsurface activities, including large-scale water abstraction and storage, enhanced geothermal systems and subsurface waste and carbon storage.

**GEOENVI – Tackling the environmental concerns for deploying geothermal energy in Europe**[30] (November 2018 – April 2021, EUR 2.5 million EU funding, topic: Market Uptake support)

The first objective of the project is to make sure that deep geothermal energy can play its role in Europe's future energy supply in a sustainable way. It aims to create a robust strategy to respond environmental concerns: (i) by assessing the environmental impacts and risks of geothermal projects operational or in development in Europe; (ii) by providing a robust framework to propose recommendations on environmental regulations to the decision-makers, an adapted methodology for assessing environment impact to the project developers, and finally (iii) by communicating properly on environmental concerns with the general public. Secondly, the project aims at engaging with both decision-makers and geothermal market actors, to have the recommendations on regulations adopted and to see the LCA methodology implemented by geothermal stakeholders.

**GEORISK – Developing geothermal and renewable energy projects by mitigating their risks**[31] (October 2018 – March 2021, EUR 2.2 million EU funding, topic: Market Uptake support)

A geothermal project development has several risky components, the most important one being the resource risk. This concerns mainly deep geothermal projects, but some shallow geothermal open systems could also be included in this category of projects. Beyond exploration, the bankability of a geothermal project is threatened by this geological risk. GEORISK works to establish such risk insurance all over Europe and in some key target third countries to cover the exploration phase and the first drilling (test).

**BigMac – Microfluidic Approaches mimicking BIoGeological conditions to investigate subsurface CO2 recyclings**[32] (November 2017 – October 2022, EUR 2 million EU funding, topic: ERC Consolidator Grant)

The strategic objective of this project is to develop and to use "Biological Geological Laboratories on a Chip - BioGLoCs" mimicking reservoir conditions in order to gain greater understanding in the mechanisms associated with the biogeological conversion process of $CO_2$ to methane at pore scale. New generic lab scale tools are also being made available for investigating

[29] https://cordis.europa.eu/project/id/722028
[30] https://cordis.europa.eu/project/id/818242
[31] https://cordis.europa.eu/project/id/818232
[32] https://cordis.europa.eu/project/id/725100

geological-related topics (enhanced oil recovery, deep geothermal energy, bioremediation of groundwater, shale gas recovery).

**ENeRAG – Excellency Network Building for Comprehensive Research and Assessment of Geofluids**[33] (October 2018 – September 2021, EUR 1 million EU funding, topic: Twinning)

The project significantly strengthens research and innovation capacities in geofluids' research and aligned geological resource assessment of groundwater, geothermal energy and hydrothermal mineral resources via staff exchanges across the participant institutions.

**GeoTwinn – Strengthening research in the Croatian Geological Survey: Geoscience-Twinning to develop state-of-the-art subsurface modelling capability and scientific impact**[34] (October 2018 – September 2021, EUR 1 million EU funding, topic: Twinning)

This project addresses the need to spread excellence and widen participation across the European Union by the twinning of research institutions. It proposes to twin the Croatian Geological Survey (HGI-CGS) with the Geological Survey of Denmark and Greenland and the British Geological Survey of the United Kingdom Research and Innovation, to significantly strengthen HGI-CGS's research, and in a number of areas transform its capability, such as (i) 3D geological surveying and modelling; (ii) groundwater flow and contaminant transport modelling; (iii) geological hazards; (iv) geothermal energy.

**MATHROCKS – Multiscale Inversion of Porous Rock Physics using High-Performance Simulators: Bridging the Gap between Mathematics and Geophysics**[35] (April 2018 – March 2022, EUR 0.8 million EU funding, topic: Research and Innovation Staff Exchange)

The project develops and exchanges knowledge on applied mathematics, high-performance computing (HPC), and geophysics to better characterise the Earth´s subsurface. The aim is to better understand porous rocks physics in the context of elasto-acoustic wave propagation phenomena. To verify and validate the developed tools and methods, results are applied to: characterise hydrocarbon reservoirs, determine optimal locations for geothermal energy production, analyse earthquake propagation, and jointly invert deep-azimuthal resistivity and elasto-acoustic borehole measurements.

**NERUDA – Numerical and ERT stUdies for Diffusive and Advective high-enthalpy systems**[36] (November 2018 – October 2020, EUR 0.2 million EU funding, topic: Individual Fellowships)

The project proposes an innovative and multidisciplinary approach to predict the role of faults on fluid flow, combining numerical simulations of fluid flow with deep Electric Resistivity Tomography (ERT). The project aims at constraining the tectonic control on fluid flow in hydrothermal systems.

[33] https://cordis.europa.eu/project/id/810980
[34] https://cordis.europa.eu/project/id/809943
[35] https://cordis.europa.eu/project/id/777778
[36] https://cordis.europa.eu/project/id/793662

### 8.4.1.3 H2020 projects started in 2019

**GeoSmart – Technologies for geothermal to enhance competitiveness in smart and flexible operation**[37] (June 2019 – May 2023, EUR 17.4 million EU funding, topic: Demonstrate highly performant renewable technologies for combined heat and power (CHP) generation and their integration in the EU's energy system)

The project works on methods to store heat energy when demand is low so that it can be released when demand is high. The project also plans to create a hybrid cooling system for the organic Rankine cycle plant that will prevent efficiency degradation due to seasonal changes. Overall, GeoSmart technologies will allow geothermal plants to cost-effectively respond to different heat and power demands.

**Geo-Drill – Development of novel and cost-effective drilling technology for Geothermal Systems**[38] (April 2019 – September 2022, EUR 5 million EU funding, topic: Developing solutions to reduce the cost and increase performance of renewable technologies)

The project aims to reduce drilling cost for geothermal systems with increased rate of penetration and reduced tripping with improved tools lives. The project is proposing drilling technology incorporating bi-stable fluidic amplifier driven mud hammer, low cost 3D printed sensors & cables, drill monitoring system, graphene based materials and coatings.

**GeoHex – Advanced material for cost-efficient and enhanced heat exchange performance for geothermal application**[39] (November 2019 – October 2022, EUR 5 million EU funding, topic: Developing the next generation of renewable energy technologies)

The project relies on the use of low cost carbon steel as base material for heat exchangers for geothermal power plants. Through modifying the surface with nano porous coating and controlling the surface chemistry (along with the surface structure), the project will significantly improve the heat transfer performance of single phase and phase change heat transfer process respectively.

**GEOPRO – Accurate Geofluid Properties as key to Geothermal Process Optimisation**[40] (November 2019 – October 2022, EUR 4.9 million EU funding, topic: Optimising manufacturing and system operation)

The project will produce experimental data on heat and mass transfer behaviour of high-concentration fluids in very high temperatures. Data will serve as input in a set of new design and operation tools that should allow the geothermal power plants to design and operate systems more effectively, reducing the levelised cost of energy to competitive levels.

**CROWDTHERMAL – Community-based development schemes for geothermal energy**[41] (September 2019 – August 2022, EUR 2.3 million EU funding, topic: Market Uptake support)

The project aims to empower the European public to directly participate in the development of geothermal projects with the help of alternative financing schemes (crowdfunding) and social engagement tools. In order to reach this goal, the project will first increase the transparency of

[37] https://cordis.europa.eu/project/id/818576
[38] https://cordis.europa.eu/project/id/815319
[39] https://cordis.europa.eu/project/id/851917
[40] https://cordis.europa.eu/project/id/851816
[41] https://cordis.europa.eu/project/id/857830

geothermal projects and technologies by creating one to one links between geothermal actors and the public so that a Social Licence to Operate (SLO) could be obtained. The project will create a social acceptance model for geothermal energy that will be used as baseline in subsequent actions for inspiring public support for geothermal energy. Parallel and synergetic with this, the project will work out details of alternative financing and risk mitigation options covering the different types of geothermal resources and various socio-geographical settings.

**GEoREST – predictinG EaRthquakES induced by fluid injecTion**[42] (February 2019 – January 2024, EUR 1.4 million EU funding, topic: ERC Starting Grant)

Forecasting injection-induced earthquakes is a big challenge that must be overcome to deploy geo-energies to significantly reduce $CO_2$ emissions and thus mitigate climate change and reduce related health issues. The objective of this project is to develop a novel methodology to predict and mitigate induced seismicity. The project proposes an interdisciplinary approach that integrates the thermo-hydro-mechanical-seismic (THMS) processes that occur in the subsurface as a result of fluid injection.

## 8.5 Other activities

### 8.5.1 DG ETIP

The European Technology and Innovation Platform on Deep Geothermal (DG ETIP) was created in 2016.[43] It complements the ETIP on Heating and Cooling, as well as the other existing thematic ETIPs on renewable energy technologies.[44]

In 2017, DG ETIP received almost €0.6m of EU funding through Horizon 2020 topic LCE-36-2016-2017. The project was launched in July 2017 and ran until June 2019. DG ETIP has developed a comprehensive Strategic Research Agenda for the geothermal sector, clarifying its R&D priorities for years to come [ETIP-DG 2018b]. The Strategic Research Agenda and Implementation roadmap for deep geothermal were published in 2019. Furthermore, DG ETIP has developed a dedicated Roadmap and suggested ways to finance geothermal energy players and projects in ad-hoc factsheets.

### 8.5.2 SET-Plan Deep Geothermal Implementation Plan

The Deep Geothermal Implementation Plan was developed by national representatives from Belgium, Cyprus, France, Germany, Iceland, Italy, Portugal, the Netherlands, Turkey, Spain and Switzerland, the European Energy Research Alliance Joint Programme Geothermal Energy (EERA JPGE), DG ETIP, the Renewable Heating and Cooling Platform, and the District Heating and Cooling European Technology and Innovation Platform. The plan was adopted in 2018 by the SETplan steering group

The Deep Geothermal Implementation Plan provides a comprehensive approach articulated in 8 key research and innovation activities and 2 non-technical barriers. It provides a blueprint for the

[42] https://cordis.europa.eu/project/id/801809
[43] https://www.etip-dg.eu/
[44] ETIPs are networks of R&D experts coordinated at European level. As such they play a pivotal role in defining the research priorities of their sectors and communicating them to decision-makers in charge of EU and national R&D funds. For this reason, they are strategic players in the EU energy and climate policy framework, contributing to the implementation of the SET-Plan and accelerating the development and deployment of low-carbon technologies.

allocation of national and EU funds for geothermal R&D [SET-Plan Temporary Working Group Deep Geothermal 2018].

A high-level Deep Geothermal Implementation Working Group (DG-IWG) has been established to advance the DG-IP, with the aim of reaching collectively the technology targets that will place Europe at the forefront of the next generation of low carbon technologies. A support unit will help the DG-IWG (SU-DG-IWG) to achieve its goals efficiently and productively. The SU-DG-IWG kicked-off early in 2019 and has three main work streams:

- to provide the DG-IWG with relevant information and data from the various stakeholder groups to support the decision making process and the implementation actions of the DG-IWG on required actions,
- to promote and organise initiatives to mobilize growth of and implementation within the geothermal community, e.g.: workshops, brokerages, consortium building and exploitation of RD&I results, and
- provide a secretariat for the DG-IWG for assistance with administration and synergies & strategy support.

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# 9. France

Christian Boissavy and Virginie Schmidlé-Bloch

Association Française des Professionnels de la Géothermie, 77 rue Claude Bernard, 75005 Paris, France.
Email: christian.boissavy@orange.fr, virginie.schmidle@afpg.asso.fr.

## 9.1 Introduction

The 2019 French Geothermal Association of Professionals, The Geothermal Market Update in France (AFGP 2019) documents the installed capacity for geothermal heating and cooling as reaching nearly 2600 MWth. About 600 MWth is related to the deep reservoirs in the Paris area with the balance linked to the recent and strong development of shallow geothermal resources across the whole country.

Since 2009 the vertical geothermal probe single housing market has dramatically decreased due to competition from natural gas and the absence of tax credits for geothermal compared to efficient gas boilers and air-air heat pumps. The market for geothermal probes for individual housing has reduced from more than 20,000 installations annually to less than 2500 between 2010 and 2018 (1/7$^{th}$ of the 2010 installs). In contrast the number of geothermal installations feeding collective housing and residential blocks, including office buildings, is growing significantly. Direct geothermal use is mainly concentrated in Ile-de-France, the construction of geothermal doublet installations recommenced with support from the Heat funds managed by ADEME, and more than 20 new deep wells have been drilled in Ile-de-France in the last 3 years.

The main barriers to more rapid geothermal uptake are the energy calculation rules for new buildings (RT 2020) which continue to encourage the use of gas. In 2023, the geothermal market will reach 3000 MWth installed; if ecologically driven 3500 MWth could be attained.

Two small capacity electricity generation ORC installations (20-40 kW) were commissioned during 2019; one at Soultz-sous-Forêts adding to the existing EGS plant and one in Chaunoy in Ile de France using old oil wells.

The following table provides information on geothermal energy use in France in 2019.

| Electricity | | Direct Use | |
|---|---|---|---|
| Total Installed Capacity ($MW_e$) | 16,7 | Total Installed Capacity ($MW_{th}$) | 2587 |
| New Installed Capacity ($MW_e$) | 0 | New Installed Capacity ($MW_{th}$) | 150 |
| Total Running Capacity ($MW_e$) | 16,7 | Total Heat Used (PJ/yr) | 17,17 |
| Contribution to National Capacity (%) | 0,013 | Total Installed Capacity Heat Pumps ($MW_{th}$) | 2015 |
| Total Generation (GWh) | 98 | Total Net Heat Pump Use [PJ/yr]s | 10,88 |
| Contribution to National Generation (%) | 0,018 | Target 2017 – 2030 (PJ/yr Primary Energy) | N/A |
| Target (% national generation in 2023) | 0,05 | Estimated Country Potential ($MW_{th}$ or PJ/yr or GWh/yr) | 100 000 MWth* |
| Estimated Country Potential ($MW_e$) | 300* | (no significant change in estimated direct use) | |

(N/A = data not available)
(* indicates estimated values)

Two geothermal doublets have been drilled near Strasbourg (3500 and 5500m depth) with successful preliminary tests. The facilities will co-generate electricity (10 MWe) and heat (20 MWth).

## 9.2 Changes to Policy Supporting Geothermal Development

The PPE (Programmation Pluriannuelle de l'Energie) has not yet been officially adopted however under the programme the FIT (246 €/MWh) for geothermal electricity in mainland France has been removed. This is expected to be a strong disincentive for new EGS deployment, however the six EGS projects that are already underway will continue to benefit from the earlier tariff. The FIT (170€/MWh) will be maintained for overseas French territories.

The SAF Environment guarantee that covers the geological risk in deep geothermal projects (dry well or lower resource output than expected) will have to be replenished by ADEME because the fund is currently oversubscribed from projects in the Paris and Bordeaux areas.

At the beginning of 2020 the GEODEEP SAS Risk mitigation fund was adopted by the European Commission. It allows ADEME to feed the fund for EGS (16 M€) in addition to funding from La Caisse des Dépôts et Consignations. This fund will cover the geological and hydrogeological risk of onshore exploration drilling for heat and/or electricity EGS projects in France, however due to the abandonment of the FIT that previously applied to the operational phase of EGS projects the deployment in the next five years is expected to be quite low.

## 9.3 Geothermal Project Development

### 9.3.1 Geothermal deep project development

A new plant launched mid 2019 on the right bank of the Garonne river will feed a district heating system constructed by Cofely Services. The geothermal production target is the Jurassic limestones which have never been drilled under the Bordeaux sector. If the deep limestones are not productive the doublet will be reoriented to produce from the already exploited Cenomano-Turonien sandstones in the Bordeaux area.

Two other projects are currently being drilled one in Ile de France (Bobigny) exploring the Triassic sandstones and the other Champs-sur-Marne targeting the Dogger limestones. They both target the Dogger aquifer (if the Triassic is unproductive in Bobigny) and are expected to furnish around 350m$^3$/h at 70°C. Champs-sur-Marne will be equipped with heat pumps in order to lower the injection temperature.

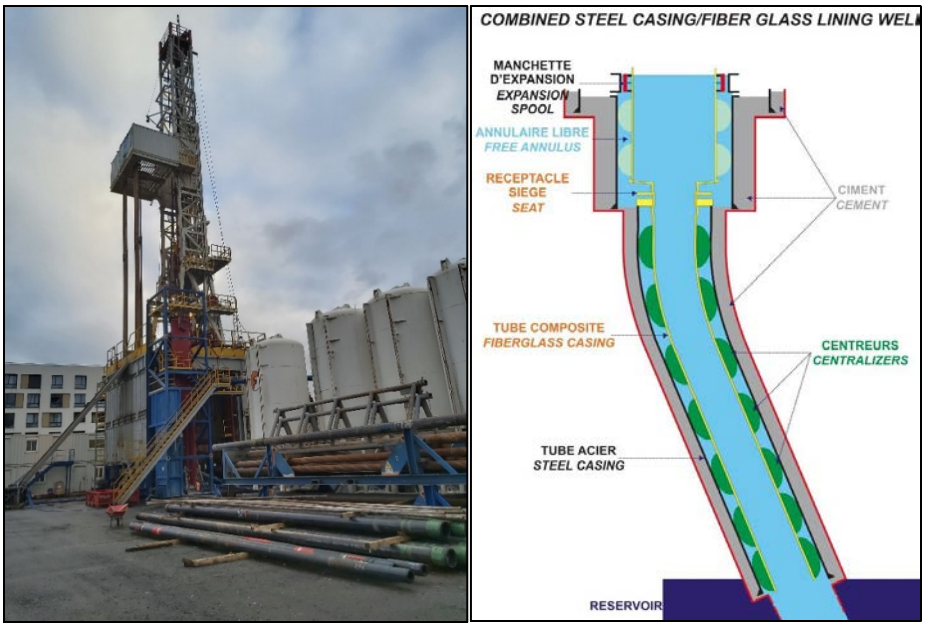

Figure 9-1 On the left, drilling rig January 2020 in Champs-sur-Marne (Engie Group) and right, new lining technology using composite casing, design for the new production well in Bonneuil (GPC IP)

The direct use of geothermal heat is very well developed in France with the 2018 production estimated at 1700 GWh from ~74 plants.

The Paris basin has five large aquifers, including the Dogger which has the largest number of low-enthalpy geothermal operations in the world, with 46 operations providing geothermal energy to ~1 million inhabitants. The geothermal use is for collective heating and cooling applications. A conventional operation in the Paris region allows the heating and the production of sanitary hot water for approximately 4,000 to 6,000 houses. The Dogger covers an area of over 150,000 km$^2$ with the temperature measured directly below the Paris region varying between 56 °C and 85 °C, according to the depth of the reservoir (between 1,600 and 2,000 m).

Only four new geothermal doublets have been drilled over the last 3 years: 2 tapping the Dogger aquifer (Grigny and Dammarie-les-Lys) and 2 tapping the Albian sands (Saclay). Other drilling work has been associated with revamping old installations creating new doublets, such as in Cachan where a new doublet using horizontal drilling technology with an 800m section in the reservoir installed, and creating triplets.

## 9.3.2 Geothermal Heat Pumps

The individual housing geothermal heat pump market has decreased since 2008 (Refer Figure 9-2).

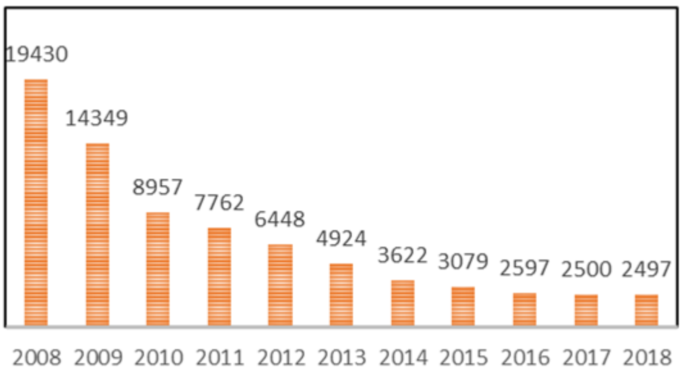

Figure 9-2 Sales of geothermal HP in the individual housing market (2008-2018)

Over the last 4 years about 2500 geothermal heat pumps have been sold each year. This market is facing strong competition from air/water and air/air systems.

The French regions leading the geothermal market (individual housing and collectives), except horizontal geothermal, are Ile de France, Rhone-Alps, Midi-Pyrenees, Brittany, Alsace and Pays de la Loire.

At the country level the distribution of the types of installations is: 5% for single housing open loop, 25% for collective open loop based on water, 25% for individual vertical exchanger and 45% for collective vertical exchanger. Horizontal loops represent about 25% of the geothermal market for individual housing. Currently thermo-active foundations remain largely underdeveloped.

For individual housing, the state efforts have been reduced, removing tax reduction benefits for capital used in geothermal GSHP installations. In 2020, a differentiated tax credit will be implemented between geothermal and air heat pumps that is expected to result in more geothermal installations in the individual housing market. Nevertheless this differentiated rate won't be effective for new buildings or for well-off households.

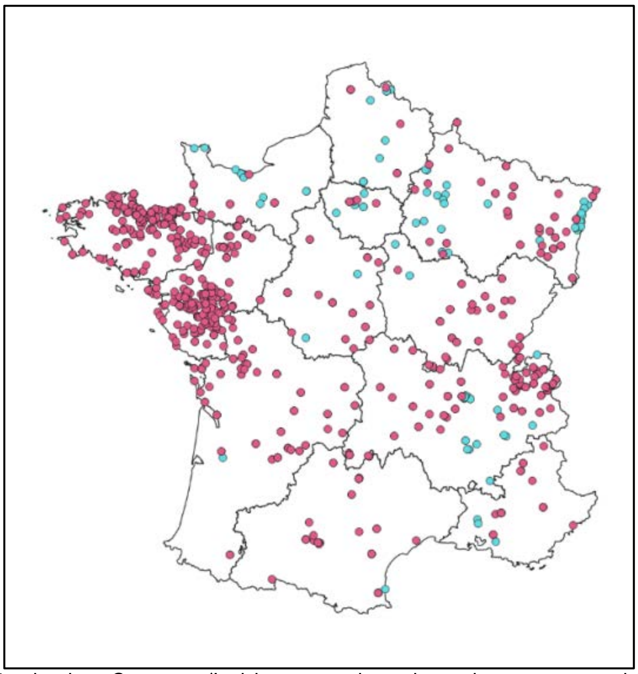

Figure 9-3 GSHP projects in the last 3years - (In blue open loop based on water and in red closed loops: mainly vertical probes)

The French energy policy is very supportive of geothermal in collective housing. For the collective buildings (housings, office, hospital, municipality buildings), a study published by Observ'ER (2018) shows there is a 10% per annum increase in the GSHP market in this sector. There were around 600 new plants installed in France in 2018. The concept of the low temperature geothermal loop has been adopted in several towns with installed capacities between 1 and 4 MW.

The regional distribution of individual housing installations is shown in Figure 9-4 which identifies that the largest percentage of geothermal facilities in individual housing is found in the Bretagne region followed by the Auvergne-Rhône-Alpes region.

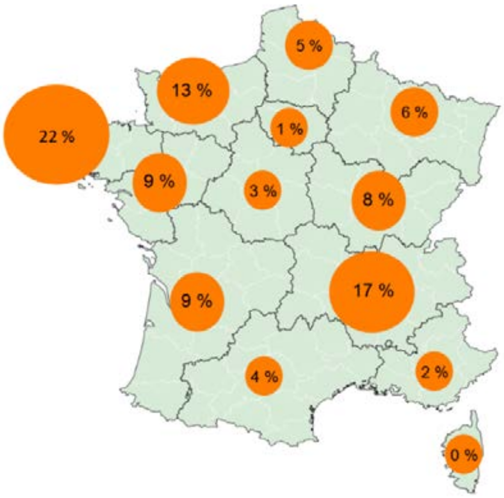


Figure 9-4 GSHP for individual housing in 2019: geographical distribution

### 9.3.3 Schemes supporting the geothermal energy industry

France has developed different schemes to assist geothermal sector development. One of them is the geological risk mitigation tool. The geological risk is linked to the fact that the exploitable geothermal energy resource can only be known after drilling the first borehole. This costly operation (more than 5 Million € for a 2000m geothermal target) may result in failure (e.g. due for instance to a lack of resources, insufficient temperature or exploitable flow rates in relation to the forecasts or the inability to exploit the geothermal fluid due to aggressive geothermal fluid chemistry). For electricity generation, the cluster Geodeep is building in cooperation with ADEME and Caisse des Dépôts et Consignations, a fund created first to support EGS technology (accepted Q1 2020 by the European Commission) and second for volcanic projects.

For deep aquifer heat production, the SAF Environment guarantee is proven, having existed for 40 years. For shallow drilling ranging up to 200m depth, the “Aquapac” guarantee (funded by ADEME, EDF and SAF), has been in place for 30 years. This covers the geological risk for the first well drilled (open loops) and then the geothermal production during 10 years of exploitation.

Furthermore there is a financial support scheme for heat production, including for successful operations. The Renewable Heat Fund (Fonds Chaleur Renouvelable in French) was created in 2009 for collective housing, tertiary, industry and agriculture. At the end of 2017, 495 geothermal installations (for district heating and geothermal heat pump) have been subsidized by the Fund. A total of 141 M€ has been given to the new heat plants (plotted by number by region) shown on Figure 9-5. The total additional heat production is some 1, 75 TWh.

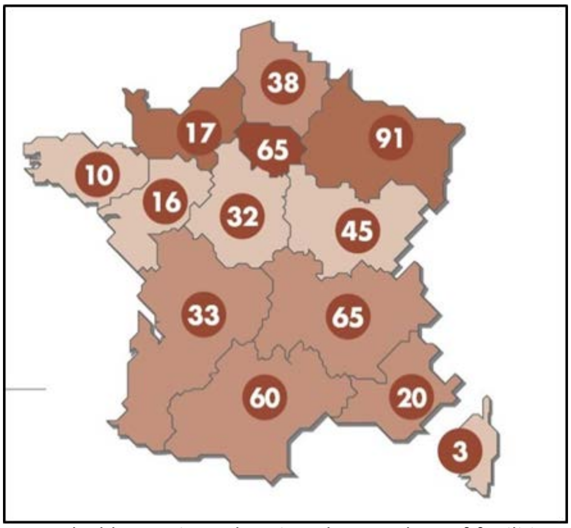

Figure 9-5 Heat fund subsidies recorded by region, showing the number of facilities supported between 2009 and 2018

## 9.4 Research Highlights

Most of the national R&D budget for geothermal energy is managed by ADEME. Some funding can be accessed through upstream research funded by ANR (National Agency for Research) and technological innovation funded by FUI (Fund for Industrial Clusters).

After two calls for projects in all research domains in France, 171 Laboratories of Excellence (LabEx) received funding awards. The “G-Eau-Thermie Profonde” Laboratory received its official quality label in March 2012. Based in Alsace, it has a focus on deep geothermal energy and received an initial 3 M€ funding award for a 9-year period. At the moment, the yearly funding is around 2M€, sustained by National and European research projects, Electricité de Strasbourg, Strasbourg University, IDEX and CNRS. This illustrates and strengthens industry-university partnership engaged in the “Investments for the Future” framework. New partners such as Total and the Engie group have joined.

An Institute of Excellence for the use of the underground in the energy transition, called Géodénergies, was created in July 2015. It aims at supporting the development of three industrial sectors:

- CO2 storage,
- energy storage, and
- geothermal energy production (heat and electricity).

This joint venture brings together industrial and public research organizations under the national funding program “Investments for the Future”. In 2019-2020 Géodénergies will evolve into a new research institute jointly owned by public and private actors.

In order to promote the development of geothermal activities, Géodénergies has launched several research projects to bridge technological gaps (drilling hammers, high temperature pumps, monitoring of reservoir cooling), developing methodologies (micro-seismic measurements exploitation and conceptual reservoir models in grabens) and developing co-activities along with heat utilisation (lithium production, CO2 storage).

In addition, several national technological clusters have been established to develop collaborative industry and research institute R&D projects including:

- GEODEEP cluster of the AFPG for the promotion of French geothermal know-how for export
- AVENIA, based in Aquitaine, deals notably with deep geothermal applications;
- SYNERGILE, based in Guadeloupe, aims at developing renewable energies in the overseas territories;
- S2E2, based in Tours, shallow geothermal energy and smart buildings.

## 9.5 Other National Activities

### 9.5.1 Geothermal Education

BRGM offers training; such as in drilling or building a geothermal energy project. AFPG is also involved in training.

The MEET project has created a geothermal spring school in March 2020 for the students of the different partners of the project.

The University of Cergy-Pontoise delivers a master's degree in Energy including a number of courses in geothermal energy.

### 9.5.2 Publications

AFPG is currently writing a technical guide on the temperate geothermal closed loop. The aim is to provide key information to engineering consultancies, so they promote the technology.

BRGM (French Geological Survey) is currently translating good practice sheets based on good practice from deep geothermal drilling.

In shallow geothermal AFPG is finalizing a technical guide with SER (Renewable Energy Union).

AFPG members have prepared many publications for the WGC 2020 in Reykjavik that will illustrate the involvement of both public and private actors in the French geothermal sector.

## 9.6 Useful Websites

BRGM website (French Geological Survey) and ADEME (the French Agency for Environment and Energy) for professionals and public at large: https://www.geothermies.fr/

AFPG (French Association of Geothermal Energy Professionals) website: http://www.afpg.asso.fr/

BRGM geological and drilling data website: http://infoterre.brgm.fr/viewer/MainTileForward.do

BRGM website with energy data (geothermal, oil & gas, etc) : http://www.minergies.fr/fr

## 9.7 Future Activity

AFPG are promoting an innovative system known as the temperate geothermal closed loop which is a thermal smart grid. The potential is enormous as different energy types can be used; such as geothermal, ocean water, lake or water treatment plant water.

In 2016 the Bouillante plant was sold by BRGM to ORMAT with the plant capacity expected to be upgraded from 15 to 25 MWe over the next few years.

French companies involved in deep geothermal energy are currently working with mining companies on the extraction of metals such as lithium from the Alsace fluids. The potential is great since from ~10 geothermal plants in Alsace (or Central Massif and Pyreneans) the production corresponds to the current needs for lithium for batteries for electric mobility in France.

There are ~20 deep geothermal projects in the pipeline waiting to be realized over the next 3 years and ~20 other projects under study, which if all get implemented will amount to an increase of the installed geothermal heating capacity of ~500 MW by 2028.

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# 10. Germany

Lothar Wissing

Project Management Jülich PTJ - ESE 4, Division: Energy System - Renewable Energies / Power Plant Technology, Geothermal Energy, Hydropower, Science Communication, Forschungszentrum Jülich GmbH, 52425 Jülich.
Email: l.wissing@fz-juelich.de

## 10.1 Introduction and Overview

The regions of Germany in which suitable conditions for geothermal electricity production are the Molasse Basin in Southern Germany (mainly in Bavaria) and the Upper Rhine Graben in South West Germany due to an especially high natural increase in temperature at increasing depths in these regions.

According to information from the German Geothermal Association (BVG), there were 37 geothermal power and heating plants in operation across Germany in 2019. Most of these plants exclusively generate heat, with the related installed capacity of 337 megawatts (thermal). Nine of the geothermal plants generate electricity – either exclusively or supplementary to heat. They have an installed electrical capacity of around 37 MW megawatts.

Table 10-1 Electricity Producing Geothermal Power Plants in Germany Jan 2019

| Region | Location | $MW_e$ | $MW_{th}$ | Power Plant |
|---|---|---|---|---|
| **Upper Rhine Graben** | Landau | 0.8 | 5 | ORC |
| | Bruchsal | 0.44 | | Kalina |
| | Insheim | 4.8 | | ORC |
| | | | | |
| **South Molasse Basin** | Durrnhaar | 6 | | ORC |
| | Sauerlach | 5 | 4 | ORC |
| | Kirchstockach | 6 | | ORC |
| | Oberhaching - Laufzon | 4.3 | 40 | ORC |
| | Oberhaching - Taufkirchen | 4.3 | 35 | ORC |
| | Traunreut | 5.5 | 12 | Kalina |
| **Total** | | 37 | 96 | |

In Germany, deep geothermal energy is being increasingly used to generate heat. In terms of the prevailing geological conditions in Germany and the existing structure of demand, projects involving heating, such as supplying local and district heating systems, have higher prospects for being economically successful than projects for the generation of electricity only.

## 10.2 National Programme

In September 2018, the Federal Cabinet adopted the 7th Energy Research Programme entitled “Innovations for the Energy Transition”. It contains the guidelines for energy research funding in the coming years. In the context of the 7th Energy Research Programme, the Federal Government is making around €7 billion available for projects.

The Federal Government lays down a new strategic approach with a focus on technology and innovation transfer. This includes the use of living labs to bring new, promising technological solutions to the market, and to explore and master the challenges under real-life conditions. The experience gained will set the course for implementing the technologies tested on a large scale later on. Greater involvement by young, creative startups will also play an important role in this process.

The new programme strengthens technology and innovation funding in the energy sector and also adds a new focus on systemic and societal questions. This involves placing a greater focus on the major, overarching trends in the energy sector. One of these is sector coupling, which enables interaction between the heat, transport and industrial sectors and is crucial for the development of the system as a whole. Another is digitisation, which plays a key role in modernising the energy system.

Lastly, the Federal Government's 7th Energy Research Programme is also designed around developing closer networking in research at both international and at European level. After all, the energy transition is, and will remain, a global-level challenge. In its preparation of the new programme, the Federal Ministry for Economic Affairs and Energy hosted a broad-based consultation process in which it surveyed a large number of stakeholders from science and business about the innovation steps needed in order to make the energy transition a success. This is because the new programme seeks to foster applied research and development in particular and to support the transformation of highly innovative ideas into successful products and processes. The results of the consultation process were fed into the development of the Energy Research Programme – undertaken by the Federal Ministry for Economic Affairs and Energy together with the Federal Ministry of Education and Research and the Federal Ministry of Food and Agriculture.

## 10.3 Industry Status and Market Development

Apart from funding carefully selected research projects, the Federal Government is also creating incentives for new projects by remunerating geothermal electricity under the Renewable Energy Sources Act (EEG). The last amendment to the EEG was adopted by the Bundestag (Lower House of Parliament) in 2017. The feed-in-tariff for geothermal electricity remains unchanged fixed at 25.2 Euro-cents per KWh. For photovoltaics and wind energy an auction model was introduced.

The market incentive programme (MAP) of the German Government promotes renewable energy systems that provide space heating, hot water, cooling and process heat. It has a section for smaller buildings administered by the Federal Office of Economics and Export Control (BAFA), and one for large buildings and commercial uses, the latter being a premium component of the KfW Banking Group renewable energies program. Several geothermal technologies can be supported by the MAP; it subsidizes the installation of efficient heat pump systems in residential buildings a repayment bonus, depending of the installation size.

The geothermal market predominantly comprises small and medium-sized enterprises from mechanical engineering, as well as some large-scale enterprises, whose portfolios belong more to the classical energy sector, such as the hydrocarbon industry.

## 10.4 Research, Development and Demonstration/Deployment

With the 7th Energy Research Programme the target of R&D funding has moved from electricity production toward direct heat use. Since more than 50% of primary energy in Germany is used to generate heating, the expansion of geothermal heating and cooling production is a key strategic target to supply energy in the future that is ultra-efficient and based on renewable energy. The increasing use of geothermal as a local energy source also reduces dependence on fuel imports and promotes added value domestically.

For broad market penetration it is important to minimize the risks associated with the use of geothermal and to increase public acceptance through transparent communication of the opportunities and risks based on scientific findings. In addition, energy production costs must be reduced and geothermal storage applications expanded.

R&D funding focuses on the following topics:

- Demonstration projects that implement innovative technological solutions that are easily transferable,
- The continued development of the technology under the aspects of cost reduction, increased efficiency, plant availability, automation and digitization of geothermal in the electricity and heating area,
- Further development of heating and cooling storage underground,
- Development of the geological database for potential geothermal uses,
- Security aspects of methods and use cases,
- Research on the material use of extracted geothermal liquids,
- Modelling and simulation of geothermal systems to increase forecasting reliability and minimize financial risk.

In addition to research institutions and companies, users such as energy suppliers and municipal utilities, in particular, will also be funded. Application-oriented research topics are to be accompanied here by targeted demonstration projects. The actors exchange knowledge in the Energy Research Networks, particularly in the Research Network ENERGIEWENDEBAUEN due to the strong relationship with heating supply. In the future, the incorporation of users will become even more visible. Users are particularly well placed to carry the knowledge transfer into widespread use and to provide important feedback to researchers.

The Federal Government also supports international R&D cooperation, for instance through activities under the IEA as well as through the implementation of the SET-Plan and by participating in transnational funding instruments such as GEOTHERMICA.

In the area of deep geothermal research, the BMWi approved funding for a total of 25 new projects with a funding volume of around 24.1 million euros in 2019. At the same time, around 13.2 million euros were invested in 94 already ongoing research projects.

## 10.5 Research Highlights

### 10.5.1 Geothermal heat for Munich

Munich is located in the region of the so-called Molasse Basin in Bavaria. The underlying geological formations here are particularly suited for the extraction of geothermal heat. The rocks are part of Malm, a geological formation that acts like an aquifer for hot thermal water due to its special structure. Stadtwerke München (SWM) intends to provide the entire district heating for Munich from renewable energies by 2040, with the majority being contributed by geothermal energy.

SWM, as the coordinator, aims to lay an important foundation for this vision with the GRAME project which finished at the end of 2018. SWM developed a consistent concept for determining what locations would be best suited for extracting the heat and how it can then be integrated into the existing district heating network. The project partners SWM and the Leibniz Institute for Applied Geophysics (LIAG) completed a three dimensional image of the subsurface in 2016 and use it to develop a suitable extraction strategy. In general, the results contribute to the better exploitation of the geothermal resources within the Molasse Basin and the utilization of the potential that will be opened up for the generation of both electricity and heat. The goal is to generate electricity of around 50 megawatts or to extract heat in the range of 400 megawatts.

The project partners were using 3D-seismic to determine the structure of the reservoir and to decide about the most promising locations for future drillings. The measurements were being taken over an area of 170 square kilometers. Investigations about the potential for a geothermal use on this scale have never previously been carried out in the region. Conducting 3D-seismic measurements beneath an urban area was also breaking new ground: Amongst other things, traffic or construction work on the surface, generate incessant vibrations that influence the measured values.

A subsequent project called GeoMARE was granted at end of 2018. The objective of the project is to provide comprehensive and conceptual design of the district heating system. A citywide efficient operation involves an adapted heat infrastructure along with sustainable reservoir management. The Heizkraftwerk Süd (southern heating plant) in Munich should become the largest inner-city geothermal plant in Europe. SWM plans to supply around 80,000 Munich residents by 2020 using climate-friendly district heating.

By the end of 2019, six holes had been drilled from one site, which were between 3,700 and 4,300 meters deep. The thermal water temperature is around 100 °C and the flow rate is between 90 and 120 liters per second. A total output of up to 50 MW is thermally calculated.


Figure 10-1 SWM Schäftlarnstraße geothermal project – Six wells drilled from April 2018 to the end of 2019

The success of this project stimulates further project developments in the Munich region and in Germany.

The main themes of R&D funding of geothermal energy addressed in 2019 were:

- Data collection (GeotIS.de)
- Corrosion and Scaling (for operating power plants)
- Advanced drilling technologies (laser, electro-impulse, plasma)
- Machinery (workover-rig, submersible pump, valves)
- District Heating (Munich, urban areas)
- Microseismisity

Germany is participant of the EU-project GEOTHERMICA. GEOTHERMICA's objective is to combine the financial resources and know-how of 17 geothermal energy research and innovation programme owners and managers from 14 countries and their regions. Together with financial support from the European Commission GEOTHERMICA has launched joint projects that demonstrate and validate novel concepts of geothermal energy deployment within the energy system, and that identify paths to commercial large-scale implementation.

## 10.6 Future Outlook

German Government supports constantly the development of renewable energies with a bundle of support mechanism, e.g. feed-in-tariffs, R&D budgets, investments subsidies.

One of the results is that the renewable energy share of gross electrical consumption is 42,1 % and the renewable based heat and cold supply remains at the level of 177 TWh - 0,7% by deep geothermal - in 2019.

Numerous efforts have already been made to develop the potential of geothermal energy as a continuously available renewable energy source. These include the exploration and exploitation of suitable reservoirs, the development of drilling technologies, and innovations in plant construction to finally use the extracted heat for power generation or heating purposes.

20.000 GSHP were sold in 2019, which is a decrease of 15 % from 2018, but with a share of around 77 % air heat pumps are dominating the market. The investments in geothermal energy increased by about 1,4 bn € in the 2019 year (heat pumps, deep geothermal power plants, ambient heat).

In the area of near-surface geothermal energy about 390,000 systems are now installed. In future, the use for heating and cooling supply as well as for seasonal heat storage will be expanded. Research projects are primarily designed to help reducing risks and costs, creating storage possibilities and to increase awareness and acceptance of this form of renewable energy.

With the 7th Energy Research Programme and further strategic approaches of the Federal Government a positive development for the use of geothermal heat can be expected.

For details and statistics, it is highly recommend to go to the websites below, often published in English.

## 10.7 Publications and Websites

Federal Ministry of Economic Affairs and Energy: https://www.bmwi.de/Navigation/EN/Home/home.html

BMWi publications in English: http://www.bmwi.de/EN/Service/publications.html

BMWI Report of Energy research: https://www.bmwi.de/Redaktion/DE/Downloads/B/bundesbericht-energieforschung-2020.pdf

Reform of the Renewable Energy Sources Act: http://www.bmwi.de/Navigation/EN/Topic/eeg-reform.html

Renewable Energy Sources Act: http://www.bmwi.de/Redaktion/EN/Dossier/renewable-energy.html

Marktanreizprogramm (Market Incentive Program, MAP) https://www.erneuerbare-energien.de/EE/Navigation/DE/Foerderung/Marktanreizprogramm/marktanreizprogramm.html

KfW-Funding energy and environment: https://www.kfw.de/inlandsfoerderung/Unternehmen/Energie-Umwelt/F%C3%B6rderprodukte/F%C3%B6rderprodukte-(S3).html

KfW-loans deep geothermal energy: https://www.kfw.de/inlandsfoerderung/Unternehmen/Energie-Umwelt/F%C3%B6rderprodukte/Erneuerbare-Energien-Tiefengeothermie-(272-282)/

German Energy statistics (AGEE-Stat): https://www.erneuerbare-energien.de/EE/Navigation/DE/Service/Erneuerbare_Energien_in_Zahlen/erneuerbare_energien_in_zahlen.html

Database of R&D-projects in renewable energies governmental sponsored: https://www.enargus.de/pub/bscw.cgi/?op=enargus.eps2

7th Energy Research Programme of the Federal Government: https://www.bmwi.de/Redaktion/EN/Artikel/Energy/research-for-an-ecological-reliable-and-affordable-power-supply.html

Project Management Jülich (Public Funding Agency): https://www.ptj.de/projektfoerderung/angewandte-energieforschung

German Geothermal Association (BVG): http://www.geothermie.de/

Geothermal Information System for Germany (GEOTIS): https://www.geotis.de/homepage/GeotIS-Startpage?url=&loc=en

GEOTHERMICA: http://www.geothermica.eu/about-geothermica

German heat pump association (bwp): https://www.waermepumpe.de/

# 11. Iceland

María Guðmundsdóttir, Jónas Ketilsson

Orkustofnun, Grensasvegi 9, IS 108 Reykjavik, Iceland. Email: maria.gudmundsdottir@os.is; jonas.ketilsson@os.is

## 11.1 Introduction

Utilisation of geothermal resources has expanded rapidly in Iceland during the last decade and is expected to increase further in the future. Electricity generation increased by 12% from 5.0 TWh in 2016 to 6.0 TWh in 2019 and geothermal heat use from 27.1 PJ in 2015 to 33 PJ in 2019. A population growth of 36% is expected by 2050, and geothermal utilization is estimated to increase by over 70% by 2050, to almost 50 PJ. Iceland's long-term objective is to ensure the sustainable utilisation of its resources, and the implementation of the Master Plan for hydro and geothermal energy resources in Iceland is a step in maintaining and sustaining this objective. Iceland has developed a great deal of know-how and experience in the harnessing of geothermal resources, both for space heating and electricity generation.

During the 20th century Iceland has emerged from being a nation dependent upon imported oil and coal, to a country where practically all stationary energy, and 82,3% of primary energy, is derived from domestic renewable sources, with near carbon-free electricity production in 2019. This is the result of an effective policy in making renewable energy a long-term priority in Iceland. Nowhere else does geothermal energy play a greater role in providing a nation's energy supply. Figure 11-1 identifies the main production wells in Iceland operated for electricity generation (red), and by heat utilities (blue) that have a natural monopoly license. Auto-producers (self producers) are excluded, of which there are over 100 in Iceland, although they only contribute 14% of the final use. However, for heat use, main activity producers dominate, with 87% (29.5 PJ) of total heat use.

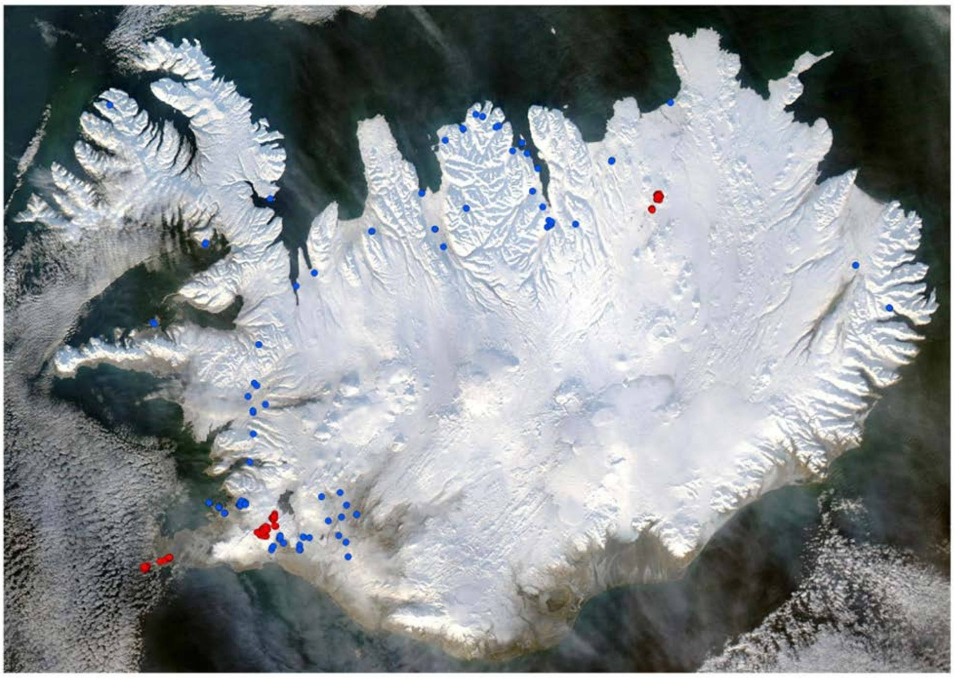

Figure 11-1 Satellite image of Iceland in winter showing geothermal production wells in operation. Geothermal power plants are shown in red, heat utilites in blue.

Table 11-1  2018 Iceland Geothermal energy use data

| Electricity | | Direct Use | |
|---|---|---|---|
| Total Installed Capacity ($MW_e$) | 755.2 | Total Installed Capacity ($MW_{th}$) | 2500* |
| New Installed Capacity ($MW_e$) | 0 | New Installed Capacity ($MW_{th}$) | 0 |
| Total Running Capacity ($MW_e$) | 753.2 | Total Heat Used (PJ/yr) [GWh/yr] | 33 PJ |
| Contribution to National Capacity (%) | 26.7 | Total Installed Capacity Heat Pumps ($MW_{th}$) | N/A |
| Total Generation (GWh) | 6010 | Total Net Heat Pump Use [GWh/yr] | N/A |
| Contribution to National Generation (%) | 30.3 | Target (PJ/yr) | N/A |
| Target ($MW_e$ or % national generation) | N/A | Estimated Country Potential ($MW_{th}$ or PJ/yr or GWh/yr) | N/A |
| Estimated Country Potential ($MW_e$ or GWh) | 4255 $MW_e$ | | |

(N/A = data not available)

(* indicates estimated values)

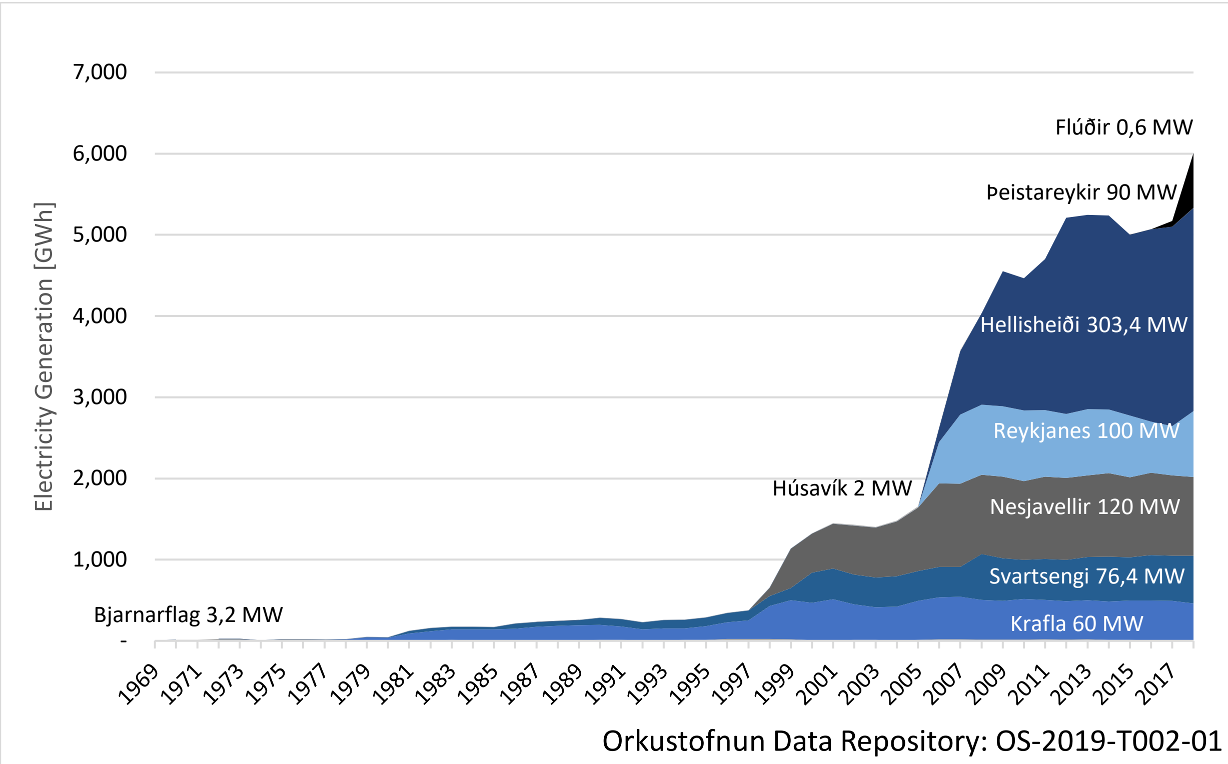


Figure 11-2: Electricity generation from geothermal power plants in Iceland 1969-2018

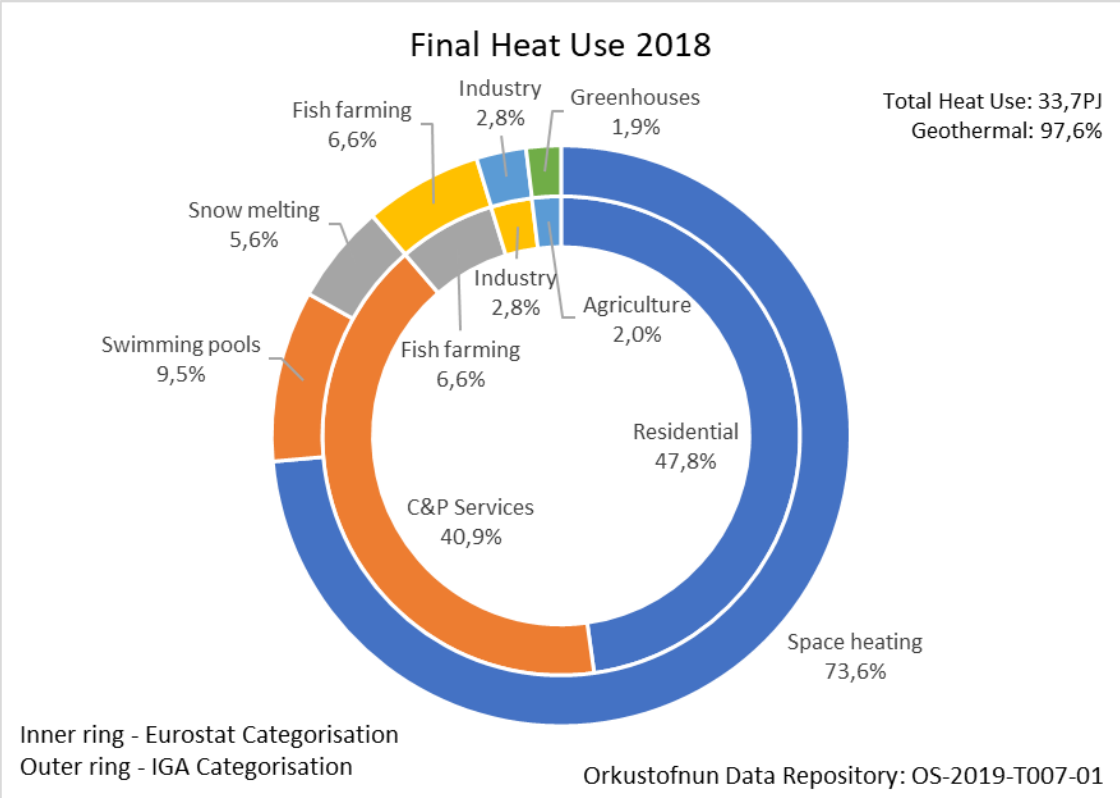


Figure 11-3: Final heat use in Iceland in 2018

## 11.2 Changes to Policy Supporting Geothermal Development

Geothermal policy has essentially remained unchanged in recent years in Iceland. Geothermal development is mature with over 90%, of households using geothermal energy for heating. Geothermal power development is not supported by any market incentives in Iceland. The Energy fund, operated by Orkustofnun, supports geothermal development in areas where geothermal is not used for heating, often referred to as "cold" areas. In the "cold" areas heating is mainly electrical and subsidized by the government, since it is more expensive than geothermal heating. A lump sum comprising 16 years-worth of subsidies is available to those who want to establish a geothermal heating system, or other more efficient means of heating, such as heat pumps.

## 11.3 Geothermal Project Development

### 11.3.1 Projects Commissioned

A new geothermal district heating system is under construction in the municipality of Hornafjörður in Southeast Iceland. This is the result of geothermal exploration by the operator RARIK, which eventually resulted in the discovery of an adequate geothermal resource at Hoffell, 20 km north of the town of Höfn. Previously, the town (pop. 1710 in 2019) and the surrounding countryside had used subsidized direct electrical heating and district heating using an electric boiler. The source of the district heating will be geothermal and the system will be expanded to parts of town that were not connected previously. Additionally, several users in the surrounding countryside will be connected to the system. The project will receive a lump sum comprising 16 years-worth of subsidies from Orkustofnun, since the users in the area will be moving from subsidized electrical heating to geothermal heating. A utilization license was issued by Orkustofnun in December 2019 and the system is expected to start operation in 2020.

### 11.3.2 Low temperature Electricity and District heating

Several geothermal fields in Iceland have medium-enthalpy geothermal fluid with a temperature of over 100°C that is being used for district heating. However, the temperature of the fluid is too high to be used directly for district heating so in many cases cold water is mixed with the geothermal fluid to bring the temperature down to around 80°C. In 2016 these areas were mapped by Orkustofnun and their electrical and thermal potential was assessed prompting interest from the geothermal sector (Björn Már Sveinbjörnsson, 2106). In 2018 a new geothermal plant at Flúðir (Kópsvatn), South Iceland, started producing electricity using water from a well that was already used for district heating. The same company, Varmaorka, has plans for two more plants, in Reykholt, West Iceland, and Efri-Reykir, South Iceland. These geothermal fields are similar to the Flúðir field, as the geothermal fluid has a temperature over 100°C and is currently being used for district heating. The plant at Flúðir uses the fluid first to produce electricity and then returns it to the district heating system at 80°C, therefore using energy that was being wasted before. There are several geothermal fields around Iceland that are in a similar situation so there is more potential to install small scale geothermal plants, with some expected to be completed in 2020.

Aside from the project in Hornafjörður described above, there are no new plans for geothermal district heating systems.

Figure 11-4. Geothermal plant in Flúðir, South Iceland (Varmaorka).

## 11.4 Research Highlights

New and effective exploration techniques have been developed to discover geothermal resources. This has led to the development of geothermal heating services in regions that were not thought to enjoy suitable geothermal resources. Iceland's geothermal industry is now sufficiently developed for the government to play a more limited role than before. Power companies now take the lead in the exploration for geothermal resources; either in geothermal fields that are already being utilized, or in discovering new fields.

The Icelandic Government supports the Iceland Deep Drilling Project (IDDP) with 342 million ISK, along with the three largest energy companies. If successful, this project could start a new era in geothermal development. The main purpose is to find out if it is economically feasible to extract energy and chemicals out of hydrothermal systems at supercritical conditions. The first well, IDDP-1 in Krafla yielded superheated steam after drilling into magma at roughly 2 km depth. The second well IDDP-2 was drilled from August 2016 to January 2017 in Reykjanes. For this phase Norwegian company Statoil joined the original partners, and the drilling was made possible with a €20 million grant from the EU Horizon 2020 programme. The drilling was successful and reached supercritical conditions at 4,659 m. The temperature was measured to be 427°C with a fluid pressure of 340 bars. Cores were retrieved for further study and the rock appears to be permeable at depth. There are exciting times ahead for this project and the third IDDP well is being planned for the Hengill area.

Figure 11-5: Hellisheiði power plant and the Hengill area where the next IDDP well is planned (ON Power).

Orkustofnun also supports several projects coordinated by the Icelandic Geothermal Research Cluster GEORG, e.g. the Deep Roots for Geothermal Systems (DRG-project) aimed at research of the roots of magma-driven high temperature geothermal systems.

The CarbFix and SulFix projects, operated by Reykjavík Energy reinject gases from geothermal fluid extracted at Hellisheiði power plant with good results. According to research the gases mineralize in the basalt bedrock in less than two years. Currently, around 65% of $H_2S$ and 30% of $CO_2$ from the power plant is being injected. The project is ongoing and there are plans to expand it at Hellisheiði to capture more emissions, as well as further developing it for use in other locations. In 2019 Reykjavík Energy founded a new subsidiary that will be focused on further developing the CarbFix method.

## 11.5 Other National Activities

### 11.5.1 Geothermal Education

The UNESCO GRÓ Geothermal training programme (previously the United Nations University-Geothermal Training Programme, UNU-GTP) has been operating in Iceland since 1979, with the aim of assisting developing countries with significant geothermal potential to establish groups of specialists in geothermal exploration and development. A graduate programme was started in 2000 in cooperation with the University of Iceland, and several UNU-GTP students have since continued their studies to obtain MSc and PhD degrees. UNU-GTP receives its funding from the government of Iceland, 5 M US$/yr. Since 1979, 718 scientists have graduated from 63 countries. They have come from countries in Africa (39%), Asia (35%), Latin America (15%), Central and Eastern Europe (10%), and Oceania (1%). Amongst these have been 169 women (23.5%). On January 1, 2020 the name of the programme was changed to UNESCO GRÓ Geothermal Training Programme, as it is now operated under the auspices of UNESCO and no longer affiliated with the United Nations University.

Iceland School of Energy was established at Reykjavik University which offers postgraduate courses in the field of renewable energy. University of Iceland also offers specialized post graduate studies in renewable energy, focusing on geothermal energy.

### 11.5.2 Conferences

Several local conferences and seminars took place as usual in Iceland 2019.

The geothermal sector in Iceland is preparing for the World Geothermal Congress 2020, which will take place in Reykjavík, Iceland.

### 11.5.3 Publications

Icelandic scientists produce numerous publications on geothermal development and research every year, in peer reviewed journals such as Geothermics.

Publications on projects supported by GEORG research group: http://georg.cluster.is/publications/papers/

## 11.6 Useful Websites

Orkustofnun Data Repository: http://www.nea.is/the-national-energy-authority/energy-data/data-repository/

UNESCO GRÓ Geothermal training programme : https://www.grocentre.is/gtp

GEORG Geothermal Research Cluster: http://georg.cluster.is/

Iceland Deep Drilling Project: http://iddp.is/

## 11.7 Future Activity

The Icelandic Government published a white paper on sustainability in the Icelandic society in 1997, in which the need for the development of a long-term Master Plan for energy use in Iceland was stressed. All proposed projects are to be evaluated and categorized on the basis of energy efficiency and economics, as well as on the basis of the environmental impact of the power developments. This Master Plan is comparable to the planning of land use and land protection in a strategic environmental assessment (SEA) process. It is not supposed to go into the details required for environmental impact assessment (EIA). The vision is to prepare an overview of the various potential energy projects in hydro and geothermal and to evaluate and rank these based on their energy and economic potential, feasibility, national economy and the estimated impact that each project would have on nature, environment, cultural heritage and the society, as well as the potential for other uses of the areas in question. The Master Plan is to be based on the best available scientific information and conclusions transparent, reproducible, and made available to the public. It was of vital importance to establish public confidence in the evaluation process. The Master Plan aims to identify power projects that rank highly from an economical point of view, have a minimum negative impact on the environment, and a positive impact on the society. Such a score card for the energy projects helps decision makers to filter out which of the proposed projects are likely to become controversial and disputed and which ones not. It also directs attention to those project areas that might have protection value and should be left untouched. The third cycle of the Master Plan, which includes 33 geothermal options, was presented to the Minister for Environment in September 2016, and in May 2017 parliament commenced reviewing the material. The third cycle had not been confirmed by parliament at the end of 2019. There are 10 planned geothermal projects categorised for utilisation in the third cycle, but since it has not been confirmed by parliament, development (drilling, construction etc.) cannot begin. The exception is geothermal projects that were also proposed in the second cycle, which is the last cycle to have been confirmed, back in 2013. Preparation for the fourth cycle has already begun, even though the third cycle is not confirmed yet.

Direct geothermal use is expected to increase with population increases. It is estimated that heat use will reach 50 PJ in 2050 (Figure 11-6).

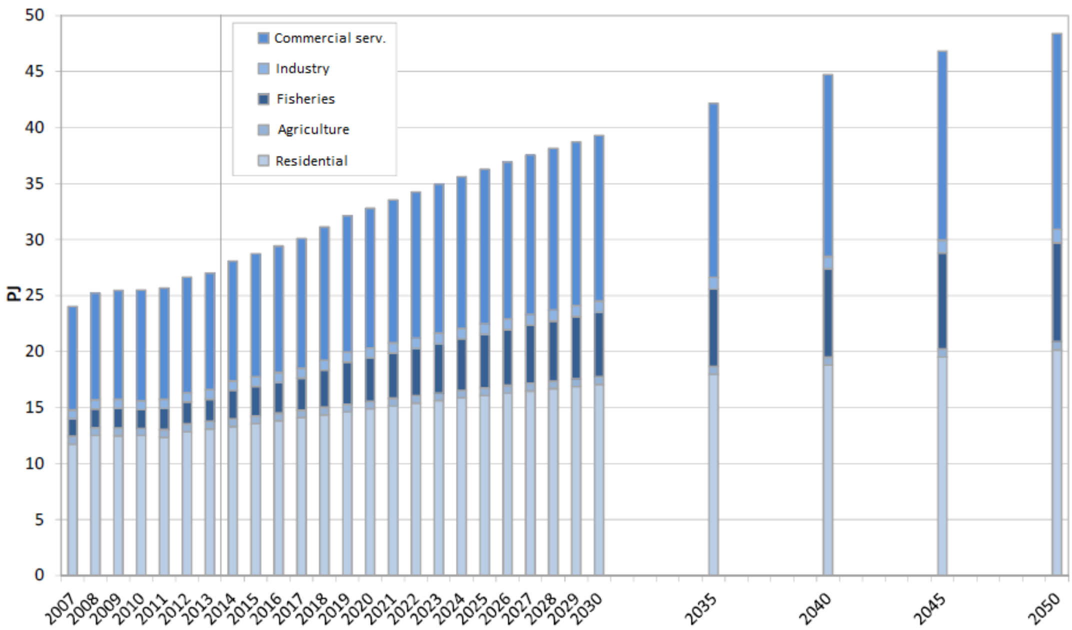


Figure 11-6: Geothermal utilization forecast 2007-2050 (Orkustofnun, 2015).

## 11.8 References


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# 12. Italy

Sara Montomoli and Marco Paci

ENEL Green Power, Geothermal Production, Via Andrea Pisano 120, 56120 Pisa, ITALY.
Email: sara.montomoli@enel.com; marco.paci@enel.com

## 12.1 Introduction

Figure 12-1: Nuova San Martino Power Plant

In Italy, geothermal resources are used for both electricity generation and direct use. Power plants are located in Tuscany in the two "historical" areas of Larderello-Travale and Mount Amiata. Direct geothermal use is widespread over the whole of Italy.

To date, Enel Green Power (EGP) is the only geo-electricity producer in Italy. At the end of 2018 the installed capacity was 915.5 $MW_e$ and the gross electricity generation for the 2018 year reached 6,105 billion kWh.

No additional capacity was commissioned during 2019.

Regarding direct geothermal use, at the end of 2017 the installed capacity reached more than 1400 $MW_t$, with a corresponding total energy use of 10915 Tj/yr (+3,7% with respect to 2016). The main sectors using geothermal energy are space heating (42% of the total energy use) and thermal balneology (32% of the total energy use). Fish farming is third with 18% of the total geo-heat utilization. Heat utilization for agricultural applications, industrial processes and other minor uses amounts to less than 8% of the total.

Ground-source heat pumps (GSHPs) constitute the main technology to exploit and deliver geothermal heat, they account for 38% of the total installed capacity and some 30% in terms of energy.

District heating systems represent about 8% of the total geothermal heat utilization (863TJ/yr) with a total installed capacity of about 150$MW_t$. The main systems are in the Tuscany Region near the geothermal electric power production areas. The other main areas of Italian direct geothermal use applications are Ferrara and Milano.

There is an overall static situation for direct use in Italy, with DHs the only sector with a significant increasing trend, followed by industrial applications, which are still a small fraction of the overall capacity and energy used.

The following table provides information on geothermal energy use for Italy. Official electricity data are for 2018, direct use data for 2017.

| Electricity (data as 2018) | | Direct Use (data as 2017) | |
|---|---|---|---|
| Total Installed Capacity ($MW_e$) | 915,5 | Total Installed Capacity ($MW_{th}$) | 1424 |
| New Installed Capacity ($MW_e$) | 0 | New Installed Capacity ($MW_{th}$) (2015-2017) | 52 |
| Total Running Capacity ($MW_e$) | 915,5 | Total Heat Used (PJ/yr) | 10.915 |
| Contribution to National Capacity (%) | 0.8 | Total Installed Capacity Heat Pumps ($MW_{th}$) | 532 |
| Total Gross Generation (GWh) | 6105 | Total Net Heat Pump Use [PJ/yr] | 3.262 |
| Contribution to National Generation (%) | 2.1 | Direct Use Targets (PJ/yr by when) | N/A |
| Target (% national generation) (data as 2016) | 1080 | Estimated Country Potential ($MW_{th}$ or PJ/yr or GWh/yr) | N/A |
| Estimated Country Potential ($MW_e$) (data as 2016) | 4000 | (no significant change in estimated direct use) | |

(N/A = data not available)

(* indicates estimated values)

## 12.2 Changes to Policy Supporting Geothermal Development

In 2018 the electricity needs of Italy reached 321.91 billion kWh, with a domestic contribution of ~87.0% and 13.0% imported (Terna 2018). As regards the 280.2 TWh of net domestic electricity generation, 66.0% comes from thermal, 17.6% from hydro and 16.4% from geothermal, wind and solar. Although the contribution of geothermal electricity generation is ~2.0% of the total Italian generation, it covers over 30% of the electricity needs of Tuscany, giving a substantial contribution in green energy generation.

In 2018 the average market price of electricity was 6.191 Eurocent/kWh (GSE, 2019). In 2018 the value of the GRIN tariff (Ex green certificates) for the geothermal plants that have access to this incentive was 9.9 Eurocent/kWh additional to the average electricity market price. To receive this an application, using the specific reduction coefficients for the technology type and the type of intervention, must be made (GSE, 2018a).

The 2016 FER Decree defined the new "Base Incentive Fee" for geothermal plants reduced by a percentage due to the auction reduction:

- 13.4 Eurocent/kWh (under 1 MWe installed Capacity),
- 9.8 Eurocent/kWh (for plants between 1 MWe and 5 MWe), and
- 8.4 Eurocent/kWh (over 5 MWe installed Capacity).

All these tariffs are inclusive of the average electricity market price (Ministerial Decree D.M. 23/06/2016).

Recent official documents forecasting energy production from renewables (RES) in Italy envisage only a small growth for geothermal energy applications. The Italian Energy Strategy released in 2017 (MISE, 2017) predicts a rather limited increase of production for electricity and declares the wish to establish a support scheme for geothermal innovative technologies demonstrating electrical power production with zero emissions. While a support scheme for zero emission or other innovative technologies has not yet been established, on January 2019 geothermal power plants were excluded from participating in the bids for incentive schemes offered to renewable power plants.

With the FER1 Ministerial Decree (4 July 2019) "Incentivazione dell'energia elettrica prodotta dagli impianti eolici on shore, solari fotovoltaici, idroelettrici e a gas residuati dei processi di depurazione (19A05099) (GU Serie Generale n.186 del 09-08-2019)", geothermal energy has now been formally excluded from incentives. In the previous, 2016 FER geothermal energy was included.

Moreover, in 2019 a new regional regulation in Tuscany has been approved "legge regionale 5 febbraio 2019, n. 7 , Disposizioni in materia di geotermia", with a significant step forward to the vision of the circular economy and environmental & sustainability improvement for geothermal power plants. The main points of the new regulation are that for the issuing of new leases (leases are expiring before 2024) it will be mandatory to:

- Use the best technology and operational procedures available
- limit the hours of non-operation of geothermal plants to no more than 2 percent of the total annual operating hours
- ensure the transfer and reuse of at least 10% of the $CO_2$ emitted (free of charge)
- ensure the reuse of at least the 50% of the residual thermal energy produced annually that is not used for the production of electricity, to be implemented within one year from the start-up of the plant;

Regarding thermal production, the Italian Energy Strategy released in 2017 (MISE, 2017) does not forecast any specific increase or promotion of heat production from geothermal energy sources, whist only vaguely referring to expanding heat pump uses and district heating infrastructure.

In Italy the promotion of RES in the heating and cooling sector is achieved through tax relief of 55% of the cost of installed RES technologies (the so-called "Conto Termico", i.e. Thermal Account), and as part of wider measures to promote energy savings in the building sector. This latter consists of:

1) for new buildings which are not yet fully operational, the obligation to cover a quota (50%) of their energy needs for domestic hot water with renewable sources, and
2) for existing buildings, the possibility of deducting 55% of the costs incurred for energy retrofit operations from personal income tax (IRPEF) or corporate income tax (IRES) obligations (so-called "Ecobonus").

Since 1998, tax incentives benefit users connected to district heating networks fed by geothermal energy sources. This mechanism pays the end user an incentive for the energy provided by district heating networks supplied by geothermal sources, which was 25.8 €/MWh up to 2014, when it was reduced to 21.95 €/MWh. Moreover, there is an installed capacity incentive of ~21.00 €/$kW_{th}$ paid to the end user through a tax credit mechanism to partially cover the cost of connection.

## 12.3 Geothermal Project Development

### 12.3.1.1 Projects Commissioned

In 2019 no additional geothermal electrical generation units were commissioned.

In 2018 Enel Green Power started the drilling phase for the construction of the 20MWe gross Monterotondo 2 geothermal power plant on a new lease located SE of the existing area, close to Lago Boracifero.

Between 2017 and 2019 four new district heating (DH) networks in geothermal areas in Tuscany have been established: two in the Travale-Radicondoli area (in Radicondoli and Chiusdino villages), and two in the Mount Amaiata area (Piancastagnaio). La Rota in the Mount Amiata area was completed in 2017 and provides heat to 19 enterprises, two farming facilities and a religious centre, with a capacity of 4,4MWt. The network in Radicondoli commenced operation in the winter of 2018-2019, with a capacity of 5.8 MWt. The Piancastagnaio village network development commenced operation in 2019 supplying 1100 buildings, while the Chiusdino network whilst only partially completed commenced production in 2019. An overall installed capacity of 9MWt is foreseen by 2020. The Chiusdino network comprises two districts (one working and one under construction) with energy delivery of 13,68 TJ/yr and 32,40 TJ/yr respectively.

Other DH networks are planned in Tuscany outside the traditional geothermal territories:

- in Castelfiorentino the planned networks will serve 1500 buildings, and
- in Montecatini the planning has recently started.

### 12.3.1.2 Projects Operational (at the end of the reporting year)

### (a) Geothermal fields

All of the Italian geothermal fields in exploitation for electricity generation are located in Tuscany, Larderello, Travale-Radicondoli, Bagnore and Piancastagnaio (the latter two being located in the Mount Amiata area).

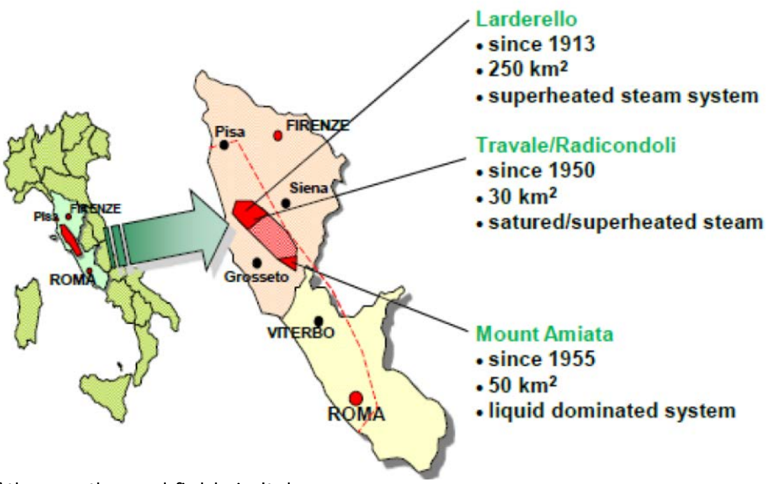


Figure 12-2: location of the geothermal fields in Italy

The activities carried out by EGP over the last three years have been concentrated in the Larderello and Travale-Radicondoli areas targeting field management optimization to reduce and ameliorate decline. Serious acceptability problems from local communities have hindered further developments in the Mt. Amiata area, where the high potential deep geothermal energy for expanded utilisation is located.

In 2018, following surface exploration started some 5 years before, EGP was granted two new development leases, one in Larderello and one in Mount Amiata: Boccheggiano and Roccalbegna.

In the period 2016 - 2018 a total of 27 geothermal wells were drilled in Italy, for a total drilled depth of 46.5 km.

### (b) Electricity generation

The historical trend of electricity generation from geothermal resources in Italy is given in Figure 12-3, where two periods of increased geothermal generation are shown: the first in the period from 1930s to the mid 1970s, related to the development of the shallow carbonate reservoir, with well depths down to about 1000 m. The second from the beginning of the 1980s to now, when the fluid production has increased due to deep drilling activity and to the recharge support of the depleted shallow reservoirs by means of the reinjection of water and condensed steam.

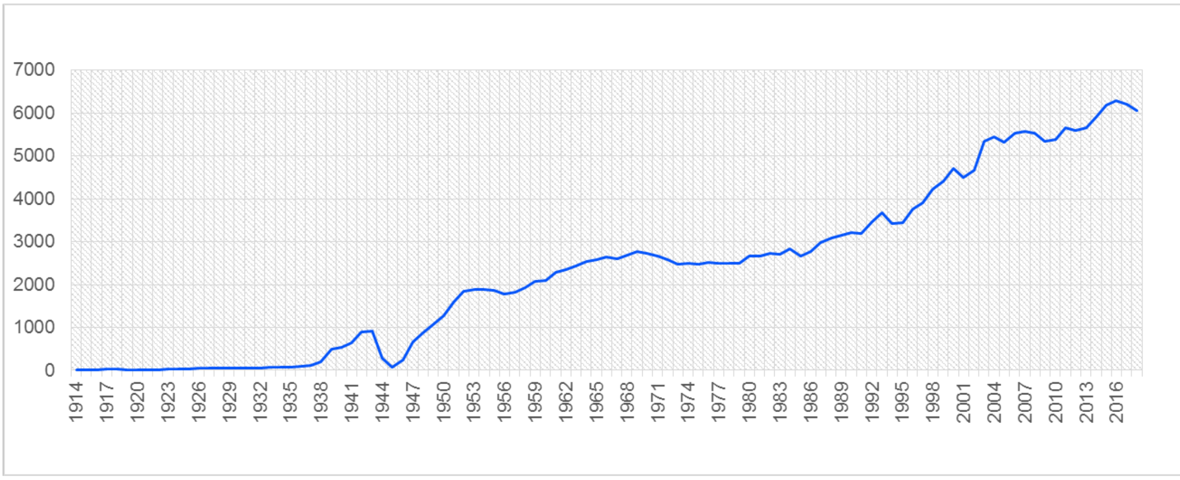


Figure 12-3: Historical trend of electricity generation from geothermal resources in Italy

All 34 of the Italy's geothermal power plants are managed by Enel Green Power. As of 2018 all these power plants had AMIS mercury and hydrogen sulphide abatement plant in operation. The average availability of the AMIS plants (hours of operation vs hours of operation of the associated power plant) exceeded 90%.

All of the geothermal power plants managed by EGP in Italy are remotely controlled and operated from a Remote Control Station located in Larderello, where 12 people work on shift around the clock (24/7) ensuring continuous operator oversight.

For 2018, with an installed capacity of 915.5 MWe, the gross electricity generation was 6064 GWh. A complete list of the operational power plants is given in Figure 12-4; taking into account the actual operating conditions in the different areas (pressure, temperature, non- condensable gas content in the steam, etc), the total running capacity, called Reference Net Capacity, is 806.6 MWe.

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash
2F = Double Flash
3F = Triple Flash
D = Dry Steam
B = Binary (Rankine Cycle)
H = Hybrid (explain)
O = Other (please specify)

| Locality | Power Plant Name | Year Com-missioned | No. of Units | Status[1] | Type of Unit[2] | Total Installed Capacity Mwe* | Total Running Capacity Mwe* | Annual Gross Energy Produced 2018 GWh/yr | Total under Constr. or Planned MWe |
|---|---|---|---|---|---|---|---|---|---|
| **Larderello** | | | | | | | | | |
| | Valle Secolo | 1991 | 2 | | D | 120 | 110,6 | 929,1 | |
| | Farinello | 1995 | 1 | | D | 60 | 52,4 | 488,6 | |
| | Nuova Larderello | 2005 | 1 | | D | 20 | 16,6 | 119,1 | |
| | Nuova Gabbro | 2002 | 1 | | D | 20 | 19,1 | 148,3 | |
| | Nuova Castelnuovo | 2000 | 1 | | D | 14,5 | 14,9 | 126,3 | |
| | Nuova Serrazzano | 2002 | 1 | | D | 60 | 47,5 | 320,9 | |
| | Nuova Sasso | 1996 | 1 | | D | 20 | 14,0 | 100,9 | |
| | Sasso 2 | 2009 | 1 | | D | 20 | 16,7 | 135,5 | |
| | Le Prata | 1996 | 1 | | D | 20 | 18,0 | 156,9 | |
| | Nuova Monterotondo | 2002 | 1 | | D | 10 | 8,0 | 52,0 | |
| | Nuova San Martino | 2005 | 1 | | D | 40 | 36,2 | 226,0 | |
| | Nuova Lago | 2002 | 1 | | D | 10 | 10,9 | 88,1 | |
| | Nuova Lagoni Rossi | 2009 | 1 | | D | 20 | 12,7 | 92,7 | |
| | Cornia 2 | 1994 | 1 | | D | 20 | 12,0 | 150,7 | |
| | Nuova Molinetto | 2002 | 1 | | D | 20 | 14,5 | 95,1 | |
| | Carboli 1 | 1998 | 1 | | D | 20 | 15,4 | 135,8 | |
| | Carboli 2 | 1997 | 1 | | D | 20 | 15,4 | 122,5 | |
| | Selva | 1997 | 1 | | D | 20 | 18,3 | 68,8 | |
| | Monteverdi 1 | 1997 | 1 | | D | 20 | 17,8 | 110,6 | |
| | Monteverdi 2 | 1997 | 1 | | D | 20 | 15,6 | 117,1 | |
| | Sesta | 2002 | 1 | | D | 20 | 13,9 | 92,8 | |
| Subtotal | | | 22 | | | 594,5 | 500,5 | 3877,8 | 0 |
| **Travale-Radicondoli** | | | | | | | | | |
| | Nuova Radicondoli | 2002 | 2 | | D | 60 | 58,5 | 358,2 | |
| | Pianacce | 1987 | 1 | | D | 20 | 14,1 | 67,7 | |
| | Rancia | 1986 | 1 | | D | 20 | 19,1 | 143,6 | |
| | Rancia 2 | 1988 | 1 | | D | 20 | 19,1 | 130,2 | |
| | Travale 3 | 2000 | 1 | | D | 20 | 16,5 | 100,1 | |
| | Travale 4 | 2002 | 1 | | D | 40 | 38,9 | 196,5 | |
| | Chiusdino 1 | 2010 | 1 | | D | 20 | 19,4 | 159,9 | |
| Subtotal | | | 8 | | | 200 | 185,6 | 1156,3 | 0 |
| **Mt. Amiata** | | | | | | | | | |
| | Bagnore 3 | 1998 | 1 | | 1F | 20 | 19,9 | 175,3 | |
| | Gruppo Binario Bagnore3 | 2013 | 1 | | B-ORC | 1 | 1,0 | 6,7 | |
| | Bagnore 4 | 2014 | 2 | | 1F | 40 | 39,6 | 363,5 | |
| | Piancastagnaio 3 | 1990 | 1 | | 1F | 20 | 20,0 | 174,7 | |
| | Piancastagnaio 4 | 1991 | 1 | | 1F | 20 | 20,0 | 171,4 | |
| | Piancastagnaio 5 | 1994 | 1 | | 1F | 20 | 20,0 | 179,2 | |
| Subtotal | | | 7 | | | 120,99 | 120,5 | 1070,9 | 0 |
| **Total** | | | **37** | | | **915,5** | **806,6** | **6105** | **0** |

* Installed capacity is maximum gross output of the plant; running capacity is the Efficient Capacity

Figure 12-4: Existing geothermal power plants, individual sites

The Enel Group Company is present in all continents, globally developing and managing renewable energy generation from a range of renewable sources, water, solar, wind and geothermal, with an annual energy production of 82 TWh, avoiding millions of tons of $CO_2$ emissions annually.

## (c) Thermal production

Between 2015 and 2017 the geothermal applications have grown in terms of both capacity (+1.6%/yr) and energy use (+1.8%/yr). Figure 12-5 and Figure 12-6 show the sector breakdown in energy use and capacity.

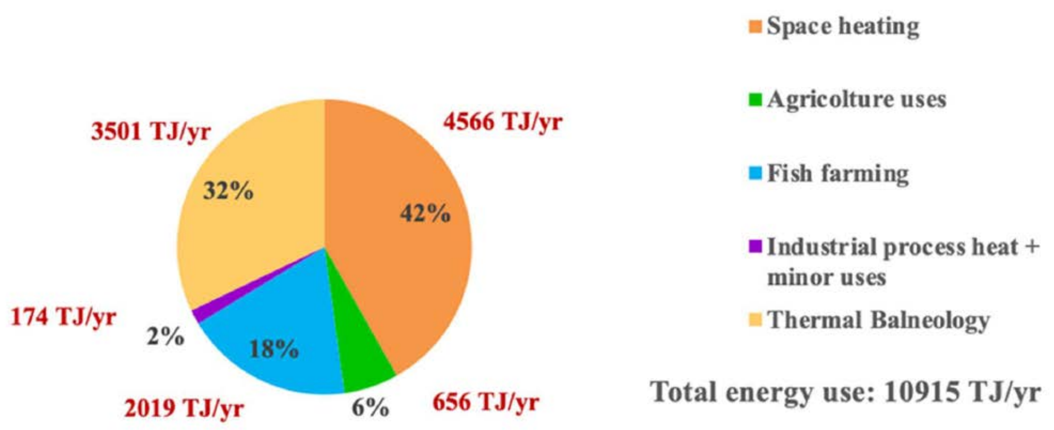


Figure 12-5: Share of geothermal energy utilization of direct uses in 2017

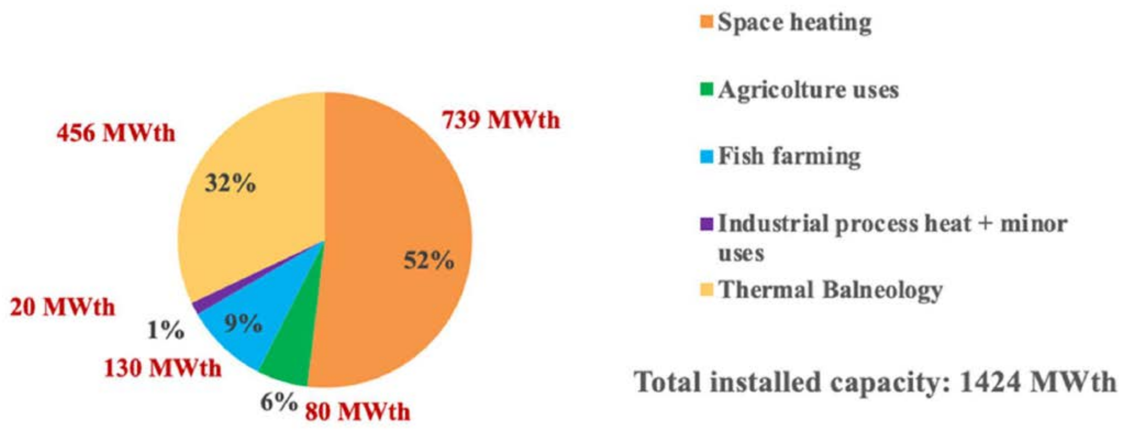


Figure 12-6: Share of geothermal installed capacity for direct uses in 2017

## 12.4 Research Highlights

In recent years, due to an increasing emphasis on sustainable development, and reducing and mitigating environmental impacts, a number of research projects have been carried out on these topics. Good results have been achieved.

In 2019 the EU H2020 program **Matching** concluded, with excellent results achieved in geothermal energy facilities. The **Matching** project achieved the target of demonstrating an up to 15% reduction in evaporative losses from cooling towers, through the replacement of wet cooling towers with hybrid towers equipped with advanced and more robust materials. The work was undertaken at the Nuova San Martino geothermal power plant.

Under the H2020 framework the **Geoenvi** project was established. Scheduled for completion by April 2021 the project aims to define Guidelines for Life Cycle Analysis (LCA) and environmental impact assessments of geothermal power plants.

The **Spirulina cultivation** project, carried out by Enel Green Power, successfully demonstrated the use of geothermal $CO_2$ and heat to grow spirulina algae. These integrated geothermal and algae production processes will reduce some $CO_2$ emissions from a geothermal plant.

Figure 12-7: Spirulina pilot plant at Chiusdino power plant

The recent evolution of the legislative framework (see section 12-2) focusses research towards reducing geothermal gas emissions (mainly $CO_2$) and the potential reuse of $CO_2$.

## 12.5 Publications


https://www.mise.gov.it/index.php/it/198-notizie-stampa/2040101-decreto-fer1-pubblicato-in-gazzetta-ufficiale

https://www.gazzettaufficiale.it/eli/id/2019/05/25/19R00137/S3


## 12.6 Useful Websites

https://www.unionegeotermica.it/

https://www.egec.org/

https://www.etip-dg.eu/

https://www.enelgreenpower.com/

https://www.enel.com/

https://www.mise.gov.it/index.php/it/198-notizie-stampa/2040101-decreto-fer1-pubblicato-in-gazzetta-ufficiale

https://www.gazzettaufficiale.it/eli/id/2019/05/25/19R00137/S3

http://matching-project.eu/

https://www.geoenvi.eu/

## 12.7 Future Activity

There are no other geothermal leases seriously under development in Italy other than the Enel Green Power geothermal developments.

Since 2010, with the liberalization of geothermal resource exploitation for power generation, ~120 new permit requests have been made. Ten of those are for permits dedicated to "Research for geothermal Resources focussed on testing with Pilot Plants", with nominal power up to 5 MW.

Currently, 34 Geothermal Research Permits have been released, listed as follows:

- Two located in Tuscany, are applying for the concession;
- Seven are currently applying for the authorization to drill exploratory wells (5 in Tuscany and 2 in Latium);
- One has obtained authorization to drill 2 exploratory wells (Tuscany);
- 20 Permit requests in Latium are waiting the final advice of award.
- Two Pilot Plants obtained EIA acceptance and are waiting for the final approval from both Region Administrations and the MISE (Ministry for Economic Development).

All the other Requests are still in the investigation phase;

The rate of development for geothermal resources for electricity generation in Italy is currently quite slow. There are many difficulties:

- time for authorization is very long and unpredictable,
- the electricity tariff is often not guaranteed for a sufficiently long period of time for business uptake or it results in an increased level of financial risk.
- Support schemes for geothermal energy are very limited in Italy, and the recent exclusion from incentive schemes for geothermal energy generation from the bids offered by RES power plants adds further difficulty, and
- the long period occurring prior to the release of the new FER2 ministerial decree is slowing down activity and investment planning in geothermal projects.

Regarding the direct use of geothermal heat, the lack of effective support schemes and regulation leads to the very slow growth of geothermal energy uptake currently seen in Italy. The situation is particularly evident for both geothermal district heating systems, which could contribute so much more towards residential heating and cooling demand, and for GSHPs, that were expected to grow at a much higher rate because it is well-established technology that is in use in numerous countries.

## 12.8 References

https://www.terna.it/it/sistema-elettrico/transparency-report/actual-generation

Manzella A., Serra D., Cesar G., Bargiacchi E., Cei M., Cerutti P., Conti P., Giudetti G., Lupi M., Vaccaro M.: Geothermal Energy Use, Country Update for Italy. Proceedings of the European Geothermal Congress 2019, Den Haag, The Netherlands, 11-14 June 2019.

https://unmig.mise.gov.it/index.php/it/dati/risorse-geotermiche

# 13. Japan

Kasumi Yasukawa

Geothermal Resource Development Department, JOGMEC, 2-10-1 Toranomon, Minato-ku, Tokyo 105-0001 Japan.
Email: yasukawa-kasumi@jogmec.go.jp

## 13.1 Introduction

Located along the Circum-Pacific Volcanic Belt "Ring of Fire," Japan is blessed with an abundance of geothermal energy. The total capacity of geothermal power plants reached over 500MW in 1995 and then mainly due to socio-economic factors the installation of new capacity stagnated for almost two decades. Measures to intensify deployment of renewable energy by the Ministry of Economy, Trade and Industry (METI), following the nuclear power plant accident in Fukushima in 2011, have renewed interest in geothermal development. Although development progress is modest, two larger capacity geothermal power plants; Matsuo-Hachimantai (7,499 kW) and Wasabizawa (46,199 kW) were commissioned in 2019. In addition many small geothermal power plants have opened in recent years. The rate of progress is in part due to the long lead times required for larger scale geothermal power plants, including time for environmental assessment processes, but also the difficulty in gaining social acceptance, especially from local hot spring resort owners who are worried about the impact of geothermal development on hot spring resources. For local social acceptance the role of the local government is quite important and in some cases the local governments are not well placed to perform this important work.

The promotion of ground source heat pump (GSHP) started in Japan at the beginning of 21st century and the number of installation has been increasing rapidly in recent years with support from Ministry of the Environment (MOE). More details are described in Section 4.

Table 13-1. Status of geothermal energy use in Japan in 2019.

| Electricity | | Direct Use | |
|---|---|---|---|
| Total Installed Capacity ($MW_e$)* | 550 | Total Installed Capacity ($MW_{th}$) *** | 2,407[2,3] |
| New Installed Capacity ($MW_e$) * | 50 | New Installed Capacity ($MW_{th}$) | N/A |
| Total Running Capacity ($MW_e$) ** | 279[1] | Total Heat Used (TJ/yr) *** | 29,958[2,3] |
| Contribution to National Capacity (%)** | 0.2% | Total Installed Capacity Heat Pumps ($MW_{th}$) ** | 163.4[4] |
| Total Generation (GWh) ** | 2,409[1] | Total Net Heat Pump Use (TJ/yr) ** | 764.9[4] |
| Contribution to National Generation (%)** | 0.2% | Target (PJ/yr) | N/A |
| Target (% of national generation) | 1.0-1.1% | Estimated Country Potential (GWh/yr) | N/A |
| Estimated Country Potential ($MW_e$) | 23,470[5] | | |

N/A = data not available
* At December 2019. "New Installed Capacity" shows the change of "Total Installed Capacity" from that of 2018 report.
** Based on the data of FY 2017 (April 2017 to March 2018), which is the latest available data. Running capacity was calculated from total installed capacity of 500MW and total generation of 2,409 GWh in FY 2017.
*** No data exists for recent years. For data year, see the data sources : [2][3] for Direct Use, and [4] for Heat Pumps.

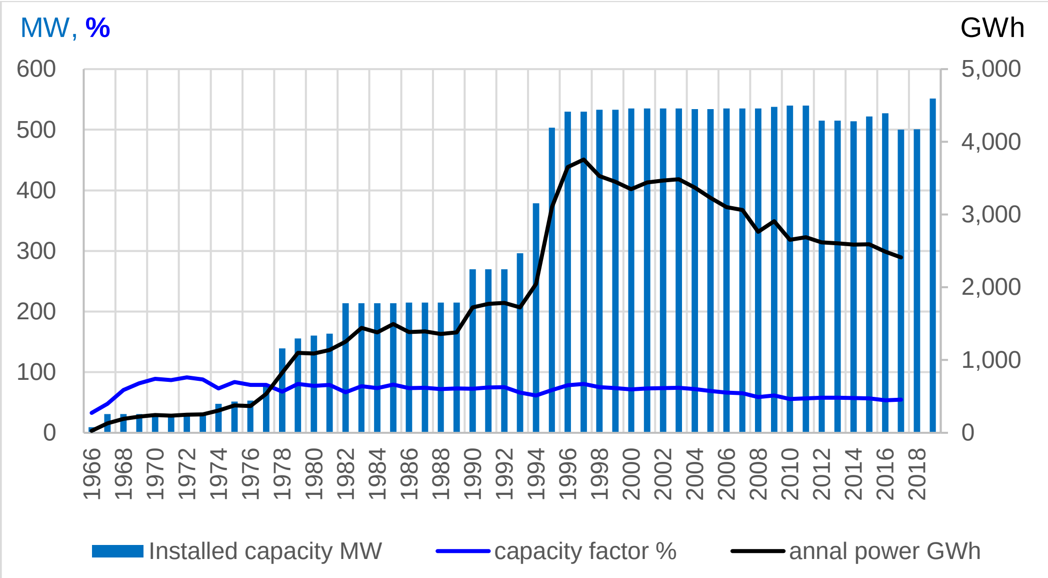


Figure 13-1 Geothermal power in Japan: total installed capacity (blue columns), power generated (black line), and capacity factor (blue line).

Figure 13-1 shows the long-term trend of geothermal power plant capacity and generation in Japan. An issue is that the average capacity factor of the geothermal power plants has been decreasing since the 1970's. The major reason is that in the 20th century, with immature knowledge of geothermal reservoir management, developers built larger capacity power plants that were beyond the ability of the reservoirs to support the facilities long-term, resulting in declining steam production with time. Since 2010 some older power plants have been decommissioned with new units of smaller capacity replacing the older units (blue bars in Figure 13-2). Therefore, although the total number of units has increased in recent years (green line in Figure 13-2), the total capacity decreased between 2012 and 2017. The increase in capacity from Wasabizawa, in Akita and Matsuo-Hachimantai in Iwate during 2019 is encouraging news for the geothermal sector. in March 2019 the Hachijojima geothermal power plant (3.3 MW) shutdown and it is planned to re-commence operation in 2022 with a larger 4.4 MW generator.

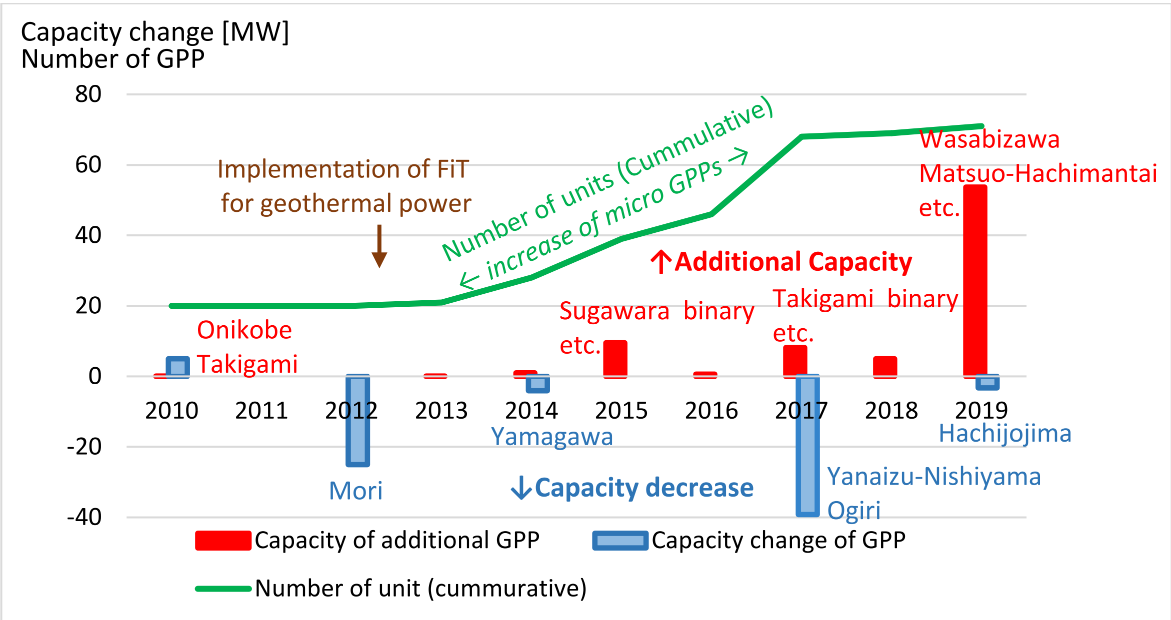


Figure 13-2 Change of installed capacity of geothermal power plants in Japan since 2010.

## 13.2 Policy Supporting Geothermal Development

The Japanese government initiated a Feed-in-Tariff (FiT) in July 2012 to accelerate the deployment of renewable energy. The FiT has been successful in bringing a higher share of renewable energies into the Japanese energy mix. Among renewables, installation of solar PV has dominated because the solar FiT was available earlier (from 2010) and also solar projects are faster to complete compared to geothermal projects, which have longer planning lead times.

The Cabinet approved a Bill partially revising the Act on Special Measures Concerning Procurement of Electricity from Renewable Energy Sources by Electricity Utilities. This Bill institutes a new FiT scheme; geothermal, hydro, and biomass power projects will benefit from this tariff framework. METI announced the tariff is applicable to projects certified in a given year "in advance", in order to reflect the longer period of time that geothermal, hydroelectric, and biomass projects take to become operational compared with other renewable energy projects. The tariff price of geothermal power has been kept high while that of solar PV has been lowered every year.

## 13.3 Geothermal Development Projects

### 13.3.1 Projects Commissioned and Supports by JOGMEC

A geothermal development project generally takes a long time from exploration to power generation. In addition, there are resource risks, which makes geothermal power projects different from other thermal power projects. In order to assist in managing these risks, JOGMEC supports the development of geothermal resources using three financial support mechanisms;

- grant subsidies,
- equity capital investment, and
- loan liability guarantees for geothermal development.

In 2019, 24 projects were accepted for grant subsidies, for which between 50-100% of the investigation cost is supported. Seven out of the 24 projects are new. In 2019 the total value of grant subsidies was ~6 billion JPY (~55 million USD).

After initial survey work is completed, developers need to estimate the production capacity. At this stage, JOGMEC may invest up to 50% of the cost. The first (2015) of JOGMEC's equity capital project investments was Matsuo-Hachimantai, which successfully reached the estimated production capacity and continued on to construction.

At the construction stage, significant funding is required to drill the wells and to construct the facilities. When private developers construct a geothermal power plant with loans from private financial institutions JOGMEC may provide a liability guarantee of up to 80% of the total loans. To date, JOGMEC have provided loan liablity guarantees for five projects; four of which have started operation, with one under construction.

Matsuo-Hachimantai is a model case in which JOGMEC's support mechanisms have worked effectively, from grant subsidies, equity capital investment, through to the liability guarantees. The operation of this power plant commenced on January 2019 (Photo Figure 13.4).

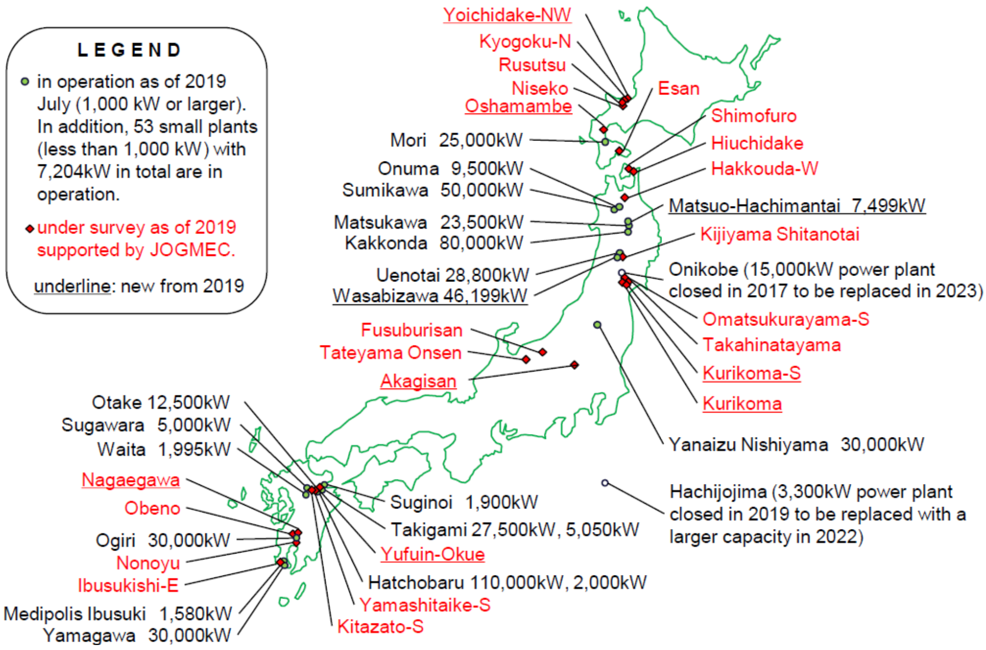


Figure 13-3 Geothermal power plants and ongoing projects in Japan

Figure 13-4 Matsuo-Hachimantai Geothermal Power Plant (7,499kW, single flash, operational 29 January 2019). Photo Iwate Geothermal Power Co., Ltd.

Onikobe geothermal power plant (since 1975) was shut down in 2017 for replacement of the facilities. The environmental assessment for the new power plant was completed in November 2018 and the project is currently under construction with operations scheduled to recommence in 2023. Hachijojima geothermal power plant (since 1999) was shut down in 2019 for replacement with the new power plant scheduled to commence operation in 2022. Construction of a new power plant at the Otake geothermal site begun in 2018 to replace the old power plant, which is still in operation. The new plant is scheduled to be operational by the end of 2020.

A FiT is applied to geothermal power plant replacements with different FiT payments applying in the case of turbine-generator replacement or in the case that includes replacement of production and/or injection wells.

## 13.3.2 Projects Operational

In 2019, Japan has 554 MW of geothermal power capacity, about 4% of the world total. In 2018, it supplied 2,409 GWh of electricity, representing about 0.2% of the country's total electricity supply. Geothermal power plays a minor role in the energy sector in the country.

In 2019, besides several small geothermal power plants, two larger geothermal power plants began commercial operation; Matsuo-Hachimantai in Iwate prefecture (7.499 MW, Figure 13-4) and Wasabizawa in Akita prefecture (46.199 MW, Figure 13-5). JOGMEC provided liability guarantees for 80% of the total development loan of these geothermal power plants.

Construction of geothermal power plants has been announced in several other areas such as Minamikayabe in Hokkaido prefecture (6.5 MW, 2022), Oyasu in Akita prefecture ("Katatsumuri-yama GPP", 15 MW, 2024) and Appi in Iwate prefecture (15 MW, 2024).

Figure 13-5 Wasabizawa Geothermal Power Plant (46,199 kW, double flush, since 20 May 2019). Photo by Yuzawa Geothermal Power Co., Ltd

The Japanese government is working to expand the areas available for geothermal development, reduce investment risk, and promote social acceptance amongst local people. METI's budget for subsidies of geothermal exploration including drilling and for low interest loans was 8.5 billion JPY in FY2019 (9 billion JPY in FY2018). These measures have brought renewed interest in geothermal development, and at least 24 locations across the country (shown in red text in Figure 13-3) are being surveyed for potential geothermal power generation by private sector organisations (such as electric power companies, oil companies, construction companies), local governments, and other entities.

# 13.4 Ground Source Heat Pump (GSHP)

## 13.4.1 Trend and Current Status

The installation of GSHP in Japan has been increasing exponentially in recent years, although the total number is still rather small (Figure 13-6). The total number of facilities using GSHPs is 2,662 including 2,314 closed-loop, 327 open-loop, and 21 using both[4]. Installed capacity of all the GSHPs is 163 $MW_t$, and annual energy use of 765 TJ/yr[7]. This is a large increase from that reported at WGC2015, which was 990 installations with a capacity of 62 $MW_t$[8]. In essence a more than doubling in uptake in 5 years.

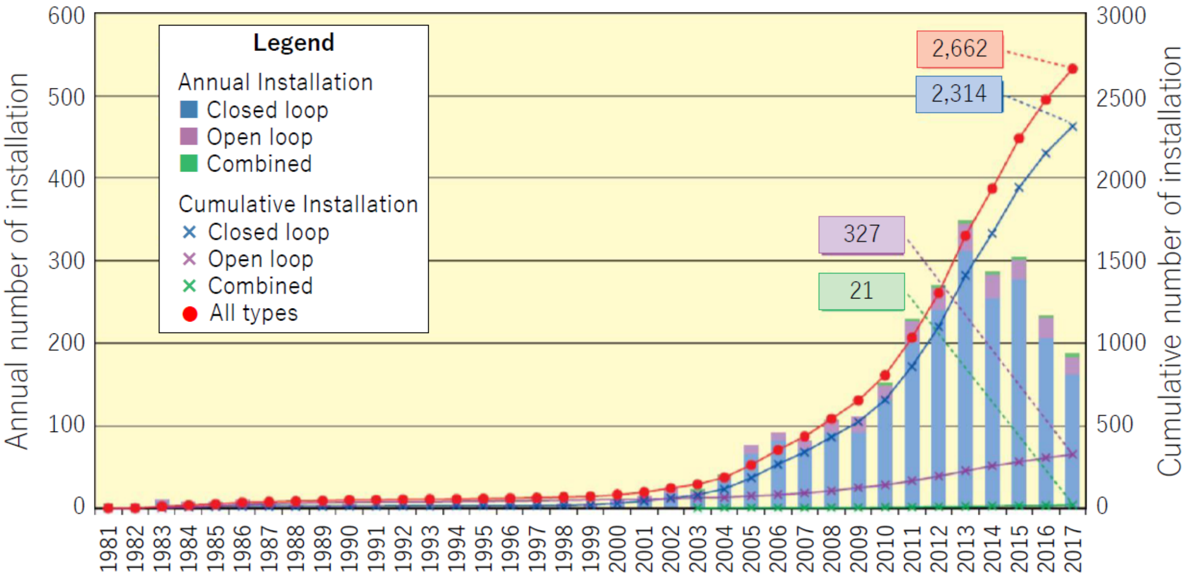


Figure 13-6 Cumulative and annual installation number of GSHP in Japan[4]

Many systems have been installed in the northern regions including Hokkaido where heating needs are intensive, indicating the economic predominance of GSHPs when they replace an old oil boiler with a GSHP (see Figure 13-7). GSHPs are also widely used in other parts of Japan; cooling needs are quite high in the middle to south-western Japan and GSHP with high performance COPs for cooling are contributing to electricity savings.

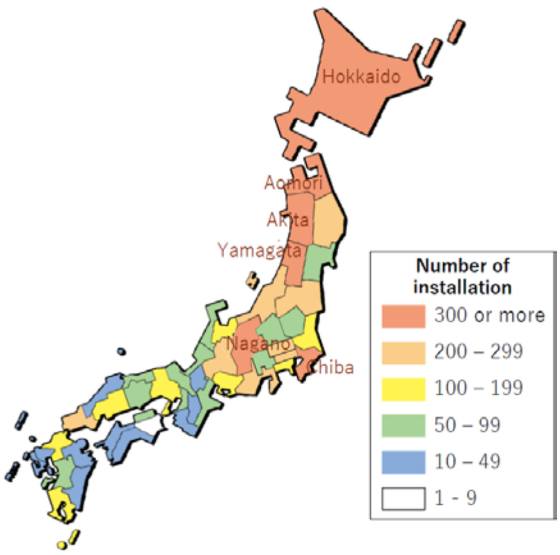


Figure 13-7 The number of GSHP installation in each prefecture in Japan [4]

Figure 13-8 shows the cumulative number of GSHP systems by different facilities[4] category. The largest share is individual houses (44%), followed by offices (12%) and public buildings (7.5%).

Many systems have been installed in the northern regions including Hokkaido where heating needs is intensive, indicating the economical predominance of GSHPs when they replace an old oil boiler into a new GSHP (see Figure 13-7). However, GSHP is widely used in whole Japan because cooling needs is quite high in middle to south-western Japan whereas GSHP shows extremely high performance (COP) for cooling, contributing to electricity saving.

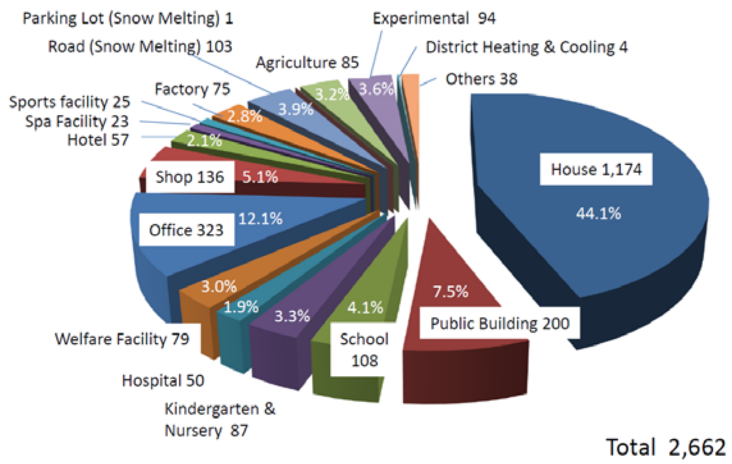


Figure 13-8 The number of facilities using GSHP system [4]

## 13.4.2 Related Studies - Suitability Mapping

Japan has been developing GSHP system suitability mapping based on groundwater flow modelling in basins and plains. The study funded by NEDO, was initiated by AIST and several universities and companies have subsequently become involved.

In Quaternary basins and plains consisting of unconsolidated sediments in monsoon Asia, effective heat conductivity of shallow underground largely differs from one place to another due to both the existence of aquifers and the advection effect of groundwater flow. Since saturated rock has a higher heat conductivity, existence of a shallow aquifer raises the heat exchange rate so that information on the water table becomes important. Also since higher water velocity gives higher heat exchange rates, information on 3D groundwater flow is useful for designing subsurface heat exchangers.

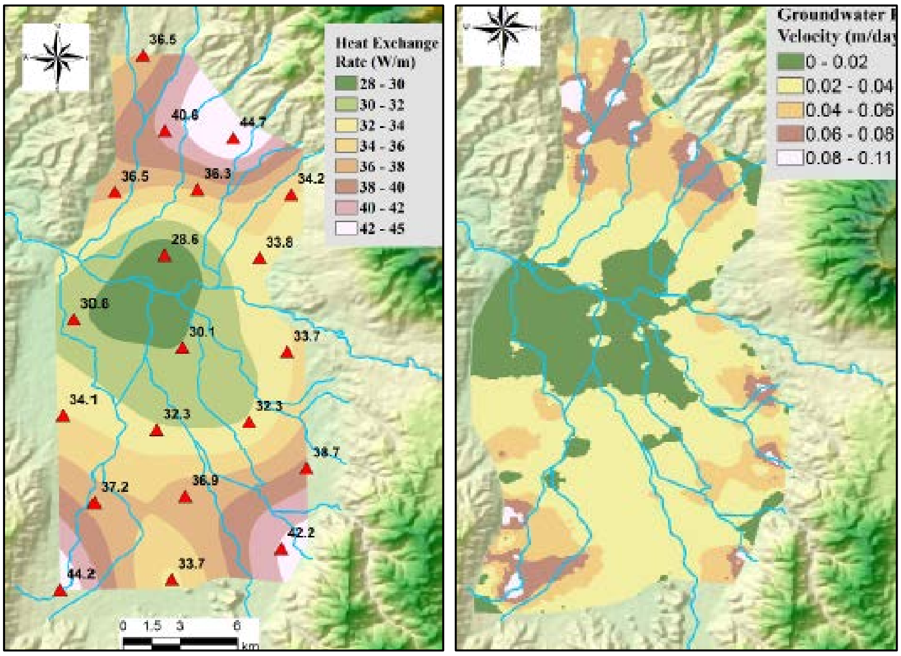


Figure 13-9 Distribution map of sustainable heat exchange rate (left) and groundwater flow velocity (right) [9]

Water table and flow velocity information is indispensable for open loop system design.

Groundwater studies based on field surveying and numerical simulation have been used to prepare separate suitability maps for open and closed loop systems. Separate maps for only heating demand, and heating and cooling demand have been prepared based on subsurface temperature data. Figure 13-9 shows an example of a suitability map for a closed loop system for heating only (Shrestha et al. 2018)[9]. This identifies suitability for open or closed loop systems according to the site location.

Based on the study results, eleven municipals in Japan have compiled GSHP suitability maps from their own budget resources and opened the information up to their citizens seeking to increase the use of GSHP in their municipality; with benefits from energy saving and the environmentally-friendly technology.

## 13.5 Research Highlights

Two METI funded agencies; JOGMEC and NEDO (New Energy and industrial technology Development Organization), started projects in 2013 developing geothermal technology. NEDO began research on subduction-origin supercritical geothermal resources with a target year of 2040 for a pilot plant to be operational. This is one of the NESTI2050 projects, which is looking to contribute to the 2050 $CO_2$ reduction targets set by the Cabinet of Japan in 2017. The NEDO work is focusing on geothermal technologies that are to be realised in the longer term whilst JOGMEC is focusing on surveys, technologies and support that are effective in the short term.

in order to promote geothermal development JOGMEC has undertaken airborne helicopter geophysical surveys since 2013 acquiring basic data for the evaluation of some geothermal prospects. Because most geothermal prospects in Japan are located within national parks or in mountainous areas where access for surface surveying is quite limited, airborne geophysical surveying is an effective method to cover a wide area and difficult topography, identifying lineaments and hydrothermal alteration zones. By the end of 2018 surveying had been conducted in 16 areas; in Hokkaido (9), Honshu (4) and Kyushu (3). JOGMEC began heat flow drilling in 2017 to ascertain the underground temperature and geological structure to a depth of about 1,000m in selected prospects. The location of the drilling sites was based on the results of the airborne surveys. During FY2018 and FY2019 heat flow drilling had been completed at 11 sites in 5 regions in Hokkaido and in northern Honshu, see the green boxes in Figure 13-10).

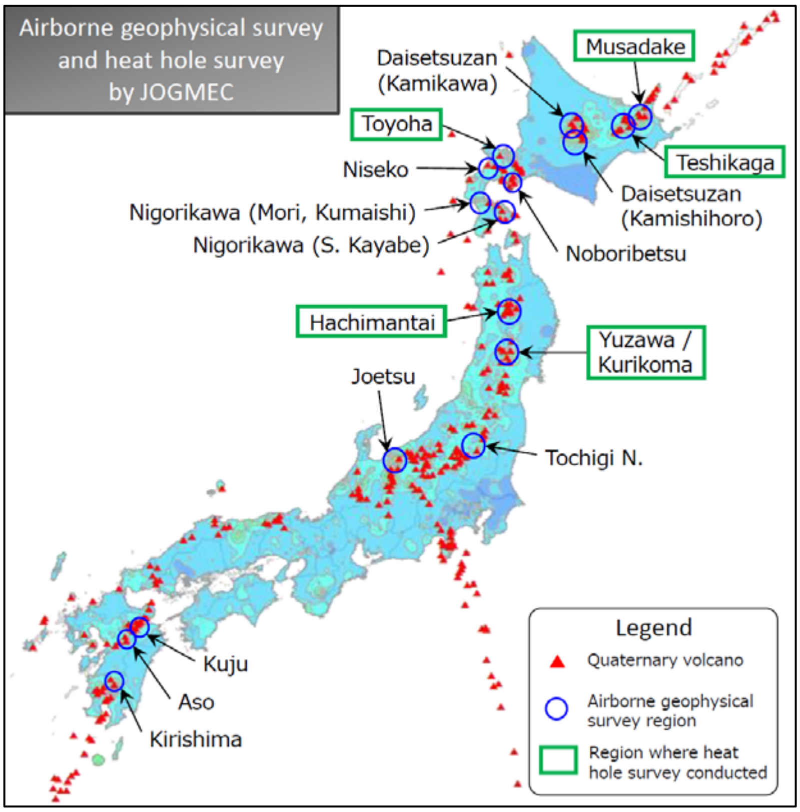


Figure 13-10 Regions for airborne geophysical survey and heat flow drilling surveys conducted by JOGMEC.

In technology development, JOGMEC has 3 R&D project themes;

- Geothermal Reservoir Evaluation and Management,
- Improvement of Exploration Accuracy, and
- Drilling Technology Development.

In the drilling technology theme a new PDC bit was developed and tested at a geothermal site in 2018. It showed high performance in both drilling rate and strength, but further study is needed for improved cost performance.

In 2017, NEDO launched an R&D project "Development of subduction-origin supercritical geothermal resources" to utilize 400 to 500°C supercritical fluid at a depth shallower than 5km. Earlier surveys suggested supercritical geothermal resources may exist in/around many of the volcanic zones in Japan with total potential possibly of several tens of giga-watts.

2040 is targeted for the operation of a pilot plant.

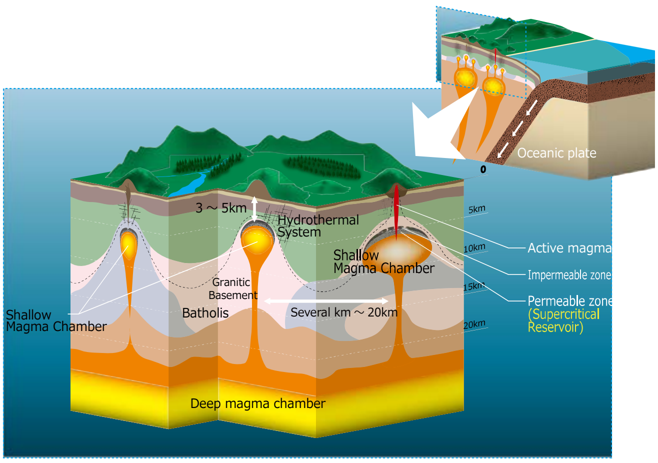


Figure 13-11 : Conceptual model of supercritical geothermal system in northeast Japan[6]

To overcome problems with acid fluid in super critical conditions, the project covers various fundamental scientific studies in rock mechanics, material science, and geo-science, as well as technology development, numerical simulation and drilling. The basic studies are being led and conducted by the National Institute of Advanced Industrial Science and Technology (AIST) and Kyoto University.

## 13.6 Other National Activities

### 13.6.1 Promotion of Geothermal Development

METI began a program in 2013 to raise social acceptance of geothermal power generation amongst local residents. It is a subsidy scheme for general public educational activities undertaken by local governments and/or private sector organisation. Thirteen projects were adopted in 2019 (15 in 2018).


Figure 13-12 Geothermal Symposium in Yuzawa held on 8 August 2019, Akita, Japan

Every year since 2013, JOGMEC has held a Geothermal Symposium promoting geothermal power generation amongst the general public, seeking to increase the knowledge and the understanding of geothermal energy use. In 2019, the symposium was held in Yuzawa city, Akita prefecture, where Uenotai and Wasabizawa geothermal power plants are located and several other geothermal development projects are underway. The programme included excellent presentations on geothermal energy use, related local attractions in Yuzawa and a panel discussion on what can be expected from geothermal energy use based on the experiences in Yuzawa and around. 465 people attended including a member of the Diet, local parliament members, local government members and local citizens.

A wide technical knowledge gap exists between geothermal energy business people and local government officials, making it difficult for the officials to moderate local opinions whilst local social acceptance is quite important for geothermal projects. Aiming at bridging this gap, JOGMEC established in June 2016 a third-party expert organization, the “Advisory Committee for Geothermal Resources Development”. Matters of consultation from six municipals were discussed in 2018 through into 2019.

### 13.6.2 International collaboration and human resource development

Human resource development is an important issue in the international geothermal community. The Japan International Cooperation Agency (JICA) is organizing training courses for geothermal specialists from developing countries. In 2019 a course was held from 11th June to 21st December at Kyushu University. The course was attended by 14 people from 6 countries (Bolivia, Djibouti, Ethiopia, Nicaragua and Philippines). The program is basically provided by Kyushu University and supported by lecturers from other universities, institutes and private companies in order to cover all the aspects of a geothermal energy development. Especially for any on-site training the contribution from the private sector is important. JICA has also been active in conducting Official Development Assistance (ODA) projects in geothermal development in Asian, African and Latin American continents for many decades.

JOGMEC and GNS Science (New Zealand), have a memorandum of understanding for collaboration in geothermal technology. Four joint workshops have been held; in Tokyo, Japan and in Taupo, New Zealand (scaling, community acceptance, reservoir engineering and geothermal geology).

For domestic human resource development, JOGMEC has been providing a three-week-long geothermal training course every December in Kosaka city, Akita prefecture. It covers the basics of geothermal energy including technical and economic aspects of geothermal energy projects. This course is valuable for private developers, many of whom have little experience in geothermal business. In 2019, 29 people mainly from private companies joined the course.

## 13.7 Useful Websites

- Ministry of Economy, Trade and Industry (METI): http://www.meti.go.jp/
- Japan Oil, Gas and Metals National Corporation (JOGMEC): http://www.jogmec.go.jp/
- New Energy and Industrial Technology Development Organization (NEDO): http://www.nedo.go.jp/
- Japan International Cooperation Agency (JICA): https://www.jica.go.jp/
- Geothermal Energy Team, Institute of Advanced Industrial Science and Technology (AIST): https://www.aist.go.jp/fukushima/en/unit/GET_e.html
- Geothermics, Faculty of Engineering, Kyushu University: https://www.eng.kyushu-u.ac.jp/e/lab_earth03.html

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# 14. Mexico

José M. Romo-Jones[1], Luis C. Gutiérrez-Negrín[2], Ismael Canchola-Félix[3]

[1] CICESE - CeMIE-Geo, jromo@cicese.mx

[2] Geoconsul, S.A. de C.V. - CeMIE-Geo, l.g.negrin@gmail.com

[3] Gerencia de Proyectos Geotermoeléctricos, CFE Generación VI, ismael.canchola@cfe.gob.mx

## 14.1 Introduction

The most recent official data published by the Mexican Secretary of Energy (SENER) for electricity generation correspond to the year 2018 and so, in this report we use the same national information previously published in the 2018 IEA Geothermal Mexico Country Report. For installed capacity SENER recently published the data for 2019 (SENER, 2020) and for geothermal data this report uses the information published in the Mexico's Update Report prepared for the World Geothermal Congress 2020 (Gutiérrez-Negrín et al., 2020).

In December 2019, the total installed capacity for electric power generation in Mexico was 79,599 $MW_e$. The installed capacity consisted of 66.4% fossil fuel, 15.9% hydro, 7.5% wind, 4.4% solar, 2.0% nuclear, 1.2% geothermal, 0.5% bio, and 2.2% from a mix of technologies implemented by private industry to produce electricity for use in their industrial processes (cogeneration power plants). It is worth mentioning that around 57% of the total power capacity in Mexico continued to be owned and operated by the government utility CFE (Comisión Federal de Electricidad), including almost all (97%) the installed geothermal-electric capacity. The remaining power plants in operation are owned and operated by private companies.

The installed geothermal electricity capacity in December 2019 was 1005.8 $MW_e$, with five geothermal fields in operation: Cerro Prieto, Los Azufres, Los Humeros, Las Tres Vírgenes, and Domo de San Pedro. The running or operational capacity was 947.8 $MW_e$ representing around 1.2% of the total installed capacity of Mexico (Table 14-1).

Table 14-1. Status of geothermal energy use for electric power generation and direct uses in Mexico in 2019.

| Electricity | | Direct uses | |
|---|---|---|---|
| Total Installed Capacity ($MW_e$) | 1005.8 | Total Installed Capacity ($MW_{th}$) | 156.0 |
| New Installed Capacity ($MW_e$) | 26.5 | New Installed Capacity ($MW_{th}$) | 7.5 |
| Total Running Capacity ($MW_e$) | 947.8 | Total Heat Used (GWh/yr) | 1,162.1 |
| Contribution to National Capacity (%) | 1.3 | Total Installed Capacity Heat Pumps ($MW_{th}$) | 0.13 |
| Total Generation (GWh) (2018) | 5,375.0 | Total Net Heat Pump Use [GWh/yr] | N/A |
| Contribution to National Generation (%) | 1.7 | Target (PJ/yr) | Not set |
| Target ($MW_e$ or % national generation) | Not set[a] | Estimated Country Potential ($MW_{th}$) | 40,589[c] |
| Estimated Country Potential ($MW_e$) | 2300[b] | | |

a) There is no specific target set for geothermal energy. A target of 35% of the total installed power generation capacity is set for clean sources by 2024. "Clean sources" are defined by law as those producing little or no greenhouse gas emissions to the atmosphere, and they include geothermal energy.

b) Estimated potential from conventional hydrothermal resources with temperatures > 150°C (Gutiérrez-Negrín, 2012). A recent estimate of EGS potential in Mexico, comprising hot-dry resources located between 3 and 7 km depth, is of around 47,000 $MW_e$ (Hernández-Ochoa et al., 2020).

c) 0.1 % of recoverable resources using a world average load factor of 0.27, based on Iglesias et al., 2015, for resources between 36°C and 208°C.

The total electrical generation in Mexico during 2018 was 317,278 GWh (SENER, 2019), with only 1.7% (5,375 GWh) from geothermal sources. Generation from fossil fuels represents 76.8%, hydroelectric plants produced 10.2%, nuclear 4.3%, wind 3.9%, and solar 0.7%. More than half (54.2%) of the total was generated by plants owned and operated by the government company CFE.

Renewable sources (hydro, wind, geothermal, solar, bioenergy, and cogeneration) produced 18.9% of the electrical energy generated in Mexico in 2018. However, the Electric Industry Law includes nuclear generation as clean energy sources, besides the renewables. Thus, electricity generated by clean energy sources in Mexico in 2018 was 23.2% of the total, which is a little bit behind what is required to reach the national goal of producing 35% of the total electrical energy from clean energy sources by 2024, set by the Energy Transition Law (Gutiérrez-Negrín et al., 2020).

Direct uses of geothermal energy have been barely developed in Mexico, being restricted basically to bathing and swimming facilities with recreational or therapeutic purposes, despite the vast amount of thermal manifestations identified at the surface. Iglesias et al. (2015) compiled the information related to hot springs and other thermal manifestations in Mexico, which has been collected mainly by CFE, and estimated that there are more than 1,600 points with above average temperature grouped into more than 900 geothermal systems, in 26 states of the country. One-half of those systems have temperatures in the range 62 to 100°C, 40% 100 to 149°C, and 10% with temperatures below 62°C (5%) or higher than 149°C (5%). The authors estimated that if only 0.1% of these resources were used it would represent more than 40,000 $MW_{th}$ of installed capacity (Iglesias et al., 2015).

Besides, the Mexican Center for Innovation in Geothermal Energy (CeMIE-Geo), a national project funded by the federal government (2014-2019), sponsored seven demonstration projects to promote the direct use of geothermal energy, including greenhouse climate control, space heating, food dehydration, and seawater desalination, by using both, heat pumps, and cascade utilization of geothermal fluids (Romo-Jones and Group CeMIEGeo, 2015). The first geothermal heat pumps (GHP) installed in Mexico followed from this effort. Today 11 units are operating in four locations in the country, representing an installed capacity of 133 $kW_{th}$. The principal purpose of these demonstration projects was to promote interest and show the feasibility of using geothermal heat as a way of saving energy in small productive projects. They were: Project 10 (feasibility analysis of a prototype of greenhouses air-conditioned by GHP), Project 11 (technological development for using low-enthalpy geothermal resources), Project 13 (demonstrative installation of GHP in Los Humeros village and Mexicali), Project 16 (development of a pilot poly-generation plant with a cascade-use of geothermal energy), Project 22 (design of module system for air-conditioning spaces with GHP), Project 27 (design and development of a food dehydrator based on geothermal heat), Project 30 (demonstrative installation of GHP in university facilities in Morelia) (data from Garciá-Gutieŕrez et al., 2019).

Balneology is still the primary direct use of geothermal heat in Mexico, representing around 155.3 $MW_{th}$ in heated pools and spas, with ~0.8 $MW_{th}$ of other direct uses (heating, drying and GHP) giving a total of 156.1 $MW_{th}$ (Table 14-1; Gutiérrez-Negrín et al., 2020).

## 14.2 Changes to Policy Supporting Geothermal Development

In December 2018, the official program of development of the national electric system (PRODESEN 2019-2033) reported 19,481 $MW_e$ of new power plants under construction, 68% of them based on renewable energy, mostly wind, and solar power plants. Among them was the 26.5 $MW_e$ geothermal power plant under construction in the Los Azufres field, commissioned in the second half of 2019 (see Table 14-1). Most of the wind and solar power plants are constructed by private companies and will be in operation in 2020.

The Geothermal Energy Law and its regulatory framework remain in force. Based on this framework, the former Geothermal Direction of the Energy Ministry (SENER) has awarded six exploitation concessions and 26 exploration permits as of December 2019. The awarded concessions were for the four geothermal fields that CFE is currently operating and for the Cerritos Colorados field that CFE explored in the eighties and is not yet under exploitation; the sixth concession was for Grupo Dragoń (Geodesa) at the Domo San Pedro field.

SENER granted one-half of the 26 exploration permits to CFE, and seven different private companies have got one or more of the remaining 13. Some of those geothermal zones are currently under exploration, with a couple of exploration wells drilled in one of them. Even though no more permits or public auctions are expected soon, the zones already awarded, if adequately explored and developed, suggest a promising development outlook over the next decade.

The Mexican government wants to strengthen energy companies owned by the state, particularly the oil company PEMEX, but also CFE. Geothermal energy might benefit from such a policy, compared with other renewables, because CFE developed geothermal technology since its inception in 1959. In contrast, solar and wind energy are younger and mainly in the hands of the private industry, so that they will depend entirely on private investment.

## 14.3 Geothermal Projects Development

### 14.3.1 Projects Commissioned in 2019

One additional condensing unit with 26.5 $MW_e$ gross capacity (25 $MW_e$ net) was commissioned in Los Azufres geothermal field in late 2019.

### 14.3.2 Projects Operational in 2019

There are five operational geothermal fields in the country. Their main features are as follows (see also Table 14-2 below):

> **Cerro Prieto, BC.** This field is in north-western Mexico. It is owned and operated by CFE. The installed capacity is 570 $MW_e$ composed of four condensing, flash units of 110 $MW_e$ each, one condensing, low-pressure unit of 30 $MW_e$ and four condensing, flash units of 25 $MW_e$ each. The operational capacity is the same (570 $MW_e$). In 2018 Cerro Prieto produced 28.17 million tons of steam, with 142 production and 28 injection wells in operation (Ramírez-Montes, 2019). The Unit 1 of Cerro Prieto IV (CP-IV), with 25 $MW_e$ of net capacity, generated 223.62 GWh in 2018, presenting the best capacity factor of the field and the country (102.1%), which means that it was operated a little above its nameplate capacity during certain times of the year. Units of CP-IV are the most recent in the field, with 19 years in operation. Also, Unit 5 of CP-I, which works with low-pressure steam, produced 250.2 GWh and reached an excellent capacity factor of 91.3%, despite its 36 years of operation. Units 1 and 2 of CP-II, with 32-33 years in operation, generated 1,157.38 GWh, at an average capacity factor of 80.1%.

**Los Azufres, Mich.** This field is in central Mexico, within the Mexican Volcanic Belt (MVB). It is owned and operated by CFE and has an installed capacity of 270.5 $MW_e$, composed of seven condensing, flash units (two of 50 and five of 26.5 $MW_e$, including the most recent, Unit 18, commissioned in 2019), seven back-pressure units each of 5 $MW_e$, and two binary cycle units each of 1.5 $MW_e$. Four out of the seven back-pressure and the two binary cycle units are out of operation, and thus the running capacity is 247.5 $MW_e$. However, the three units of 5 $MW_e$ each that were operating in 2019 will be out of operation in 2020. The 5 $MW_e$ back-pressure Unit 10 produced 41.32 GWh during the year, operating at the best capacity factor unit of the field at 94.3%, and the 25- $MW_e$ Unit 16 reached an 89.4% capacity factor with 207.48 GWh of electric output.

**Los Humeros, Pue.** This field is in the central-eastern part of Mexico, also inside the MVB. CFE is the owner and operator of the field, which has an installed capacity of 119.8 $MW_e$. It is composed of three condensing, flash units of 26.6 $MW_e$ each, and eight back-pressure units each of 5 $MW_e$. The running or operational capacity is 94.8 $MW_e$ because five of the back-pressure units are out of operation. One of the 25 $MW_e$ single flash units (Unit HUM II-B) was out of operation most of the year, and the electricity generation from the field was 501.5 GWh, at an average capacity factor of 60.3%, reducing substantially from 94.7% reported in 2013 (Gutiérrez-Negrín et al., 2015). However at an individual unit level, Unit 6 reached a capacity factor of 94.3%, and the other two condensing units were operating at 88-89%.

**Las Tres Vírgenes, BCS.** This field is located in the middle of the Baja California Peninsula and is operated and owned by CFE. It has two condensing, flash type power units with a capacity of 5 $MW_e$ each, and its operational capacity is the same (10 $MW_e$). These power units started operation in 2002. In 2018 the plants generated 47.55 GWh at an annual average capacity factor of 54.3%. This capacity factor is the lowest of all the fields operating in Mexico, yet Las Tres Vírgenes has a significant role, as it provides about 30.7% of the electrical demand to the Mulegé system (SENER, 2019), which is a small electric network independent of the national grid.

**Domo San Pedro, Nay.** It is the most recently developed field in Mexico; it is in central-western Mexico, also inside the MVB. It is owned and operated by the private company Grupo Dragón, and has an installed capacity of 35.5 $MW_e$ currently. It is composed of two back-pressure units, each of 5 $MW_e$ that started operation in 2015 and one condensing flash power plant of 25.5 $MW_e$ commissioned in 2016. The back-pressure units have been out of operation since April 2016, when the flash plant was commissioned to supply the 25.5 $MW_e$ capacity unit. The total estimated electric output in 2018 in this field was 126.6 GWh, at an average capacity factor of 56.7%.

The data from every field are reported in Table 14-2.

Table 14-2. Geothermal fields in operation in Mexico in 2019 (* 2018 data.).

| Field | Capacity (MW) | | Owner / Operator | Wells in operation* | |
|---|---|---|---|---|---|
| | Installed | In operation | | Production | Injection |
| **Cerro Prieto, BC** | 570.0 | 570.0 | CFE | 142 | 28 |
| **Los Azufres, Mich.** | 270.5 | 247.5 | | 48 | 6 |
| **Los Humeros, Pue.** | 119.8 | 94.8 | | 28 | 3 |
| **Las Tres Vírgenes, BCS** | 10.0 | 10.0 | | 3 | 1 |
| **Domo San Pedro, Nay.** | 35.5 | 25.5 | Grupo Dragón | 4 | 3 |
| **Total** | **1005.8** | **947.88** | | **225** | **41** |

## 14.4 Research Highlights

In February 2017, the GEMex project started officially in Mexico, which was a bilateral initiative between Mexico and the European Community under the umbrella of the European Horizon 2020 and the SENER-CONACyT Energy Sustainability Fund in Mexico. The objective of this ambitious project is to investigate two unconventional geothermal opportunities: a possible EGS system in Acoculco, Pue., and a superhot system in Los Humeros, Pue., both sites licensed to CFE for geothermal exploration and exploitation. The Mexican group is led by the Universidad Michoacana de San Nicolás de Hidalgo (UMSNH), while the GFZ German Research Centre for Geosciences leads the European group. Public information is available at http://www.gemex-h2020.eu/index.php?lang=en. The European workgroups finished their tasks in February 2020, and the Mexican groups are scheduled to finish in July 2021.

At the end of 2019, 32 projects sponsored by SENER-CONACyT through the CeMIEGeo consortium concluded (Romo-Jones et al., 2020). After five years of work, the projects conducted by this consortium produced significant results in four strategic areas:

- Evaluation of national geothermal resources
- Development and innovation of exploration techniques
- Technological developments for exploitation
- Direct uses of geothermal heat

Most significant results were published in specialized journals or thesis. CeMIEGeo's initiative allowed Mexico to set-up world-class geothermal laboratory infrastructure. Capacity building in geothermal disciplines was promoted and developed as never before. CeMIEGeo's digital collection contains references to technical papers and thesis generated by CeMIEGeo's projects. It also includes collections of papers about all the Mexican geothermal fields, published in international journals since the '70s (https://colecciondigital.cemiegeo.org).

## 14.5 Other National Activities

### 14.5.1 Geothermal Education

Several Mexican universities offer training in science or engineering in topics relating to geothermal energy. Most offer undergraduate programs in geosciences, physics, chemistry, engineering, and energy. Specialized graduate programs are available at a few universities and scientific research institutions.

CeMIEGeo promoted the inclusion of geothermal courses in the teaching programs of several academic institutions. It also offered specialized classroom and online courses, sponsored student research stays abroad, and also supported student participation in research projects. Through the last five years, more than a hundred students graduated completing theses related to geothermal projects, both at the undergraduate and graduate levels. Additionally, CeMIEGeo offered twelve short courses taught by international experts, both foreign and national, with the participation of at least thirty students in each course. The online course Introducción a la Geotermia has registered almost 9,000 attendees and graduated more than 600 students (https://es.coursera.org/learn/geotermia).

### 14.5.2 Conferences

The Mexican Geothermal Association (AGM: Asociación Geotérmica Mexicana), held its 26th Annual Congress in Morelia City, Michoacán, in April 2019. The technical program included 30 oral presentations and seven posters sharing results about geothermal activity in Mexico. There was a pre-congress, eight-hour workshop on "Introduction to Drilling and Reservoir Tests During this Stage", offered by experts from CFE's geothermal division. The 27th annual congress, originally scheduled for 2020, has been postponed to 2021 due to the Covid-19 pandemic.

The Workshop on Final Results of CeMIEGeo projects was held in Ensenada, B.C., in February 2019. The project-leaders presented results and products generated by the 32 projects for the evaluation of the SENER-CONACyT Energy Sustainability Fund.

The 4th and 5th Workshops of the Mexican consortium in the GEMex project were held in Morelia, Mich., in January and November 2019, respectively. The participants of the Mexican consortium shared and discussed advances and results about their work activity on Los Humeros and Acoculco geothermal areas. Several Mexican researchers involved in the project presented their findings in the GEMex Final Conference held in Potsdam, Germany, on 18-19 February 2020 (http://www.gemex-h2020.eu/index.php?lang=en).

### 14.5.3 Publications

CeMIEGeo's Digital Collection includes 114 papers in refereed international journals, 118 thesis, and 45 conference posters. It contains 1,727 registers of papers published about Mexican geothermal fields since 1970. These were compiled from the GRC Geothermal Library, IGA's Geothermal Paper Database, DOE Scientific and Technical Information repository, SCOPUS, and WEB of Science.

### 14.5.4 Useful Websites

Asociación Geotérmica Mexicana (in Spanish): www.geotermia.org.mx

Centro de Investigación Científica y de Estudios Superiores de Ensenada (CICESE) (in Spanish): http://www.cicese.edu.mx/

Centro Mexicano de Innovación en Energía Geotérmica (CeMIEGeo) (in Spanish, with parts in English): http://www.cemiegeo.org/?lang=1

Colección digital CeMIEGeo: https://colecciondigital.cemiegeo.org/xmlui/

Comisión Federal de Electricidad (in Spanish): http://www.cfe.gob.mx/paginas/Home.aspx

Instituto Nacional de Electricidad y Energías Limpias (INEEL) (in Spanish): https://www.ineel.mx//inicio.html

Secretaría de Energía (SENER) (in Spanish): http://www.gob.mx/sener#prensa

## 14.6 Future Activity

The expected geothermal electric capacity in 2025 is 1,061 $MW_e$. This figure considers removing 30 $MW_e$ of the oldest power units in Los Azufres and Los Humeros geothermal fields, to be replaced by one unit of 26.5 $MW_e$ in each field, one of them is already in operation in Los Azufres. It also includes the probable installation of small plants of 10 $MW_e$ in some of the geothermal zones currently under exploration by the CFE and other private companies. The expected geothermal capacity in 2025 is about 12% higher than the operating capacity in December 2019 (or 5.6% higher than the installed capacity), and it is in agreement with the Geothermal Technology Roadmap for Mexico, which anticipates 1,025 $MW_e$ in 2024 (SENER, 2017).

Regarding the total electric capacity in Mexico, it is estimated that by 2025 it could reach almost 108 $GW_e$, of which fossil-fueled power plants will drop to 58.6% from 66.4% in December 2019. That current projection of the energy ministry (SENER, 2019) means an increase of around 36% from the current installed capacity of 79.6 $GW_e$.

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# 15. New Zealand

Chris Bromley

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

## 15.1 Introduction

During 2019, most geothermal generation units ran at near maximum capacity. Geothermal contributed a total of ~17.4% of the national electricity supply (similar to 2018). Two planned turbine/generator replacements were completed at Nga-Awa-Purua and Kawerau. Operational optimization of the existing geothermal power-plants continued, with adjustments in well operation for changes in production well discharge enthalpy, and injection strategy adjustments undertaken to improve efficiency and sustainability. Preparations commenced in late 2019 for a staged expansion of the Tauhara II project using resource consents (up to 250 MWe) already permitted. These include drilling and testing four wells. Construction of the Top Energy Ngawha geothermal project expansion (unit 3) by 31.5 MWe is on track, with injection well drilling (3 wells) completed in January 2019 and commissioning expected ahead of schedule in October 2020. The Te Ahi O Maui ~25 MW binary power plant at Kawerau successfully completed its 1st year of operation.

There are indications of increased interest from policy makers and investors in direct geothermal heat use in New Zealand. The Bay of Plenty Region and the Taupo District (Bay of Connections) are promoting geothermal business development seeking to increase the direct use of geothermal energy. A Geothermal Business Development Lead was funded for 2 years (2018 and 2019) by the Bay of Connections, industry partners, the Government and the New Zealand Geothermal Association.

Implementation continued of a nation-wide geothermal direct use strategy initiative through the New Zealand Geothermal Association. Several operators and investors are working on commercial projects that would benefit economically from a supply of geothermal fluids. One example is a recently expanded pellet drying facility at Tauhara ("Natures Flame"). This uses geothermal heat from Contact Energy bores to process sawdust waste (https://contact.co.nz/aboutus/media-centre/2019/07/25/contact-energy-and-natures-flame-reducing-carbon-emissions-together ). The following table provides information on geothermal energy use for New Zealand during 2019. Electricity generation information is from MBIE, a government ministry (www.mbie.govt.nz), while the direct use information is from material prepared for the New Zealand Country update report to the WGC2020.

| Electricity | | Direct Use | |
|---|---|---|---|
| Total Installed Capacity ($MW_e$) | 1034 | Total Installed Capacity ($MW_{th}$) | 500 * |
| New Installed Capacity (MWe) | 0 | New Installed Capacity (MWth) | 0 |
| Total Running Capacity (MWe) | 1004 | Total Heat Used (PJ/yr) | 9.7 |
| Contribution to National Capacity (%) | 11% | Total Installed Capacity Heat Pumps (MWth) | ~20 |
| Total Generation (GWh) | 7612* | Total Net Heat Pump Use [PJ/yr] | 0.4 |
| Contribution to National Generation (%) | 17.4% | Target 2017 – 2030 (PJ/yr Primary Energy) | +7.5 |
| Target (% national generation) | 20-25% | Estimated Country Potential (MWth or PJ/yr or GWh/yr) | N/A |

| | | | |
|---|---|---|---|
| Estimated Country Potential (MWe) | 4000 | (no significant change in estimated direct use) | |

(N/A = data not available), (* indicates estimated values)

In 2019, the weighted average $CO_2$ (equiv) emissions factor from New Zealand Geothermal power stations was 76 g/KWh with an interquartile range for individual power stations of 45 to 93 g/KWh (McLean, NZGW2019). This is a significant reduction from previous weighted average emissions factor calculations for New Zealand (140 g/KWh in 1990, MBIE) and the global weighted average published by Bertani and Thain in 2002 (122 g/KWh). The emission factors in New Zealand are declining because of degassing of the reservoirs and reduced output from Ohaaki, a relatively gas-rich reservoir.

## 15.2 Changes to Policy Supporting Geothermal Development

There are no government subsidies for renewable energy to reduce greenhouse gas emissions in New Zealand. No significant changes to legislation, or the regulatory environment occurred during 2019, and no new market incentives were announced. However, a strategic target of 100% renewable electricity generation by 2035, in a normal hydro-generation year, was announced by the government early in 2019. (This is in addition to the previous target of 90% renewable by 2025). Subsequent studies have suggested, however, that 100% may be too ambitious and economically unrealistic. https://www.iccc.mfe.govt.nz/what-we-do/energy/

The New Zealand government is also exploring the establishment of targets for renewable heat and electrified transport in addition to its targets for renewable electricity.

The Energy Efficiency and Conservation Authority in conjunction with MBIE is developing a strategy on Process Heat in New Zealand. In January 2019 a technical paper on Process Heat in New Zealand: Opportunities and barriers to lowering emissions (MBIE 2019a) was released. A discussion document on Accelerating Renewable Energy and Energy Efficiency (MBIE 2019b) was released in December 2019. Additionally, a number of useful Process Heat Factsheets were published online in 2019.

## 15.3 Geothermal Project Development

### 15.3.1 Projects Commissioned

No new geothermal power projects were commissioned in 2019.

### 15.3.2 Projects Operational (at the end of the reporting year)

During 2019, normal operation of most existing geothermal power plants continued at near maximum generation capacity, specifically at Wairakei-Tauhara, Mokai, Rotokawa, Ngatamariki, Kawerau and Ngawha. Ohaaki has continued to operate at reduced capacity owing to constraints on fluid supply, as described previously. New Zealand geothermal power-plant availability factors are typically 85-99%. These vary depending on individual turbine performance (including refurbishments that facilitate operation at greater than nameplate capacity), seasonal atmospheric conditions (e.g. air-cooling efficiency), and reservoir performance (especially fluid enthalpy and operating pressure).

Mercury Energy successfully completed a shut-down swapping out the 132 MWe single-shaft triple pressure turbine at Nga Awa Purua, Rotokawa, and installing a refurbished (rebladed) version of the original 19 year old turbine rotor. At Kawerau, Mercury also successfully completed a swap out of the 10 year old, 106 MWe turbine/generator rotor. At Kawerau, production well

KA57 was drilled to 2000m (using large diameter casing) and successfully completed and tested, indicating a production capacity of at least 30 MWe (or 250 MWth for direct heat) for NTGA.

A collaborative development at Ohaaki, by Geo40, Contact Energy, and Ngati Tahu Trust, has seen expansion of a demonstration silica removal plant into a successfully commercial operation. The potential for silica scaling of reinjection wells has thereby reduced and the colour of the Ohaaki pool, which is supplied by separated brine, has changed from milky white to a natural clear colour. The cost is about NZ$20/MWh of generation. Commercially viable quantities of silica sol were produced https://geo40.com/. Geo40 are investigating the extraction of various metals including lithium through small scale trials they have bolted onto the silica extraction process.

The 31.5 MWe expansion of the Ngawha project is proceeding, with 3 directional production wells completed in 2018 and the last of 3 reinjection wells completed in 2019. Production and injection testing also went according to plan, so pipeline, power-station and transmission line construction are proceeding and should be complete by October 2020. http://ngawhageneration.co.nz/constructing-the-new-power-stations/.

Large industrial direct use applications (paper manufacture, timber drying, space heating, aquaculture, milk processing and horticulture) at Kawerau, Tauhara, Ohaaki, Wairakei and Mokai, continued as per previous years. In addition to Norske Skogg, industrial direct heat uses in Kawerau include CHH wood products, Asaleo Care (tissue paper), Oji Fibre Solutions (pulp and paper), Sequal Lumber (timber drying) and the Waiu milk drying factory (about 20 MWth). While the demand for newsprint has diminished, the demand for renewable energy to process pulp, toilet and tissue paper has expanded. Smaller-scale direct-use applications for bathing, building heat, tourist facilities, etc, also continued at a similar level to previous years.

## 15.4 Research Highlights

Core geothermal research, funded by the government at about NZ$2.5M / yr continued at GNS Science under the title “New Zealand’s Geothermal Future”. Topics are:

- Shallow resources and direct use,
- TVZ - Structure and Dynamics;
- TVZ – Source models; and
- Reservoir Chemistry.

The “Endeavour Fund” has supported research into “Empowering Geothermal Energy; Increased Utilisation of Geothermal Energy Through New Integrated Geoscience Methods”. This project addresses the geoscientific uncertainties of accessing underground resources. The project is funded at NZ$1.3M / yr until 2022.

A 5-year Endeavour fund research program, funded at a level of about NZ$2M / yr, commenced in July 2019 into the topic of supercritical (high temperature and high pressure) fluid resources that are likely to occur in the deep roots of volcanic-hosted geothermal systems of New Zealand. https://www.gns.cri.nz/Home/News-and-Events/Media-Releases/energy-future. This research project has a high degree of international collaboration and will also investigate technologies to capture and reinject gas emissions.

A 2- year “Marsden” research project commenced in 2019 addressing the topic of improved understanding of natural $CO_2$ flux passing through Taupo Volcanic Zone geothermal systems.

Industry-funded research activities continue. They include applied research projects through collaboration between government-funded, company-funded and university graduate research programs. These focus on opportunities and practical problem-solving tasks associated with diverse topics such as: scaling, tracer performance, mineral extraction, subsidence, reservoir simulation and injection technology.

MB Century continues to improve and develop practical technology for servicing the geothermal industry, both locally and internationally. These include a well-head repair tool (GWERT), scale treatment, downhole logging technology, and casing corrosion detection (HTCC-MF). Western Energy continue to improve their "on-line well-bore scale-removal" tools and have achieved a 50% cost saving in well-abandonments, using coiled tubing equipment.

Waikato and Bay-of-Plenty Regional Council science staff continue investigating methods and commissioning research to improve environmental monitoring of surface geothermal features (ranking for significance, drone infrared surveys for ecological change assessment and heat-loss monitoring, etc.). in September 2019 the Bay of Plenty Regional Council commenced a series of community workshops to discuss the future management of the Rotorua Geothermal System.

A feasibility study investigating the potential for direct heat applications on the West Coast of the South Island, utilizing low enthalpy resources associated with the Alpine fault, was completed. Also, the potential for utilisation of deep hot brines in abandoned oil wells within the Taranaki province (west coast North island) is still under investigation.

## 15.5 Other National Activities

### 15.5.1 Geothermal Education

The University of Auckland operated the PGCert geothermal diploma course, with about 20 to 30 participants in 2019. Government-sponsored scholarships (up to 25 students) target the training needs of countries such as Indonesia, Philippines, Mexico, Kenya and the Caribbean. There is also a Master of Energy program and other international short courses. The Geothermal Institute also supervises research, involving Masters or PhD students, on a variety of topics including reservoir modelling, subsidence, induced seismicity, 2-phase flow, etc.

The University of Canterbury runs a geothermal graduate program (Geothermal Energy Systems Engineering Group within Department of Mechanical Engineering, and Geothermal Resource Research Group within Department of Geological Sciences).

Regular geoscience and engineering professional training courses are run by GNS Science and universities in several geothermal nations.

The NZ Ministry of Foreign Affairs and Trade (MFAT) working with NZTE (Trade and Enterprise) provides funds for joint off-shore geothermal projects in Africa (NZAfrica Geothermal Facility, Comoros partnership), Indonesia (geothermal training, scholarships, and technical assistance for the World Bank), and Latin America– Caribbean (partnership).

### 15.5.2 Conferences

The 2019 (41st) New Zealand Geothermal Workshop was organised by the Geothermal Institute, and was held at the University of Auckland on 25-27th of November, involving 60 aural presentations, 10 posters and an industry update session http://www.geothermalworkshop.co.nz . Papers can be accessed through the IGA website. The workshop was themed: "Innovation and the Future of Geothermal in a Low Carbon World". International keynotes speakers were invited from NREL (Colorado), Ormat Technologies Inc. (Nevada), ENEL Green Power (Italy) and PT Supreme Energy (Indonesia).

A one-day seminar was organised by the New Zealand Geothermal Association (NZGA website) in Taupo (11 July 2019). Presentations covered a wide range of topics including innovative mineral extraction technology, and documenting changes in green-house gas emissions. The seminar attracted a wide representation of industry representatives, operators, contractors and researchers. A highlight was the trial tasting of beers from a newly established brewery ("Rogue-Bore", named after an infamous Wairakei geothermal well that blew-out in the 1960's). This brewery is to be established in the Wairakei borefield using geothermal energy in the brewing process. https://nzgeothermal.org.nz/app/uploads/2019/07/2019_NZGA_Seminar_Schedule.pdf

A second NZGA mini-seminar was held in Wellington. It involved NZGA and New Zealand Government representatives (MFAT, MBIE, ICCC) and was held on the 26th of September, 2019. Presentations were given on the topics of "Direct use Opportunities" and "Geothermal Operations Carbon Footprint".

### 15.5.3 Publications

Publications documenting recent geothermal research and operational history from New Zealand can be found in the following conference and journal proceedings for 2019: 41st NZ Geothermal Workshop, 44th Stanford Geothermal Workshop, Geothermal Resources Council conference, European Geothermal Congress and Geothermics Journal.

## 15.6 Useful Websites

NZGA: https://nzgeothermal.org.nz/

GHANZ: http://www.ghanz.org.nz

Geoheat: http://www.nzgeoheat.nz

MBIE: https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-publications-and-technical-papers/new-zealand-energy-quarterly/

Geothermal Institute: http://www.geothermal.auckland.ac.nz/

GNS: http://data.gns.cri.nz/geothermal

IPGT: https://ipgtgeothermal.org/about-us/

## 15.7 Future Activity

Figure 15-1 shows an updated historical (to 2019) and projected growth (to 2025) in geothermal electricity generation for New Zealand, relative to other generation options. The projection assumes a demand growth rate of 0.5% per year. Although recent demand growth has been relatively static, electric vehicle uptake is expected to contribute to renewable electricity demand growth, perhaps by up to 15% over the next 10 years (NZGA website). Solar power is expected to grow from 0.2% to 0.5% of total generation, and bio-gas/wood waste generation to about 1.5 %. If new or expanded geothermal (rising to 24%) and wind projects (rising to 8%) eventuate, as predicted, then coal-fired generation is expected to reduce to near zero, and gas-fired generation to about 9%, resulting in more than 90% renewable generation, which is a key 2025 strategy target set by the government.

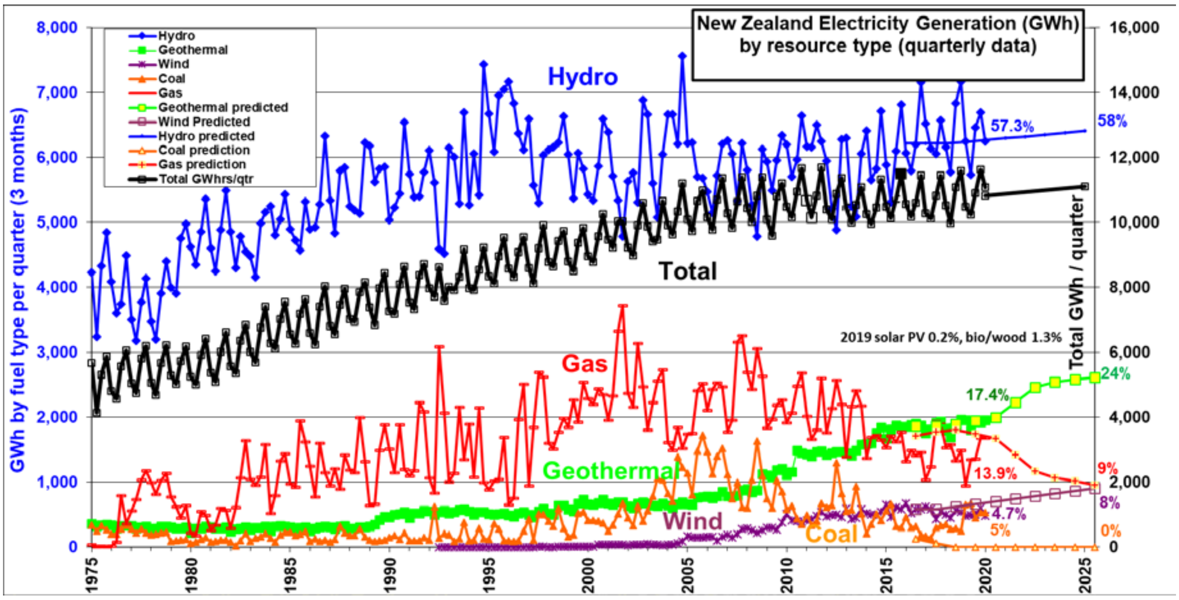



Figure 15-1 Updated plot of actual (>1975) and projected (2010-2025) growth in generation fuel-types in New Zealand. Increased geothermal and wind generation is displacing coal and gas. The geothermal share of 17.4% in 2019 is projected to grow to as much as 24% by 2025, if investment conditions are favourable. Historical data source: MBIE (2019c).

Kawerau: the Te Ahi O Maui (TAOH) (Eastland Generation) 25 MW binary power plant at Kawerau (up to 15 kt/day fluid) completed its first year of commercial operation in November 2019. NTGA (Kawerau) has consents in place for an expansion of fluid take and injection (45 kt/day) for industrial direct heat and power. A group of 11 Maori Trusts through the Poutama Trust constructed Waiu, a $32M geothermally-powered, milk-processing factory, modelled on the Miraka plant at Mokai. Demand for steam from NTGA is growing, with Carter Holt Harvey Wood products installing 2 new continuous timber drying kilns, the Waiu facility for milk drying, Sequal Lumber constructing 2 new timber drying kilns during 2019, along with Oji-fibre Solutions taking plant steam from the NTGA clean steam plant to power some of their pulp production. With the drilling of KA57, NTGA anticipate they will be able to supply up to the maximum abstraction level permitted. This, along with modifications made to the clean steam facility, enable demand growth in both geothermal steam and process steam to be met.

Ngawha: In 2019 construction of the first of two planned 31.5 MWe ORC binary power plants began at Ngawha (Ngawha III expansion), following successful testing of newly drilled production wells (3) and injection wells (3). Expected project cost is US$119M. The outcome of the proposed 2-stage expansion could ultimately mean the Far North Region (Northland) will become self-sufficient in electricity.

Ngatamariki power station has space for two more ORC units (~40 MWe additional capacity), and the operators (Mercury Energy) are at the early stages of planning for this proposed capacity increase.

Wairakei-Tauhara: As noted above, the Tauhara II 250 MW project has commenced incremental stages of expansion. Well testing and drilling has started (initially 2 production and 2 reinjection wells), and further design and planning work is anticipated in 2020. Wairakei Power Station consents expire in 2026, and preparations are underway for new consent applications.

Drilling activities in 2019 included completion of the last injection well for Ngawha III (using the Icelandic Odinn rig), and 1 injection and 1 production well for Mercury (Kawerau) using the "Big Ben" rig (Todd Energy). A production makeup well was also drilled for NTGA using the MB Century rig. Planning for 2020 includes a production makeup well at Rotokawa, using the "Big-Ben" rig.

At Tauhara, in late 2019, Contact Energy started drilling 4 wells using the MB-Century rig for the proposed Tauhara expansion. These wells are expected to be completed through 2020.

## 15.8 References

Climo, M., Bendall, S., Carey, B., 2017, Geoheat Strategy for Aotearoa NZ, 2017–2030. New Zealand Geothermal Association, ISBN 978--0-473-38264-3 https://nzgeothermal.org.nz/app/uploads/2017/06/Geoheat_Strategy_2017-2030__Web_Res_.pdf

Climo, M., Blair, A, Carey, B, Bendall, S., 2018, Action Plan 2018 – 2019; Geoheat Strategy for Aotearoa NZ., New Zealand Geothermal Association ISBN 978-0-473-43417-5 https://docs.zoho.com/file/0gw4j3499b6a5bd2442d89d715d9614403c03

GNS Science website with Google based map - database of Geothermal Use throughout NZ (2019): http://data.gns.cri.nz/geothermal/

GHANZ (2019) New Zealand Geothermal Heat Pump Association: http://www.nzgeothermal.org.nz/ghanz/news-and-events/

Geothermal Institute (2019) University of Auckland, Engineering Faculty, PGCert and NZ Geothermal Workshop: http://www.geothermal.auckland.ac.nz

Geo40 Limited (2019) http://geo40.com/about

IGA newsletter (2019) IGA_News_110.pdf, p30, https://www.geothermal-energy.org/download/

MBIE (2019a) Process Heat in New Zealand: Opportunities and barriers to lowering emissions. Technical paper. January 2019. Download https://www.mbie.govt.nz/dmsdocument/4292-process-heat-in-new-zealand-opportunities-and-barriers-to-lowering-emissions

MBIE (2019b) Discussion Document Accelerating renewable energy and energy efficiency, ISBN 978-1-98-857067-9, December 2019. Download https://www.mbie.govt.nz/dmsdocument/10349-discussion-document-accelerating-renewable-energy-and-energy-efficiency.

MBIE (2019c) Ministry of Business, Innovation and Employment, New Zealand Energy Quarterly: https://www.mbie.govt.nz/building-and-energy/energy-and-natural-resources/energy-statistics-and-modelling/energy-publications-and-technical-papers/new-zealand-energy-quarterly/

NZGA Newsletters (2019) : http://www.nzgeothermal.org.nz/

# 16. Norway

Jiri Muller

Institute for Energy Technology, P.O. Box 40, 2027 Kjeller, Norway. Email: jiri@ife.no

## 16.1 Introduction

Geothermal energy use in Norway is dominated by the relatively widespread deployment of geothermal heat pumps. Since 2018 several wells have been drilled to about 1500m that are being used to supply low temperature heat for winter pavement de-icing operations. There is no electricity production from geothermal resources, and no geothermal energy installations with wells deeper than 1500m in operation. As the third-largest exporter of energy in the world and with an electricity supply almost totally dominated by hydropower, Norway has a large share of renewable energy in both its total primary energy supply and in its electricity supply. Although energy use per capita is close to the average for European countries, the electricity consumption ratio is very high (23 MWh per capita), second only to Iceland.

There is a strong lobby from academic institutions (universities / research institutes) and industry to promote geothermal energy (including deep geothermal) to politicians and the public. The umbrella organisation is the "Norwegian Centre for Geothermal Energy Research" (CGER) established in 2009. Membership of CGER has been steady since 2016. With the joining together of IRIS, Uni Research and CMR in 2018 there are now 14 partner organisations: Equinor, GCE NODE, Greenstat, Huisman, IFE, NORCE, Norhard Geo, NORSAR, NTNU, Rock Energy, SINTEF, UiB, UiS, and Well ID AS.

Increasing the use of geothermal energy in Norway is aligned with the country´s energy policy of increasing the use of renewable energy resources. Additionally, the Norwegian industrial and academic expertise in off-shore technologies should be able to be readily utilised in an emerging geothermal industry with an emphasis on deep drilling, well technology, reservoir management, corrosion and scaling mitigation, and tracer technology.

To date almost all geothermal installations in Norway are geothermal heat pumps (GHP). Statistics from the Norwegian heat pump organization (NOVAP) identifies a peak of 3600 GHP installations in 2011 (Figure 16-1). For 2014, 3000 were installed and since then the annual installations number about 2500.

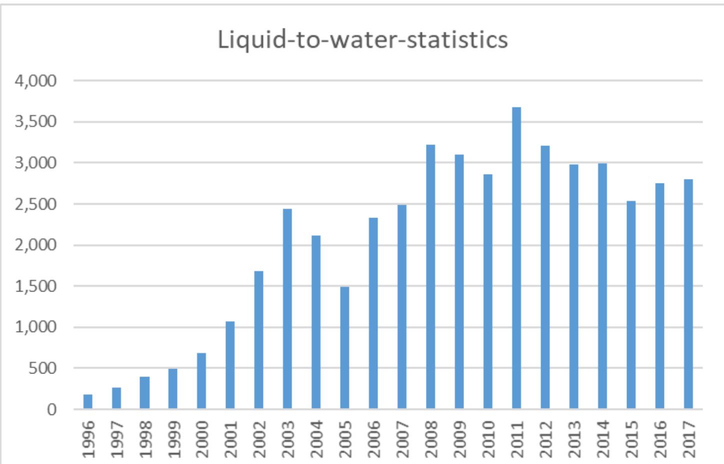



Figure 16-1: Geothermal Heat pump sales statistics for Norway from 1996 to 2017. Source: NOVAP

NOVAPs statistics cover approximately 90% of the Norwegian heat pump market. NOVAP has estimated that there are about 45,786 liquid-to-water units sold in Norway in the period 1996-2017.

The majority of the GHP systems in Norway are vertical closed loop systems extracting heat and/or cold from crystalline rocks through borehole heat exchangers (BHE).

A typical Norwegian GHP is based on one or more boreholes drilled to between 50 and 300 meters. A trend towards deeper boreholes has been observed, partly due to reduced drilling costs for deeper boreholes. The average borehole depth in fields with 4 or more boreholes increased to more than 200 meters in 2009 and to about 230 meters by 2014 / 2015 (Figure 16-2).

A typical Norwegian GHP system uses a 115 mm diameter borehole with a single 40 mm U tube installed. Some BHEs use alternative collectors, such as coaxial arrangements or collectors with a rougher surface which produce turbulent flow at lower flow rates. The Norwegian drilling industry has historically been dominated by Norwegian companies, but in the last few years some companies from Finland and Sweden have also been servicing the market.

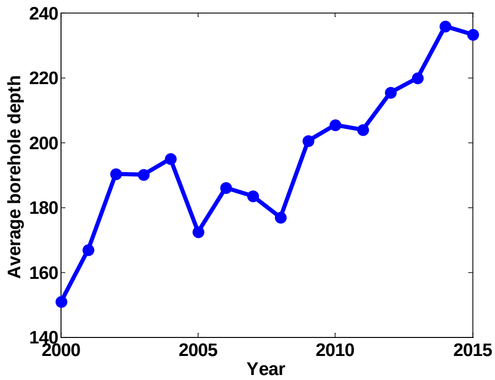



Figure 16-2 Average borehole depth for fields with 4 boreholes or more for Norway from 2000 to 2015. Source: GRANADA/NGU

NOVAP (Norwegian Heat Pump Association) collects statistics on heat pump systems in Norway from the leading suppliers in the 0-20kW range. In the over 20kW size, there are a few suppliers that do not provide sales data. NOVAP is seeking to collect this data and will include it in future reports when available. The data from NOVAP is for all types of liquid-to-water heat pumps including systems that source energy from rock, the sea, ground (subsoil) water etc. However, by far the dominant source is heat from rocks. Summary data from NOVAP on liquid-to-water systems is displayed in Table 16.1.

Table 16-1 summarises the status of geothermal energy use in Norway in 2017.

| Electricity | | Direct Use | |
|---|---|---|---|
| Total Installed Capacity ($MW_e$) | 0 | Total Installed Direct Use (MWth) | na |
| Contribution to National Capacity (%) | 0 | Total Heat Used TJ/yr<br>Total Heat Used TWh/yr | 5746<br>1,6 |
| Total Generation (GWh) | 0 | Total Installed Capacity for Heat Pumps (MWth) | 904 |

(The data is based on NOVAP statistics. na=data not available )

It should be emphasized that data in Table 16.1 includes only liquid-to-water heat pump systems which are considered truly geothermal. However, Norwegian buildings are primarily heated by less efficient (but cheaper) air-to-air systems and by air-to-water systems. NOVAP also collects statistics for these systems. In the period 1996-2017, there have been sold 40,175 air-to-water systems and 967,158 air-to-air systems with the corresponding heat production in 2017 of 0.6 TWh/yr and 6TWh/yr, and installed capacities of 541 MWth and 5,091 MWth. NOVAP identifies the SPF for both of these systems to be 2,5, while the SPF value is 3,5 for liquid-to-water systems.

## 16.2 Changes to Policy Supporting Geothermal Development

The Research Council of Norway (RCN) is supporting geothermal research projects through its programme "ENERGIX". Some of the recent projects are briefly described in Chapter 3. Funding from national agencies "Enova" and "Innovation Norway" is also possible for larger industrial projects such as deep well drilling. Norway is contributing to the EU funded Horizon 2020 programme, and some Norwegian organisations have been involved in these geothermal projects.

## 16.3 Research Highlights

The following section describes the research highlights (snapshots) of some organisations involved in geothermal energy in Norway.

### 16.3.1 CGER - Norwegian Center for Geothermal Energy Research

The GeoEnergi conference 2019 was arranged by CGER, February 4th – 5th at NORCE Fantoft in Bergen. The conference was divided in two main parts: Part 1 - day 1, Devoted to technology status, market status, opportunities and networks, research priorities and funding opportunities. Other presentations on geothermal energy research projects in Norway were presented. Part 2 - day 2: Devoted to ground source heat pump systems including innovative and integrated geothermal energy solutions. Most participants on Part 2 of the conference were from Sweden and Norway.

The conference gathered 81 participants from both industry and research institutions. Feedback from the conference participants indicated that this is an important meeting place for all the participants in the geothermal energy sector in Norway, both within research and industry.

The presentations are available through http://cger.no/index.cfm?id=443076.

Several partners in CGER are involved in European activities which include Horizon 2020 projects and European organisations such EERA-JPGE, ETIP-DG and EGEC.

### 16.3.2 NORCE

The following major geothermal energy projects are currently ongoing in NORCE:

- GeMex (EU project, NORCE is partner): Cooperation in Geothermal energy research Europe-Mexico for development of Enhanced Geothermal Systems and Superhot Geothermal Systems
- RockStore (KPN project, led by NORCE): Smart solutions for storage of energy in the underground
- Hospital building (IPN project, NORCE is partner): Smart energy use and storage in hospital building including geothermal systems

- GeoWell (EU project, NORCE is partner): Developing reliable, cost effective and environmentally safe technologies for design, completion and monitoring of high-temperature geothermal wells
- InnoDrill (KPN project, NORCE is partner): Extend, demonstrate, and make available a research-based technology platform to enable new and significantly more cost-effective drilling tools and systems for deep geothermal wells in hard rock formations

### 16.3.3 University of Bergen

Current research activities at the University of Bergen includes the research projects TheMSES (Thermo-Mechanical Subsurface Energy Storage, 2016-2021), ANIGMA (An Integrated Geological and Mathematical Framework for the Characterization, Modelling and Simulation of Fractured Geothermal Reservoirs, 2015-2019) and ERiS (Enhancing Geothermal Reservoirs – Modelling and Analysis of Hydraulic and Thermal Stimulation, 2017-2020), which in total have involved seven faculty members and 12 PhD and postdoc fellows at the University. The work is a combination of basic and applied research, where cooperation with industry is central in the latter. Most of the effort is oriented towards mathematical and numerical modelling of processes in fractured geothermal systems and implementations are available in the Open Source code PorePy (https://github.com/pmgbergen/porepy).

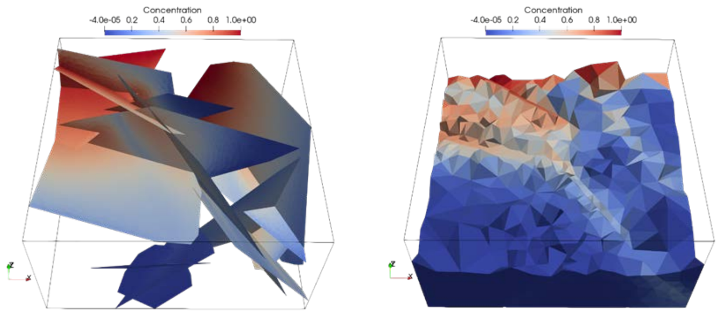



Figure 16-3 Concentration profile in fractures and matrix computed using the Open Source Code PorePy [Keilegavlen, Berge, Fumagalli, Starnoni, Stefansson, Varela, Berre, submitted, arXiv:1908.09869, 2019]

### 16.3.4 Equinor

As part of the Equinor (formerly Statoil) focus on renewable energy, a technology development initiative has been established for production of electricity from geothermal energy. The key focus is the "DeepVision" partnership and field piloting through the Iceland Deep Drilling Project. The drilling of the IDDP2 well in HS Orka's site at Reykjanes was completed in early 2017 and the planning of the IDDP3 well at Reykjavik Energy's Hengill site is ongoing. Equinor is also taking part in EU Horizon 2020 projects DEEPEGS and GeoWell.

### 16.3.5 Other National Activities

### 16.3.6 Geothermal Education

Refer to previous Norway country reports.

### 16.3.7 Conferences

CGER is planning the international conference GeoEnergi in 2021 with participation from international scientific guests, politicians and media.

## 16.4 Useful Websites

www.rcn.no
www.cger.no
www.enova.no
http://www.energi21.no/
www.novap.no
www.innovasjonnorge.no
www.nve.no

## 16.5 Future Activity

The geothermal community in Norway continues expanding its activities. This involves more than academic institutes and universities. Small Norwegian enterprises which are spin-offs from a declining oil industry are motivated to penetrate emerging domestic and international geothermal markets. They are encouraged and co-financed by the Norwegian government organizations (RCN, ENOVA, INNOVATION NORWAY) and EU which support development and deployment of renewable energies.

# 17. Republic of Korea

Yoonho SONG, Tae Jong LEE

Deep Subsurface Research Center, Korea Institute of Geoscience and Mineral Resources (KIGAM), Gwahang-no 124, Yuseong-gu, Daejeon 34132, Korea, Email: song@kigam.re.kr; megi@kigam.re.kr

## 17.1 Introduction

Geothermal utilization in Korea is primarily direct use from ground-source or geothermal heat pump (GHP) installations, because there are no high temperature resources associated with active volcanoes or tectonic activity. Installed GHP capacity has increased rapidly since the middle of the 2000's, with more than 100 $MW_{th}$ of new installation annually, and the total installed capacity estimated to have exceeded 1,400 $MW_{th}$ as at the end of 2019 (See Table 17-1 below).

All activities associated with deep geothermal development or exploration were stopped after the 15th November 2017 Mw 5.4 earthquake which occurred in the vicinity of the Pohang EGS pilot plant site. 'The Korean Government Commission on Relations between the 2017 Pohang Earthquake and EGS Project' officially reported the conclusion stating that "the Pohang earthquake was triggered by the EGS stimulation. Seismicity induced by injection activated a previously unmapped fault zone, which in turn triggered the mainshock" on March, 2019. Thereafter, the Pohang EGS project has been officially terminated by the funding agency and all other activities stopped. However, there are widely divergent technical and scientific opinions regarding the cause of the earthquake, this is particularly so in academia.

Table 17-1 Geothermal utilization in Korea as of December 31, 2019.

| Electricity | | Direct Use | |
|---|---|---|---|
| Total Installed Capacity ($MW_e$) | - | Total Installed Capacity ($MW_{th}$) | 43.6 |
| New Installed Capacity ($MW_e$) | - | New Installed Capacity ($MW_{th}$) | 0 |
| Total Running Capacity ($MW_e$) | - | Total Heat Used (PJ/yr) [GWh/yr] | 0.594 [164.9] |
| Contribution to National Capacity (%) | - | Total Installed Capacity Heat Pumps ($MW_{th}$) | 1,434.3* |
| Total Generation (GWh) | - | Total Net Heat Pump Use [GWh/yr] | 800.8* |
| Contribution to National Generation (%) | - | Target (PJ/yr) | N/A |
| Target ($MW_e$ or % national generation) | 200 MWe | Estimated Country Potential ($MW_{th}$ or PJ/yr or GWh/yr) | N/A |
| Estimated Country Potential ($MW_e$ or GWh) | 19,600 MWe | | |

(N/A = data not available)

(* indicates estimated values)

## 17.2 Changes to Policy Supporting Geothermal Development

Renewable energy is becoming a more important element in the national energy policy, as yet geothermal is not separately specified in the policy. The Third National Energy Master Plan which was finalised and declared on June 2019 by the Korean Government has a vision of "Sustainable growth and improving the quality of people's life through energy transition".

It specifies five major tasks:

1) Converting energy policy paradigm to focusing on consumer innovation,
2) Switching to the clean and safe energy mix,
3) Enlarging distributed and participatory energy systems,
4) Strengthening global competitiveness of energy industry, and
5) Expansion of foundation for energy transition.

For Task 2, it states a target of renewable share of power generation being 30-35% by 2040. There are ongoing subsidy programs and mandatory act supporting renewable energy deployment including geothermal heat pump installation.

Renewable power generation, especially solar PV and wind, is expected to increase rapidly under the policy, but investment in geothermal power may not be active due to growing concern on possible links with damaging earthquakes. Table 17-2 shows geothermal R&D expenditure for the past five years. There was a considerable decrease in R&D investment in 2016 at the time that the government funding to the Pohang EGS project ended in 2015. Because there is no other investment in deep geothermal since the exploration program for hydrothermal resources at the remote Ulleung Island finished in 2016, the total R&D expenditure is decreasing. Especially, there can be seen a notable decrease of R&D funding in 2019 which means that R&D investments not only for deep geothermal but also for GHP significantly declined in the year.

Table 17-2 Geothermal R&D expenditure for the period 2015-2019 (in *US$ 1,000).

| | 2015 | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|---|
| Government | 9,232 | 6,464 | 5,842 | 5,672 | 1,362 |
| Industry | 5,772 | 2,530 | 2,073 | 399 | 301 |
| Total | 15,004 | 8,994 | 7,915 | 6,071 | 1,663 |

*Exchange rates (in KRW/USD) are as of July 1st each year such as 1,140 (2015), 1,168 (2016), 1,165 (2017), 1,134 (2018), and 1,183 (2019).

## 17.3 Geothermal Project Development

### 17.3.1 Projects Commissioned in 2019

No new projects were commissioned in 2019. There was active planning for a project initiating geothermal power generation at a remote Ulleung island in the East Sea (see 2016 Country Report). However, after the official report on the relation between the Pohang earthquake and the EGS project, the project development was stopped.

### 17.3.2 Projects Operational at the end of 2019

The Pohang EGS pilot project, which was the only active development in Korea, was terminated due to the earthquake, and thus there are currently no operational projects.

## 17.4 Research Highlights

There were no notable results or publications on EGS or deep geothermal in 2019.

Monitoring of the performance of the new GHP system in comparison to the air-source heat pump by alternating the use of both systems in a KIGAM building at different times started in early 2019 (see 2018 Korea Country Report), but no comprehensive analysis is available yet.

As part of Working Group 8 activities of IEA Geothermal, we developed a new data collection spreadsheet for GHP statistics. Data for the new statistical scheme is collected through an Excel spreadsheet with input options for installations including individual residential houses, commercial/institutional/multi-family buildings and others such as greenhouses, separately. By adopting a concept of gross and net energy production with input of equivalent full load hours and seasonal performance factors which are different not only for each installation type but also depending on heating or cooling, annual thermal energy use and renewable energy production are automatically calculated for heating and cooling application, separately. The information sources and the accuracy of the information can also be added, allowing to evaluate the reliability of the statistics. Additionally, the new statistical questionnaire of IEA Geothermal includes a separated sheet for 'free cooling', if data is available. This questionnaire comes with a user guide for better understanding of the underlying principle. All the technical details will be presented at the World Geothermal Congress 2020 (Song et al., 2020).

## 17.5 Other National or Academic Activities

No national or academic activities regarding deep geothermal development are available from 2019. GHP installations continue to track with more than 100 $MW_{th}$ of installations per year since 2012 resulting in more than 1,400 $MW_{th}$ cumulative capacity at the end of 2019. Figure 17.1 shows the increasing trend of GHP installation since 2006.

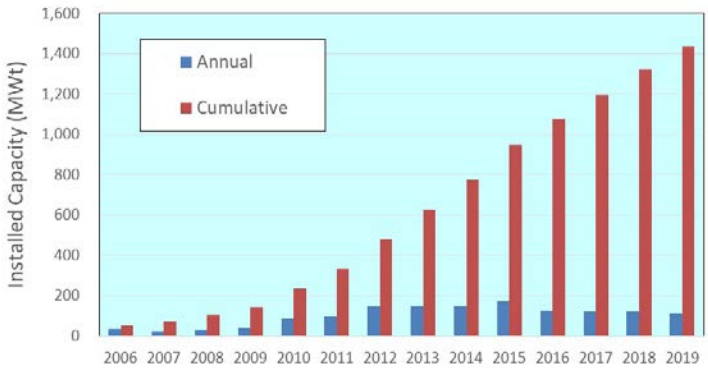



Figure 17-1 Increasing trend of GHP installation since 2006.

## 17.6 Future Activity

Geothermal utilization in terms of GHP installation will continue to rapidly increase over the next few years: more than 100 $MW_{th}$ annually is expected. This is due to the active subsidy programs and the special 'Mandatory Act'. There are some concerns about the low performance or malfunctioning of GHP systems because the rapid increase in market deployment is accompanied with some installations being of lower quality, without proper design or performance validation. Long-term performance modelling and validation are important tasks to keep GHP installation uptake growing, especially for large systems bigger than 1 $MW_{th}$ capacity.

Geothermal utilization statistics are an on-going issue. In Korea, official geothermal energy statistics deal only with GHP and thus other direct uses including space heating, spas, and greenhouse heating are not included in the national statistics. Korea has been reporting other direct use statistics to IEA Geothermal with the help of hot spring survey data. For GHP statistics, there is no official distinction between heating and cooling, but just a lump sum of all energy production throughout a year, which does not consider what the 'pure geothermal contribution' as yet. Effort is needed to establish a revised method of collecting official statistics on geothermal uses that is compatible with international standards such as the IEA statistics. Since 2018, IEA Geothermal has collected GHP statistics with the new scheme proposed as a result of IEA Geothermal Working Group 8 activities (see Chapter 4) and this scheme could guide the updating of Korean GHP statistics once it is accepted by the international community.

The outlook for geothermal power generation in Korea is not positive due to growing concerns of possibly damaging earthquakes. After the Mw 5.4 earthquake occurred close to the Pohang EGS site, all deep geothermal exploration activity was stopped and all projects are currently in hiatus. The government is very keen to foster renewable energy deployment to substitute for nuclear power, but even so the outlook for geothermal investment is not promising for the time being.

## 17.7 References

Song, Y., Link, K., Yasukawa, K., and Weber, J., 2020, Proposal of new data collecting spreadsheet for geothermal heat pump statistics - An outcome of IEA Geothermal Working Group activities, Proceedings World Geothermal Congress 2020, Reykjavik, Iceland, April 26 - May 2, 2020.

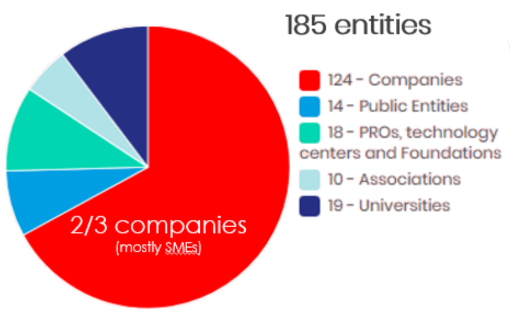
# 18. Spain

Margarita de Gregorio, Paloma Pérez

Spanish Geothermal Technology Platform, Doctor Castelo 10, 3 C-D. 28009, Madrid, SPAIN.
Email: margadegregorio@geoplat.org pperez@geoplat.org

## 18.1 Introduction

The Spanish Geothermal Technology and Innovation Platform (GEOPLAT) is a sectorial coordination group led by industry, consisting of all relevant stakeholders in geothermal energy in Spain (Companies, SMEs, Technology Centres and Foundations, Associations and Cooperatives, Universities, Public Entities, Public Research Centres). It aims at identifying and developing sustainable strategies for the promotion and marketing of geothermal energy in Spain.




GEOPLAT is a public-private entity promoted by the Spanish Ministry of Science and Innovation.

GEOPLAT focuses on geothermal energy as a renewable resource and associated technologies. It covers the identification and evaluation of geothermal resources, as well as sustainability and regulatory aspects.

GEOPLAT has a Steering Committee to coordinate the actions of the platform, to monitor progress of the objectives by each of the working groups, and to encourage participation and connection between them.


GEOPLAT focuses mainly on identifying and developing sustainable strategies for the promotion, implementation and dissemination of geothermal energy in Spain. It covers research, development and innovation activities including the identification and evaluation of resources across all forms of geothermal energy use and technologies. Sustainability and regulatory aspects are considered in all activities of the Platform, as well as connections and collaboration with other similar platforms, both national and European.

Specific objectives:

- To provide a framework within which all agents work together in a coordinated manner to ensure the commercial viability and continuous growth of geothermal, in a competitive and sustainable form.
- To analyse the status of geothermal energy in Spain considering all stages of the value chain, from the different types of resources to its end use, considering all the technologies that allow its use.
- To identify R&D needs and to recommend funding for research in strategic areas.
- To coordinate different participants of the science-technology companies involved in the technological chain (at national and international level), and to encourage business participation in the development of action plans, R&D and marketing.
- To participate in international forums and other activities.
- To publicize the potential of geothermal energy as well as the results and recommendations of GEOPLAT in all related sectors.
- To promote training at all levels related to geothermal energy, to raise awareness and to mobilize society and governments at national, regional and local levels.

Main activities of GEOPLAT:

Close collaboration with public bodies and institutions with competencies in the geothermal sector at a national level.

Participation in European and international activities including European Technology Platforms (Deep Geothermal and Renewable Heating and Cooling; Deep Geothermal ETIP), and IEA Geothermal.

Official training courses on geothermal energy. Establishment of the basis of an official professional qualification in geothermal.

Communication and dissemination: Editing of official documents, reports and analysis from the geothermal sector. Organization of workshops and geothermal events.

## 18.2 Geothermal Highlights in 2019

2019 began with the adoption of important standards for the European and Spanish energy sector. Under the Clean Energy for All Europeans framework three key pieces of legislation came into force on 24 December 2018:

- The revised **Renewable Energy Directive (EU) 2018/2001** establishes a binding EU target of at least 32% for 2030 with a review for increasing this figure
- The revised **Energy Efficiency Directive (EU) 2018/2002** sets a 2030 target of 32.5%, also with a possible revision in 2023
- The new **Governance Regulation (EU) 2018/1999** includes the requirement for Members States to draw up integrated National Energy and Climate Plans for 2021 to 2030 outlining how to achieve the targets and submit the draft to the European Commission by the end of 2018.

At national level, the Spanish government has sent the European Commission the draft National Integrated Energy and Climate Plan 2021-2030, which lays the foundations for the modernization of the Spanish economy; for Spain to take a leading position on renewable energies, for the development of the rural environment, and for improving the health of citizens, the environment and social justice. The document proposes a reduction of between 20% and 21% of greenhouse gas emissions compared with 1990 levels. It targets 42% of renewable energy use by 2030. As regards electricity generation, the percentage of renewables will stand at 74%. The country's energy efficiency would improve by 39.6% by 2030.

In this context, geothermal exchange systems for heating and cooling are positioned as the best available technology (BAT) to play a role in the decarbonization and in the energy supply for cities (energy sinks with high emissions) as part of a sustainable energy transition. It is possible to supply heating, cooling and DHW with the same systems, in an uninterrupted manner 24 hours, 365 days a year. Geothermal energy can also provide cooling, heating and DHW through highly efficient systems to individual users or groups of users, as well as to other applications with thermal energy demand (such as industries, agriculture, etc.).

In 2019, geothermal energy in Spain continued to advance in thermal energy use at the domestic, commercial and industrial scale. In addition the installation of geothermal exchange systems for heating and cooling in public administration facilities has increased due to new public buildings conforming to the Nearly zero-energy buildings (NZEB) approach promoted by the European Union. This approach has been favourable for the implementation of this type of facility in Spain during 2019.

In addition, within the framework of the just transition and the circular economy, progress has also been made. The use of a geothermal system associated with a heat pump, which uses the energy contained in the mine water, represents an example of rational and sustainable use of mining infrastructure once the mining activity has ceased. In addition to promoting the use of local renewable resources. Currently, the HUNOSA Group supplies geothermal energy to heating and cooling district heating network in Mieres, based on the use of mine water from Pozo Barredo. The district heating of Mieres provides heating and air conditioning to various buildings in the area. This project has received the recognition of the International Energy Agency in the framework of the 'Global District Energy Climate Awards' in 2019.

As a reflection of the interest generated by the geothermal resource associated with mining activity within the Spanish framework of the ecological and just transition, GEOPLAT has collaborated with Fundación Santa Bárbara, Junta de Castilla y León and Regional Energy Body of Castilla (EREN) in the organization of the conference ‘Shallow Geothermal: approach to geothermal, current situation and unique experiences'. The conference, was held last November in La Ribera del Folgoso (León), addressed, among other issues, the potential of geothermal exploitation of the abandoned mines in the region and the Demonstrator Center on geothermal energy built in the mining facilities of the Santa Barbara Foundation in La Ribera del Folgoso was visited.

The growing international interest in the development of geothermal energy in Spain was evident in 2019 with the celebration of an International Workshop on Geothermal Energy in Gran Canaria. GEOPLAT, jointly with the International Energy Agency Geothermal Implementing Agreement (IEA Geothermal), organized an International Workshop on Geothermal Energy in Spain and host the 41st IEA Geothermal Executive Committee meetings in Gran Canaria. The event was supported by the Government of the Canary Islands and Instituto Tecnológico de Canarias (ITC). The main objectives of this workshop were to promote the internationalisation of the Spanish geothermal sector and to learn about efficient and cost-effective geothermal energy use, to gain knowledge about innovations and emerging geothermal energy technologies and not least to enhance knowledge and strengthen international cooperation and information exchange.


In 2019, GEOPLAT celebrated its Tenth Anniversary Assembly. In 2009, the Platform was established as a scientific-technical coordination group for the geothermal sector consisting of all relevant stakeholders in Spain. During the Tenth Anniversary Assembly, GEOPLAT reviewed the Platforms achievements over these ten years and reported on activities that are underway: for example, working with public administrations and collaborating with other national and European platforms, the training of professional guilds and improving the quality of geothermal facilities through courses and through the development of UNE standards and professional qualifications.


## 18.3 Geothermal Activities in 2019

### 18.3.1 Projects Commissioned in 2019

#### 18.3.1.1 Geothermal heating & cooling projects

The sector of shallow geothermal for HVAC (heating, ventilation, and air conditioning) and DHW (domestic hot water) in Spain maintains a slow deployment. According to information provided by the Spanish Association of Heating and Cooling Networks (ADHAC), in 2019 in Spain there were 7 geothermal district heating & cooling systems and 2 planned GeoDH systems. Of the 414 district heating & cooling systems accounted, geothermal networks represent little more than 2%.

| GeoDH – operational in 2019 | | | |
|---|---|---|---|
| **Name / Operator** | **Location** | **Energy consumed** | **Supply** |
| DH Aroyo Bodonal | Madrid | Geothermal | Heating and Cooling |
| DH&C Club Pollentia Resort | Puerto de Pollensa (Balearic Islands) | Geothermal | Heating and Cooling |
| DH Olot | Olot (Girona) | Trigeneration: geothermal+biomass+natural gas | Heating and Cooling |
| DH Hotel Teguise | Las Palmas (Canary Islands) | Geothermal | Heating |
| Plaza de Lleó | Barcelona (Catalonia) | Geothermal | Heating |
| DH Camping la Noguera | Lérida (Catalonia) | Trigeneration: geothermal+biomass+solar thermal | Heating and Cooling |
| DH Neiker – Tecnalia | Álava (Basque Country) | Biomass+geothermal | Heating and Cooling |

Source: Spanish Association of Heating and Cooling Networks (ADHAC)

| GeoDH – development/investigation | | | | |
|---|---|---|---|---|
| **Name /Operator** | **Location** | **Status** | **Energy consumed** | **Supply** |
| DH Pozo Barredo – HUNOSA* | Mieres (Asturias) | Year commissioned 2019 | Geothermal | Heating |
| DH Pozo Fondón – HUNOSA** | Langreo (Asturias) | Projected by 2020 | Geothermal | Heating |

Source: GEOPLAT

*It will be operational in 2020
** It will be operational in 2021

Of the 414 district heating and cooling systems, geothermal networks represent little more than 2%.

### 18.3.2 Geothermal R&D projects

The EU Research and Innovation program, Horizon 2020, awarded 2 geothermal projects in 2019 with Spanish participation in its consortium (5 Spanish entities). These geothermal projects are:

**REGEN-BY-2. Next REnewable multi-GENeration technology enabled by TWO-phase fluids machines**

- Topic: LC-SC3-RES-1-2019-2020 Developing the next generation of renewable energy technologies
- Funding scheme: RIA - Research and Innovation action
- Spanish participation in this project: Fundación CARTIF, R2M SOLUTION SPAIN SL, Asociación Española de Normalización (UNE)

**CROWDTHERMAL. Community-based development schemes for geothermal energy**

- Topic: LC-SC3-RES-28-2018-2019-2020 Market Uptake support
- Funding scheme: IA - Innovation action
- Spanish participation in this project: La Palma Research Centre for Future Studies SL, GEOPLAT
- More info: https://cordis.europa.eu/project/id/857830

At the national level, geothermal R&D projects are approved in the subsequent calls for proposals (every two years) of the Spanish R&D Programme named RETOS-COLABORACIÓN managed by the Spanish State Research Agency. The aim of the Retos-Colaboración funding is to support cooperation projects between companies and research organizations, in order to promote the development of new technologies, the business application of new ideas and techniques, and to contribute to the creation of new products and services.

The last call of RETOS-COLABORACIÓN Programme opened in 2019. The results of this call will be published next year.

### 18.3.3 GEOPLAT participation in geothermal projects during 2019

GEOPLAT works for commercial uptake of geothermal energy in Spain; competitive growth and sustainably. GEOPLAT is participating in several European geothermal energy projects, which address aspects such as geothermal resources exploration, increasing the competitiveness of European SMEs, development of alternative financing schemes and public acceptance of this type of energy.

- **GEO-URBAN. Identification and Assessment of Deep Geothermal Heat Resources in Challenging Urban Environments**

  The GEO-URBAN project aims to explore the potential of deep geothermal resources in low-enthalpy regions and to evaluate this energy source as a heating supply for urban areas. The ability to use geothermal resources to generate heat in urban areas, where demand is highest, has the potential to significantly reduce dependence on fossil fuels and to support sustainable national and European Union energy policies. The project focuses on two areas, Dublin, Ireland, and Vallès, Catalonia, Spain, and will provide a feasibility analysis for the commercial utilisation of geothermal resources in these regions with different types of geology.

  The financing of this project is part of the "GEOTHERMICA Cofund" call, which is part of the European Union's ERA-NET plan. The consortium is formed by 10 members from 3 participating countries of the European Union: Ireland (Dublin City Council, DIAS, GDG, GIA, ICRAG), Denmark (GEOOP) and Spain (BSC, ICGC, UB, GEOPLAT). GEOPLAT is responsible for dissemination and communication tasks, as well as the organization of a workshop in Spain, where the results obtained will be shared. The project will last three years, finishing in June 2021.

- **GEO-ENERGY EUROPE. Geo-Energy for the XXIst Century**

  GEO-ENERGY EUROPE is a transnational cluster dedicated to improving the development and competitiveness of European small and medium enterprises using the subsurface to obtain geothermal energy in transnational (EU) and global markets. The consortium is composed of 8 members from 7 participating countries of the European Union and the COSME programme (Programme for the Competitiveness of Enterprises and Small and Medium-sized Enterprises): POLE AVENIA (project coordinator) and GEODEEP in France, EGEC in Belgium, GEOENERGY CELLE in Germany, CAPES in Hungary, JESDER in Turkey, GEOSCIENCE IRELAND in Ireland and GEOPLAT in Spain. This project began in January 2018 and ended in December 2019. However, the partners have been working on a new proposal to participate in a second phase of the project, which has been submitted to a new call of the COSME programme.

  Among the achievements of the project, there is the creation of a European metacluster of SMEs working in geothermal energy, with special emphasis on those dedicated to high enthalpy; the expansion of the metacluster due to the recent incorporation of the Italian cluster DTE$^2$V; and the international mission to Turkey under the framework of IGC-Turkey

2019, where SMEs members of the metacluster were invited to promote their technology and to get to know the Turkish geothermal sector. During the project, the partners have focused mainly on networking activities, technology transfer, and cross-sector competences, as well as market studies and internationalization strategies aimed at boosting the emerging industry associated with the development of deep geothermal energy for electricity generation and thermal generation in urban and industrial applications.

- **CROWDTHERMAL. Community-based development schemes for geothermal energy**

  The CROWDTHERMAL project aims to enable the European public to directly participate in the development of geothermal projects with the help of alternative financing systems, such as crowdfunding, and social commitment tools. The project has been funded under the European Union's research and innovation programme Horizon 2020. The consortium is led by the European Federation of Geologists (EFG) and consists of 10 partners from 7 countries, with extensive experience in the development of large-scale geothermal projects, alternative financing, social media engagement, innovation, education and international geothermal energy networks (EFG, IZES, UoG, GeoT, LPRC, CrowdfundingHub, SZDH, GEORG, Eimur, and GEOPLAT).

  CROWDTHERMAL aims to generate new tools and financial services for different types of geothermal resources; as well as facilitating the social acceptance of geothermal energy in different geographical environments, developing mechanisms for decision-making, evaluation protocols, analysis and assessment of case studies. Through the project a model for geothermal energy social acceptance will be created to be used to inspire public support for geothermal energy. The models will be developed and then validated using case studies in Iceland, Hungary, and Spain.

## 18.4 Other National Activities

### 18.4.1 Geothermal Education and Training

GEOPLAT, jointly with the National Institute of Qualifications of the Spanish Ministry of Education (INCUAL), has worked on the development of professional qualification for installers and maintainers of geothermal heat exchange systems. These qualifications will serve to create advanced vocational training courses, as well as vocational training courses for the unemployed. In addition, they will be used to officially accredit experienced installers already operating in the sector. This official qualification will advance professionalism, assisting to improve the quality of installations in the sector.

During 2019 the work entered its final phase with two qualifications ready to be published – ‘Installations, commissioning and maintenance of closed-loop geothermal exchange facilities’ (level 2) and ‘Organization and projects of closed-loop geothermal exchange facilities’ (level 3).

### 18.4.2 Conferences

Round table ‘R&D&I in the energy technologies of the transition’. European Meeting on Science, Technology and Innovation – TRANSFIERE 2019 (Málaga, 13th February 2019) Info

International Workshop on Geothermal Energy in Spain (Gran Canaria, 8th and 9th April 2019) Info

GEOPLAT Annual Assembly 2019 – 10th Anniversary Assembly (Madrid, 19th June 2019) Info


Workshop 'Shallow Geothermal: approach to geothermal, current situation and unique experiences' organized by Fundación Santa Bárbara, in collaboration with Junta de Castilla y León, Regional Energy Body of Castilla (EREN) and GEOPLAT (La Ribera del Folgoso. León, 14th November 2019) Info

United Nations Climate Change Conference - COP 25. GEOPLAT participated as an actor for the climate in the official sessions "Emerging energy technologies" and "Technologies for the empowerment of the energy consumer" (Madrid, 5 and 7th December 2019) Info


## 18.5 Useful Websites

- GEOPLAT Website: www.geoplat.org
- GEOPLAT Blog: http://blog.geoplat.org
- Spanish Institute for Diversification and Saving of Energy (IDAE): http://www.idae.es
- Geological Survey of Spain (IGME): http://www.igme.es/
- GEO-ENERGY EUROPE project: https://www.geoenergyeurope.com/
- Crowdthermal project: http://www.crowdthermalproject.eu/

## 18.6 Future Activity

In 2020, the fourth edition of the formal training course in Design of Geothermal Exchange Systems, organized by GEOPLAT, will be carried out, in collaboration with the International Association of Geo-Education for a Sustainable Geothermal Heating and Cooling Market (GEOTRAINET), in line with the pursuit of excellence of geothermal energy in Spain, which is the driving force behind GEOPLAT activity. GEOPLAT is the entity in charge of carrying out official geothermal training in Spain.

Also, GEOPLAT will explore other opportunities for collaboration in training with the Hunosa Group and with the Department of Geosciences at the Complutense University of Madrid (Spain).

In 2020 GEOPLAT will participate in two very important events of the geothermal sector. GEOPLAT will attend GeoTHERM - expo & congress, that will be taking place in Offenburg in March 2020, the largest international meeting point simply not to be missed by anyone involved in the geothermal market.  GEOPLAT also will attend WGC2020 - World Geothermal Congress

2020 that will be held in Reykjavik in April 2020. The World Geothermal Congress will bring together the global geothermal community in Reykjavik.

## 18.7 References


- 2019 Census on the existing DHC networks in Spain (ADHAC)
  http://www.adhac.es/Priv/ClientsImages/AsociacionPerso8_1573032822.pdf

- Spanish Centre for Industrial Technological Development (CDTI)
  https://www.cdti.es/

- Spanish State Research Agency (AEI)
  http://www.ciencia.gob.es/portal/site/MICINN/aei

- National Institute of Qualifications of the Spanish Ministry of Education (INCUAL)
  https://www.educacion.gob.es/educa/incual/ice_incual.html

- CORDIS. European Commission
  https://cordis.europa.eu

# 19. Switzerland (2018)

Katharina Link[1], Gunter Siddiqi[2]

[1] Geo-Future GmbH, Rebstrasse 3, CH-8500 Frauenfeld. Email: info@geo-future.expert

[2] Swiss Federal Office of Energy, Mühlestrasse 4, CH-3063 Ittigen. Email: gunter.siddiqi@bfe.admin.ch

## 19.1 Introduction

Switzerland's uptake of shallow geothermal continues unabated and unconstrained by natural potential. The theoretical potential for direct use geothermal and geothermal for power generation is considered very large. Yet arguably, realistic estimates of the technical and economic potential (with support mechanisms) is limited to between 1 and 20 TWh along with associated co-produced heat.

Switzerland's entirely revised Energy Act and a partially revised $CO_2$-Act, in force since 1 January 2018, contain measures, some of which pertain to geothermal energy for direct use and power generation, supporting Switzerland's Energy Strategy 2050.

Table 19-1 Status of geothermal energy use in Switzerland (figures from 2018)

| Electricity | | Direct Use | |
|---|---|---|---|
| Total Installed Capacity ($MW_e$) | 0 | Total Installed Capacity ($MW_{th}$) | 24.8 |
| New Installed Capacity ($MW_e$) | 0 | New Installed Capacity ($MW_{th}$) | 0.1 |
| Total Running Capacity ($MW_e$) | 0 | Total Heat Used (PJ/yr) [GWh/yr] | 0.72 (201.0) |
| Contribution to National Capacity (%) | 0 | Total Installed Capacity Heat Pumps ($MW_{th}$) | 2'172.0 |
| Total Generation (GWh) | 0 | Total Net Heat Pump Use [GWh/yr] | 3'491.1 |
| Contribution to National Generation (%) | 0 | Target (PJ/yr) | N/A |
| Target 2050 (GWh/yr) | 4'400 | Estimated Country Potential ($MW_{th}$ or PJ/yr or GWh/yr) | N/A |
| Estimated Country Potential (GWh/yr) | N/A | | |

(N/A = data not available)

## 19.2 Changes to Policy Supporting Geothermal Development

Since 2008 Switzerland has operated a geothermal guarantee scheme for geothermal power projects. Under this scheme, up to 50% of the subsurface development cost may be reimbursed to project developers on failure to find a suitable geothermal resource. Additionally, geothermal power production is remunerated by a feed-in tariff.

The Swiss government has developed the Energy Strategy 2050, which targets reducing energy consumption, improving efficiency, and enhancing the utilisation of renewable energies.

Several new measures and incentives aim to boost the development of geothermal energy, e.g.:

- Increasing the guarantee scheme for geothermal power projects from 50% to max. 60% and extending the eligible costs to include prospecting expenses. Under current legislation, the scheme runs until 31.12.2030.
- Direct financial support for prospecting and exploration (proving the presence of a reservoir), max. 60% of the eligible cost with a cap of Fr. 50 million (1 Fr. ~ 1 US$) per year (in lieu of the geothermal guarantee). Under current legislation, the scheme runs until 31.12.2030.
- Direct financial support for direct use geothermal energy projects, max. 60% of the eligible costs. The scheme is funded from Switzerland's carbon levy on fossil fuels used for stationary heat with a cap of Fr. 30 million per year. Under current legislation, the scheme runs until 31.12.2025.
- To account for a revised weighted average cost of capital (now set at 5.44% for a reference plant), feed-in tariffs for power production from hydrothermal and EGS plants have been re-calculated; the feed-in tariff applies now for a period of 15 years instead of 20 years prior to 2018. Under current legislation, no new projects will be admitted to the feed-in tariff scheme after 1.1.2023.

Table 19-2 Current (2019) feed-in tariffs for geothermal power production:

| Capacity ($MW_e$) | Hydrothermal Feed-in tariff (Rappen/kWh)* | EGS Feed-in tariff (Rappen/kWh) |
|---|---|---|
| ≤5 MW | 46.5 | 54.0 |
| ≤10 MW | 42.5 | 50.0 |
| ≤20 MW | 34.5 | 42.0 |
| >20 MW | 29.2 | 36.7 |

*Rappen is one hundredth of a Swiss Franc.

Another important measure is to make publicly available primary and processed primary subsurface data obtained from subsidized projects (seismic data, logs etc.); this process is handled by the Swiss Geological Survey of the Swiss Federal Office of Topography Swisstopo.

The Energy Strategy 2050 also includes an "action plan coordinated energy research".

Financial support for geothermal research and innovation has grown considerably in the last 5 years from about US$ 10 million to US$ 20 million per year.

## 19.3 Geothermal Project Development

### 19.3.1 Projects Commissioned

The following projects are in the planning and execution phase in 2018:

| Project name | Project developer | Technology | Energy use |
|---|---|---|---|
| GEothermie 2020 | Services Industriels de Genève (SIG) | All geothermal applications / technologies considered | Heat, cooling, storage |
| Geothermie Schlattingen (TG) | Grob Gemüse GmbH | Hydrothermal | Heat for agriculture; Wells completed, long term production test |
| EnergeÔ Vinzel | EnergeÔ SA | Hydrothermal | Heat; planning phase, planned start production in 2021/22 |
| Geothermie Brig-Glis (VS) | Geothermie Brig-Glis AG | Hydrothermal | Heat; Planning phase |
| AGEPP in Lavey-les-Bains (VD) | JV of regional energy utilities, cantons and communities | Combined heat and power - hydrothermal | Heat, power; planned drilling: start end 2019 |
| Aquifer thermal energy storage Forsthaus Bern (BE) | Energie Wasser Bern (ewb) | Energy storage in a sandstone with geothermal potential – radial drilling for reservoir creation | Seasonal storage of heat co-generated at a waste-to-energy plant; district heating; Permit; start drilling in 2020 |
| Haute Sorne (JU) | Geo-Energie Suisse AG | EGS | Power (and heat); Permit granted |
| Etzwilen (TG) | Geo-Energie Suisse AG | EGS | Power (and heat); Planning phase, currently suspended |
| Triengen (LU) | Geo-Energie Suisse AG | EGS | Power (and heat); Planning phase, currently suspended |
| Pfaffnau (LU) | Geo-Energie Suisse AG | EGS | Power (and heat); Planning phase, currently suspended |
| Avanches (VD) | Geo-Energie Suisse AG | EGS | Power (and heat); Planning phase, currently suspended |

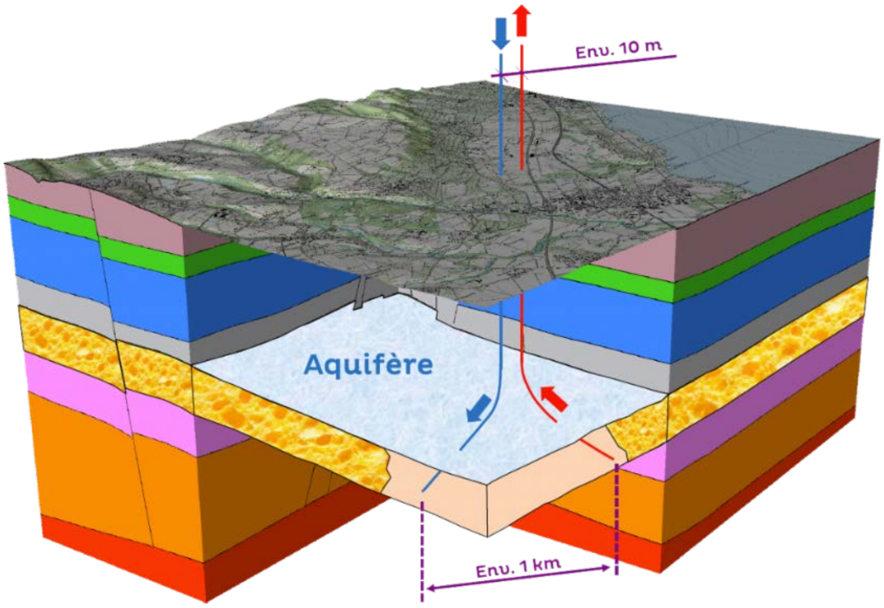



Figure 19-1 Hydrothermal heat project "EnergeÔ Vinzel" in Western Switzerland (Courtesy of EnergeÔ SA).

### 19.3.2 Projects Operational

There are no geothermal power projects in operation in 2018. Geothermal direct and indirect use projects in operation in 2018 are listed below, all figures are from 2018:

| Heating project | Capacity [MW]*) | Heating energy [GWh/yr] | Geothermal contribution (without heat pump) |
|---|---|---|---|
| Lötschberg base tunnel, Frutigen, direct Tunnel water | NA | 2.00 | See left |
| Riehen (BS), direct | 1.5 MW | 5.2 | See left |
| Riehen (BS), heat pumps | 3.5 | 15.22 | 11.90 |
| Bassersdorf (ZH) | 0.24 | 0.47 | 0.24 |
| Itingen (BL) | 0.08 | 0.18 | 0.13 |
| Kloten (ZH) | 0.24 | 1.50 | 1.37 |
| Seon (AG) | 1.35 | 2.70 | 1.90 |
| Furka Railway tunnel, Oberwald (VS) | 1.43 | 2.87 | 2.11 |
| Gotthard road tunnel, Airolo (TI) | 0.72 | 0.86 | 0.65 |
| Ricken railway tunnel, Kaltbrunn (SG) | 0.16 | 0.25 | 0.17 |
| Lötschberg base tunnel, Frutigen (BE/VS) | 1.08 | 1.93 | 1.33 |
| Hauenstein railway tunnel, Trimbach (SO) | 0.37 | 0.38 | 0.20 |
| Mappo Morettina, road tunnel, Minusio/Tenero (TI) | 0.09 | 0.08 | 0.03 |

Thermal spas in operation in 2018, all figures from 2018:

| Thermal spa | Capacity [MW]*) | Heating energy [GWh/yr] |
|---|---|---|
| Andeer (GR) | 0.04 | 0.37 |
| Baden (AG) | Currently (2018) under reconstruction | |
| Bad Ragaz (SG) | 2.65 | 22.01 |
| Bad Schinznach S3 (AG) | 0.97 | 8.07 |
| Brigerbad (VS) | 3.71 | 30.85 |
| Kreuzlingen | 0.03 | 0.28 |
| Lavey-les-Bains (VD) | 4.19 | 34.89 |
| Leukerbad (VS) | 7.17 | 59.69 |
| Lostorf (SO) | Currently not in operation (2018) | |
| Ovronnaz (VS) | 0.16 | 1.30 |
| Saillon (VS) | 2.51 | 20.87 |
| Stabio (TI) | 0.01 | 0.07 |
| Val d'Illiez (VS) | 0.56 | 4.66 |
| Vals (GR) | 0.29 | 2.44 |
| Yverdon-les-Bains (VD) | 0.23 | 1.89 |
| Bad Zurzach (AG) | 0.78 | 6.45 |
| **Total** | **23.23** | **193.84** |

## 19.4 Research Highlights

Research and innovation is funded by the Swiss National Science Foundation (fundamental research), the Swiss Federal Office of Energy (applied research, piloting and demonstration) and Innosuisse (market-driven research). Some of the federally funded Swiss Federal Institutes of Technology have allocated funds to be used for geothermal energy research and innovation. Of the five institutes, ETH Zurich, EPF Lausanne and the Paul Scherrer Institute engage in geothermal research and innovation.

Eight Swiss Competence Centers for Energy Research (SCCER), launched in 2014 and that run until the end of 2020, have been established to develop (human) capacity, and initiate research and innovation in areas deemed critical for Switzerland's Energy Strategy 2050. One of the SCCERs, SCCER – Supply of Electricity or SCCER-SoE, has a focus on geothermal energy and particularly on technologies required to unlock Engineered Geothermal Systems, and as of 2017 for direct use geothermal energy and heat storage. The SCCER's are set up along the lines of a public-private partnership with industry players encouraged to participate.

R&D funds for 2017 were at a level of US$ 20 million, approximately US$ 3 million of which for pilot and demonstration projects, with similar levels expected in 2018 and 2019.

Table 19-3 Swiss public investment in research, development and deployment of geothermal energy as reported to the IEA. Slightly ahead of countries subscribing to Mission Innovation, Switzerland has effectively doubled its investment into geothermal energy

| | 2017 | | | 2016 | | | 2015 | | | 2014 | | | 2013 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| All figures in Million CHF (1 CHF ~ 1 USD) | R&D | Pilot & Demo | Total | R&D | Pilot & Demo | Total | R&D | Pilot & Demo | Total | R&D | Pilot & Demo | Total | R&D | Pilot & Demo | Total |
| **Geothermal energy** | **17.46** | **2.72** | **20.19** | **14.45** | **6.00** | **20.44** | **13.67** | **0.42** | **14.09** | **9.14** | **2.33** | **11.47** | **8.69** | **0.73** | **9.42** |
| from hydrothermal resources | 1.23 | 1.58 | 2.81 | 1.35 | | 1.35 | 0.99 | | 0.99 | 1.10 | 0.20 | 1.30 | 1.57 | 0.06 | 1.64 |
| from EGS (hot dry rock) resources | 2.80 | 0.98 | 3.78 | 1.89 | 5.61 | 7.50 | 2.11 | | 2.11 | 0.82 | | 0.82 | 0.78 | | 0.78 |
| Advanced drilling and exploration | 4.53 | | 4.53 | 2.34 | | 2.34 | 1.16 | 0.26 | 1.42 | 0.34 | 1.23 | 1.57 | 5.23 | 0.30 | 5.53 |
| Other geothermal energy (incl. low temp. resources | 0.66 | | 0.66 | 0.42 | | 0.42 | 0.59 | 0.16 | 0.75 | 0.23 | 0.90 | 1.13 | 0.10 | 0.29 | 0.39 |
| Unallocated geothermal energy | 8.23 | 0.17 | 8.41 | 8.45 | 0.38 | 8.83 | 8.82 | | 8.82 | 6.66 | | 6.66 | 1.01 | 0.08 | 1.08 |

One highlight has been the research activities of the SCCER-SoE on controlled hydraulic stimulation experiments at the Grimsel Test Site, an underground laboratory in the crystalline basement of the Alps. An important milestone was the construction of the new "Bedretto Underground Laboratory for Geoenergies" with inauguration planned for May 2019. The Bedretto Lab is located 1.5 km below surface in the middle of a 5.2 km long tunnel.

Since 1 January 2017, Switzerland returned to being a fully associated member of the EU research framework program, Horizon 2020. Also, the Swiss Federal Office of Energy, via its dedicated funding program for geothermal energy research and innovation, cooperates with European funding agents in the European Union through the European Research Area Network GEOTHERMICA with a joint call for research, development and deployment of novel geothermal energy concepts. Of the eight projects funded in GEOTHERMICA's first call, Switzerland leads the projects ZoDrEx and COSEISMIQ, and is a major contributor to HEATSTORE. A second joint call is planned for 2019.

The Swiss Federal Office of Energy also participates in the International Partnership for Geothermal Technology (with the USA, Iceland, Australia and New Zealand). The longest standing backbone of Switzerland's international engagement continues to be the IEA's Geothermal Technology Collaboration Program.

Industry engages in geothermal development activities mostly in the areas of hydrothermal project development, subsurface heat storage, and EGS. Financial information is not available.

Geothermal research highlights in 2018:

- ThermoDrill (International) – fast track innovative drilling system for deep geothermal challenges in Europe (http://thermodrill.unileoben.ac.at/)
- DESTRESS (International) – Demonstration of Soft Stimulation treatments of geothermal reservoirs (http://www.destress-h2020.eu/home/)
- GEOTHERMICA ZoDrEx (International) – Zonal Isolation, Drilling and Exploitation of EGS Projects (http://www.geothermica.eu/projects/zodrex/)
- GEOTHERMICA Heatstore (International – https://www.heatstore.eu/)
- GEOTHERMICA COSEISMIQ (International – http://www.geothermica.eu/projects/coseismiq/)
- DG-WOW – Deep Geothermal Well Optimisation Workflow
- RT-RAMSIS – Real-Time Risk Assessment and Mitigation System for Induced Seismicity
- Hydraulic stimulation / fracking tests at the Grimsel Test Site

- Construction of the Bedretto Underground Laboratory for Geosciences

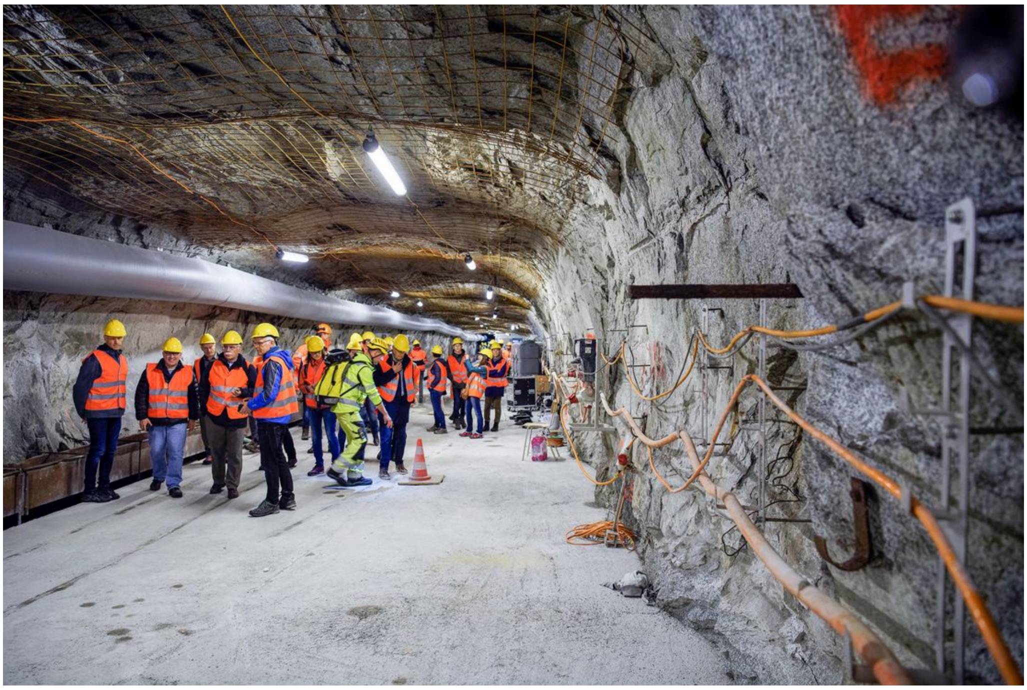


Figure 19-2 The Bedretto Underground Laboratory for Geoenergies (Inauguration in May 2019).

Research activities in the area of shallow geothermal applications are concentrating on smart thermal grids (including geothermal heat storage), quality assurance and control, as well as enhancing efficiency.

## 19.5 Other National Activities

### 19.5.1 Geothermal Education

The University of Neuchâtel runs a successful and popular Certificate for Advance Studies on Exploration & Development of Deep Geothermal Systems (CAS DEEGEOSYS). Through the SCCER-SoE, the significant number of tenured and tenure-track professorships at ETH Zurich, EPF Lausanne, and at the Universities of Geneva and Neuchâtel has given rise to a number of undergraduate and graduate level courses in geothermal energy. An overview of education and training courses related to geothermal energy can be found here: https://geothermie-schweiz.ch/aus-und-weiterbildungen/

### 19.5.2 Conferences

In 2018, a number of national and international geothermal conferences and conferences with significant geothermal interest took place in Switzerland:

- Journées romandes de la géothermie 2018, Geneva (GE), 28-29 January 2018
- Geothermie Forum 2018, Zurich (ZH), 26 June 2018
- SCCER-SoE Annual Conference in Horw (LU) from 13-14 September 2018.

### 19.5.3 Publications

See the publication websites of the Swiss Federal Office of Energy (https://www.bfe.admin.ch/bfe/de/home/news-und-medien/publikationen.html) and of the SCCER-SoE (http://www.sccer-soe.ch/publications/)

## 19.6 Useful Websites

| | |
|---|---|
| Geothermie-Schweiz (Swiss Geothermal Association) | http://geothermie-schweiz.ch |
| Fachvereinigung Wärmepumpen Schweiz FWS (Swiss Heat Pump Association) | http://www.fws.ch |
| Swiss Competence Center for Energy Research – Supply of Energy (SCCER SoE) | http://www.sccer-soe.ch<br>http://www.sccer-soe.ch/research/geo-energy/ |
| Bedretto Underground Laboratory for Geoenergies | http://www.bedrettolab.ethz.ch/home/ |
| Grimsel Test Site (Grimsel rock laboratory) | http://www.grimsel.com |
| Geo-Energie Suisse AG (EGS projects) | www.geo-energie.ch |
| GEothermie 2020 | https://www.geothermie2020.ch/ |

## 19.7 Future Activity

Project development in Western Switzerland advances at a brisk pace and is driven largely by Cantons with a focus on decarbonizing the heating sector. Figure 19-3 identifies the approach the Canton of Geneva is taking to investigation work with depth of investigative work proposed to increase over time. In 2018, the Bernese energy utility EWB received the permission to construct an underground heat storage reservoir. Geo-Energie Suisse AG plans to realise the EGS project in Haute Sorne (JU) for power and possibly heat production. In the Bedretto Underground Laboratory for Geoenergies, project activities will be carried out which are expected to have a significant impact on the development and operation of EGS projects.

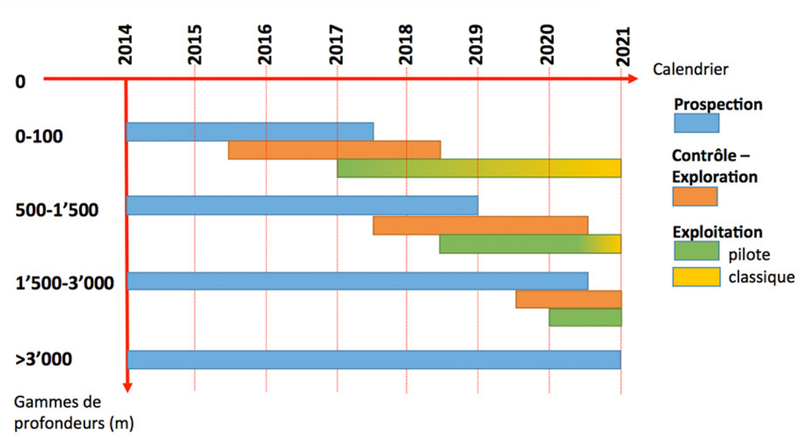



Figure 19-3 Canton of Geneva: Roadmap for the coordinated and efficient prospecting, exploration and exploitation of geothermal energy (Courtesy of GEothermie 2020).

## 19.8 References

Statistical data of geothermal energy use are from:

Link, Katharina: Statistik der geothermischen Nutzung in der Schweiz – Ausgabe 2018. Schlussbericht, 30. Juli 2019.

# 20. United Kingdom

Jon Busby[1], Noramalina Mansor[2]

[1] Team Leader Renewables & Energy Storage, British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK. Email: jpbu@bgs.ac.uk

[2] Energy Engineering, Science and Innovation for Climate and Energy, Department for Business, Energy and Industrial Strategy (BEIS), 1 Victoria Street, London, SW1H 0ET, UK. Email: Noramalina.Mansor@beis.gov.uk

## 20.1 Introduction

The United Downs Deep Geothermal Power project (UDDGPP) made significant progress during 2019, with two wells completed. This project, led by Geothermal Engineering Ltd., is the first commercial project in the UK to develop deep geothermal for power generation. The project aims to utilise the natural permeability of the Porthtowan Fault in the Carnmenellis granite in Cornwall. Drilling commenced in November 2018 of two deviated wells to intersect the fault at two different depths in order to create a closed loop circulation system vertically along the fault. The first well, UD1, has a drilled length of 5275 m (5057 m total vertical depth) and is the production well. The second well, UD2, has a drilled length of 2393 m (2214 m total vertical depth) and will act as the injection well. The wells are completed with 9 5/8" casing strings with the final sections of both wells having a drilled diameter of 8 ½". The drill rig was removed from the site in July 2019. Initial results include a measured bottom hole temperature of 190 °C in UD1 and circulation losses during drilling at the intersection of the fault that indicate deep fracture permeability. Pump and injection tests to characterise the geothermal system and assess the resource are planned for spring 2020.

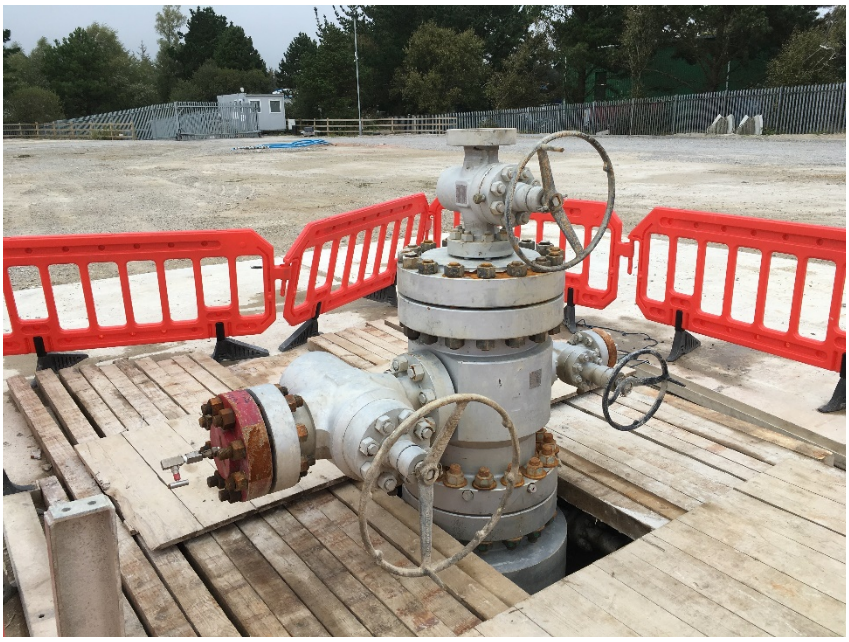


Figure 20-1 The UD1 well head at the United Downs Deep Geothermal Power project in Cornwall. Photo credit: Chris Rochelle, British Geological Survey

A second deep geothermal project has been awarded funding from the European Regional Development Fund. The project is also based in Cornwall, at the Eden project, and is situated on the St Austell granite. The project is being developed by Eden Geothermal Ltd., which has shareholders comprising Eden Project Ltd., EGS Energy Ltd. and BESTEC (UK) Ltd. The project is also targeting a deep crustal fracture and an initial well to a depth of 4.5 km will be used to heat Eden's Biomes, offices and greenhouses. A subsequent phase to the project will drill a second well to 4.5 km seeking to utilise horizontal flow along the deep fracture for electricity generation. Drilling is due to commence in the summer of 2020.

The Department for Business, Energy and Industrial Strategy (BEIS) has been supporting the development of district heat networks. This comprises support through the development stages by the Heat Networks Delivery Unit (HNDU) and projects seeking capital support from the Heat Networks Investment Project (HNIP). A range of energy technologies are supported, very often in combination. Of 75 proposed projects, 4 include a geothermal component, as follows:

Blackburn – The primary energy source is gas combined heat and power (CHP), but supported by ground sourced heat pump (GSHP) closed loop.

Whitehaven – 4MW minewater heat scheme delivered via heat pumps.

Plymouth – Open loop GSHP of 350 kW and gas CHP.

Swaffham (Cambridgeshire) – Closed loop GSHP to serve 300 homes.

The installation of the Glasgow Geothermal Energy Research Field Site (GGERFS) is nearing completion. The infrastructure comprises 12 wells equipped with high resolution monitoring technology. It will enable the UK science community to study the low temperature mine water geothermal environment at shallow depth. The site will be operational and available to third party researchers from April 2020.

| Electricity | |
|---|---|
| New capacity installed in 2019 (MWe) | 0 |
| Total Installed Capacity (MWe) | 0 |
| **Direct Use** | |
| New capacity installed in 2019 (MWth) | 0 |
| Total Installed Direct Use (MWth) | 3.0 |
| Total Heat Used (TJ/yr) [GWh/yr] | 55.3 [14.8]+ |
| **Ground source heat pumps** | |
| New capacity installed in 2019 (MW) | 38# |
| Total Installed Capacity for Heat Pumps (MW) | 706 |
| Total Net Heat Pump Use [GWh/yr] | 1150* |

+ Note this is lower than previous years due to maintenance of the plant at Southampton.
# These data are from a forecast made in April 2019 based on market trends.
* in calculating the net heat pump use it has been assumed that the hrs/year heating equivalent full load is 1800 hrs/year for domestic systems and 1500 hrs/year for commercial systems.

## 20.2 Changes to Policy Supporting Geothermal Development

In March 2019 the government announced a Future Homes Standard to be introduced in 2025. The standard includes a ban on all fossil fuel heating in new homes. It is anticipated that much of the heating requirement will be met from air and ground source heat pumps, district heating and direct electrical heating. Therefore, there is likely to be an increase in the development of heat networks via geothermal sources, which is supported by the HNIP and HNDU funding schemes. In order to ensure market growth beyond the lifetime of HNIP, the Government has also published "Heat Networks: ensuring sustained investment and protecting consumers"45 which sets out three priorities for the market framework: ensuring consumers receive sufficient protections; building investment in the sector; and maximising the potential decarbonisation benefits of heat networks.

Incentives for renewable heat from geothermal are paid through the Renewable Heat Incentive (RHI) scheme. Rates for domestic and non-domestic GSHP and deep geothermal heat in 2019/20 are:

- Non-domestic GSHP has a 2-tiered tariff comprising 9.81 p/kWh for the first 1314 hours of use (tier 1) and 2.93 p/kWh thereafter (tier 2), paid for 20 years.
- Domestic GSHP tariff is 20.46 p/kWh payable for 7 years, but note that new build properties other than self-build are not eligible
- Deep geothermal (defined as from a minimum depth of 500 m) tariff of 5.49 p/kWh for 20 years.

Geothermal continued to be eligible to compete in the Contracts for Difference under pot 2 (less established technologies). Contracts for Difference is a mechanism by which the government buys power from renewable technologies with 15-year contracts.

## 20.3 Geothermal Project Development

### 20.3.1 Projects Commissioned

No new projects were commissioned in 2019.

### 20.3.2 Projects Operational

The only operating deep geothermal project is in the City of Southampton which contributes heat to an inner-city district heating network. This scheme has been under maintenance, and therefore at reduced capacity.

## 20.4 Research Highlights

UK geothermal research is largely concentrated on developing the potential of less conventional resources as deep hot sedimentary aquifers are only found in a few regions and often not in regions of high heat demand. Much research is undertaken within the Higher Education sector, usually as part of PhD programs.

The EU Horizon 2020 programme has recently awarded EUR 2.3m to the CROWDTHERMAL project. The project is implemented by a consortium of 10 partners from 7 European countries, including the UK (University of Glasgow) and aims to empower the public to participate in the development of geothermal projects through social engagement tools and alternative financing schemes like crowdfunding.

[45] https://www.gov.uk/government/publications/heat-networks-developing-a-market-framework

### 20.4.1 Selected publications

Banks, D. , Athresh, A., Al-Habaibeh, A. and Burnside, N. (2019) Water from abandoned mines as a heat source: practical experiences of open- and closed-loop strategies, United Kingdom. Sustainable Water Resources Management, 5(1), pp. 29-50. (doi:10.1007/s40899-017-0094-7)

Banks, D. , Steven, J. K., Berry, J., Burnside, N. and Boyce, A. J. (2019) A combined pumping test and heat extraction/recirculation trial in an abandoned haematite ore mine shaft, Egremont, Cumbria, UK. Sustainable Water Resources Management, 5(1), pp. 51-69. (doi:10.1007/s40899-017-0165-9)

Boon, D.G., Farr, G.F., Abesser, C., Patton, A.M, James, D.R., Schofield, D.I. and Tucker, D.G. (2019) Groundwater heat pump feasibility in shallow urban aquifers: Experience from Cardiff, UK. Science of the Total Environment, 697, 1-11 pp. (https://doi.org/10.1016/j.scitotenv.2019.133847)

Watson, S. M., Westaway, R. and Burnside, N. M. (2019) Digging deeper: the influence of historic mining on Glasgow's subsurface thermal state to inform geothermal research. Scottish Journal of Geology, (doi:10.1144/sjg2019-012)

## 20.5 Other National Activities

### 20.5.1 Geothermal Education

There are no specific higher education course devoted to the exploration and utilisation of geothermal energy in the UK. However, earth science and renewable energy university courses will often have modules on aspects of geothermal energy.

### 20.5.2 Conferences

The principal UK geothermal energy conference is the London Geothermal Symposium held on the 5th November 2019. The conference included sessions on 'UK and Industry Updates', 'De-risking Geothermal', 'UK Geothermal Research', 'People and Places', 'Research beyond UK' and 'Policy and Regulation'.

## 20.6 Useful Websites

Contracts for Difference

https://www.gov.uk/government/policies/maintaining-uk-energy-security--2/supporting-pages/electricity-market-reform

Renewable Heat Incentive

www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/incentive/incentive.aspx

http://www.energysavingtrust.org.uk/scotland/Generating-energy/Getting-money-back/Renewable-Heat-Incentive-RHI2

Renewable Energy Association Deep Geothermal Group

www.r-e-a.net/member/deep-geothermal

Ground Source Heat Pump Association

www.gshp.org.uk/

## 20.7 Future Activity

Interest and awareness in geothermal continues to increase, but funding to develop projects remains challenging.

## 20.8 References

BSIRA 2019. Heat pump market 2018 - United Kingdom. Report 60482/13

# 21. United States of America

Lauren Boyd

Enhanced Geothermal Systems Program Manager, Geothermal Technologies Office, Energy Efficiency and Renewable Energy, Department of Energy, USA. Email: Lauren.Boyd@ee.doe.gov

## 21.1 Introduction

The United States (U.S.) in 2019 remained the world leader in installed geothermal capacity with approximately 3.85 gigawatts (GW), a slight gain over 2018. Ninety-five percent of this capacity is located in California and Nevada. Geothermal resources in the U.S. are found primarily in the western states, where broad volcanic and mountain-building activity have occurred. Eminent geothermal provinces include portions of the San Andreas Fault, running through California from the Imperial Valley to the Golden Bay; the Basin and Range system in Nevada and Utah; the subduction zone off the coast of northern California, Oregon, and Washington; and the Cascade volcanism in the Northwest.

Geothermal direct-use output (excluding heat pumps) decreased slightly in 2019, with a reduction in the number of commercial aquaculture and greenhouse projects in California.

Geothermal heat pumps maintain >3% annual growth, with current installations at 1.686 million (equivalent 12 kW) units. Most growth continues to occur in the central and eastern states.

Multiple federal agencies are involved in advancing the U.S.'s geothermal sector; leading the charge is the Department of Energy's (DOE) Geothermal Technologies Office (GTO), which is committed to developing a portfolio of innovative technologies that address critical geothermal exploration and development challenges. GTO and its partners research, develop, and validate cost-competitive technologies and tools to help make geothermal energy more affordable, and to locate, access, and develop geothermal resources within the United States.

### 21.1.1 *GeoVision* Analysis and Report

GTO published its much-anticipated *GeoVision*[46] report in May 2019, triggering an immediate uptick in interest in geothermal energy among policymakers and legislators, including both the U.S. Senate and House of Representatives as well as State and local governments. The *GeoVision* analysis assessed geothermal potential across several scenarios, and the final report includes a detailed roadmap with various actions critical to achieving notable levels of domestic deployment by 2050. In the months following the report's launch, Congressional hearings were held and two geothermal-specific bills were introduced: S.2657 – Advanced Geothermal Innovation Leadership Act (AGILE) and H.R. 5374 – Advanced Geothermal Research and Development Act.

The *GeoVision* analysis includes the following conclusions:

- Optimized permitting could cut geothermal development timelines in half, leading to a doubling of geothermal (13 GWe by 2050) versus business-as-usual;
- Over the next 30 years, direct use could increase from a current total of 21 geothermal district heating installations to as many as 17,500 nationwide. Geothermal heat pumps could increase to 28 million.

[46] U.S. Department of Energy: *GeoVision* – Harnessing the Heat Beneath Our Feet

- Geothermal power deployment could reach 60 GWe by 2050 – more than 8 percent of national capacity – with aggressive technology improvements.

### 21.1.2 2019 U.S. Electricity and Direct-Use Figures

| Electricity | | Direct-Use | |
|---|---|---|---|
| Total Installed Capacity ($MW_e$) | 3,850 MWe | Total Installed Capacity ($MW_{th}$) | 485 MWth[47,48] |
| New Installed Capacity ($MW_e$) | 52 MWe (since 2018) | New Installed Capacity ($MW_{th}$) | |
| Total Running Capacity ($MW_e$) | 2,518.6 MWe | Total Heat Used (PJ/yr) [GWh/yr] | 2,120.3 GWh |
| Contribution to National Capacity (%) | 0.32%[49] | Total Installed Capacity Heat Pumps ($MW_{th}$) | 19.7 GWt (2019) |
| Total Generation (GWh) | ~16,000 GWh[50] | Total Net Heat Pump Use [GWh/yr] | N/A |
| Contribution to National Generation (%) | 0.4%[4] | Target (PJ/yr) | N/A |
| Target ($MW_e$ or % national generation) | N/A | Estimated Country Potential (GWth) | 231 GWth by 2050[51] |
| Estimated Country Potential ($GW_e$) | ~530 GWe [52] | | |

(N/A = data not available)

## 21.2 Geothermal Project Development

GTO funds geothermal research and development (R&D) to help stimulate the growth of the geothermal industry and encourage adoption of geothermal technologies by the public and private sectors.

GTO's work focuses on four program areas: enhanced geothermal systems (EGS); hydrothermal resources; low temperature and coproduced resources; and data, modelling, and analysis.

### 21.2.1 Projects Commissioned and/or Continued in 2019

#### 21.2.1.1 Frontier Observatory for Research in Geothermal Energy (FORGE)

In June 2018, after three years of planning, site characterization, and competition, DOE announced the selection of the University of Utah's proposed site outside Milford, Utah, as the location of the Frontier Observatory for Research in Geothermal Energy (FORGE). Over the past year, considerable site preparation work, baseline data gathering and analysis, reservoir testing,

47 United States Direct Utilization Update 2019; Lund, et al., World Geothermal Congress 2020; link pending
48 U.S. Geothermal Direct-Use Installations Database: https://gdr.openei.org/submissions/911
49 U.S. Energy Information Administration: https://www.eia.gov/electricity/data/eia860m/
50 U.S. Energy Information Administration: https://www.eia.gov/tools/faqs/faq.php?id=427&t=3
51 Estimated Country Potential, Oak Ridge National Laboratory presented March 28, 2018 at International Ground Source Heat Pump Association Conference, Orlando, FL
52 Estimated total for 30 GWe undiscovered hydrothermal resources per the United States Geologic Survey (https://pubs.usgs.gov/fs/2008/3082/pdf/fs2008-3082.pdf ) plus an estimated 500 GWe EGS potential per the Massachusetts Institute of Technology (https://energy.mit.edu/wp-content/uploads/2006/11/MITEI-The-Future-of-Geothermal-Energy.pdf)

predictive modeling, and planning for Phase 3 drilling occurred in addition to the preparation of competitive research solicitations to be publicly released in early 2020. Funding has been appropriated by Congress to conduct cutting-edge geothermal research and development through 2024.

The FORGE site is dedicated to research focused on EGS, or manmade geothermal reservoirs. Work performed at this site and the critical knowledge gained will facilitate access to more than 500 GW[53] of geothermal energy in the United States alone and usher transformational change in the geothermal industry.

Critical to broad EGS deployment, FORGE serves as a laboratory where scientists and researchers can learn how to reproducibly engineer these manmade systems. Through the work performed at FORGE, the geothermal community will gain a fundamental understanding of the key mechanisms controlling EGS success; develop, test, and improve new techniques in an ideal EGS environment; and rapidly disseminate technical data and communicate with the public.

A recent video on the FORGE Utah activity can be download through this link.

#### 21.2.1.2 EGS Collab

GTO continued funding the multi-lab, multi-year EGS Collab effort throughout FY 2019. The EGS Collab was launched in 2017 and serves as an intermediate-scale field site where the geothermal reservoir modelling and research community is validating against controlled, small-scale, in-situ experiments focused on rock fracture behavior and permeability enhancement. Led by Lawrence Berkeley National Laboratory, the project brings together world-class scientists in subsurface process modelling, geophysical monitoring, and experimentation. Over three years, research performed at Collab will act as a bridge between small laboratory-scale mechanics studies and the large field-scale of FORGE Utah.

Located 4,850 feet below ground in the Sanford Underground Research Facility (SURF) in Lead, South Dakota, Collab Experiment 1 provided a first-time opportunity to validate geothermal reservoir and fracture models with real-time geophysical and other fracture characterization data during stimulation. In 2019, the EGS Collab team concluded its work on Experiment 1, which began the previous year and involved testing fracture stimulations, monitoring the stimulations in high resolution, and performing flow tests with the goal of advancing technologies to be employed in future EGS development.

In Experiment 1, the first of three planned experiments, the EGS Collab team successfully drilled a well and performed multiple stimulations, creating three separate fracture sets from 1 meter to more than 3 meters in extent. The team used tracers to map the fracture networks. Despite challenges with equipment and unexpected flow into a monitoring well, nearly 10 months of chilled flow tests have been performed following several months of ambient water injection. With data from these tests, the effects of poroelasticity and thermoelasticity are being teased out, along with results allowing the team to distinguish flow pathways. The combined ensemble of geophysical tools deployed is providing detailed information on processes occurring during tests.

The conceptual design of Experiment 2 is nearly complete and planned for the level 4100 feet below ground surface at SURF with details being addressed between the EGS Collab Team and

[53] The Massachusetts Institute of Technology (https://energy.mit.edu/wp-content/uploads/2006/11/MITEI-The-Future-of-Geothermal-Energy.pdf)

SURF. The final tests for Experiment 1 are under way including pressure tests and high rate flow tests, and the site will be decommissioned as the space is needed for other purposes.

#### 21.2.1.3 Play Fairway Analysis

Play Fairway Analysis (PFA), a technique adapted from oil and gas exploration, aims to help geothermal energy experts reduce exploration uncertainty by targeting the best locations to drill in order to find a geothermal resource. Establishing more effective exploration techniques will address a major barrier, namely high upfront risk and related cost of project development. By improving success rates for exploration drilling, PFA could significantly lower the costs of geothermal energy while opening up new areas to development.

PFA began in 2014 with 11 Phase 1 teams conducting data analyses to assess geothermal favourability over various geographic regions. In Phase 2, projects moved from desktop analysis to field work, acquiring new geochemical, geophysical, and geological data to develop conceptual models.

PFA entered into Phase 3 in 2018 with the ultimate goal of validating the conceptual models by drilling temperature gradient wells into the resources identified in earlier phases. Drilling and assessment continued in 2019 and was completed late in the year. Drilling sites included two in Nevada, one in Idaho, two in Washington, and one in Hawaii. Initial data is favourable and validates the PFA methodology for use in geothermal exploration and development. For example: the Hawaii team, led by University of Hawaii researchers, drilled one kilometre down on the island of Lanai, confirming a temperature gradient of 40°C/km – significantly higher than the background temperature at depth across the islands.

#### 21.2.1.4 Deep Direct-Use

Deep direct-use (DDU) systems are an emerging technology area in the geothermal sector that draw on lower temperature geothermal resources for direct use applications.

Advancing DDU could result in large-scale, low-temperature geothermal applications that create greater opportunities for geothermal resource development throughout the United States. DDU technologies could usher in the use of low-temperature, thermal resources in subsurface reservoirs in U.S. regions lacking conventional hydrothermal resources. Additionally, at a large scale, DDU applications can potentially be used to replace conventional district heating and cooling systems in military installations, hospital complexes, office buildings, hotels, and other large energy end-uses, expanding geothermal as a renewable thermal energy in large portions of the United States.

Beginning in October 2017, GTO sponsored six Deep Direct-Use (DDU) projects to conduct feasibility studies of large-scale, low-temperature deep-well geothermal systems coupled with advanced direct-use applications and cascaded surface technologies. The studies show potential for GDHC technology beyond the western U.S. especially where very low-temperature geothermal resources are combined with temperature-boosting technologies such as heat pumps and (where steam is needed) natural gas fired boilers as a secondary heat source, integrated with the geothermal system. For example, a proposed DDU system in the eastern U.S. at West Virginia University (where the geothermal gradient is estimated to be in the range of 22-29°C/km) could replace the existing coal-based system. A DDU system would not only serve the campus of 33,000 students, it would also serve the largest hospital in West Virginia. A GDHC at West Virginia University would also advance local efforts to achieve a reliable and clean energy source for a central steam generation system as part of a campus sustainability plan.

The feasibility studies have collectively demonstrated the economic viability of DDU. With the studies concluded, a funding opportunity aimed at the next phase of DDU development was issued as part of GTO's Advanced Energy Storage Initiative. GTO plans to further communicate DDU feasibility study results in 2020 to the geothermal trades and to International District Energy Association members.

#### 21.2.1.5 Efficient Drilling for Geothermal Energy

In 2018, GTO funded seven projects to advance geothermal drilling development. The projects will focus on improving drilling efficiency and speed through innovative R&D, which can improve the economics of geothermal development significantly. Drilling operations comprise up to 50% of the cost of geothermal development, so more efficient drilling can reduce risk and cost and help spur increased geothermal development in the near-term.

In 2019, the selected project leads began research into early-stage R&D techniques and technologies for drilling geothermal wells that reduce non-drilling time and improve rates of penetration. Research highlights should be made available in 2020.

#### 21.2.1.6 Waterless Stimulation

In July 2018, GTO awarded three projects led by national laboratories to conduct early-stage research and development to advance state-of-the-art waterless stimulation technologies applied to geothermal wellbores. Significant progress was made in 2019, including the development of a testing apparatus to simulate and gather data on variable conditions in a geothermal reservoir, and a full laboratory demonstration of energetic stimulation producing an anhydrous shockwave.

The most commonly applied wellbore stimulation technology, fluid injection, relies on the use of fresh or treated water. GTO supports stimulation methods that require little to no water – reducing the usage needed for geothermal progress and easing constraints on water consumption. In addition, there are crosscutting applications with oil and gas, including addressing the amount of water disposal after similar operations have been completed.

#### 21.2.1.7 Zonal Isolation

GTO awarded funding to four projects supporting early-stage research and development of tools and technologies for EGS. These projects, selected in 2018, seek to improve the performance and increase the cost-effectiveness of EGS through research in zonal isolation, which can dramatically improve the performance and economics of EGS. These technologies create extensive and optimized fracture networks by targeting stimulation activities to specific zones efficiently and predictably. In turn, this reduces costs and risks associated with EGS development and operation, and facilitates increased power generation from fewer wellbores.

Research in 2019 focused on developing reliable zonal isolation tools and technologies that 1) present low risk to wellbore integrity or the conductivity of fractures, and 2) ; operate extensively at high temperatures (and in differential pressures) in corrosive, hard rock environments. R&D efforts collectively will result, over the coming year, in prototypes that have been tested and validated in a simulated wellbore.

## 21.3 Research Priorities

In late 2019, the U.S. Congress finalized its appropriations report for geothermal research funding in FY 2020. Highlights include:

- $20,000,000 for the Frontier Observatory for Research in Geothermal Energy (FORGE), with activities to include ongoing novel subsurface characterization and full-scale well drilling.
- A solicitation for near-field enhanced geothermal systems demonstrations.
- Not less than $10,000,000 for the Wells of Opportunity program.
- $10,000,000 is provided to fund at least one demonstration project in an area with no obvious surface expression.
- Work with the Department of Interior on opportunities to improve geothermal permitting.
- At least one demonstration of geothermal technologies for innovative distribution of heat through ground-source heating and cooling of district heating.

### 21.3.1 Geothermal Education

GTO's 2019 student competition, focusing on data-driven analytics, data visualization, and subsurface science at the FORGE site, drew an unprecedented number of entries and resulted in the cash award and DOE recognition of three undergraduate teams. GTO announced its 2020 student competition, focusing on geothermal communication and visualization through GIS tools and software. Graduate, undergraduate, and high school students across the nation are eligible to participate. Teams of 2-3 students with varied backgrounds are encouraged to submit their visualizations and analyses by the end of March 2020.

In September 2019, GTO took action on the *GeoVision* roadmap by launching a dedicated geothermal education and outreach push to universities and regional policy institutions nationwide. GTO staff visit campuses and present an overview of geothermal energy and its potential. Particular focus is given to discussing geothermal career prospects with interested students. This outreach will continue through 2020.

### 21.3.2 Conferences

GTO delivered an annual keynote at Stanford University's 44th annual geothermal workshop. This conference unites engineers, scientists, and managers involved in geothermal reservoir studies and developments; provides a forum for the exchange of ideas on the exploration, development and use of geothermal resources; and enables prompt and open reporting of progress.

The Geothermal Resources Council (GRC) held its 2019 Annual Meeting, at which GTO exhibited its *GeoVision* study, provided a keynote overview of funded research, and led multiple technical sessions. The meeting provides an international forum for the exchange of new and significant research information on all aspects of geothermal resource characterization, exploration, development, and utilization.

The American Geophysical Union (AGU) hosted its 2019 Fall Meeting in San Francisco. AGU remains the largest Earth and space science meeting in the world. GTO Director Susan Hamm gave a much-anticipated talk on the *GeoVision* study and led a related poster session focusing on key outcomes and roadmap action areas.

## 21.4 Useful Websites

DOE Website: energy.gov

DOE's Office of Energy Efficiency and Renewable Energy Website: energy.gov/eere/office-energy-efficiency-renewable-energy

GTO Website: energy.gov/eere/geothermal

*GeoVision* Website: energy.gov/geovision

FORGE Website: energy.gov/forge

GMI Website: energy.gov/grid-modernization-initiative

U.S. Geological Survey - Geothermal Publications:
energy.usgs.gov/OtherEnergy/Geothermal.aspx

GRC Website: www.geothermal.org

AGU Website: www.agu.org

Stanford University Geothermal Website: geothermal.stanford.edu

## 21.5 Future Activity

FORGE - 2020 marks the transition of FORGE from site preparation to initial competitive R&D solicitations that will be open to the public.

EGS Collab - Experiment 2 at the 4,100-foot level will transpire throughout 2020, with a focus on further design, execution, and monitoring of hydraulic shearing of fractures and associated predictive modelling.

Machine Learning - The coming year will mark a key phase of research in application of machine learning techniques to geological, geophysical, geochemical, borehole, and other relevant datasets, with the goal of finding new resources and improving operations.

Subsurface Stress and Lost Circulation – This area of research advances our ability to characterize, monitor, and predict subsurface in situ state of stress and its geomechanical linkages to drilling operations and related wellbore challenges. Improved understanding of the interplay between these concepts in U.S. geothermal settings is key to improving drilling efficiency and reducing the overall costs of geothermal development.

Geothermal Manufacturing Prize – A series of four progressive competitions to harness the rapid advances that additive manufacturing can provide in tool design and functionality. The DOE is funding $3.25 million to support a research prize designed to spur innovation and address manufacturing challenges fundamental to operating in harsh geothermal environments. U.S.-based researchers are eligible to compete.

Energy Storage – As part of the DOE's newly-launched Advanced Energy Storage Initiative (AESI), GTO will be involved in energy storage research in 2020. The office will specifically fund investigations into geothermal applications and conditions suitable for subsurface storage. Particularly notable is DOE's recognition of the importance of subsurface research to grid modernization.

# Appendix 1 – IEA Geothermal Executive Committee


**Chair**
Dr Lothar Wissing
ForschungszentrumJülich GmbH
Project Management Organization
D-52425 Jülich
GERMANY
E-mail: l.wissing@fz-juelich.de



**Vice-Chair**
Betina Bendall
Department of State Development
Government of South Australia
GPO Box 1264
Adelaide SA 5001
AUSTRALIA
E-mail: Betina.Bendall@sa.gov.au



**Executive Secretary**
Brian Carey
GNS Science
Wairakei Research Centre
Private Bag 2000
Taupo 3352
NEW ZEALAND
E-mail: iea-giasec@gns.cri.nz

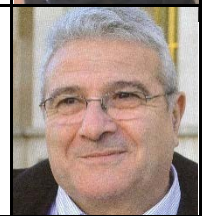


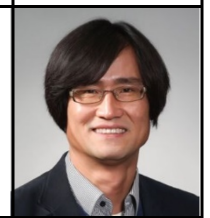
**Vice-Chair**
Chris Bromley
GNS Science
Wairakei Research Centre
Private Bag 2000
Taupo 3352
NEW ZEALAND
E-mail: c.bromley@gns.cri.nz



**Vice-Chair**
Jiri Muller
Institute for Energy Technology
P.O. Box 40
NO-2027 Kjeller
NORWAY
Email: Jiri.Muller@ife.no


# Appendix 2 - IEA Geothermal Members and Alternates

| Country / Name | Delegate | Organization / address | e-mail and phone | | Alternate | Address, etc. (where different) | |
|---|---|---|---|---|---|---|---|
| **AUSTRALIA** | **Barry Goldstein** | **Director**<br>**Energy Resources Division**<br>**Department of Premier and Cabinet South Australia (DPC)**<br>Government of South Australia<br>GPO Box 1264<br>Adelaide SA 5001<br>AUSTRALIA | barry.goldstein@sa.gov.au<br>Tel: +61-8-8463-3200 | | Betina Bendall<br>*Vice-Chair* | **Energy Resources Division**<br>**Department of Department of Energy and Mining**<br>Betina.Bendall@sa.gov.au<br>Tel: +61-8-8463-3243 |  |
| **EUROPEAN COMMISSION** | **Matthijs Soede** | **Policy Officer**<br>**European Commission**<br>DG Research and Innovation<br>Directorate for Energy<br>Unit G.3 – Renewable Energy Sources<br>Rue du Champs de Mars, 21 (CDMA 00/060)<br>1049 Brussels<br>Belgium | matthijs.soede@ec.europa.eu<br>Tel +32 2 29 58201 |  | Samuel Carrara | **European Commission – Joint Research Centre**<br>**Directorate for Energy, Transport and Climate**<br>**Unit C7 'Knowledge for the Energy Union'**<br>**Westerduinweg 3, 1755 LE Petten / The Netherlands**<br>samuel.carrara@ec.europa.eu<br>Tel: +31 224 56 5118 |  |
| **FRANCE** | **Virginie Schmidle-Bloch** | Secretary General<br>French Geothermal Association of Professionals (AFPG)<br>77 rue Claude Bernard<br>750005 Paris<br>France | virginie.schmidle@afpg.asso.fr<br>Tel. +33(0)7 86 58 67 17 |  | Christian Boissavy | GEODEEP<br>77 rue Claude Bernard<br>75005 Paris<br>France<br>christian.boissavy@orange.fr<br>Tel: +33 (0)6 38 83 93 52- |  |
| **GERMANY** | **Lothar Wissing**<br>***Chair*** | **Forschungszentrum Jülich GmbH**<br>Project Management Organization<br>D-52425 Jülich<br>GERMANY | l.wissing@fz-juelich.de<br>Tel: +49-2461-61-48-43 |  | Manuela Richter | **Forschungszentrum Jülich GmbH**<br>ma.richter@fz-juelich.de<br>Tel: +49-2461-61-9165 |  |
| **GEOPLAT** | **Margarita de Gregorio** | **Spanish Geothermal Technology Platform (GEOPLAT)**<br>**Doctor Castelo 10,**<br>**3 C-D. 28009.**<br>**Madrid**<br>**SPAIN** | margadegregorio@geoplat.org<br>Tel:+34 91 400 96 91 |  | Paloma Pérez | **GEOPLAT**<br>pperez@geoplat.org<br>Tel:+34 91 400 96 91 | |
| **ICELAND** | **Jónas Ketilsson** | **Orkustofnun**<br>Grensásvegur 9<br>108 Reykjavik<br>ICELAND | jonas.ketilsson@os.is<br>Tel: +354-569-6000 | | Guðni Axelsson | **Iceland GeoSurvey**<br>Grensásvegur 9<br>IS-108<br>Reykjavik<br>ICELAND<br>gax@isor.is<br>Tel: +354-528-1500 |  |
| **ITALY** | **Sara Montomoli** | **Head of Geothermal Innovation**<br>**ENEL Green Power**<br>Via Andrea Pisano 120 -56120 Pisa, ITALY | sara.montomoli@enel.com<br>Tel: :+39 3287264589 |  | Paci Marco | **Head of Geothermal and Biomass Laboratories**<br>**ENEL Green Power**<br>Via Andrea Pisano 120 -56120 Pisa, ITALY<br>Tel:+393498304052<br>marco.paci@enel.com | |

| Country / Name | Delegate | Organization / address | e-mail and phone | | Alternate | Address, etc. (where different) | |
|---|---|---|---|---|---|---|---|
| **JAPAN** | **Kasumi Yasukawa** | **Councilor, Geothermal Unit**<br>**Japan Oil, Gas and Metals National Corporation (JOGMEC)**<br>Toranomon Twin Building 2-10-1, Minato-ku<br>Tokyo 105-0001<br>JAPAN | yasukawa-kasumi@jogmec.go.jp<br>Tel: +81-3-6758-8643 |  | Susumu Nagae | **Director, Exploration Division, Geothermal Unit**<br>**Japan Oil, Gas and Metals National Corporation**<br>10-1,Toranomon 2-chome, Minato-ku, Tokyo 105-0001, JAPAN<br>nagae-susumu@jogmec.go.jp<br>**+81-3-6758-8476** | |
| **MEXICO** | **Jose Manuel Romo Jones** | **Technical Representative at CEMIE-Geo**<br>**Depto. de Geofisica Aplicada , CICESE**<br>Carretera Ensenada-Tijuana #3918,<br>Fraccionamiento Zona Playitas,<br>22860 Ensenada B.C., Mexico. | jromo @cicese.mx<br>Tel.: +52 (646) 175 0500 | | Thomas Kretzschmar | **Representative of Specialized Laboratories System at CEMIE-Geo Depto. de Geologia, CICESE**<br>Carretera Ensenada-Tijuana #3918,<br>Fraccionamiento Zona Playitas, 22860 Ensenada B.C., Mexico.<br>tkretzsc@cicese.mx<br>Tel.: +52 (646) 175 0500 | |
| **NEW ZEALAND** | **Chris Bromley**<br>***Vice-Chair*** | **GNS Science**<br>Wairakei Research Centre<br>Private Bag 2000<br>Taupo 3352<br>NEW ZEALAND | c.bromley@gns.cri.nz<br>Tel: +64-7-374-8211 |  | To be appointed | | |
| **NORWAY** | **Jiri Muller**<br>***Vice-Chair*** | **Institute for Energy Technology**<br>P.O. Box 40<br>NO-2027 Kjeller<br>NORWAY | Jiri.Muller@ife.no<br>Tel: +47-6380-6185 |  | Carsten F. Sørlie | **Equinor ASA**<br>Arkitekt Ebbells veg 10, 7053 Ranheim, NORWAY<br>cso@equinor.com<br>(+47) 90961827 |  |
| **ORMAT Technologies, Inc.** | **Shimon Hatzir** | Vice-President Engineering<br>**ORMAT Technologies, Inc.**<br>6225 Neil Road<br>Reno, Nevada 89511-1136<br>UNITED STATES | Shatzir@ormat.com<br>Tel: +1-775-356-9029 | | To be appointed | | |
| **REPUBLIC of KOREA** | **Yoonho Song** | **Geothermal Resources Department**<br>**Korea Institute of Geoscience & Mineral Resources (KIGAM)**<br>92 Gwahang-no<br>Yuseong-gu<br>Daejeon 305-350<br>KOREA | song@kigam.re.kr<br>Tel: +82-42-868-3175 |  | Tae Jong Lee | **KIGAM**<br>megi@kigam.re.kr<br>Tel: +82-42-868-3051 |  |
| **SWITZERLAND** | **Gunter Siddiqi** | **Swiss Federal Ministry of the Environment, Transport, Energy and Communications – UVEK**<br>**Federal Office of Energy (BFE)**<br>Division of Energy Economics/Energy Research<br>CH 3003 Berne<br>SWITZERLAND | gunter.siddiqi@bfe.admin.ch<br>Tel: +41-31-322-5324 |  | Christian Minnig | **Swisstopo**<br>Swiss Geological Survey<br>Seftigenstrasse 264<br>CH-3084 Wabern<br>SWITZERLAND<br>Christian.Minnig@swisstopo.ch<br>Tel. +41 31 963 2568 |  |
| **UNITED KINGDOM** | **Noramalina Mansor** | **Energy Engineering**<br>**Science and Innovation for Climate and Energy Directorate**<br>1 Victoria Street<br>London SW1H 0ET<br>UNITED KINGDOM | noramalina.mansor@beis.gov.uk<br>Tel: + 44 | | Jonathan Busby | **British Geological Survey,**<br>Kingsley Dunham Centre,<br>Keyworth,<br>Nottingham NG12 5GG.<br>jpbu@bgs.ac.uk<br>Tel: +44 115 9363 440 |  |

| Country / Name | Delegate | Organization / address | e-mail and phone | | Alternate | Address, etc. (where different) | |
|---|---|---|---|---|---|---|---|
| **UNITED STATES OF AMERICA** | **Lauren Boyd** | **Program Manager**<br>**Enhanced Geothermal Systems (EGS)**<br>**Office of Energy Efficiency and Renewable Energy**<br>**US Department of Energy**<br>1000 Independence Ave, SW<br>Washington, DC 20585<br>UNITED STATES of AMERICA | Lauren.Boyd@ee.doe.gov<br>Tel: +1- 202-287-1818 |  | To be appointed | - | |

IEA Geothermal

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