IEA GEOTHERMAL

IEA Geothermal

Implementing Agreement

Annual Report 2011

4 October 2013

Contents

IEA-GIA Website: http://www.iea-gia.org/

Cover Photographs

Well IDDP-1 (Photo courtesy of Jonas Ketilsson, Orkustofnun, Reykjavik, Iceland)

Message from the Chair

Chris Bromley
Chairman, IEA-GIA Executive Committee

During 2011, members of the IEA Geothermal Implementing Agreement consolidated their 3rd term work program and made considerable progress towards achieving their objectives. Again, in regard to these achievements, I want to take this opportunity to thank our Executive Secretary, Dr Mike Mongillo, for his enthusiastic, proactive, and visionary approach to the role. I thank, also, the members of the Executive Committee, and Annex participants, who can justifiably be proud of their input into the IEA-GIA's accomplishments, achieved through considerable voluntary effort, enthusiasm, good humor and dedication. The enthusiasm displayed during ExCo meetings for better collaboration amongst members, sharing of past experiences and learning from past mistakes, has always been very satisfying to observe. The work of the GIA is well presented on its Web site, through its publications and presentations by members at key conferences, and by its contributions to the IEA which publishes information on geothermal technology.

Some of the highlights of the 2011 year included collaboration with the IEA to complete, and publicize the "Geothermal Roadmap". This important visionary document will help track global geothermal deployment into the future. Annex XI, 'Induced Seismicity' held a joint meeting with the 'International Partnership of Geothermal Technology - Induced Seismicity Working Group', epitomizing the growing trend towards collaboration and rationalization of research effort. Discussion commenced on a 'Protocol for Estimating and Mapping Global EGS potential' which set the scene for another important task of Annex III ('EGS'). Members also welcomed renewed participation from the United Kingdom by supporting the First UK EGS Symposium held in London in November in tandem with our regular Executive Committee and Annex meetings. Finally, the IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation was published in May 2011. Two years of effort had previously been invested in the Geothermal Chapter by four GIA ExCo Members and the Secretary. The results of this work were also presented at leading geothermal workshops and conferences (e.g., Stanford and GRC).

Such activities and other Annex related work undertaken during the 2011 year are presented in this comprehensive Annual Report. I highly recommend that you take the time to read the Annex, Country and Sponsor chapters, in particular. A wealth of information is embedded in these chapters, and they represent an impressive amount of effort by participants to collate up-to-date information. This report also provides background information for a new annual report series that the IEA-GIA has recently initiated under Annex X. The "Trends in Geothermal Applications" report series assesses global trends in deployment of renewable energy technology, by using annual information from GIA participating countries. Information is the backbone that supports renewable energy deployment projections, and under-pins government policies. Indeed, we believe that these Annual and Trend reports are helping to improve recognition of the potential role of Geothermal Energy as a significant player in the renewable energy marketplace of the future.

Chris Bromley
Chairman, IEA-GIA Executive Committee

Executive Summary

Te Mihi 166 MWe power station under construction at Wairakei
(Mt Tauhara and Taupo town in the background).
(Photo courtesy of Chris Bromley)

Introduction

2011 saw the continued success of the IEA Geothermal Implementing Agreement (GIA) efforts. Especially noteworthy was the renewed membership of the United Kingdom, who re-joined the GIA in September 2011 after having withdrawn in 2003. In "celebration", the 26th ExCo Meeting was held in London in association with the First UK Geothermal Symposium on *Engineered Geothermal System Energy in the UK and a Global Perspective*. The post meeting fieldtrip visited the Rosemanowes EGS site in Cornwall and the site for a new EGS well to be drilled by EGS Energy, the hosts of the London ExCo Meeting. Mr Greg Barker, Minister for the Department of Energy & Climate Change (DECC), attended partly in recognition of the UK's renewed membership, and discussed the UK Government's commitment to renewable and geothermal energy.

Also important in 2011 was the continuation of the GIA proposal funding programme, which makes available a portion of the GIA Common Fund to support Annex and other GIA activities and which amounted to US$ 46 k in 2011. In 2011, proposal funding was used to support the participation of the GIA Chair and Secretary as international experts at the week-long Peer Review of the US DOE Geothermal Technologies Program held in Bethesda, Maryland, USA, in June 2011. Taking advantage of the associated opportunity, both Chair and Secretary gave presentations describing the GIA and its activities (sustainability, research collaboration and deployment growth to mitigate climate change). In addition, financial support was provided for special 2011 GIA activities including the Secretary's presentation of the GIA Mid-3rd Term Report to the IEA REWP meeting and attendance at the IEA Renewable Energy from Analysis to Action workshop in Paris, France, in March 2011; and the Chair's participation at the IEA-GIA-IPGT and AGEC 2011 Meetings in Melbourne, Australia. Such expanded efforts are possible because of the stable Common Fund support provided by GIA's membership (20 Members in 2011) and the comparatively steady and controlled cost for operating the GIA Secretariat.

The GIA's information dissemination effort R&D activities were further supported by the ExCo's decision to proceed with the re-design of the GIA website; as well as extended with the initial production of the first (2010) GIA Trend Report by Annex X, which endeavours to collect geothermal energy statistics on installed capacity, generation, direct heat use, CO_2 production avoidance, and other information, and publish it in a stand-alone report. With the data and information procedures and detailed design of the GIA Trend Report completed, the 2010 Trend Report is expected to be formally published in 2012.

The GIA's 2011 membership remained at 20, with the addition of new Country Member, the United Kingdom, and the loss of Industry Member ORME Jeotermal (Turkey). As of December 2011, membership comprised 14 Country and 5 Sponsor (industry/industry organization) Members, plus the EC. This membership, from continental Europe, Scandinavia, Asia, the Americas and Oceania, provides a broad international base of experience and knowledge for collaboration on a whole host of R&D projects and for sharing information in order to overcome technical and other challenges to advance the sustainable development of geothermal energy worldwide and so contribute to the mitigation of climate change.

The Intergovernmental Panel on Climate Change (IPCC) Special Report on Renewable Energy Sources and Climate Change Mitigation was published in May 2011, the successful conclusion to a large international project which several GIA ExCo Members and the GIA Secretary participated in as Coordinating Lead, Lead and Contributing Authors for Chapter 4 Geothermal Energy.

In 2011, the 9 GIA Member Countries with geothermal generation had a combined installed capacity of 6,975 MW_e and total generation of 41,740 GWh/yr, contributing about 63% of the global geothermal installed capacity and 61% of the geothermal power. For GIA Member Countries with non-negligible contributions, the contribution to national geothermal installed capacity and power generation ranged from 1.7-24.8% and 2.4-27.3%, respectively; with an average generation per installed capacity of 6.0 GWh/MW_e, by far the highest of all renewables.

This Executive Summary provides an introduction to, and brief summary of, the 2011 GIA Annual Report. It describes the current world energy situation, discusses the global scene in which the IEA-GIA operates, and outlines the extensive worldwide geothermal energy potential and the contribution that geothermal made to the global energy supply in 2011. A description of the IEA-GIA and a review of the six Annexes' activities and summaries of their accomplishments are presented. Highlights of GIA Members' 2011 activities are provided and the major achievements of the GIA as an organization are described. Finally, the GIA's plans for 2012 and beyond are outlined. All references to chapters, sections, etc., here refer to those in the 2011 Annual Report.

Current World Energy Situation

The global total demand for energy has grown nearly continuously since 1971 (Figure ES1), with a slight (~1%) decrease in the 2009 worldwide total primary energy supply to 12,150 Mtoe (508.7 EJ_{th}) compared to 2008 (12,267 Mtoe, 514 EJ_{th}) and a ~0.6% decrease in electricity generation to 20,055 TWh (IEA, 2010; 2011), likely consequences of the global financial crisis. However, this slight drop was followed by an overwhelming ~5% increase in primary energy demand to 12,707 Mtoe (532 EJ_{th}) in 2010, with associated CO_2 emissions of 30.4 Gt, an increase of 5.3% over 2009 (Birol, 2011; IEA, 2012); and indications are for continued increases in 2011, with CO_2 emissions rising to 31.2 Gt (2.6% increase on 2010) (WEO, 2012). Fossil fuel subsidies in 2011 rose to US$ 523 B, almost 30% higher than in 2010; while renewables received total financial support of US$ 88 B in 2011 (ibid.).

CO_2 emissions arising from current energy use trends are consistent with a 6 °C average global temperature increase by the end of this century, and associated alarming environmental and economic consequences. The possibility of achieving the global climate change objective of limiting the temperature increase this century to 2 °C above the pre-industrial levels is becoming more and more problematic, especially with the present preoccupation of policy makers with national economic growth over climate change issues. The timeframe for successful action is narrowing with associated required costs escalating (Birol, 2012). Though a new international climate change protocol is expected to be completed by 2015, and implemented by 2020 (COP17, 2012), IEA analysis indicates that by delaying action on climate change mitigation until 2020 would avoid US$ 150 B of investment; however, to then achieve the 2 °C goal, would incur extra investment costs of US$ 650 B through 2035 (ibid.). Consequently, it is in everyone's interests to adopt policies that encourage the shift to low-carbon energy production and increased energy efficiency as early as possible. In addition, reducing the 20% portion of the world's population (~1.3 billion) currently without access to electricity is a priority.

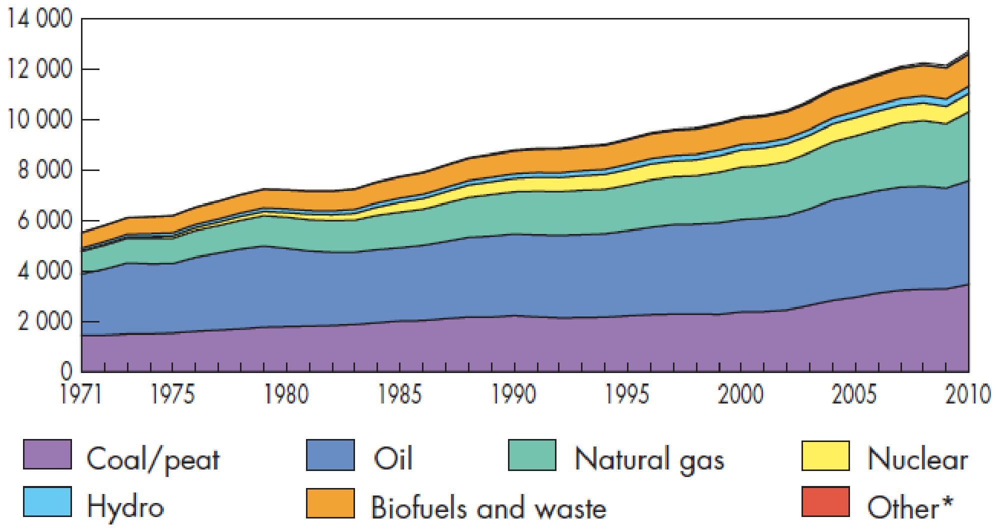


Figure ES1 *World total primary energy supply by fuel (in Mtoe) for the period 1971-2010. Other includes geothermal, solar, wind, heat, etc. (IEA, 2012).*

Assuming that all new developments and government policy commitments are implemented, termed the New Policies Scenario, in the period to 2035, total energy demand will grow by over 30%, electricity demand by over 70%, and CO_2 emissions rise to 37 Gt; emerging economies will increasingly determine energy market dynamics, with fossil fuels continuing to be the main energy sources. About 90% of the population and energy demand growth occurs in non-OECD countries, with China becoming the largest energy consumer (demand rising by 60%), followed by India (demand doubles from 2010) and the Middle East. Energy consumption rates in OECD grow by only 3% and the share of oil and coal in its energy mix drop 15% to 42%. Though the demand for all fuels increases, the fossil fuels share decreases from 81% in 2010 to 75% in 2035, however, natural gas does increase its share in the global mix, the result of unconventional resource development. The share of nuclear power electricity production decreases to 12% due to policy changes in several countries arising from the Fukushima Daiichi accident (11 March 2011). Renewable energies, mainly hydro and wind, triple their contribution to electricity generation in the period 2010 to 2035, with their proportion of the energy mix increasing from 20% in 2010 to 31% by 2035. The outcome of the New Policies Scenario leads to a temperature increase of 3.6 °C, compared to the Current Policies Scenario, which results in a temperature increase of ≥6 °C. Consequently, neither of these policies is sufficient, resulting in failure to achieve sustainable global energy utilization and provide universal energy access (WEO, 2012).

To achieve the 2 °C limit as formulated in the 450 Scenario (450 ppm CO_2-eq greenhouse gas concentration), 80% of the total energy related CO_2 emissions permissible by 2035 are now "locked-in" by the existing capital stock of power plants, buildings, factories, etc. Furthermore, if no new action is taken by 2017, all of the CO_2 emissions allowed by the 450 Scenario up to 2035 will be generated by the energy related infrastructure then in place. Consequently, only extremely costly "zero-carbon" power plants, factories and other infrastructure could be added between 2017 and 2035 (Birol, 2011). However, IEA's Efficient World Scenario provides the opportunity to realize the potential of energy efficiency, through the rapid deployment of energy-efficient technologies, which can postpone to 2022, the complete "lock-in" of CO_2 emissions allowed for in the 2 °C pathway, providing the extra time needed for the global climate agreement to be attained (2020). But, achieving the 2 °C goal will still require the use of low-carbon technologies. (WEO, 2012).

Therefore, urgent and tough action is required to achieve the climate change objective. Major energy efficiency improvements are needed, and can contribute 50% of the required energy emissions reductions. The fossil fuel subsidies must be abolished and disincentives, such as sufficient carbon pricing, need to be established to support more low-carbon technologies. Also of great importance is the scale-up and protection of energy sector R&D. Technologies based on renewable and nuclear energies, and carbon capture and storage (CCS) have important and large roles to play (Birol, 2011).

Awareness of the current global energy situation and possible dire future climate change outcomes are strong incentives for urgent action, particularly for expanding the use of clean, renewable energy resources. Providing affordable, reliable and clean energy to meet future needs while mitigating major climate change is an enormous challenge, and geothermal energy can make an important contribution.

Geothermal Energy- A Global Perspective

The main sources for geothermal energy are the heat flow from the earth's core and mantle (~50%), and that generated by the gradual decay of radioactive isotopes U^{238}, Th^{232} and K^{40}, in the earth's mantle and continental crust (~50%) (KamLAND, 2011). Together, these result in an average terrestrial heat flow rate of 44 TW_{th} (1,400 EJ/yr), some 2.6 times the 2010 worldwide total primary energy supply, 532 EJ_{th}/yr, (IEA, 2012), which is about 5% higher than the 2009 value (509 EJ_{th}/yr). Though the world's geothermal heat resources are enormous and ubiquitous, it is difficult to accurately determine global potentials due to their generally *hidden* nature (subsurface). This uncertainty is exacerbated because the technologies used to develop geothermal resources are constantly evolving, so continuing to extend capabilities and reduce costs, and thereby increase technical and economic potentials. Therefore, there are considerable uncertainties in estimating the global geothermal resource potentials, and revisions are expected as more information and new technologies become available.

The most likely worldwide total technical potential for geothermal resources located along tectonic plate boundaries and near volcanic hot spots has been estimated to be about 6.5 TW_{th} (205 EJ_{th}/yr) (Stefansson, 2005), about 40% of the 2009 worldwide total annual supply. Of this total, identified hydrothermal resources capable of development for electricity generation using conventional methods (T > 130 °C) amount to some 200 GW_e (5.7 EJ_e/yr, or 57 EJ_{th}/yr), assuming a 10% electrical conversion efficiency. The remaining 4.7 TW_{th} (148 EJ_{th}/yr), comprise lower temperature resources (T ≤ 130 °C) considered useful mainly for direct heat applications. These estimates may increase by factors of 5-10 if approximations for as yet hidden/unidentified resources are included (ibid.). Power generation potentials are also increasing as a result of technological advances providing conversion efficiencies now ranging up to 20% for high temperature (> 180-200 °C) fluids.

In addition to hydrothermal resources, several other potentially significant geothermal sources capable of power generation and direct heat use exist: 1) binary generation from the use of the hot water discharged from conventional plants (co-generation) and that available from the lower temperature geothermal resources (75-130 °C); 2) the cascaded use of hot water discharged from geothermal power stations for direct heat applications; 3) the massive geothermal energy potential available within drilling depths (3-10 km) in the hot rock of the earth's crust using enhanced geothermal systems technology (EGS); 4) the energy resources in the form of super-critical fluids inferred to exist deep beneath hydrothermal systems (3-5 km); 5) hot water produced from oil and gas wells; 6) hot water present in deep sedimentary basins; 7) off-shore (under-sea) hydrothermal resources located along the submarine rifts and identified by the presence of hydrothermal vents and 8) the ubiquitous shallow geothermal resources utilized by geothermal heat pumps for heating and cooling and available almost anywhere on the earth's surface.

Recent estimates indicate that using current technology hydrothermal resources, available at some 10-15% of the earth's surface and home to ~15% of the world's population, could provide

70-80 GW_e by 2050. In addition, development of other geothermal resources, including: EGS, super-critical fluids, hot water co-produced with oil and gas, hot water from deep sedimentary basins, and off-shore (under-sea) "hydrothermal" resources located along submarine rifts, using "advanced" technologies could deploy another 80 GW_e by 2050, resulting in a total global geothermal power deployment of some 150 GW_e generating 1,182 TWh/yr by 2050. This would provide an estimated 3% of world's electrical power and save about 1 Gt of CO_2 emissions if displacing coal-fired generation (Goldstein et al., 2011).

Direct use technical potential has recently been assessed at >300 EJ/yr, with a probable deployment of 800 GW_{th} and utilization of 7.6 EJ/yr providing about 5% of the heating and cooling demand by 2050 and saving a further 0.8 Gt of CO_2 emissions (ibid.).

Geothermal is an important global renewable energy resource, with many valuable characteristics, including its: extensive global distribution, environmentally friendly character, independence of season, immunity from weather effects, indigenous nature, contribution to development of diversified power, effectiveness for distributed application, sustainable development capabilities and small areal foot-print. Though geothermal predominantly operates as a baseload provider of electricity with availability and load factors typically well above 90%, it can also operate in a load-following capacity, although at lesser efficiency.

Geothermal electricity generation and direct use development have experienced high growth rates worldwide for the past few years (Figure ES2; Tables ES2 and ES3) and future prospects continue to look extremely positive.

Geothermal resources have the potential to make a sizable contribution towards meeting the world's current and future energy needs well into the future, while contributing to the reduction of emissions and the mitigation of climate change. The global geothermal potential is enormous; however, attaining maximum deployment will require long-term R&D.

Status of Global Geothermal Energy in 2011

Worldwide geothermal data were comprehensively collected for reporting at the World Geothermal Congress 2010, held on 25-29 April 2010, in Bali, Indonesia (Bertani, 2010; Lund 2010). In 2011 and 2012, these 2010 data were carefully assessed, with the global results published by Bertani (2012) and Lund et al. (2011). Twenty-four countries were producing electricity from geothermal resources, with a total geothermal installed capacity exceeding 11,079.3 MW_e, with electricity generation of 67,954.3 GWh, based on 2010 data (Bertani, 2012), updated with 2011 GIA Country Member data (Figure ES2, Table ES1). In 2011, the 9 GIA Member Countries having geothermal generation contributed about 63% of the global installed geothermal capacity, and 61% of the total geothermal power generated.

During the period 1950 to 1970 the worldwide geothermal installed capacity growth rate was quite small, then began to accelerate following the energy crisis of the early 1970s, increasing by a factor of >6.5 between 1970 and 1985. Between 1985 and 2005, the worldwide geothermal installed capacity increased by a factor of about 2.3, at a very uniform rate of ~210 MW_e/yr (Figure ES2). However, between 2005 and 2011, the rate of increase grew significantly, with a linear trend of about 352 MW_e/yr to the end of 2011; more than 1.7 times the rate of the previous 5 year period. The capacity increase in GIA Member Countries was: 2011 (6,975.3 MW_e) – 2005 (5,449 MW_e) = 1,526.3 MW_e, or about 28% (4.7%/yr). Table ES1 presents the 2011 data for GIA Member Countries and 2010 data for the other 15 countries with geothermal power generation (Bertani, 2012). Table ES2 illustrates the growth in installed capacity (1950-2011) and generation (1995-2011), with 2006, 2007, 2008, 2009 and 2011 representing minimum estimates.

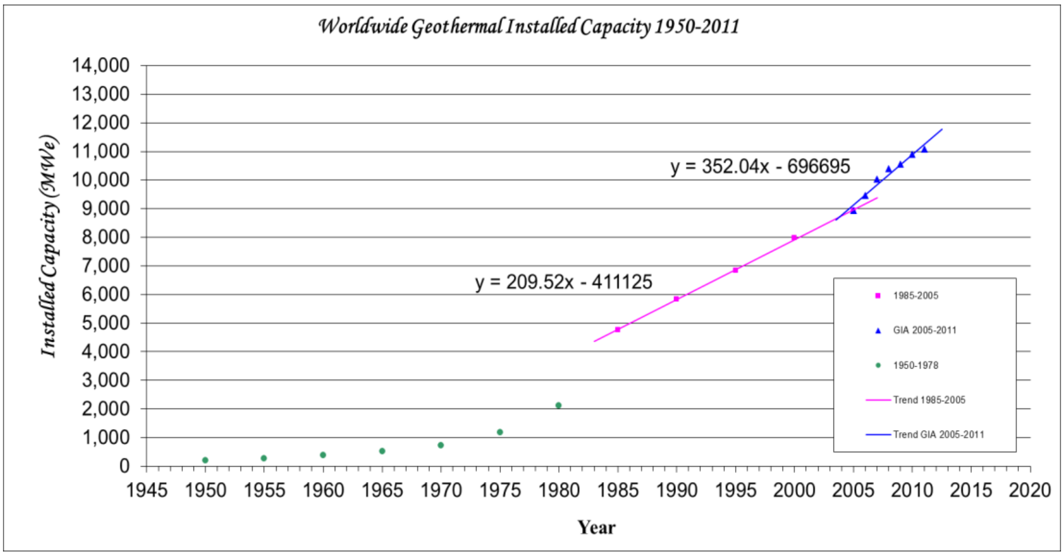


Figure ES2 *Worldwide geothermal installed capacity for the period 1950-2011. The 2005-2011 data [blue triangles] includes GIA data for 2005-2011 and data for the other countries from Bertani (2005; 2007, 2012), and has a trendline slope of 352 MW_e/yr. Data for 1950-2005 is from Bertani (2010), with the 1985-2005 data [magenta squares] having a trendline slope of 210 MW_e/yr. Data for 1950 to 1980 [green stars] is from Bertani (2010).*

As shown in Table ES1, geothermal energy provides a major contribution to the national capacity and national generation for several countries. For eight countries (including, Tibet, Lihir [New Guinea] and San Miguel Islands [Portugal]), the geothermal installed capacity now exceeds 10% of national capacity, and six of these obtain 17-75% of their electricity from geothermal. In 2011, the contribution to national installed capacity for GIA Member Countries with *non-negligible* installation/generation ranged from 1.7-24.8%, with a corresponding range in contribution to national generation of 2.4-27.3%.

The total GIA geothermal generation of 41,739.5 GWh/yr is equivalent to a savings of about 10.5 Mtoe (using GIA conversion (Mongillo, 2005)) and avoided CO_2 emissions of 34.23 Mt. The equivalent savings for the worldwide total generation of 67,954.3 GWh/yr is about 17.2 Mtoe and avoided CO_2 emissions of some 55.5 Mt (*ibid.*).

A good indicator of the contribution a renewable energy resource makes is the ratio of the power they generate to the installed capacity, which for the GIA Countries in 2011 was 5.98 GWh/yr/MW_e, with the global average being 6.13 GWh/yr/MW_e. This quantity takes into account the amount of time that the generator actually produces power, i.e., the *availability factor*. For geothermal, this incorporates the resource availability (usually sustained by make-up drilling), plant availability (affected by repairs and maintenance), and transmission or load-following constraints. Geothermal's very high availability factors make it possible to operate at high capacity factors, which for new installations are above 90%, making geothermal valuable for baseload generation.

***Table ES1** Geothermal power installed capacity and electricity generation for GIA Member Countries for 2011, with 2010 data for the 15 non-GIA countries** (Bertani, 2012).*

Country*	Installed Capacity (2011) [MW]	Annual Electricity Generated (2011) [GWh/yr]	% of National Capacity	% of National Energy
Australia*	***0.1***	***1.9***	***Negligible***	***Negligible***
Austria	1.4	3.8	Negligible	Negligible
China (Tibet)	24	150	30	-
Costa Rica	166	1,131	8	13
El Salvador	204	1,422	15	26
Ethiopia	7.3	10	-	-
France	***17.7***	***56.6***	-	***0.01***
Germany #	***7.3***	***18.7***	***Negligible***	***Negligible***
Guatemala	52	289	-	-
Iceland	***664.6***	***4,701.0***	***24.8***	***27.3***
Indonesia	1,197	9,600	-	-
Italy	***882.5***	***5,315.0***	-	***1.8***
Japan	***540.1***	***2,652.2***	***0.2***	***0.3***
Kenya	202	1,430	14	22
Mexico	***958.0***	***6,524.0***	***1.7***	***2.4***
New Zealand	***794.0***	***5,770.0***	***7.4##***	***13.4***
Nicaragua	88	310	11	-
Papua New Guinea (Lihir Island)	56	450	75	75 (Lihir)
Philippines	1,904	10,311	12	17
Portugal (San Miguel Island)	29	175	25	40 (San Miguel)
Russia	82	441	Negligible	Negligible
Thailand	0.3	2.0	Negligible	Negligible
Turkey	91	490	Negligible	Negligible
USA	***3,111.0***	***16,700.0***	**Negligible**	***0.4***
Total GIA Countries	***6,975.3***	***41,739.5***	-	-
Total- Global***	**11,079.3**	**67,954.3**	-	-

* GIA Member Country in bold font, data from 2011 Country Reports
** The Bertani (2012) data is for the period to the end of 2009
\# GIA data from 2011 GIA Trend Report (2013)
\#\# From NZ Country Report September 2012 Geothermal Update, Bromley, 28th ExCo Meeting, Pisa, Italy
*** Using 2010 data for non-GIA Member countries

In 2011, 78 countries were utilizing geothermal energy for direct heat applications, including: geothermal heat pumps (GHPs); space, greenhouse and aquaculture pond heating; agricultural drying; industrial uses; bathing and swimming; cooling; and snow melting (Lund *et al.*, 2011). The total worldwide installed capacity to the end of 2009 was about 48,493 MW_{th}, with a total thermal energy usage of about 423,830 TJ/yr (Table ES3) (*ibid.*). In 2011, the 13 GIA Member Countries had a total installed thermal power capacity of approximately 26,869 MW_{th} and utilized about 204,583 TJ/yr (Table ES3). It is estimated that in 2011, some 1.5 million GHP units were installed in GIA Member countries (GIA, 2013), with a total of about 2.76 million (12 kW equivalent) installed worldwide in 2010 (Lund et al., 2011.).

Table ES2 *Worldwide installed geothermal capacity (1950-2011) and electricity generation (1995-2011). The generation for 2006-2011 utilizes GIA Member Country data.*

Year	1950*	1955*	1960*	1965*	1970*	1975*	1980*	1985*	1990*	1995*	2000*	2005#	2006#	2007#	2008#	2009#	2010	2011
Geothermal Installed Generating Capacity (MW_e)	200	270	386	520	720	1,180	2,110	4,764	5,834	6,833	7,972	8,933	9,452	10,026	10,405	10,565	10,892	11,079.3
Electricity Generation (GWh/yr)	-	-	-	-	-	-	-	-	-	38,035	49,261	53,649	55,209	56,782	57,957	58,494	66,184	67,954.3

* Installed capacity data for 15 countries from Bertani (2012) with updates for GIA countries for 2007-2011
\# Generation data for 1995 and 2000 is from Bertani (2012); 2005 from Bertani (2007) and 2008-2011 from Bertani (2012) with updates for GIA countries

Table ES3 *Worldwide direct use categories and their development 1995, 2000, 2005 and 2010 (from Lund et al., 2011), and incorporating updates for GIA Member countries for 2007, 2008, 2010 and 2011.*

Category	Installed Capacity (MW_{th})							Utilization (TJ/yr)						
	1995	2000	2005	2007	2008	2010#	2011	1995	2000	2005	2007	2008	2010#	2011
Geothermal heat pumps	1,854	5,275	15,384	-	-	33,134	-	14,617	23,275	87,503	-	-	200,149	-
Space heating	2,579	3,263	4,366	-	-	5,394	-	38,230	42,926	55,256	-	-	63,025	-
Greenhouse heating	1,085	1,246	1,404	-	-	1,544	-	15,742	17,864	20,661	-	-	23,264	-
Aquaculture pond heating	1,097	605	616	-	-	653	-	13,493	11,733	10,976	-	-	11,521	-
Agricultural drying	67	74	157	-	-	125	-	1,124	1,038	2,013	-	-	1,635	-
Industrial uses	544	474	484	-	-	533	-	10,120	10,220	10,868	-	-	11,745	-
Bathing and swimming	1,085	3,957	5,401	-	-	6,700	-	15,742	79,546	83,018	-	-	109,410	-
Cooling/snow melting	115	114	371	-	-	368	-	1,124	1,063	2,032	-	-	2,126	-
Others	238	137	86	-	-	42	-	2,249	3,034	1,045	-	-	955	-
Worldwide Total (Lund)	8,664	15,145	28,269	-	-	48,493	-	112,441	190,699	273,372	329,270	329,880	423,830	-
Worldwide Total (GIA)	-	-	-	-	-	-	54,200©	-	-	-	-	-	-	459,000©
GIA Countries**														
Australia	-	-	-	-	-	132	37	-	-	-	-	-	1,314	324
France	-	-	-	-	-	2,016	2,016	-	-	-	-	-	14,557	12,937
Germany	-	-	-	-	-	3,063	3,183	-	-	-	-	-	11,449	16,558
Iceland	-	-	-	-	-	2,065	2,061		-	-	-	-	24,621	25,200
Italy	-	-	-	-	-	1,000	1,000	-	-	-	-	-	12,599	12,599
Japan	-	-	-	-	-	2,099	2,100	-	-	-	-	-	25,698	25,708
Korea	-	-	-	-	-	273	462	-	-	-	-	-	1,497	2,240
Mexico	-	-	-	-	-	156	156	-	-	-	-	-	2,558	2,558
New Zealand	-	-	-	-	-	385	396	-	-	-	-	-	10,156	10,160
Norway	-	-	-	-	-	1,000	1,000	-	-	-	-	-	10,800	10,800
Spain	-	-	-	-	-	92	96	-	-	-	-	-	688	703
Switzerland	-	-	-	-	-	1,366	1,497	-	-	-	-	-	7,152	6,876
UK	-	-	-	-	-	-	301	-	-	-	-	-	-	1,801
USA	-	-	-	-	-	12,564	12,564	-	-	-	-	-	76,119	76,119
Total GIA Countries	-	-	-	*20,547*	21,000	26,211	26,869	-	-	-	*154,560*	*155,170*	199,208	204,583

* Data for 2009 excluded due to lack of data for this year from some GIA Member countries
** GIA data from 2007, 2008, 2010 and 2011 GIA Country Reports and 2011 GIA Trend Report
\# Lund et al. (2011) data is for the period to the end of 2009
© From 2011 GIA Trend Report

Worldwide direct use installed capacity has increased by about 90% between 2005 and 2011 (Table ES3), with corresponding direct energy use increasing by about 68%. The total use of about 459,000 TJ/yr is equivalent to an annual savings of about 16.2 Mtoe/yr in fuel oil and 52.2 Mt/yr in avoided CO_2 emissions (GIA conversions, Mongillo (2005)). Direct use in GIA Member Countries, 204,583 TJ/yr in 2011, was equivalent to a savings of 7.1 Mtoe/yr and avoided CO_2 emissions of about 23.2 Mt/yr.

The IEA-GIA- an Overview

The IEA-GIA was founded in 1997, and was in the 5th year of its 3rd Term of operation at the end of 2011. At the request of the IEA, the GIA agreed in 2010 to extend the 3rd Term by one year, taking it to 28 February 2013. The GIA provides a versatile framework for comprehensive international cooperation in geothermal R&D by establishing links between national and industry programmes for exploration, development and utilization of geothermal resources, with emphasis on enhancing effectiveness through connecting geothermal experts in the participating countries and industries. The general scope of the GIA's activity consists of international scientific collaborative efforts to: compile and exchange improved information on worldwide geothermal energy R&D concerning existing and potential technologies and practices, develop improved technologies for geothermal energy utilization, and improve the understanding of the environmental benefits of geothermal energy and ways to avoid or minimize its environmental impacts. GIA collaboration provides researchers with opportunities for information exchange via meetings, workshops and networking. Members may also participate in R&D projects and help in the development of databases, models and handbooks. Participants may obtain an international perspective on geothermal issues, opportunities and environmentally-appropriate development strategies. New studies and activities are implemented when needs are established.

The GIA's 3rd Term Mission is:

To promote the sustainable utilization of geothermal energy throughout the world by improving existing and developing new technologies to render exploitable the vast and widespread global geothermal resources, by facilitating the transfer of know-how, by providing high quality information and by widely communicating geothermal energy's strategic, economic and environmental benefits, and thereby contribute to the mitigation of climate change.

To realize this Mission, six Strategic Objectives focus the GIA's activities:

- To actively promote effective cooperation on geothermal RD&D through collaborative work programmes, workshops and seminars
- To collect, improve/develop and disseminate geothermal RD&D policy information for IEA Member and non-Member Countries
- To identify geothermal energy RD&D issues and opportunities and improve conventional and develop new geothermal energy technologies and methods to deal with them
- To increase membership in the GIA
- To encourage collaboration with other international organizations and appropriate implementing agreements
- To broaden and increase the dissemination of information on geothermal energy and the GIA's activities and outputs to decision makers, financiers, researchers and the general public

Activities, called Tasks, are defined and organized in broad topics termed Annexes. Participants must take part in at least one Annex. Annex titles, status, leadership and participation are provided in Table 1.2, Chapter 1. An Executive Committee (ExCo), consisting of one voting Member from each Member Country and Sponsor (industry/industry organization), supervises the GIA and its decisions are binding on all Members.

Since the GIA's formation, the Annexes have operated under the task-sharing finance mode, whereby participants allocate specified resources and personnel to conduct their portion of the work at their own expense. Total Annex efforts conducted under the auspices of the GIA are estimated to amount to several man-years time (GIA, 2006).

In March 2003, the ExCo established a GIA Secretariat to provide it with administrative and other assistance. The Secretariat is funded through cost-sharing, with all GIA Members contributing to a Common Fund according to a "share" allocation defined by the ExCo.

At the end of 2011, there were 20 IEA-GIA Members: the European Commission; 14 countries: Australia, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Norway, the Republic of Korea, Spain, Switzerland, the United Kingdom and the United States; 3 industry Sponsors: Geodynamics, Green Rock Energy and ORMAT Technologies; and 2 organization Sponsors: the Canadian Geothermal Energy Association (CanGEA) and the Geothermal Group of the Spanish Renewable Energy Association (GG-APPA).

Collaborative Activities

The Annexes

In 2011, GIA participants worked on five broad research topics, and contributed to the GIA's geothermal data collection and analysis effort, specified in the following Annexes:

- Annex I- Environmental Impacts of Geothermal Energy Development
- Annex III- Enhanced Geothermal Systems
- Annex VII- Advanced Geothermal Drilling Techniques
- Annex VIII- Direct Use of Geothermal Energy
- Annex X- Data Collection and Information
- Annex XI- Induced Seismicity

Annexes I and III have been operating since the original implementing agreement was initiated in 1997, and have continued programmes into the current term. In October 2009, Annexes I, III and VII were extended by the ExCo for a further 4 years, to 2013. Annex VIII, which officially started in 2003, was unanimously continued by the ExCo to 2013. Annexes X and XI were both opened in October 2009, with their activities begun in 2010. Four other Annexes have been drafted since the start of the organization, with II- Shallow Geothermal Resources and IX- Geothermal Market Acceleration subsequently closed. The possibility remains for draft Annexes V- Sustainability of Geothermal Energy Utilization and VI- Geothermal Power Generation Cycles to be initiated if sufficient interest arises. The status of the Annexes is presented in Table 1.2, Chapter 1 of the 2011 Annual Report.

A few of the GIA's major activities and Annex highlights for the 2011-Year are presented below. Details are available in Chapter 1 and in the Annex Reports included in Chapters 2-7 of the 2011 Report.

IEA-GIA ExCo and Annex Meetings in 2011

The IEA-GIA held two ExCo Meetings in 2011, and they are briefly described in Chapter 1 of this Annual Report. The 25^{th} ExCo Meeting met at the IEA Headquarters in Paris, France, in early May 2011, as part of the GIA's efforts to maintain its close relationship with the IEA and keep them up-to-date with the organization's activities. Participation was relatively high (23), with three IEA representatives attending, including Paolo Frankl, IEA Head of the IEA Renewable Energy Division. Annexes I, III, VII and X held technical meetings, each ~2 hours long, and Annex XI held a day-long joint meeting with the IPGT Induced Seismicity Group during the two-day period prior to the ExCo Meeting. Annex meetings provide the opportunity to discuss and assess current and planned activities. Important issues related to Annex activities that have arisen during the year, e.g., induced seismicity and sustainability, are also examined. The status of

Annex operations, including activities, achievements, challenges, etc., is also reported at the ExCo meetings.

The 26th ExCo Meeting was held in London, UK, at the end of September 2011, in association with the First UK Geothermal Symposium on *Engineered Geothermal System Energy in the UK and a Global Perspective.*, in which six ExCo Members also participated. Twenty-three people attended the ExCo Meeting, and Mr Greg Barker, Minister for the Department of Energy & Climate Change (DECC), talked about the UK Government's commitment to renewable and geothermal energy. Annexes I, III, VII and X met on the day prior to the ExCo Meeting.

US DOE Geothermal Technologies Program Peer Review, Bethesda, Maryland, USA

Several GIA ExCo Members and the Secretary participated at the week-long US DOE Geothermal Technologies Peer Review held in early-June 2011, thus providing international experience and perspective to the process. The GIA Chair and Secretary were supported through the GIA's proposal funding mechanism and together reviewed 19 projects. In addition, both made lunch-time presentations describing the GIA's activities.

EGS Energy in the UK and a Global Perspective Seminar, London, UK

Six GIA ExCo Members and an Annex III participant contributed to this 1-day seminar with discussions of EGS development in the USA, Germany, Australia, France and South Korea; as well as other pertinent topics, including the global geothermal and EGS potential; and scaling-up, sustainability, and industrial partnerships.

Stanford Geothermal Reservoir Workshop, Stanford, California, USA

GIA ExCo Members presented two papers at the 36th Stanford Geothermal Reservoir Workshop, in early-2011 covering the expectations for geothermal energy to the end of this century and real-time monitoring at EGS system sites.

Geothermal Resources Council Annual Meeting 2011, San Diego, California, USA

The GIA participated at the 2011 Annual Meeting of the GRC held in San Diego, California, USA, in October 2011. A paper providing a summary of current global geothermal utilization and recent estimates of global potential for direct use and power generation was presented.

IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation

Several GIA participants played key roles in the preparation of Chapter 4 Geothermal Energy of the IPCC Special Report on Renewable Energy Sources (SRREN) by acting as Coordinating, Lead and Contributing Authors. This extremely important document was published in May 2011.

Continuation of GIA Proposal Initiative for Supplementary Activities

The GIA's ongoing strong financial position has allowed its proposal funding scheme to continue, making funds from the GIA Common Fund available for approved supplementary activities related to ExCo initiatives or Annex Task activities. In 2011, a proposal requesting support for the Chair and the Secretary to participate at the US DOE Geothermal Technologies Program Peer Review was funded.

GIA Participation in IEA Activities

In 2011, the GIA continued its active involvement with the IEA through its participation at several events, including the REWP Renewable Energy conference, attendance and contributions to two IEA workshops, presentation of the GIA's Mid-3rd-Term Report to the 59th REWP Meeting; and by providing a final review and comments on the ***IEA Technology Roadmap for Geothermal Heat and Power***, which was published in June 2011.

Geothermal Energy Utilization and the Environment (Annex I)

Geothermal energy is a renewable resource that produces significantly less CO_2 emissions than fossil fuels, and accordingly, has major potential for reducing global warming effects. Its utilization is mostly environmentally benign, though some local environmental problems may occur. To expand the use of geothermal energy, it is important to identify possible adverse and beneficial environmental effects, and to devise and adopt measures to avoid or minimize adverse impacts, while encouraging the beneficial ones.

Annex I- Environmental Impacts of Geothermal Energy Development activities aim to encourage the sustainable development of geothermal energy resources in an economic and environmentally responsible manner; to quantify and balance any adverse and beneficial impacts that geothermal energy development may have on the environment, and to identify ways of avoiding, remedying or mitigating adverse effects.

The sustainable utilization of geothermal resources is an internationally recognized goal, and three years' effort by several Annex I participants, along with other geothermal specialists, successfully contributed to it with the completion of the chapter on geothermal energy in the ***Intergovernmental Panel on Climate Change (IPCC) Special Report on Renewable Energy Sources and Climate Change Mitigation,*** which was published in May 2011 (IPCC 2011 Geothermal Chapter). Supplementary papers derived from this work were presented at two international geothermal meetings in 2011 and other sustainable deployment advice was incorporated in the final published ***IEA Technology Roadmap for Geothermal Heat and Power*** in June 2011.

In addition, Annex participants took part in technical collaborative meetings in association with the two 2011 ExCo Meetings (Paris, France and London, UK) and numerous papers were presented by Annex I participants on environmental research, improved sustainability strategies and monitoring methods at four conferences. New collaborative efforts were also initiated on several topics, including satellite IR monitoring and the protection of hot springs from potential development beneath national parks.

Accessing Geothermal Resources Using Enhancement Techniques (Annex III)

Huge heat resources consisting of high temperature, water-poor rock are available within current drilling depths (>3 km) almost anywhere on earth. Annex III- Enhanced Geothermal Systems (EGS) has been designed to investigate new and improved technologies (e.g., hydraulic fracturing) via international collaboration to develop engineered heat exchangers at depth to enable commercial heat extraction for electricity production and, in some cases, co-generation of heat for direct use applications. These technologies can also be used to help sustain and enhance energy production at existing conventional hydrothermal developments through increasing permeability and via reinjection. The successful development of EGS is presently one of the major challenges facing the international geothermal community. Reduced funding available to the various participants in 2011 led to further revision of the Annex's major efforts and activities.

Reducing Geothermal Drilling and Logging Costs (Annex VII)

Drilling is an essential and expensive part of geothermal exploration, development, and utilization. Drilling, logging, and completing geothermal wells are expensive because of the high temperatures and hard, fractured formations encountered. The consequences of reducing these costs are often impressive, because drilling and well completion can account for more than half of the capital cost for a geothermal power project. Drilling cost reduction can result from faster drilling rates, increased bit or tool life, less trouble (twist-offs, stuck pipe, etc.), higher per-well production through multi-laterals, and others.

Annex VII- Advanced Drilling and Logging Technology aims to promote ways and means to reduce the cost of geothermal drilling through the following activities: 1) developing a detailed understanding of worldwide geothermal drilling costs, 2) compiling a directory of geothermal drilling practices and how they vary globally and 3) developing improved drilling and logging technologies. Major objectives include: a) gaining a quantitative understanding of global drilling costs and identifying ways to reduce them while maintaining or enhancing productivity; b) identifying and developing new/improved technologies for significantly reducing geothermal well construction costs; c) informing the international geothermal community about these drilling technologies; and d) providing a means for international cooperation, field tests, etc.

The most significant Annex activity for 2011 was the initiation of work on the well cost model.

Direct Use of Geothermal Heat (Annex VIII)

Geothermal water has been used for centuries for various applications. Initially, only the hot geothermal water present in surface springs was used, mainly for bathing, cooking and for therapeutic purposes. In recent decades, direct use of geothermal water has grown, and today, geothermal energy is available everywhere and used for many applications that require heat, such as: such as heating buildings, individually or for whole towns (district heating); raising plants in greenhouses, drying crops, heating water at fish farms, snow melting, bathing and for therapeutic purposes and several industrial processes. Heating and cooling with the help of constant temperatures in the shallow subsurface (<300 m depth) through the well-known technology of ground-source heat pumps (GSHP) or geothermal heat pumps (GHP) has now become the most important form of direct use and rapidly grows in terms of capacity and also worldwide deployment.

Though many direct use applications are well developed and economically viable, implementation difficulties and unfavourable economics are still major challenges. Annex VIII- Direct Use of Geothermal Resources, was established to promote further direct use of geothermal heat through collaborative activities.

The objectives of this Annex are to: define and characterize direct use applications with emphasis on defining barriers to their widespread application; identify and promote opportunities for new and innovative applications, define and initiate research to remove barriers, enhance economics and promote implementation; test and standardize equipment; and develop engineering standards.

In 2011, Annex activities and outputs were described at various seminars, barrier identification and opportunity for direct use results obtained were used to design and be incorporated into the second annual GIA Trend Report (Annex X), engineering standards for design documents and references were collected from five countries, and the basic data/information required for presenting data on GIS has been identified and that remaining to be obtained determined.

Geothermal Data and Information (Annex X)

The value of collecting, analyzing and publishing geothermal use data and information is well recognized, and Annex X Data Collection and Information was initiated to collect essential data on geothermal energy uses, trends and developments in GIA countries and to publish these data in an annual report. This report shall provide a brief overview of the geothermal energy data, such as installed capacities, produced electricity and heat, supplemented by political and economic information relevant to the development of geothermal energy in GIA member countries. There are plans to extend this data collection to include non-GIA Member Countries, if reliable data can be obtained.

In 2011, the required data/information was collected through providers completing a spreadsheet questionnaire, and comparison was made with additional worldwide data obtained from sources such as the World Geothermal Congress publications. A draft GIA Report, Trends in Geothermal Applications, was completed using 2010 data, and the final report is available on the GIA website (GIA, 2012).

Induced Seismicity (Annex XI)

A seismic event is an earthquake that is induced by man-made activities such as fluid injection, reservoir impoundment, mining, and other activities. In terms of EGS activities, induced events can occur during the operations of fracture stimulation, fluid injection and/or fluid withdrawal.

Annex XI encourages international cooperation to determine the steps needed to be taken to make EGS/fluid injection a safe and economic technology that is accepted by the public and useful to the industry. This includes not only steps to allow acceptance of EGS technology by the public, regulators and policy makers, but also allows induced seismicity to become a useful tool to optimize EGS applications.

In 2011, the specific objectives of the Annex were aimed at reducing uncertainty associated with acceptability issues to facilitate and accelerate geothermal energy development. Objectives included: a) develop accepted approaches for addressing technical and public acceptance issues that industry can use as a guide; b) develop a methodology to assess risk; c) identify areas of collaboration/cooperation; and d) identify key barriers and areas of technology development and research.

The first Annex XI meeting was held at IEA HQ, Paris, in May 2011, as a joint session with the 7th IPGT Induced Seismicity Group, with 12 participants from seven countries. Eight strategic issues were defined, including tasks to investigate the establishment of demonstration areas and global test sites, to develop frameworks for hazard and risk assessment, and to develop mitigation options. Persons/countries responsible for the tasks were also identified. The draft new induced seismicity protocol developed by USDOE was discussed. A second joint Annex XI/IPGT meeting was held in Melbourne, Australia, in November 2011, and attended by participants from seven countries. Several task-related actions were defined, including decisions to: a) compile a glossary of terms; b) define what data should be collected; c) link the various international demonstration projects at a website to make data more available; and d) draft an induced seismicity white paper on hazard and risk/mitigation.

Plans for 2012 include development of a more detailed task list, completion of a draft white paper, and continued pursuit of various forms of communication for public, regulators and operators.

National Activities

The geothermal programmes of the GIA Country Members provide the basis for the cooperative IEA-GIA geothermal activities. These programmes focus on the exploration, development and utilization of geothermal resources. A comprehensive description of the current status of geothermal activities for each of the participating countries and the EC is provided in this Annual Report (Chapters 8-22).

In 2011, Contracting Parties from 14 countries and the European Commission (EC) participated in the IEA-GIA. The Member Countries were: Australia, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Norway, the Republic of Korea, Spain, Switzerland, the United Kingdom and the United States.

Contributions of GIA Members to Power Generation and Direct Use

In 2011, the nine GIA Member Countries with geothermal generation had a combined installed capacity of about 6,975 MW_e, or about 63% of the total global geothermal capacity of 11,079 MW_e; and generated 41,740 GWh/yr, or about 60% of the total geothermal generation of 67,954 GWh/yr (Tables ES1 and ES4). The United States was by far the largest producer, generating about 16,700 GWh/yr, with Mexico second with 6,524 GWh/yr and New Zealand third with 5,770 GWh/yr. The percent of national installed capacity contributed by geothermal in the 5 IEA-GIA Member Countries with non-negligible power development ranged from 0.2% for Japan to 24.8% for Iceland, with an average of about 8.5%. The contribution of geothermal to national generation in Member Countries ranged from 0.3% for Japan to 27.0% for Iceland, with an average of 7.6%.

Table ES4 *Total geothermal installed capacity, electricity generation and direct use in GIA Member Countries in 2011.*

Country	Electrical Installed Capacity (MW)	Annual Energy Generated (GWh/yr)	% of National Capacity (Range)	% of National Energy (Range)	Installed Thermal Power (MW_{th})	Annual Energy Used (TJ/yr)
GIA Member Countries	6,975	41,740	0.2-24.8	0.3-27.3	26,869	204,583
Worldwide Total**	11,079	67,954	-	-	54,200	459,000
GIA % of Worldwide Total	63	61	-	-	55	45

** For sources of worldwide total data see Tables ES1 and ES3 above.

All 13 GIA Member Countries utilized geothermal in direct applications in 2011, with a total installed capacity of 26,869 MW_{th} and total thermal energy used amounting to 204,583 TJ/yr (Table ES5). The three largest users of geothermal heat by far were the USA (76,119 TJ/yr), Japan (25,708 TJ/yr), and Iceland (25,200 TJ/yr). However, the non-high enthalpy geothermal countries, France (12,937 TJ/yr), Germany (16,558 TJ/yr), Norway (10,800 TJ/yr and Switzerland (6,876 TJ/yr) also had very high utilization, mainly due to the large and growing geothermal heat pump usage.

Table ES5 *Geothermal direct use in GIA Member Countries in 2011.*

Country	Installed Thermal Power (MW_{th})	Annual Energy Used (TJ/yr)
Australia	37	324
France	2,016	12,937
Germany	3,183	16,558
Iceland	2,061	25,200
Italy	1,000	12,599
Japan	2,100	25,708
Mexico	156	2,558
New Zealand	396	10,160
Norway	1,000	10,800
Republic of Korea	462	2,240
Spain	96	703
Switzerland	1,497	6,876
USA	12,564	76,119
Total for GIA*	**26,869**	**204,583**

* Total excludes the EC

Sponsor Activities

At the end of 2011, the GIA had 5 Sponsor Members, 3 from industry: Geodynamics Limited and Green Rock Energy Limited from Australia; and Ormat Technologies, Inc. from the USA; and 2 industry organizations: the Canadian Geothermal Energy Association (CanGEA) and the Geothermal Group of the Spanish Renewable Energy Association (GG-APPA).

Industry Sponsors

Geodynamics Limited

Geodynamics Limited, Australia's most advanced geothermal energy developer, is a public company, incorporated and domiciled in Australia, and was listed on the Australian Securities Exchange on September 2002. Geodynamics has a specific focus on the economic extraction of heat from hot rocks using enhanced geothermal systems (EGS) technology. While the Company holds geothermal exploration licences in South Australia, New South Wales, Northern Territory and Queensland, the majority of efforts are currently focused on extracting heat from its geothermal tenements near Innamincka in South Australia, where high-heat-production granite buried 3.6-4 km beneath the Cooper and Eromanga Basins approaches temperatures of 280 °C at 5 km depth.

The company spent the 2011 year planning for the drilling of a replacement well for well Habanero 3. Habanero 3 suffered a catastrophic failure in April 2009 when the three casing strings fractured in the top 6m of the well. Habanero 4 was designed to mitigate two possible causes of casing failure, (1) hydrogen embrittlement from the native granite formation water, with failure related to corrosion at relatively low temperatures, and (2) caustic cracking from alkaline fluids likely to have remained in the top of the inner annulus after an inadequate cement job, with failure related to corrosion at high temperatures.

The drilling of Habanero 4 is scheduled to commence in early 2012.

Green Rock Energy Limited

Green Rock Energy Limited is a public energy company listed on the Australian Securities Exchange. Its geothermal energy focus is on developing two commercial scale power projects from geothermal energy recovered from hot sedimentary aquifers. One project is in Hungary and the other in the North Perth Basin in Western Australia.

During the 2011-year the Company's activities for both projects have been directed to proving there are natural permeable reservoirs with sufficient geothermal fluid flow potential to sustain commercial scale power projects. Green Rock's work in the North Perth Basin concentrated on locating and mapping permeable fractured reservoirs within areas of highest heat flows near existing power transmission lines.

Green Rock Energy is active in Hungary through the Hungarian joint venture company Central European Geothermal Energy (CEGE) which was established in 2008 with MOL, Hungary's largest company. CEGE has been waiting to be awarded the concession and formal approvals to enable it to proceed with drilling a production well into the identified naturally permeable reservoir. CEGE formulated plans to carry out a magneto-telluric survey of the area to delineate the extent of fluid-saturated, naturally-fractured reservoirs at depth.

Ormat Technologies, Inc.

Ormat Technologies, based in the USA, is a leading vertically integrated company engaged in the geothermal and recovered energy (i.e., from "waste heat") power business. Ormat has over 40 years' experience with ORC and 25 years of its applications to geothermal development. Ormat explores, develops, designs, builds, owns and operates clean, environmentally friendly geothermal and recovered energy (RE)-based power plants. In addition, the company also designs, manufactures and sells power units and other power generating equipment for geothermal and RE-based electricity generation (REG).

As of December 2011, Ormat owned and operated ~503 MW_e of geothermal and ~53 MW_e REG in the United States. In total, Ormat has built approximately 1,500 MW_e of geothermal, REG and solar installations worldwide, in 24 countries. Geothermal represents over 90% of the total installation. In the U.S, Ormat has deployed approximately 70% of the geothermal capacity installed since 2000. Ormat has grown to a team of more than 1,200 employees worldwide, with approximately 526 in the United States. It also has its own in-house drilling company, GeoDrill, with nine rigs capable of drilling to 5,500 m and over 100 staff.

In 2010 and 2011, Ormat added approximately 160 MW_e of gross geothermal capacity worldwide; of which, two power plants developed in Nevada, demonstrate Ormat's ability to develop greenfield projects. As of September 2012, Ormat owned 586 MW of geothermal and recovered energy in the US, Nicaragua, Kenya and Guatemala.

In 2011, Ormat achieved strong results, completing new projects, making considerable progress in production, development and exploration activities, and receiving record orders. Total revenues increased by 17% (relative to 2010) to US$ 437 M, with product increases of 39% to US$ 13.2 M. Electricity revenues grew to US$ 323.8 M, about 11% per annum growth rate.

Ormat has various leases and concessions for geothermal resources of approximately 675,000 acres in 42 sites located in Alaska, California, Nevada, Hawaii, Oregon, Idaho and Utah in the United States, and in Chile, Guatemala and New Zealand.

Ormat is involved in several R&D projects, including EGS (with US DoE at Brady's Hot Springs and Desert Peak, Nevada), innovative exploration and drilling technology (with US DoE in Hawaii, Oregon and California; and in Alaska), and co-production with oil wells (with US DoE at the Rocky Mountain Oil Test Center). Ormat is also exploring, with Sandia National Laboratories, oil & gas/shale/mining drilling technologies and operational methods, in attempts to identify commercially available drilling technologies and drilling operations which can fit, with proper modifications, to geothermal drilling needs.

Organization Sponsors

Canadian Geothermal Energy Association

The Canadian Geothermal Energy Association (CanGEA), an industry organization Sponsor Member of the GIA, is a non-profit association that promotes the development and use of sustainable geothermal energy in Canada. Their focus is on moderate to high temperature resources (> 70 °C) for power generation.

CanGEA hosted two successful conferences in September and November 2011 that demonstrated strong international representation. These conferences included the Annual Geothermal Conference & Investment Forum in Toronto, which commenced with the opening of the TSX by CanGEA members, and the Annual Geothermal Power Forum in Calgary. CanGEA also presented at the Opening Session of the GRC Annual Meeting in October 2011. Initial funding has been secured for the first steps of the work on the roadmap, while remaining funding is being sought with government and corporate sponsors.

The Canadian geothermal energy industry continued to promote investor confidence with its Canadian Geothermal Code for Public Reporting. The Code provides a minimum set of requirements for the public reporting of Exploration Results, Geothermal Resources and Geothermal Reserves. CanGEA has also begun work on preparation of data sets for a national geothermal database, starting with the province of Alberta. This is based on an international protocol for assessing geothermal resource data and the Canadian Geothermal Code for Public Reporting. Partial funding from Alberta Innovates- Energy and Environment Solutions and through an industry champion has already been secured.

CanGEA has maintained a wide membership consisting of approximately 45 members. These members include geothermal developers, equipment manufacturers and utilities, and firms specializing in the consulting, engineering, construction, financial, and legal aspects of geothermal energy.

CanGEA intends to host a Technology Information Session on the Canadian Geothermal Power & Direct Use of Heat Technology Roadmap and Implementation Plan in early 2012.

Geothermal Department- Spanish Renewable Energy Association

The Geothermal Department of the Spanish Renewable Energy Association (APPA) represents the geothermal members' interests in politics, civil society and the media, and participates in the development of Spanish energy and environmental policy. APPA itself represents more than 500 producers, businesses and other associations in the Spanish renewable energy sector, with the Geothermal Department comprising six company members in the high enthalpy geothermal section and 30 members in the low enthalpy one.

The most important milestone achieved in 2011 was the inclusion of geothermal energy within the Spanish Renewable Energy Plan (PER) 2011-2020. This is the first time geothermal energy has been incorporated into the national energy planning and its potential use considered as a contributor towards its objectives. The objectives established within the new PER 2011-2020 are quite modest compared to the true potential of both high enthalpy geothermal energy for electricity production and low enthalpy geothermal energy for heat production. The sector is valued very positively Spain, and a number of specific measures have been proposed to promote its development in the coming years.

The industrial sector has worked throughout 2011 to promote the progress of geothermal energy at all levels, both institutional (national and regional) and in civil society. To do this, in 2011, at the policy level, the sector has been involved in the process of revising the RITE (Regulations on Thermal Installations in Buildings) and the development of the RITE standard publication "Designing Systems Geothermal Heat Pump". It has also been involved in developing the standard of AENOR (Spanish Association for Standardization and Certification) for the design, implementation, and monitoring of shallow closed loop vertical geothermal installations to be extended for all the other geothermal heat exchanger facilities. Since there are currently no specific regulations for such shallow geothermal instillations, it is essential to establish a regulatory framework to ensure quality and proper functioning of the facilities.

Plans for 2012 and Beyond

The GIA plans to extend its efforts and will continue to pursue new membership in 2012, and onwards. The GIA will maintain its joint efforts with the IPGT Induced Seismicity Group to encourage international cooperation to determine the steps required to make EGS/fluid injection a safe and economic technology that is accepted by the public and useful to the industry.

Based upon the success of the first (2010) GIA Trend Report produced by Annex X, the GIA will continue to strongly support production of this annual document into the future, and use it along with the GIA Annual Report to disseminate geothermal data/information and to represent the GIA at international meetings, etc.

The GIA will continue its strong support of the IEA by providing current geothermal data/information, contributing to IEA publications, and by taking part in REWP meetings. The GIA will also be preparing its End-of-3rd-Term report and its 4th-Term Strategic Plan as part of its request for extension for another 5-year term of operation.

Participation at important international scientific meetings will continue to be emphasized. In 2012, GIA will hold its spring ExCo Meeting in Oslo, Norway, in association with the Oslo Geothermal Week. The GIA Chair and Secretary will also be participating at the Understanding Geological Systems for Geothermal Energy Course at Erice, Sicily, Italy in autumn 2012. Continued participation at the annual NZGW, Stanford and GRC workshops is also expected.

The GIA's strong financial position at the end of 2011 will allow continuation of the successful proposal funding programme (using a portion of the GIA Common Fund) to support special

GIA efforts and Annex related activities to increase/enhance the organization's outputs and its international status. Several proposals are already expected.

The global financial crisis that commenced at the end of 2008 continues to be felt throughout the international geothermal community, though growth in geothermal development continues in several countries, providing some optimism for the future. Geothermal energy can make a considerable contribution to providing sustainable renewable energy for future global energy needs, and the GIA sees its activities continuing and growing to make this a reality.

References

Bertani, R. (2012) Geothermal power generation in the world 2005-2010 update report. Geothermics, 41, 1-29.

Bertani, R., 2010. Geothermal Power Generation in the World, 2005-2010 Update Report. *Proc. World Geothermal Congress 2010*, Bali, Indonesia, 25-29 April 2010, 41 p.

Bertani, R., 2007. World geothermal generation in 2007. *Proc. European Geothermal Congress 2007*, Unterhaching, Germany, 30 May- 1 June 2007. 11 p.

Bertani, R., 2005. Worldwide geothermal generation 2001-2005: state of the art. *Proc. World Geothermal Congress 2005*, Antalya, Turkey, 24-29 April 2005.

Birol, F. (2012) 2015: Pricey delay for climate action. Journal of the International Energy Agency, 2, Spring 2012, 37.

Birol, F. (2011) "Locked in" on Climate? Journal International Energy Agency, 1, Autumn 2011, 40-41.

COP17 (2012) The Main Outcomes of COP 17 Durban 2011, 18 slides. Available at: http://www.kzncogta.gov.za/Portals/0/Documents/DisasterManagement/No.%2010%20COP%2017%20Resolutions%20TB.pdf

GIA (2013) 2011 GIA Trend Report. IEA-GIA Implementing Agreement Annex X, July 2013, 40p.

GIA (2012) 2010 GIA Trend Report: Trends in Geothermal Applications- Survey Report on Geothermal Utilization and Development in IEA-GIA Member Countries in 2010, with trends in geothermal power generation and heat use 2000-2010. 38 p.

GIA, 2006. IEA-GIA End of Term Report 2002-2007. 30 October 2006, 36 p. Available at: http://www.iea-gia.org/documents/GIAEoTReport2002-2007FinalVer30October06websecur15Jan07.doc

Goldstein, B., et al. (2011) Geothermal Energy, Chapter 4 in: IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, May 2011.

IEA (2012) IEA Key World Energy Statistics 2012. OECD/IEA, Paris, France.

IEA (2011) IEA Key World Energy Statistics 2011. OECD/IEA, Paris, France.

KamLAND (2011) Partial radiogenic heat model for Earth revealed by geoneutrino measurements. Nature Geoscience, 4, 647-651.

Lund, J.W., Freeston, D.H. and Boyd, T.L. (2010) Direct utilization of geothermal energy 2010 worldwide review. Proc. World Geothermal Congress 2010, Bali, Indonesia, 25-29 April 2010, 23p.

Lund, J.W., Freeston, D.H. and Boyd, T.L. (2011) Direct utilization of geothermal energy 2010 worldwide review. Geothermics, 40 (3) 159-180.

Mongillo, M.A., 2005. Savings factors for geothermal energy utilization. IEA Geothermal Implementing Agreement document, January 2005. (available on IEA-GIA website: Savings Factors.pdf)

WEO (2012) WEO 2012 Fact Sheets. Available at: http://www.worldenergyoutlook.org/media/weowebsite/2012/factsheets.pdf

Author and Contact

Mike Mongillo
IEA-GIA Secretary
GNS Science
Wairakei Research Centre
Box 2000
Taupo 3352
NEW ZEALAND
E-mail: mongillom@reap.org.nz

IEA Geothermal R & D Programme

Chapter 1

The Implementing Agreement

Champagne Pool at Waiotapu Geothermal Field, a ***protected geothermal system*** *in the Waikato Region.*
(Photo courtesy of GNS, New Zealand)

1.0 The IEA Geothermal Research and Technology Programme

IEA's efforts in geothermal energy began in 1978, with two 3-year long studies that were completed in 1981. Following a 16-year hiatus, the IEA Implementing Agreement for a Cooperative Programme on Geothermal Research and Technology, or Geothermal Implementing Agreement (GIA), was established on 7 March 1997, with an initial term of five years. By 2011, the GIA was in its 3rd 5-year term of operation, which continues to 28 February 2013.

The GIA provides a flexible framework for international cooperation in geothermal research and development by linking national and industry programmes for exploration, development and utilization of geothermal resources. Emphasis is on increasing effectiveness through establishing direct cooperative links among geothermal experts in the participating countries, industries and organizations. The general scope of the GIA's activities consist of international collaborative efforts to compile and exchange current and accurate information on global geothermal energy R&D, develop improved technologies for geothermal energy use, and improve the understanding of the environmental benefits of geothermal energy utilization and ways to avoid or minimize its environmental impacts. The GIA's activities are chiefly directed towards the coordination of national and industry geothermal programmes; with the provision of opportunities for members to participate in joint R&D projects and assist with the development of databases, models and handbooks; as well as chances for information exchange via meetings, workshops and networking; and provide an international perspective on geothermal issues.

The GIA's present efforts cover a range of geothermal topics from "conventional" power generation and direct use of heat, to cutting-edge technologies pertinent to enhanced geothermal systems (EGS), advanced geothermal drilling and logging techniques, sustainable utilization strategies, investigation into the causes and control of induced seismicity, and the collection of data and information and its dissemination on the Web. New studies are encouraged and implemented when needs are demonstrated.

As of December 2011, the IEA-GIA had 20 Members: 15 Contracting Parties from 14 countries: Australia, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Norway, the Republic of Korea, Spain, Switzerland, the United Kingdom, the United States, and the European Commission (EC); and five industry Sponsor Members: the Canadian Geothermal Energy Association, Geodynamics Limited, the Geothermal Group- Spanish Renewable Energy Association, Green Rock Energy Limited and ORMAT Technologies, Inc. See Table 1.1 for details.

1.1 Strategy and Objectives

Geothermal energy has huge global potential and its development can contribute significantly towards meeting the growing global renewable energy demand in both developed and developing countries, while helping alleviate the world's energy-climate dilemma. Globally, geothermal development continues its rapid growth phase, and to maintain this accelerated development, it is essential to improve and develop new technologies, reduce development costs, promote the benefits of sustainable geothermal utilization, and better educate the public, financial, and policy sectors.

The GIA's 3rd 5-year term began in April 2007 with these goals firmly in mind, aiming to use its extensive international cooperation to focus particularly on disseminating authoritative information; improving environmental outcomes; enhancing EGS prospects, including developing means to properly deal with induced seismicity; reducing drilling costs; promoting direct use applications; and encouraging long-term sustainable development strategies that will also contribute to the mitigation of climate change. To these ends, the IEA-GIA set its ***3rd Term (2007-2013) Mission (GIA, 2006a; 2011):***

To promote the sustainable utilization of geothermal energy throughout the world by improving existing and developing new technologies to render exploitable the vast and widespread global geothermal resources, by facilitating the transfer of know-how, by providing high quality information and by widely communicating geothermal energy's strategic, economic and environmental benefits, and thereby contribute to the mitigation of climate change.

To accomplish this mission, the GIA developed six ***Strategic Objectives:***

- To actively promote effective cooperation on geothermal RD&D through collaborative work programmes, workshops and seminars
- To collect, improve/develop and disseminate geothermal energy RD&D policy information for IEA Member and non-Member countries
- To identify geothermal energy RD&D issues and opportunities and improve conventional and develop new geothermal energy technologies and methods to deal with them
- To increase membership in the GIA
- To encourage collaboration with other international organizations and appropriate implementing agreements
- To broaden and increase the dissemination of information on geothermal energy and the GIA's activities and outputs to decision makers, financiers, researchers and the general public

1.2 Collaborative Activities

The GIA's programme operates through participation in *collaborative activities* called *Tasks*, which are specific studies included within broader *topic areas*, called *Annexes*. After approval by the ExCo, detailed descriptions of new Tasks, or of new Annexes, are appended to the IA (see Chapters 2-7). Each Annex, referred to by its annex number, is managed by an Operating Agent organization from one of the Member Countries or industry/organization Sponsor Members.

In 2011, participants worked in five broad research areas, specified in Annexes: I- Environmental Impacts of Geothermal Energy Development; III- Enhanced Geothermal Systems; VII- Advanced Geothermal Drilling Techniques; Annex VIII- Direct Use of Geothermal Energy and Annex XI- Induced Seismicity. In addition, a sixth annex, Annex X- Data Collection and Information, collects, compiles and analyzes Member country geothermal data and information.

Annexes I and III, initiated at the start of the GIA in 1997, have continued their activities throughout 2011; as have Annexes VII (started in 2001) and VIII (begun in 2003). Annexes X and XI were established in 2009. Annex V- Sustainability of Geothermal Energy Utilization has remained in draft form; however, a Sustainable Utilization Strategies Task E operates within Annex I. Annex VI- Geothermal Power Generation Cycles also remains in draft form.

A list of Annexes, Operating Agents, Annex Leaders, participants, and an indication of Annex status as of December 2010 are provided in Table 1.2. Complete descriptions of objectives, results for 2010 and work planned for 2011 for the active Annexes are presented in the Annex Reports included in Chapters 2-7. Brief summaries of the current draft and the closed Annexes are given in Table 1.3.

GIA Participants must take part in at least one Annex, with their involvement determined by their current interests, and research and development programmes. Not all Participants are necessarily active in all Tasks in those Annexes in which they participate. However, all GIA Country Members participate in Annex X since this annex deals with the collection and analysis of Member Country geothermal data. GIA Member Annex involvement is shown in Table 1.1.

To date, GIA Annexes have operated under the "task-sharing" mode of financing, whereby participants allocate specified resources and personnel to conduct their portion of the work at their own expense. Though precise figures are not available, the "costs" associated with the total Annex work conducted under the auspices of the GIA during the 2^{nd} Term were estimated to be well over US$ 310,000/yr plus several man-years (GIA, 2006b).

The GIA Secretariat was established in March 2003 to provide the ExCo with administrative and other assistance, as well as to assist with expanding its activities. It is funded through "cost-sharing", i.e., all Members contribute to a Common Fund according to the number of "shares" they have been allocated (see Section 1.4 for details).

The geothermal status, activities and achievements of each Member Country and a company and organization profile and description of activities for each Sponsor (industry/organization) Member are provided in the Country and Sponsor Reports in Chapters 8-21 and 22-26, respectively.

Further information about the GIA and its activities may be obtained by contacting the GIA Secretary at: mongillom@reap.org.nz or by visiting the GIA website: www.iea-gia.org.

Table 1.1 *Contracting Parties, Sponsors, funding sources and periods of operation for the Annexes active to the end of December 2011.*

Annex		I	III	VII	VIII	X	XI
Country/Industry	**Contracting Party/Sponsor**	**Environmental Impacts of Geothermal Development**	**Enhanced Geothermal Systems**	**Advanced Geothermal Drilling Techniques**	**Direct Use of Geothermal Energy**	**Geothermal Data and Information**	**Induced Seismicity**
Australia	Primary Industries & Resources-South Australia (PIRSA)	G	G	G		G	G
Canadian Geothermal Energy Association (CanGEA)	CanGEA, Canada		IO	IO	IO	IO	
European Commission (EC)	The Commission of the European Communities, Belgium		G	G		G	
France	Bureau de recherches géologiques et miniéres (BRGM)		G		G		
Geothermal Group of Spanish Renewable Energy Association (GG-APPA)	GG-APPA, Spain		IO		IO	IO	
Germany	Forschungszentrum Jülich GmbH		G			OA, G	G
Geodynamics	Geodynamics Limited, Australia		OA (to 09/11), I			I	
Green Rock Energy	Green Rock Energy Limited, Australia		I			I	
Iceland	Orkustofnun	G, I		G	OA, G	G	
Italy	ENEL Green Power	I	I			I	
Japan	National Institute of Advanced Industrial Science and Technology (AIST)	R	R		R	R	
Mexico	Instituto de Investigaciones Electricas (IIE)	G		G		G	
New Zealand	GNS Science	OA, R, I		I	R	R	R
Norway	Norwegian Science Research Council (NFR)		R, I	R, I	R	R	
ORMAT Technologies	ORMAT Technologies, Inc, United States		I			I	
Republic of Korea	Korea Institute of Geoscience & Mineral Resources (KIGAM)		R		R	R	R
Spain	Institute for Diversification and Saving Energy (IDAE)		G		G	G	
Switzerland	Swiss Federal Office of Energy	G	G		G	OA, G	G
United Kingdom	Department of Energy & Climate Change		R		R		
USA	United States Department of Energy (US DOE)	N	OA (from 09/11), N	OA, N	U	N	OA, N
Annex Start Date		1997	1997	2001	2003	2009	2010
Date Current Term of Annex Continues To		2013	2013	2013	2011	2013	2013
End Date*		Ongoing	Ongoing	Ongoing	Ongoing	Ongoing	Ongoing

G = Government; I = Industry; R = Research Institute (government funded); N = National Laboratory (government funded); U= University; IO=Industry Organization; OA = Operating Agent; * Ongoing means no fixed end date yet determined

Table 1.2 Annex Title, Operating Agent and Status of GIA Annexes at December 2011.

Annex Number	**Title** **Operating Agent (OA)** **Annex Leader (AL); Affiliation; Contact E-mail** **Participants**	Status
I	**Environmental Impacts of Geothermal Development** OA: GNS Science (GNS), New Zealand AL: Chris Bromley; GNS, New Zealand; c.bromley@gns.cri.nz Participants: Australia, EC, France, Iceland, Italy, Japan, Mexico, New Zealand, Switzerland, USA	Active since 1997, Continuing through 2013
II	Shallow Geothermal Resources	Closed
III	**Enhanced Geothermal Systems** OA: Geodynamics Limited, Australia, to September 2011; then US Department of Energy (DOE) ALs: Jay Nathwani; jay.nathwani@ee.doe.gov and Doone Wyborn; Doone.Wyborn@geodynamics.com Participants: Australia, CanGEA, EC, France, Geodynamics, Germany, GG-APPA, Green Rock Energy, Italy, Japan, Norway, ORMAT, Republic of Korea, Spain, Switzerland, UK, USA	Active since 1997, Continuing through 2013
IV	**Deep Geothermal Resources**	Closed September 2006
V	**Sustainability of Geothermal Energy Utilization**	Draft
VI	**Geothermal Power Generation Cycles**	Draft
VII	**Advanced Geothermal Drilling Techniques** OA: Sandia National Laboratories, for the US DOE, United States AL: Steven Bauer; Sandia National Laboratories, USA; sjbauer@sandia.gov Participants: Australia, CanGEA, EC, Iceland, Mexico, New Zealand, Norway, USA	Active since 2001, Continuing through 2013
VIII	**Direct Use of Geothermal Energy** OA: The Federation of Icelandic Energy and Waterworks, Iceland AL: Einar Gunnlaugsson; The Federation of Icelandic Energy and Waterworks, Iceland; einar.gunnlaugsson@or.is Participants: CanGEA, France, GG-APPA, Iceland, Japan, New Zealand, Norway, Republic of Korea, Spain, Switzerland, UK, USA	Active since 2003, Continuing through 2013
IX	**Geothermal Market Acceleration**	Closed
X	**Geothermal Data and Information** OA: Projekttraeger Juelich, PTJ EEN Germany; Geothermal Energy Research Program; Federal Office of Energy (BFE) AL: Britta Ganz, Leibniz Institute for Applied Geophysics, Germany; britta.ganz@liag-hannover.de Participants: Australia, CanGEA, EC, France, Geodynamics, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Norway, Republic of Korea, Spain, Switzerland, UK, USA	Opened 2009, Continuing through 2013
XI	**Induced Seismicity** OA: Lawrence Berkeley National Laboratory; United States AL: Ernie Majer; Lawrence Berkeley National Laboratory, USA; elmajer@lbl.gov Participants: Australia, France, Germany, Iceland, New Zealand, Republic of Korea, Switzerland, USA	Opened 2009, Continuing through 2013

Table 1.3 *Annex number, name, description and status for draft and completed Annexes as of December 2011.*

Annex Number	Title Description	Status
II	**Shallow Geothermal Resources** The GIA ExCo made the decision in October 2000 to close this Annex after it reached the draft stage. Its major topic, which was associated with the application of geothermal heat pumps, is now included in Annex VIII- Direct Use of Geothermal Energy, which was initiated in September 2003.	Closed
IV	**Deep Geothermal Resources** The GIA ExCo decided to close this Annex in September 2006 after the successful completion of much of its work, and because of the overlap of the remaining activities with those in Annexes III and VII. The unfinished studies were transferred to Annexes III and VII.	Closed September 2006
V	**Sustainability of Geothermal Energy Utilization** This proposed Annex would investigate alternative scenarios for energy production from representative geothermal resources with the goals of (1) defining methods and requirements for sustaining production from these resources, and (2) of estimating the long-term economic sustainability of such production not only for representative resources but for the worldwide geothermal resource as a whole. The issue of "sustainable" energy production has grown in recognition and importance over the past few years. Consequently, during 2006, the GIA ExCo made a preliminary decision to initiate a sustainability Task in Annex I. However, if activities expand in the future, it is possible that this Annex would be activated.	Draft
VI	**Geothermal Power Generation Cycles** This proposed Annex would develop scenarios as a basis for comparison of cycles, plant performance and availability, economics and environmental impact and mitigation. The output would be a database and guidelines of best practice. A draft of this Annex was prepared in 2001, and may be revised if interest in the topic grows.	Draft
IX	**Geothermal Market Acceleration** Geothermal electricity production and direct heat use are well developed and economically viable in many parts of the world, however, there are large untapped resources in many countries. The ExCo explored ways to hasten geothermal energy development, or market acceleration, in these countries during the last few years, and decided that a more pro-active approach was needed, possibly including: identifying a few regions with high geothermal potential, collating resource assessments on a few sites and discussing with key players (government, utilities, developers, financiers, *etc.*) the barriers to progress in their regions. Consequently, this market acceleration Annex was drafted. In October 2004, following the IEA's decision to initiate its own market acceleration type of IA, the ExCo made the unanimous decision to close this Annex.	Closed

1.3 Structure of the GIA

The GIA is managed by an Executive Committee (ExCo), which consists of one Member and one Alternate Member designated by each Contracting Party and each Sponsor. There is currently one Contracting Party for each GIA country member, which is a government department or agency, or independent company (industry). The ExCo meets twice each year, in spring and autumn, to exchange information, discuss activities and review progress of the organization as a whole, and in each of the Annexes, participating countries, industries and organizations; and to plan future activities of the organization. Non-financial decisions are made by majority vote (unless otherwise specified in the Implementing Agreement), with financial decisions requiring a ***unanimous*** vote; with each Contracting Party and each Sponsor allowed one vote. In 2002, the GIA ExCo decided to increase its scope of activities, and as a result, created a dedicated Secretariat, which began operations in March 2003, and is funded by a cost-shared Common Fund.

GIA research and activity results are extensively disseminated through participation at international geothermal and renewable energy conferences and workshops, and publication in scientific and technical journals, conference proceedings and in the GIA's Annual Reports and Executive Summaries. In addition, information is made widely available on the GIA's public website (www.iea-gia.org), through promotional material produced by the GIA Secretariat, and via IEA publications and workshops, and the IEA website (www.iea.org).

In 2011, 14 countries, the EC, two international organizations and three industries formally participated in this programme (Table 1.1). One of GIA's five Sponsor Members, ORME Jeotermal, was withdrawn.

1.4 The Executive Committee

Officers

In 2011, Chris Bromley (New Zealand) was re-elected Chairman; Barry Goldstein (Australia) was elected to serve as Vice-Chair for Policy, and Jonas Ketilsson (Iceland) was elected as Vice-Chair for Administration. The ExCo also decided to initiate a third Vice-Chair position, and Yoonho Song (Republic of Korea) was elected to it.

Membership

There were significant changes in the composition of the GIA ExCo in 2011: Tae Jong Lee replaced Hyoung Chan Kim as Alternate Member for the Republic of Korea; Alexander Richter was appointed as Alternate Member for CanGEA; Delton Chen resigned as Alternate Member for Geodynamics leaving the position vacant; Ruggero Bertani replaced Paolo Romagnoli as Alternate Member for Italy, Paolo Romagnoli replaced Guido Cappetti as ExCo Member for Italy; Naoki Kumazaki replaced Akihiro Takaki as Alternate Member for Japan; Jane Nilsen Aalhus replaced Pål Edvard Andersen as Alternate for Norway; and Alexandra Pressman resigned as USA Alternate Member leaving a vacancy for the position.

The list of ExCo Members and Alternates as at December 2011 is provided in Appendix C.

ExCo Meetings

The ExCo held two Meetings in 2011 to discuss and review the GIA's efforts and plan future activities.

25th ExCo Meeting, 5-6 May 2011, Paris, France

The 25th ExCo Meeting was held on 5-6 May 2011, at the IEA Headquarters, Paris, France. There were 23 attendees in total, including nine ExCo Members, three Alternate Members and 11 Observers, including three representatives from the IEA and the GIA Secretary (see photo in Appendix A). Since only nine voting Members attended the meeting, the quorum of 10 voting

Members was not met; consequently, business decisions had to be confirmed by e-mail vote following the meeting.

Paolo Frankl, Head of the IEA Renewable Energy Division, welcomed GIA participants and stated that the RE Division valued the GIA's activities, and appreciated its recent assistance with preparation of the IEA Essentials Geothermal brochure and the Geothermal Roadmap, and thanked the GIA for its financial contribution toward production of the Roadmap. He was keen on expanding GIA collaboration, and was especially happy with GIA's improved ability to provide up-to-date geothermal data through Annex X.

The large size of the GIA's annual reports was discussed, and the idea of reducing it by shifting much of the production and use data to the new annual Annex X GIA Trend Report was debated.

Annexes I, III, VII and X held meetings on 4 May 2011; with Annex XI (Induced Seismicity) meeting jointly with the IPGT Induced Seismicity Group for an all-day session on 3 May 2011. Progress reports from all six Annexes: I, III, VII, VIII, X and XI, and 9 Countries were presented and discussed. The Annex X questionnaire for collecting data/information to be used to prepare the first (2010) GIA Trend Report was discussed. The current form of the GIA website, first created in 2005, was considered with the ExCo decision made to support its re-development. The ExCo also discussed the *EGS Protocol* as presented in the May 2011 paper: ***A Protocol for Estimating and Mapping Global EGS Potential*** (Beardsmore, Rybach, Blackwell and Baron) and decided to call an e-mail vote on its GIA endorsement, thus allowing its consideration by all ExCo Members. The Protocol was accepted on 9 September 2011.

The Secretary reported on the Secretariat operation, including the work accomplished and status of budgets, for the entire 2010-year and the 2011-year to 20 April 2011. A work plan and revised budget for the remainder of 2011 was presented and an update on the Common Fund given, all unanimously accepted by the ExCo. Estimates indicated that GIA's excellent financial position would continue and allow a carry-over of the agreed 125% of the current year's estimated GIA Secretariat operations cost to the next financial (calendar) year, as well as make up to US$ 50 k available to fund proposals for work that supports supplementary organization and Annex activities. The Secretary informed that the GIA Mid-term Report presented to the REWP meeting in Paris, in March 2011, had been accepted with no comments. He also reported that the revised GIA Implementing Agreement document had been unanimously accepted by the ExCo in February 2011.

Takatsune Ito presented the IEA Secretariat report which reviewed IEA's recent activities and publications. The IEA's recent procedural changes and submission dates for IA requests for extension were described, noting that the GIA's End-of-Term Report and new Strategic Plan would be due in early-July 2012, with presentation to REWP meeting in October 2012. The new publications: ***Deploying Renewables: Worldwide Prospects and Challenges*** and ***Harnessing Variable Renewables*** were described, and the IEA's Renewable Energy Roadmaps and Renewable Energy Essentials brochures, including the GIA's ***Geothermal Essentials***, were reviewed. The value of the ***IEA OPEN Bulletin*** was described, noting that it had >15,000 subscribers in 127 countries. In addition, Milou Beerepoot, IEA analyst, gave a Guest presentation, in which she described the IEA Geothermal Roadmap to the meeting and informed that it would be launched by the IEA Executive Director, Mr Tanaka, at the Eurelectric Conference, Stockholm, on 13 June 2011.

The ExCo was invited to hold its Annex and 26th ExCo Meetings in London, United Kingdom, on 28-30 September 2011, in association with the First UK Geothermal Symposium (27 September 2011), with a fieldtrip (1 October 2011) to EGS sites and the Eden Project in Cornwall. EGS Energy will host the meetings, Symposium and fieldtrip.

26th ExCo Meeting London, 29-30 September 2011, United Kingdom

The 26th ExCo Meeting was hosted by EGS Energy, and held at the Royal Institution of Great Britain, London, UK, on 29-30 September 2011, in association with the First UK Geothermal Symposium on *Engineered Geothermal System Energy in the UK and a Global Perspective*.

Twenty-three people attended the ExCo Meeting, including: 11 ExCo Members, five Alternate Members, the GIA Secretary and six Observers. Included amongst the latter was the Minister for the Department of Energy & Climate Change (DECC), Mr Greg Barker, who attended partly in recognition of the United Kingdom's very recent membership in the GIA, and who discussed the UK Government's commitment to renewable and geothermal energy. EGS Energy also hosted a fieldtrip to Cornwall, where EGS Energy's deep well site, the historic Rosemanowes EGS site and the Eden Project were visited. The United Kingdom participated for the first time since re-joining the GIA in September 2011 (having withdrawn from the GIA in 2003).

Six GIA ExCo Members also participated in the *Engineered Geothermal System Energy in the UK and a Global Perspective* seminar covering global geothermal potential, and EGS development in the UK, USA, Germany, Australia, France and South Korea.

Annexes I, III, VII and X held meetings on 28 September 2011. The US DOE replaced Geodynamics as the Operating Agent of Annex III.

Progress reports from Annexes I, III, VII and X, and 12 Country reports and one Sponsor report were presented and discussed. The ExCo agreed to fund the GIA website update; and options for encouraging new GIA membership such as holding workshops/seminars in countries of interest and GIA Member sponsorship of the Common Fund contribution of less financially capable countries were considered.

The Secretary reviewed Secretariat activities since the 25th ExCo Meeting and submitted work plans and budgets for the remainder of 2011, a Common Fund report, and draft Work Plan and associated budget for 2012; all were unanimously accepted by the ExCo. The Secretary participated with the Chair as international members of the US DOE Geothermal Technologies Program Peer Review in June 2011, with financial support obtained through a GIA proposal.

The GIA's financial position remains very strong, and an estimated US$ 46 k funding remained available in the GIA Common Fund for new proposals supporting GIA/Annex-related activities. A proposal for funding GIA participation at the US DOE Peer Review (mentioned above) was the only 2011 proposal funded to date.

The ExCo voted unanimously to hold annual ExCo Officer Elections at the autumn ExCo meetings, with those elected taking office the following calendar year. It was also decided that individuals could only hold office for three consecutive terms, beginning with autumn 2012 elections.

The ExCo Chair presented the IEA Secretariat report, describing several IEA activities and projects. The 59th REWP Meeting was held in March 2011, where the GIA Secretary presented the GIA Mid-Term Report; and the IEA's procedure and schedule for GIA's request for extension for a 4th Term were discussed. It was reported that data on global RE policies and measures are collected by the IEA and made available in their website; and the IEA OPEN Bulletin web-based newsletter was discussed.

The ExCo had earlier agreed to hold the 27th ExCo and Annex Meetings, and associated events in Oslo, Norway, during the Oslo Geothermal Week period 21-26 May 2012, hosted by Statoil and IFE.

1.5 GIA Participation in IEA Activities in 2011

The GIA continued an active involvement with the IEA in 2011. The GIA Secretary attended the REWP Renewable Energy from Analysis to Action conference, held in Paris, France, on 15-16 March 2011; and presented the GIA's Mid-3rd-Term Report to the 59th REWP Meeting on 17 March 2011 (Mongillo and Bromley, 2011a). The GIA also participated at the IEA Energy Technology Network Communication and the REWP Renewables Policy and Market Design Challenges Workshops. Subsequent to providing significant direct input in 2010, the GIA contributed final comments on the ***IEA Technology Roadmap for Geothermal Heat and Power***, which was published in June 2011, and a summary presented by the Chair, on behalf of the IEA-GIA, in Melbourne, Australia (Bromley and Beerepoot, 2011).

1.6 Other GIA Activities

The GIA Secretary and Chair participated as international experts for the week-long US DOE Peer Review Meeting in early-June 2011, with 19 geothermal projects reviewed between them. In addition, the Chair gave a lunch-time presentation during the Peer Review: (Bromley, 2011a) and the Secretary a lunch-time presentation at the IPGT Meeting (Mongillo and Bromley, 2011b).

The GIA took part in several international meetings and workshops in 2011, including:

- The *EGS Energy in the UK and a Global Perspective Seminar*, London, UK, in September 2011, with presentations by six GIA ExCo Members and an Annex III participant on EGS development in the USA (Jay Nathwani), Germany (Lothar Wissing), Australia (Barry Goldstein), France (Romain Vernier) and South Korea (Yoonho Song); Geothermal and EGS Potential Worldwide (Chris Bromley); and Scaling-up, Sustainability and Industrial Partnership (Roy Baria, Annex III)
- The *36th Stanford Geothermal Reservoir Workshop*, held in early-February 2011 in Stanford, California, USA, covering great expectations for geothermal energy to the end of this century (Goldstein et al., 2011a) and real-time monitoring at EGS system sites (Nathwani et al., 2011)
- The *Geothermal Resources Council (GRC) 2011 Annual Meeting*, San Diego, California, USA, describing the contribution that sustainable geothermal energy development could make to the global energy demand for heat and power (Goldstein et al., 2011c)
- The *IEA-GIA~IPGT Induced Seismicity Workshop*, Paris, France (Bromley, 2011b; Muraoka and Takaki, 2011); the IEA-GIA~IPGT Meeting, Melbourne, Australia (Majer, 2011).

The ***IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation*** was published in May 2011, having had input to ***Chapter 4 Geothermal Energy*** from four GIA ExCo Members and the Secretary who contributed as Lead Authors, Contributing Authors, Reviewers and Coordinating Lead Author (Goldstein et al., 2011b).

The continued excellent financial position of the GIA has allowed the organization to continue expanding its efforts through its proposal funding mechanism, which in 2011 supported GIA participation at the US DOE Geothermal Program Peer Review in June 2011.

The GIA's public website (**www.iea-gia.org**) remains an important source for information dissemination and discussion.

1.7 Costs of the Agreement

The IEA-GIA Secretariat is currently situated in New Zealand. It is operated by a part-time Secretary, who handles the administration, assists with the management of the organization and provides a major part of the information dissemination, including the preparation of GIA documents and publications, the GIA annual reports and maintenance of the GIA website.

The expenses for operating the GIA Secretariat, including the Secretary's salary and travel, website hosting and maintenance, and other common costs of the ExCo, are met from a GIA Common Fund. In 2011, these costs amounted to a total of about US$ 108,000. In addition, the GIA funded several projects and proposals:

- GIA Projects (total: ~US$ 9,000): contributed to costs associated with Secretary's presentation of GIA's Mid-3rd Term Report to the REWP, Paris, France; Chair's presentation of the IEA Geothermal Roadmap at the AGC Meeting, Melbourne, Australia; and purchase of ***Geothermics Special Issue on Sustainable Utilization of Geothermal Energy*** (Guest editors M.A. Mongillo and G. Axelsson, December 2010) for ExCo Members.

- Proposal Funding (total: US$ 20,000): funded proposal contributions for the Chairs and Secretary to participate as international experts at the US DOE Geothermal Technologies Program Peer Review, and paid 2010 proposal for the GIA contribution to the Induced Seismicity Workshop held in Reykjavik, Iceland, in 2010.

Consequently, the total costs of GIA operations in 2011 amounted to about US$ 137,000.

Table 1.4 *Common fund share apportionment among the GIA Members as of December 2011.*

Australia	2	Republic of Korea	2
European Commission	4	Spain	2
France	4	Switzerland	2
Germany	4	United States	4
Iceland	1	CanGEA	1
Italy	2	Geodynamics	1
Japan	4	GG-APPA	1
Mexico	1	Green Rock Energy	1
New Zealand	1	ORMAT	2
Norway	2	-	-
Total = 41 shares			

The Common Fund is supported through cost-sharing, with each GIA Member paying an annual contribution based upon a fair apportionment in the form of an allocated number of shares.

The number of shares assigned to each new Member is determined by the unanimous agreement of the ExCo. The apportionment for the current GIA Membership is shown in Table 1.4. In 2011, the Common Fund was administered by a Custodian, the National Renewable Energy Laboratory (NREL), based in Golden, Colorado, USA, who also conducted an annual review of its financial operations.

The cost per Common Fund share, set by unanimous ExCo decision, was US$ 3,500/yr in 2011. Contributions are made annually on a calendar year basis.

1.8 References

Bromley, C.J. (2011a) "International cooperation to promote global sustainable geothermal development and mitigate climate change". Invited presentation for participants of the US DOE Geothermal Technology Programme Review, 6 June, 2011; Bethesda Marriott North Hotel, Washington DC, USA.

Bromley, C.J. (2011b) Induced seismicity in geothermal developments of New Zealand. IEA-GIA~IPGT Annex XI Workshop, 3 May 2011 Paris, France.

Bromley, C.J., M. Beerepoot, 2011, "Global Geothermal Deployment – the IEA Roadmap for the Future", Proc. 2011 Australian Geothermal Energy Conference, 16-18th Nov. 2011, Geoscience Australia Record 2011/43 Geocat#73026, Keynote Address and extended abstract, 2p.

GIA (2006a) IEA-GIA Strategic Plan 2007-2012, 9 November 2006, 23 p.

GIA (2006b) IEA-GIA End-of-Term Report 2002-2007, 30 October 2006, 36 p.

GIA (2011) The 3rd Term of the IEA-GIA was extended to 28 February 2013 at the request of the IEA CERT.

Goldstein, B.A., Hiriart,G., Tester, J.W., Bertani, R., Bromley, C.J., Gutiérrez-Negrín, L.C., Huenges, E., Ragnarsson, A., Mongillo, M.A., Muraoka, H., Zui, V.I. (2011a) Great expectations for geothermal energy to 2100. Proceedings 36th Workshop on Geothermal Reservoir Engineering, Stanford University, California, Jan.31–Feb.2, 2011. SGP-TR-191, p5-12.

Goldstein, B.A.; Hiriart, G.L.; Bertani, R.; Bromley, C.J.; Gutierrez-Negrin, L.; Huenges, E.; Muraoka, H.; Ragnarsson, A.; Tester, J.W.; Zui, V.I. (2011b) Geothermal energy. Chapter 4 (50 p.) In: Edenhofer, O.; Pichs-Madruga, R.; Sokona, Y.; Seyboth, K.; Matschoss, P.; Kadner, S.; Zwickel, T.; Eickemeier, P.; Hansen, G.; Schloemer, S.; von Stechow, C. (Eds.) IPCC special report on renewable energy sources and climate change mitigation.

Goldstein, B.A., Hiriart, G., Tester, J.W. , Bertani, R., Bromley, C.J., Gutiérrez-Negrín, L.C., Huenges, E., Ragnarsson, A., Mongillo, M.A., Muraoka, H., Zui, V.I. (2011c) Great expectations for geothermal energy to 2100- messages for now. Proc. 2011 GRC Annual Meeting, San Diego, USA, 23-26 October 2011.

Majer, E.L. (2011) Induced seismicity associated with EGS issues, status, challenges, needs. Australian Geothermal Meeting, Melbourne, Australia, 17 November 2011.

Mongillo, M.A., Bromley, C.J. (2011a) IEA Implementing Agreement on Geothermal Energy mid-3rd Term Review. Presentation at 59th REWP Meeting, Paris, France, 17 March 2011.

Mongillo, M.A., Bromley, C.J. (2011b) IEA-GIA International Cooperation for Sustainable Geothermal Utilization. IPGT Induced Seismicity Workshop, 10 June 2011, Bethesda, Maryland, USA.

Muraoka, H., Takaki, A. (2011) Overview on induced seismicity in Japan. IEA-GIA~IPGT Annex XI Workshop, 3 May 2011 Paris, France.

Nathwani, J., Majer E. L., Boyle, K, Rock, D., Peterson, J.E., Jarpe, S.E. (2011) DOE Real time seismic monitoring at enhanced geothermal system sites. Proceedings Thirty-Sixth Workshop on Geothermal Reservoir Engineering. Stanford, University, Stanford, California, 31 January-2 February 2011.

IEA Geothermal R & D Programme

Chapter 2

Annex I- Environmental Impacts of Geothermal Energy Development

Figure 2.1 *Historic Great Wairakei Geyser (dormant since 1960's), Wairakei Thermal Valley, Taupo, New Zealand.*
(Photo courtesy of Chris Bromley)

2.0 Introduction

Geothermal is, in general, an environmentally-benign renewable energy source, with some significant benefits relative to fossil fuels regarding global carbon-dioxide emissions. There are, however, some local environmental problems sometimes associated with geothermal utilization. To facilitate increased use of geothermal energy, it is important to identify possible adverse and beneficial environmental effects, and devise and adopt measures to avoid or minimize adverse impacts, while reinforcing those effects that are beneficial.

The goals of Annex I of the IEA-GIA are: to encourage the sustainable development of geothermal energy resources in an economic and environmentally responsible manner; to quantify and balance any adverse and beneficial impacts that geothermal energy development may have on the environment, and to identify ways of avoiding, remedying or mitigating any adverse effects.

Participating countries in Annex I are: Australia, Iceland, Italy, Japan, New Zealand, Switzerland and the United States.

GNS Science, Wairakei Research Centre, New Zealand, is the Operating Agent. Chris Bromley, of GNS Science, is the Annex Leader.

2.1 Tasks of Annex I

In 2011, Annex I activities consisted of five Tasks, described below.

2.1.1 Task A - Impacts on Natural Features

(Task Leader: Chris Bromley, GNS Science, New Zealand)
(Participants: Iceland, USA, Japan, Italy, New Zealand)

Natural geothermal features such as geysers, hot springs and fumaroles, often have significant economic value for tourism and cultural value for indigenous peoples. They should be monitored and changes documented. Techniques are devised to separate natural from induced changes. Where such changes are caused by geothermal developments, methods are devised to avoid or mitigate the adverse impacts. Beneficial changes are identified and promoted.

2.1.2 Task B - Discharge and Reinjection Problems

(Task Leader: Robert Reeves, GNS Science, New Zealand)
(Participants: Iceland, USA, Japan, Italy, New Zealand)

Adverse impacts of geothermal developments on the environment include the effects on air quality of gas emissions from geothermal power plants; the effects of toxic chemicals in waste fluid that may be discharged into the ground or into rivers; and the effects of ground subsidence resulting from pressure decline. Projects examine the problems associated with disposal of waste geothermal fluids (e.g., arsenic and boron) and the effects of gas emissions, (e.g., CO2, Hg and H2S), along with mechanisms and mitigation options. Examples are the use of injection to mitigate ground subsidence, and chemical treatment, removal or re-injection of gas emissions and waste fluids.

Figure 2.2 *Exposed reinjection pipelines, Philippines.*
(Photo courtesy of GNS Science)

2.1.3 Task C - Methods of Impact Mitigation and Environmental Procedures

(Task Leader: Chris Bromley, GNS Science, New Zealand)
(Participants: Australia, Iceland, Italy, Japan, New Zealand, Switzerland, USA)

An effective environmental analysis process reduces the risks of adverse effects from development, by early identification and mitigation of environmental issues. Reducing the costs of environmental compliance, and stream-lining the process for project consenting, also help contribute to the responsible and timely deployment of future geothermal energy projects. The objective is to identify and publicize strategies that result in improved environmental outcomes from field management. Successful mitigation schemes are also identified, documented and publicized. Such strategies provide developers and regulators with options for the compensation of unavoidable effects. Comparison of policies and compliance procedures helps identify those that are efficient and effective.

2.1.4 Task E - Sustainable Utilization Strategies

(Task Leader: Guðni Axelsson, Iceland Geological Survey (ISOR), Iceland)
(Participants: Australia, USA, Iceland, Italy, Japan, Switzerland, New Zealand)

Case histories of reservoir models of geothermal developments are studied to see what strategies have been successful. Additional modelling of long term reservoir behaviour is undertaken to select optimum future strategies given different recharge and resource size scenarios. Different sustainable development scenarios are compared to determine relative environmental and economic benefits. Different conceptual and hypothetical reservoir model predictions are compared using long-term scenarios. Long-term reservoir behaviour, recharge factors, recovery times, and optimised cyclic or staged operation strategies are investigated.

2.2 Progress in 2011

Several participants in Annex 1 (Chris Bromley, New Zealand; Barry Goldstein, Australia; Hirofumi Muraoka, Japan; and Ruggero Bertani, Italy), along with other geothermal specialists from the IEA-GIA participating countries (Mexico, USA, Iceland, and Germany) completed the geothermal energy chapter of the Intergovernmental Panel on Climate Change (IPCC) Special Report on Renewable Sources (SRREN) which involved a voluntary contribution over 3 years by all the participants. The final version of the report was published in 2011 (IPCC 2011 Geothermal Chapter). Supplementary publications derived from this work were also presented at geothermal meetings at Stanford (Stanford Workshop on Geothermal Reservoir Engineering) and San Diego (Geothermal Resources Council [GRC]). Further work in the area of global sustainable geothermal deployment potential led to provision of advice regarding the completion of the IEA Geothermal Road Map, and its subsequent promotion.

2.2.1 Task A- Impacts on Natural Features

Meetings of task participants were held in Paris, (6 May 2011) and London (26 September 2011). Presentations covered aspects of on-going work on changes observed at thermal features caused by geothermal developments. Strategies to mitigate, recover or enhance thermal features using targeted injection and strategic production were further discussed, along with policies to help monitor and manage effects on thermal features in a practical manner. Results of work focussed on improved monitoring techniques for surface thermal features were presented in papers and presentations at two international conferences in San Francisco. These described ways of identifying and monitoring surface feature changes, heat flux changes and thermally tolerant vegetation.
Discussions also addressed the issues faced by Japan with its significant geothermal resource potential located within protected National Parks and near iconic hot spring resorts. The focus of future collaborative work is expected to be on how to undertake development in such settings with negligible environmental risks to thermal habitats, thermal features and landscape values.

Figure 2.3 ***a)*** *Hot spring & thermal algae (with forest fire) at Yellowstone (USA);*
b) *Steaming ground at Reykjanes, Iceland.*
(Photos courtesy of Chris Bromley)

2.2.2 Task B- Discharge and Reinjection Problems

At the Annex 1 meetings in Paris and London environmental issues related to discharge and injection were discussed. These included improved water management. Best practice injection strategies, including scaling treatment and avoidance, methods of reduction of CO_2 emissions by injection, and arsenic reduction through silica precipitation were further discussed. Injection/production management tools using an adaptive approach to reverse or avoid adverse effects on surface features and on reservoir sustainability were also addressed. The importance of improved understanding of reservoir permeability, through tracer test interpretation, and the consequences of subsurface boiling and condensation processes was stressed. Research into the transient behaviour of fluid-rock-gas interactions was further advanced to better explain scaling, dissolution, deposition and acid alteration processes.

Discussions also addressed the mechanisms for subsidence and ground inflation in geothermal fields. Methods to better detect anomalies and predictive modelling tools using coupled reservoir and subsidence models are advancing. Collaboration between research organisations who work into these and related topics (particularly improvement of coupled simulation models), is becoming better established through joint workshops.

A strong focus of the Task B work in 2011 was on the mechanisms of geothermal subsidence using New Zealand case histories. Research results from this work, were published at international geothermal workshops in New Zealand and USA.

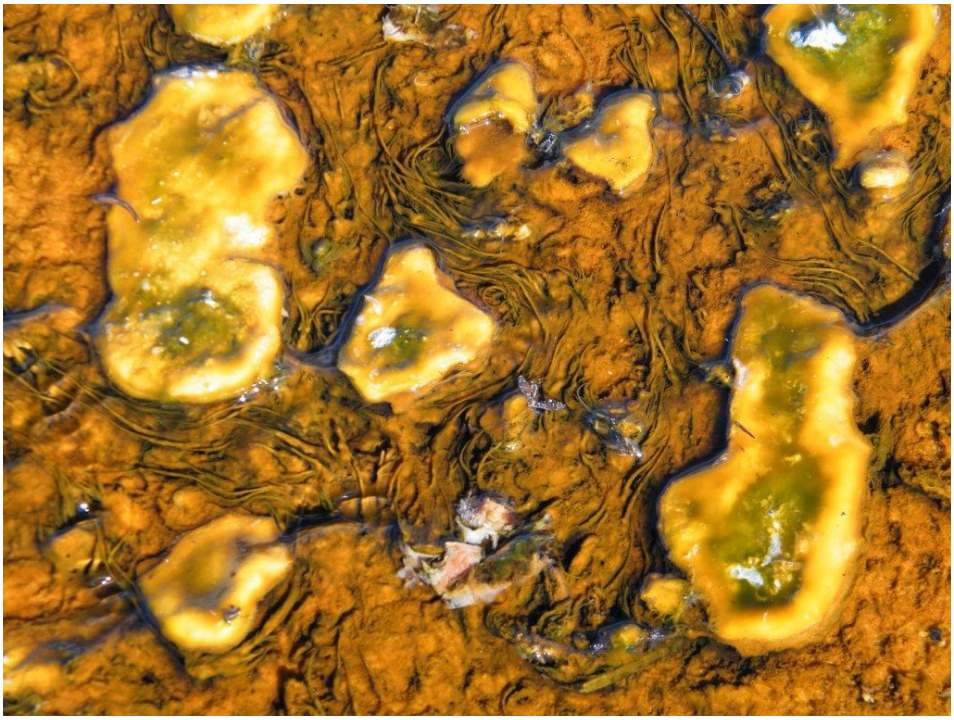


Figure 2.4 *Geothermal habitat with extremophile micro-organisms (Yellowstone, USA). (Photo courtesy of Chris Bromley)*

2.2.3 Task C- Methods of Impact mitigation and Environmental Procedures

Geothermal policy and best-practice planning guidelines were discussed at the Annex meetings. Examples of successful mitigation strategies were collated. Barriers to accelerated development, such as concerted lobbying against large scale power development by hot spring associations, land access constraints imposed by National Park status in remote volcanic settings, and water allocation in arid areas, were debated.

Discussion included integration of social and economic 'sustainability assessment protocol' issues with environmental impact assessment risk issues.

A new initiative focused on setting up a set of standard procedures or protocols for ranking the significance of geothermal features and geothermal fields, in order to assist policymakers in making choices regarding issuing consents for developments of various sizes. Early work has been published using New Zealand case histories. Expansion to other regions is being contemplated.

2.2.4 Task D- Seismic Risk from Fluid Injection into Geothermal Systems

During the October 2010 IEA-GIA ExCo meeting, it was agreed that induced seismicity work was of sufficient importance to warrant it being transferred to a new Annex (Annex XI) where it was combined with the induced seismicity work undertaken under Annex III (EGS). Hence, from 2011 onwards, Task D is no longer active in Annex I.

2.2.5 Task E- Sustainable Utilization Strategies

Reservoir modelling issues concerning long term sustainability and reservoir performance were discussed at 2011 Annex meetings along with incorporation into sustainability the concepts of economic and social factors.

Resources that are depleted in pressure and temperature are considered to be recoverable (i.e., renewable) over time frames that are dependent on the recharge permeability. Additional issues include: how to improve resource assessments through better capacity and recovery factors; when to recommend a staged development strategy to reduce risks; and the importance of planned make-up drilling. Highlights of the work are posted on the IEA-GIA website. This includes a reference list on the topic of geothermal sustainability. 2011 publications on this topic included papers by a range of authors from participating countries and were presented at workshops in San Diego (GRC), California (Stanford), and Melbourne (Australia).

Figure 2.5 *Steaming ground at Larderello, Italy.*
(Photo courtesy of Chris Bromley)

2.3 Highlights and Achievements of Annex I for 2011

The highlights for the 2011-year were:

- Papers were presented by Annex participants and their work colleagues on environmental research, improved environmental sustainability strategies and monitoring methods at the 2011 New Zealand Geothermal Workshop, the 2011 Stanford Geothermal Reservoir Workshop, the 2011 Australian Geothermal Energy Conference, and the 2011 Geothermal Resources Council Conference in San Diego, US.

- Participants helped promote global sustainable geothermal development and mitigation of climate change, through presentations at a variety of venues, including Washington DC, Melbourne and London.

- Several Annex I participants published joint papers and a geothermal chapter for the IPCC SRREN report on the topic of mitigation of climate change through increased deployment and utilisation of renewable geothermal energy resources.

- Annex participants took part in technical collaborative meetings at Paris (May 2011) and London (September 2011), where improved methods of monitoring, avoiding or mitigating environmental effects, such as subsidence, gas and heat emissions, were further developed and possible new initiatives discussed.

- New collaboration between members was initiated in the areas of: satellite infrared monitoring tools, protection of hot springs from effects of potential development beneath parks, documentation of thermal micro-biology habitats (extremophiles), and establishment of protocols to rank systems and features for possible protection status.

2.4 Outputs for 2011

2.4.1 Papers Published and Presentations by IEA-GIA Participants on Environmentally Sound and Sustainable Development

Bromley, C.J. (2011) International cooperation to promote global sustainable geothermal development and mitigate climate change. Invited presentation for participants of the US DOE Geothermal Technology Programme Review, 6 June, 2011; Bethesda Marriott North Hotel, Washington DC, USA.

Bromley, C.J., M. Beerepoot (2011) Global Geothermal Deployment – the IEA Roadmap for the Future. Proc. 2011 Australian Geothermal Energy Conference, 16-18 Nov. 2011, Melbourne, Geoscience Australia Record 2011/43 Geocat#73026, Keynote Address and extended abstract, 2 p.

Bromley, C.J. (2011) Geothermal environmental issues: sustainability, mitigation and avoidance strategies, geochemical problems, thermal feature monitoring. Presentations at Annex 1 meetings of IEA-GIA in Paris, 5 May 2011 and London, 29 September 2011.

Mongillo, M.A. (2011) International cooperation for sustainable geothermal utilization. Presentation at International Partnership for Geothermal Technology Meeting, Bethesda, Washington DC, USA, 10 June 2011.

2.4.2 IEA-GIA Participation at IPCC SRREN for Global Climate Change Mitigation (five collaborating IEA-GIA co-authors)

Goldstein, B.A.; Hiriart, G.L.; Bertani, R.; Bromley, C.J.; Gutierrez-Negrin, L.; Huenges, E.; Muraoka, H.; Ragnarsson, A.; Tester, J.W.; Zui, V.I. (2011) Geothermal Energy. Chapter 4 (50 p.) In: Edenhofer, O.; Pichs-Madruga, R.; Sokona, Y.; Seyboth, K.; Matschoss, P.; Kadner, S.; Zwickel, T.; Eickemeier, P.; Hansen, G.; Schloemer, S.; von Stechow, C. (Eds.) IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation.

Goldstein, B.A., Hiriart,G., Tester, J.W., Bertani, R., Bromley, C.J., Gutiérrez-Negrín, L.C., Huenges, E., Ragnarsson, A., Mongillo, M.A., Muraoka, H., Zui, V.I. (2011) Great expectations for geothermal energy to 2100. Proc. 36th Workshop on Geothermal Reservoir Engineering, Stanford University, California, 31 January–2 February 2011. SGP-TR-191, 5-12.

Goldstein, B.A., Hiriart, G., Tester, J.W., Bertani, R., Bromley, C.J., Gutiérrez-Negrín, L.C., Huenges, E., Ragnarsson, A., Mongillo, M.A., Muraoka, H., Zui, V.I. (2011) Great expectations for geothermal energy to 2100- messages for now. Proc. 2011 GRC Annual Meeting, San Diego, USA, 23-26 October 2011.

2.4.3 Additional Environmental Publications Relevant to Task A

Bromley C.J.; S.M. van Manen, Graham, D. (2011) Monitoring surface geothermal systems using time series of aerial- and ground-based photographs. Poster and abstract submitted to AGU, 13-17 December 2010, San Francisco, California, USA. Paper IN 33B-1308.

Bromley, C.J., van Manen, S.M., Mannington, W. (2011) Heat flux from steaming ground: reducing uncertainties. Proc. 36th Workshop on Geothermal Reservoir Engineering, Stanford University, California, 31 January-2 February 2011. SGP-TR-191, 925-931.

2.4.4 Additional Environmental Publications Relevant to Task B

Brockbank, K.; Bromley, C.J., Glynn-Morris, T. (2011) Overview of the Wairakei-Tauhara subsidence investigation." Proc. 36th Workshop on Geothermal Reservoir Engineering, Stanford University, California, 31 January-2 February 2011. SGP-TR-191, 68-74.

Powell, T. (2011) Natural subsidence at the Rotokawa geothermal Field and implications for permeability development. Proc. 33rd New Zealand Geothermal Workshop, University of Auckland, paper #15, 4 p.

Ramsay, G., Glynn-Morris, T., Pender, M., Griffiths, M. (2011) Geotechnical investigations of subsidence in the Wairakei-Tauhara Geothermal Field. Proc. 33rd New Zealand Geothermal Workshop, University of Auckland, paper #49, 4 p.

2.4.5 Additional environmental publications relevant to Task C

Bromley, C.J. (2011) Suggested criteria for geothermal feature ranking and geothermal system categorization. Proc. 33rd New Zealand Geothermal Workshop, 21-23 November 2011, University of Auckland, Submission #90, 7 p.

2.4.6 Additional Environmental Publications Relevant to Task E

Axelsson, G. (2011) Using long case histories to study hydrothermal renewability and sustainable utilization. Trans. Geothermal Resources Council, Vol. 35., 1393-1400, ISSN 0193-5933, ISBN 0-934412-96-0.

Satman, A. (2011) Sustainability of geothermal doublets. Proc. 36th Workshop on Geothermal Reservoir Engineering, Stanford University, 31 January-2 February 2011, 9 p.

Sutter, D., Fox, D., Anderson, B., Koch, D., von Rohr, P., Tester, J. (2011). "Sustainable Heat Farming of Geothermal Systems: A Case Study of Heat Extraction and Thermal Recovery in a Model EGS Fractured Reservoir." Proceedings 36th Workshop on Geothermal Reservoir Engineering, Stanford University, 31 January-2 February 2011.

Ungemach, P., Antics, M., Lalos, P (2011) Sustainable geothermal reservoir management – a modelling suite. Proc. Australian Geothermal Energy Conference, 16-18th Nov. 2011, Melbourne, Geoscience Australia Record 2011/43, p267-275, Geoscience Australia, ISSN 1448-2177 ISBN 978-1-921954-56-6.

Juliusson, E., Horne, R. N., Sweeney, J., Hart, M., Rich, J., Sandler, J. (2011) Optimal extraction of geothermal resources. Trans. Geothermal Resources Council, Vol. 35, 1457-1466, ISSN 0193-5933, ISBN 0-934412-96-0.

2.5 Plans for 2012 and Beyond

Work is planned to continue on the four existing Tasks. A new focus is being signalled for several additional efforts as described below. Some of these environmental tasks need supportive funding, in particular: preparation of an international geothermal environmental code-of-practice, sustainability modelling workshops, PhD scholarships, field trials using targeted shallow reinjection of hot fluids to remedy adverse effects, gas injection in geothermal wells, and water treatment to remove toxic elements.

2.5.2 Task A- Impacts on Natural Features

- Establish protocols and methods of drilling/producing/injecting deep beneath protected areas with negligible surface impact
- Establish lower-risk methods of deep resource use from protected areas

- Distinguish natural from induced variations in thermal discharges
- Model groundwater changes arising from deep pressure changes
- Rank thermal features, habitats, & geothermal systems for protection
- Classify vulnerability of thermal features to reservoir pressure changes

2.5.3 Task B- Discharge and Reinjection Problems

- Mitigate corrosion
- Document results of subsidence mitigation by targeted injection
- Investigate biochemical remediation/ treatment of condensates
- Monitor casing integrity to protect groundwater
- Geothermal CO_2 capture/purification for horticulture and bottling
- CO_2 sequestration by injection or biological/chemical fixing
- Arsenic/boron removal from waste water by bio- or chemical- processing
- Protection of potable water aquifers from out-field reinjection effects
- Improved prediction of subsidence and effects avoidance or mitigation

2.5.4 Task C - Methods and Costs of Adverse Impact Mitigation

- Rank geothermal systems for protection status using appropriate categories & criteria
- Streamline EIA timeframes by standardising common issues and good practice procedures through programmatic approach
- Itemize experience and best practice options for cooling, stimulation and make-up water resource issues for EGS projects
- Test the use of targeted injection to rejuvenate failed geysers/springs or halt subsidence
- Review international geothermal environmental policies and procedures
- Review costs of mitigation options for environmental effects
- Produce global environmental code of practice for geothermal utilisation

2.5.5 Task E- Sustainability

- Investigate permeability changes with time & interference between neighbouring systems
- Publish more case studies
- Design & test a geothermal sustainability protocol using monitoring policies and reservoir performance indicators, and addressing the economic and social aspects of sustainability
- Plan make-up production from deep roots
- Improve the use of tracers for predictive modelling of long-term reservoir performance;
- Convene further workshops or sustainability sessions at conferences
- Collect additional long-term (>30 yrs) case histories to improve modelling confidence and better understand long-term reservoir behaviour

- Improve models, focussing on boundary conditions, recharge, dynamic recovery factors, long-term injection effects, thermal energy management, and EGS sustainability
- Establish funded PhD work in the area of modelling to optimise >100 yr and periodic utilisation strategies
- Address long-term production pressure drawdown and injection cooling effects
- Address potential interference between adjacent (interconnected) geothermal areas
- Reduce uncertainties in long-term resource sustainability assessments by identifying key requirements for pre-exploitation and early development information

2.6 Websites Related to Annex I Work

- IEA Geothermal Implementing Agreement website hosting protocols, sustainability reference list, etc.: http://www.iea-gia.org
- IPCC report, Chapter 4, Geothermal: http://www.ipcc-wg3.de/publications/

Figure 2.6 *Tourists digging hot pools at Hot Water Beach, Coromandel, New Zealand*
(Photo courtesy of Chris Bromley)

2.7 Author and Contact

Chris Bromley
GNS Science
Wairakei Research Centre
Box 2000
Taupo 3352
NEW ZEALAND
E-mail: c.bromley@gns.cri.nz

IEA Geothermal R & D Programme

Chapter 3

Annex III- Enhanced Geothermal Systems (EGS)

Fluid flow from Habanero 3 at Geodynamics' EGS project in the Cooper Basin, South Australia.
(Photo courtesy of Geodynamics Limited)

3.0 Introduction

Engineered or Enhanced Geothermal Systems (EGS) are gradually being recognised as having a great potential for future global energy supply. This is clearly highlighted in the recent road map document prepared by the International Energy Association (IEA) ***Technology Roadmap: Geothermal Heat and Power***. The road map suggests that by 2050, more than half of the projected geothermal increase comes from exploitation of ubiquitously available hot rock resources, mainly via enhanced geothermal systems (EGS). Substantially greater research, development and demonstration (RD&D) resources are needed in the next decades to ensure EGS becomes commercially viable by 2030.

Additionally, the road map indicates that policy makers, local authorities and utilities need to be more aware of the full range of geothermal resources available and of their possible applications in order to develop consistent policies accordingly. This is particularly true for geothermal heat, which can be used at various temperatures for a wide variety of tasks. Important R&D priorities for geothermal energy include accelerating resource assessment, development of more competitive drilling technologies and improving EGS technology as well as managing health, safety and environmental (HSE) concerns. Advanced technologies for offshore, geo-pressured and super-critical (or even magma) resources could unlock a huge additional resource base.
The realisation that the combination of heat and power is more attractive in an industrialised world due to the increasing cost of hydrocarbon energy sources for both applications is taking

place somewhat slower than expected. This may be due to expected lower cost of abundant shale gas and oil, but oil prices are increasing year by year. The relatively low visual and carbon dioxide impacts are also helping EGS to be recognised as one of the attractive energy resources of the future. This is reflected in the increasing membership of the IEA-GIA by countries who wish to cooperatively develop EGS technology. The IEA-GIA is the appropriate vehicle to promote international cooperation and share technological development.

The IEA has clearly recognized that one of the most important greenhouse gas mitigation opportunities lies in the increasing use of renewable energy. The ***Energy Technology Perspectives 2008*** report concluded that if we are to reduce energy related CO_2 emissions by 50% from today's level by 2050, 21% of the necessary greenhouse gas emissions reductions will have to come from renewable energy production. Owing to the recent accelerated annual growth in installed capacity for geothermal power generation and the significant progress achieved in EGS development in Europe, Australia and North America, the IEA envisions geothermal energy to make a significant contribution to the growth of the renewable portfolio. However, a significant number of technology development and demonstration, legal and regulatory, and public policy issues must be addressed if the potential of geothermal energy is to be unlocked.

Recognising the importance of EGS for the environment and worldwide resource availability, IEA-GIA has put additional effort in encouraging participating countries to cooperate, carry out joint research and share the data to improve the understanding of EGS technology and move towards the commercialisation of the technology. The goal of the IEA-GIA is to provide guidance to government and industry decision makers as they set priorities and accelerate efforts to develop and deploy technologies that will enlarge the contribution of geothermal power and direct heat use in the energy mix. The EGS Annex is structured to improved technologies via international collaboration so that the huge heat resources present in the majority of the continental land masses can be accessed by developing engineered heat exchangers at depth, and at commercially viable costs. Further, application of EGS techniques at existing hydrothermal fields will also help to increase energy extraction and improve sustainability. Baria et al. (2012) published a paper in the Encyclopaedia of Sustainability Science and Technology by Springer Press to demonstrate the sustainability of such projects and the scaling up to produce power in the range of 50 to 200 MW_e.

Once the technology is demonstrated and accepted, it will bring into play a significant worldwide geothermal resource to generate base load power, supply heat for industrial applications and district heating schemes, and reduce environmental pollution. It will also help sustain and expand hydrothermal systems through the use of stimulation techniques and reinjection.

The countries and organizations that participated in Annex III in 2011 were: Australia, the European Commission (EC), France, Germany, Italy, Japan, Norway, Republic of Korea, Switzerland, USA, Geodynamics Limited, Green Rock Energy Ltd. and ORMAT Technologies Inc.

The Operating Agent for Annex III is Geodynamics Limited, located in Milton, Queensland, Australia. The Co-Annex Leaders are Roy Baria (MIL-TECH, UK) and Doone Wyborn, of Geodynamics Limited, Australia.

3.1 Tasks of Annex III

Annex III has been working on five Tasks, described below. Many of these Tasks were revised during 2011.

3.1.1 Task A- Geothermal Energy Resource, Reserve & Depletion (Production Profile) Estimates

(Provisional Task Leader: Barry Goldstein)

Task A, which originally involved the evaluation of the economics of EGS systems was successfully completed in 2001 and numerical models were developed by the US and other countries. However, this task was re-activated in 2007 in order to incorporate the quantification and definition of EGS resources in a form that can be internationally accepted. Additionally, many commercially funded projects have commenced and will require a common terminology to make them comparable. It is becoming apparent that the development of EGS is moving from fundamental research to demonstration and application. New EGS projects are taking place on different continents, with varying geological conditions and stress regimes, and the knowledge gained in the past will need to be applied to new conditions. It is important for the success of EGS that the processes developed through international research and cooperation are applicable in different stress regimes and geological settings. With this in mind, details of this Task are being reassessed and implementation sought. It is also becoming apparent that the flow of information is decreasing as privately funded projects regard the knowledge they obtain as intellectual property rights associated with their investment.

In the past, economic models were used to evaluate what tasks or technologies were sensitive to economic viability, and those that were, were given preferential treatment for research and development. Today, the use of economic models has changed; they are now used to raise capital on the financial market.

There is concern that financiers may be disenchanted with some of the optimistic claims made previously and projects may not fulfil the requirements for the successful take-up of this technology. A standardised economic model is needed that will take into consideration the local incentives, local labour and environmental requirements and conditions. This should maintain the credibility of the technology and support those organisations that are experienced and can deliver on time and within budget. A part of this Task now incorporates EGS resource assessment, so that the market can compare like with like quantification of resources. A draft report has been prepared by the Australian Geothermal Association to address this aspect and is currently being reviewed. It is anticipated that this Task will continuously evolve depending on the regional requirements, the strategic importance of the resources and their economic viability.

Some of the important parameters to be defined are: life-cycle of an EGS system, separation between wells, production flow rate, flow impedance, water loss, thermal drawdown, contact surface area and reservoir rock volume. These factors will be defined and updated based on experience gained.

Anticipated deliverables or outputs will be: (i) ready access to established and emerging Codes (e.g., Australian, Canadian, US Codes, etc.), (ii)a summary of common and diverging aspects of established and emerging Codes, (iii) an evergreen international lexicon (expansive glossary) as a guide to how geothermal resources and reserves can be estimated for reporting purposes, (iv) an evergreen international code to cover a minimum, mandatory set of requirements for the reporting of geothermal resources and reserves, with sufficient flexibility to meet local market requirements, (v) Code compliant estimates of the earth's theoretical resource, technical resource, economic (developed and undeveloped) reserves and supplies of geothermal energy (for direct use and power generation) from the full spectrum of geothermal resources (hydrothermal through magmatic and conductive resources that require enhancement of permeability to attain flows, e.g., EGS)

At present the provisional Task leader is Barry Goldstein but a permanent leader with appropriate experience in this field is being sought.

3.1.2 Task B- Technology Crossover between Hydrothermal and Engineered Geothermal Systems

(Task Leaders: Ezra Zemach (ORMAT, USA) and Ann Robertson Tait (GeothermEx, USA)

This task was redefined to encourage cross fertilisation of the established technology from hydrothermal systems to be integrated with the new developments from EGS and to encourage both technologies to benefit from each other's knowhow. Geothermal has always been regarded as a continuum of resources from high permeability such as hydrothermal to relatively low permeability such as EGS. Recent development indicates the knowhow of the preferential direction of fluid flow in a certain stress regime can be applied to all natural subsystems including the hydrothermal and EGS. This task is also aimed to modify conventional hydrothermal development technologies, such as horizontal drilling, fracture detecting and mapping, and pumping, for application to EGS energy development.

This cross fertilisation of technologies is being tested at an existing hydrothermal field (ORMAT) at Desert Peak, near Reno, Nevada, USA. It is anticipated this task may significantly help the sustainability of existing hydrothermal fields, increase the power output and expand the hydrothermal resource.

3.1.3 Task C- Data Acquisition and Processing

(Task Leader: To be appointed; Germany)

Task C involves the collection of information necessary for the realization of a commercial EGS energy producing plant at each stage of reservoir characterization, design and development, and of construction and operation.

The progress of the development of EGS has shown that the basic principle of fluid flow in a certain stress regime remains the same, but there are likely to be some variations associated with each project. It becomes important to study past EGS projects and understand the effect of some of the variables on the resultant fluid flow in that environment. This can be achieved by either processing the old data with new processing techniques or understanding the results obtained. This requires the access to the old data, processing techniques and reports containing the results.

Access to past data and reports from various projects has always been difficult. The US DOE developed the "Legacy Project", which provides access to some of the reports from previous EGS projects. This scheme needs reinforcing with the addition of missing reports and a better search engine (refinement of the existing one, or its replacement). Alternative means are being considered to address this data and information access problem, such as via financial support from the GIA Common Fund, or the full program being funded by an organisation, joint consortium of partners, etc.

Access to all the data is still a serious problem, as some of it will have been lost or be regarded as confidential. The data which is available, should to be accessible to anyone who wishes to work on it, gain from the past experience, or develop new interpretation methods. Such data may be divided into four categories:

- In-situ data: geology, stress profile, temperature with depth, in-situ fluid composition and pressure, joint network and orientation, etc.
- Hydraulic data: all hydraulic testing, stimulations and circulations of wells
- Microseismic data: both located events and raw data
- Reports and papers

This task is still struggling to be taken up although its importance has not waned. Such a data base with international aspects is difficult and complex to implement as it is not just the translation from various languages to a common recognised such as English, but also the format of the database and the search engine associated with it to deliver the result. There are approximately 20 old EGS projects (Japan: 4, Europe: 10, USA: 3, Australia: 3). The provisional Task leader is Roy Baria until a suitable organisation can be found in Germany that is prepared to take on this task and maintain it for a foreseeable future. The provisional task leader is struggling to find the right organisation with funding to establish such a database.

3.1.4 Task D- Reservoir Evaluation

(Task Leader: Doone Wyborn, Geodynamics Limited, Australia)

The overall objective of Task D is to compile and make clear what kind of methods, techniques, and tools are effective for reservoir evaluation; and then establish the evaluation methods best applied to develop a new EGS site. Creation of an economically viable reservoir is the single most important item in EGS technology. Methods used for evaluation of the data have developed from past EGS projects and others are borrowed from the oil and gas industry and nuclear waste disposal research. The plan is to define agreed procedures to test and evaluate the reservoir parameters so that they can be compared. Some of the parameters have been defined for discussion and are presented below. The work has progressed slowly but additional support is being considered and investigated.

The Geodynamics Habanero 1 MW EGS power station (centre), with station air coolers (right) and brine air coolers (left), Cooper Basin, South Australia. (Photo courtesy of Geodynamics Limited)

Some of the procedures that could be standardized are:

- Well testing models
    - ***Before stimulation***: for the assessment of undisturbed *in-situ* permeability which can then be compared to that of after stimulation; near wellbore, and if possible, far field
    - ***For stimulation:*** for the assessment of the degree of enhanced permeability following stimulation; near wellbore and far field
    - ***For circulation:*** for the assessment of the further changes in permeability due to cooling and precipitation and dissolution processes, i.e., is the reservoir improving or degrading over time; both near and far field
- Borehole measurements
    - ***Wellbore images:*** Wellbore images are necessary to identify joint network and flow exits. Borehole imaging tools such as BHTV, FMI, etc., are commonly used for this purpose. Higher temperatures can make the use of existing tools/methods impractical; although, cooling of wells and use of heat shields can allow them to work for a limited time.
    - ***Temperature:*** Temperature is a very important heat resource and flow exit/inlet identification tool. Analogue and digital tools are available to work at up to 200 °C. Higher temperature tools can be attained using heat shield technology. Temperature sensors with low thermal mass are preferable because they respond faster to changes in temperature for identifying small flow exits. The use of optic fibre distributed temperature sensors (DTS) has great potential.

- ***Flow:*** Impeller flow meters are preferred as they are a simpler device and very sensitive to flow. The larger the diameter of the impeller the higher the sensitivity. For higher temperature, the impeller can be made of Teflon and Teflon coated bearings are used to reduce friction and corrosion. Standardised methods for flow measurement and interpretation would be useful.

- ***Pressure:*** High temperature electronics is allowing down-hole measurement of pressure over longer time intervals. DTS methods are also being developed for pressure.

- Water management

  - ***Open system:*** The characterisation of the in-situ condition of rock mass is essential to plan stimulations, well trajectories and water requirement/management. One of the tests used for assessing an open or closed system is a shut-in test after the stimulation. In an open system the pressure decays rapidly and microseismicity generation slows down rapidly giving an indication of the likely far-field water leak off.

  - ***Closed system:*** The requirements and tests are the same as those for the open system but here the pressure decays very slowly (microseismicity generation decays slowly as well) and gives an indication of the likely low far-field water leak off and therefore the constraint of circulation pressure may be necessary to limit further growth of a reservoir. Again, a preferred method and procedure may be useful to compare sites in terms of economic viability and stability of a reservoir.

  - ***Over-pressured system:*** Where the fracture network is over-pressured special conditions exist during drilling since permeable fractures at different depths cannot be in connection with a wellbore fluid at the same time when the pressure is controlled by mud weight. No pump is required in a production well under these conditions. It is not yet clear how widespread these conditions are in the Earth's crust.

- Review of numerical methods

  - ***Flac 3D***
  - ***uDec and 3Dec***
  - ***Geocrack***
  - ***FRIP***
  - ***Feflow***
  - ***Kappa***
  - ***Tough (various)***
  - ***Fracod***
  - ***Others***

- Microseismic measurements

  - **Design of network and errors:** One of the main reasons for the use of a microseismic system is the need to track fluid pressure during stimulation for the creation of an EGS reservoir. The design has to take into consideration the layout of the sensors to optimise errors in the location of these events. This entails the layout of the sensors with respect to the proposed stimulation volume, the local environmental situation for background noise, transmission of the data to the base station, the local geology where the seismic stations will be positioned, the sensitivity and the bandwidth of the seismic sensors etc. It is also important to get a good handle on the in-situ velocity model (P and S wave) for improving the location of seismic events.

- **Automatic location of data:** Automatic location of microseismic events is very helpful during the creation of the reservoir to assess the growth and the direction of the reservoir. There are a number of location algorithms available and each has its advantages and disadvantages. Commercial software is available to do automatic locations and also to help interpret the data.

- **Interpretation of data:** This, like any other interpretation, requires knowledge and experience. As mentioned above there is software available to process the microseismic data for Fault Plane Solutions, source parameters, collapsing methods, moment tensors, etc. It is important and a good practice to integrate all the other information such as the hydraulic history, joint network, stress regime, geology and other in-situ parameters to obtain meaningful interpretation of the data.

- **Quantification of stimulated area and heat transfer volume:** Both of these parameters are needed to assess the life of an EGS system under operating conditions. This is difficult and still in a development stage. Information from microseismic, tracers, joint network, numerical modelling and geology is used to calculate the heat transfer area and heat transfer volume. Work is continuing on these topics. There are not enough EGS reservoirs in a circulation mode to carry out experiments to assess and confirm predictions.

- Tracer studies

  - **Selection of tracers:** Quite an amount of work has been done on this topic to select the right tracer for a specific task. The work is in the process of being written up.

  - **Sampling, breakthrough time and modal volume:** Although procedures for specific tests have been established, the interpretation needs to be better defined with the help of numerical models.

  - **Heat transfer area:** This is a difficult parameter to assess because of the dependence on the nature of the system, i.e., open or closed.

  - **Life of a reservoir:** This is an important parameter to define the return on investment. Some numerical models are available which rely on the hydraulic, tracer, microseismic and geochemical data but it is difficult to give supporting evidence due to the absence of any circulating EGS system for a prolonged period. Results from task 3.1.5 (below) will be very helpful in defining the procedure and interpretation on this task.

3.1.5 Task E- Field Studies of EGS

(Task Leaders: J. Muller, IFE, Norway, and Co-Leader: Albert Genter, EEIG, France)

The objective of Task E is to conduct research and development on working EGS with an emphasis on reservoir management and reservoir enhancement technologies. This topic covers a broad area, including fracture and stress analyses, hydraulic and chemical stimulation, and fluid-flow modelling of hydraulic and chemical stimulation processes, tracer technologies and geophysical methods. This is a collaborative task between the originally EC funded European Project at Soultz-sous-Forêts (France) and the IEA-GIA member (Norway) with participation of other members. The Soultz project broke much new ground and demonstrated that this technology can be technically feasible and commercially viable. At present, this project is funded and supervised by a European industrial consortium.

This task was established and operated as a joint cooperative effort between the EC and USA until 2008, when the EC funding ended. This Task will now become part of a new reservoir management Task, a stage that is only now being reached for EGS systems. This includes scaling, corrosion, dissolution, precipitation, etc. The three EGS systems that were circulated for prolonged periods during early phases of EGS investigations were the Los Alamos, Rosemanowes and Hijiori sites. Some management investigations were carried out at these sites, but they require updating and integration with the limited experience at the Soultz site.

3.2 Work Performed in 2011

Many of the Task activities were revised during 2010. As a consequence of reduced funding from various participating organizations, efforts on Task related projects were much reduced. It is expected that this will pick up in the future as more funding becomes available.

3.2.1 Task A- Geothermal Energy Resource, Reserve & Depletion (Production Profile) Estimates

The major effort in this Task involved its re-establishment with new objectives (see Section 3.1.1 above). The work on redefining economic related parameters is continuing. It is recognised that assessment of geothermal resources has to be comparable in an international scenario in order to encourage investment. A new task leader is being sought with enough experience to lead this important task.

3.2.2 Task B- Technology Crossover between Hydrothermal and Engineered Geothermal Systems

The US Department of Energy continues to fund research projects bridging hydrothermal technology and technology that is more specific to Enhanced Geothermal Systems development. Results of these projects are summarized in "EGS Program Review" (http://www1.eere.energy.gov/geothermal/egs_prog_review.html), and described in the EGS sessions of the GRC (2007) and the SGERW (2007).

This task was redefined to encourage cross fertilisation of the established hydrothermal technology to be integrated with the new developments from EGS and to encourage both technologies to benefit from each other's knowhow. Recent observations and data have indicated that knowledge gained from the development of EGS on preferential fluid flow direction due to the *in-situ* stress regime can also be applied to hydrothermal fields to enhance permeability and recover additional energy.

This cross fertilisation of the technology is being tested at the existing hydrothermal field (ORMAT) at Desert Peak, near Reno, Nevada, USA. This is funded jointly by the US DOE and ORMAT technologies. A dry well which was found to be favourably aligned with the local stress field was selected to test the application of EGS knowhow to a hydrothermal field. Following an integrated study of fluid flow, fracturing, stress and rock mechanics, silicified rhyolite tuffs and metamorphosed mudstones were hydraulically and chemically stimulated in Desert Peak well 27-15 as part of an Enhanced Geothermal System (EGS) project. The target well is located on the margins of an operating geothermal field, and the stimulated zones lie at a depth from 915 to 1,070 m where temperatures range from 180 to 195°C. A long initial period of shear stimulation was carried out at low fluid pressures (less than the least horizontal principal stress, Shmin), which increased injectivity by more than one order of magnitude. After this, chelating agents and mud acid treatments were used to dissolve mineral precipitates and open up partially sealed fractures. This chemical stimulation phase temporarily increased injectivity, but led to increased wellbore instability.

After a wellbore clean-out, a large-volume hydraulic fracturing operation was carried out at high pressures (exceeding Shmin) and high injection rates over 23 days to promote fluid pressure transfer to greater distances from the borehole, resulting in an additional 4-fold increase in injectivity. Locations of microearthquakes (MEQs) and tracer testing demonstrated growth of the stimulated volume between well 27-15 and active geothermal wells located approximately 400 m to 2,000 m to the SSW. The seismic array has been augmented and a final phase of hydraulic fracturing and shear stimulation is being considered to further improve permeability in the region around well 27-15 (Chabora et al., 2012).

3.2.3 Task C- Data Acquisition and Processing

During 2011, no specific work was conducted within this Task. However, a handbook that facilitates the planning of specific EGS project steps and provides an overview to the state of art of commercially available services, which was completed in 2005: Enhanced Geothermal System

Project Management Decision Assistant or EGS-PMDA is still being distributed at a cost only to cover reproduction and postage.

Various avenues are being considered to reactivate this Task due to its long-term importance. Both public and private sectors are being contacted to fulfil this important task. The Task is much larger than expected and needs to involve long-term commitment from an organisation that will have to do the archiving and website maintenance. It is likely that this task will be absorbed in the data base established by the US DoE and the Australian Institutions. The final decision will be made at the next meeting of IEA-GIA.

3.2.4 Task D- Reservoir Evaluation

The restructuring of this task continues, and entails defining recognised definitions and a way to process these parameters to suit economic evaluation and site comparison. However, progress is slower than expected due to the demands of the task leaders on other commercial programs. The information is being put together on the topics listed in the previous section on this task.

3.2.5 Task E- Field Studies of EGS Reservoir Performance

The 2010 circulation test began at Soultz in November 2009, after a maintenance period, and lasted until October 2010, when a new maintenance period was programmed. This 11 months experiment is the longest circulation ever performed on the Soultz project. This test involved GPK2 (production), and GPK3 and GPK1 (reinjection). A tracer test was also done during this period. A detailed discussion of microseismicity activity is described in Cuenot et al. (2011), with tracer test results provided in Sanjuan (2011).

During the IEA-ExCo Meeting in Oslo, Norway, in May 2012, IFE organized a workshop on the topic: "Corrosion, scaling and the use of tracer technology in connection with reservoir management and reservoir enhancement technologies". An oil well was used as the example.

The general theme of the operation was as follows:

- Reservoir volumes are calculated based on known or estimated reservoir data
- Identification of suitable tracer based on temperature and other conditions
- Calculation of necessary tracer amounts
- Application for use of tracer chemicals (if applicable)
- Injection of tracer
- Sampling of produced fluids
- Shipment of samples to lab
- Analysis of samples and reporting of results
- Evaluation of data
- Take necessary actions

The conclusion following the use of the tracer was:

- New Tracer test after filler material had been placed confirmed no communicated via Well 2B sidetrack
- Oil production increased from 0 to 3000 BOPD
- Water decreased from 100 % to 65 %
- Less than 2 bbls filler material clean up required in Well 2

- Breakthrough time of water after filler placement (FBA well-to-well tracer test : ~250 days
- Total project cost was less than 10 % of re-drill case

The meeting was well attended and showed how knowledge gained in a hydrocarbon can be applied to geothermal fields.

3.3 Work Planned for 2012 and Beyond

The lack of new developing or operating EGS projects in the world has slowed down many of the Task efforts in this Annex, but it is anticipated that the activities will increase as US, Australian, German and South Korean funding begin to bring new EGS projects on-line. Additionally, these Tasks have been slow in progressing because of adverse publicity associated with the generation of larger (>Ml 2) microseismic events in EGS reservoirs, the difficulty with obtaining funding (private and public) due to the financial crisis, and the lack of willingness of privately funded EGS projects to disclose much of the information gained, as it is considered confidential for commercial reasons.

Although attempts were made to rectify the slowdown in the take up of EGS technology and there are signs that this may accelerate in the near future, Annex III was restructured in 2012 with the main operating agent being the US DOE, with support from Geodynamics. The Tasks in Annex III were restructured and the emphasis is now on producing workable documents (such as a best practice guide) based on the current experience. The aim is to help potential and new EGS projects.

The new description and work program associated with this Annex are as follows:

3.3.1 Task A: Proposal for Global Review of Geothermal Reporting Terminology

3.3.1.1 Introduction

The United Nations Economic Commission for Europe recently published a report entitled ***The United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009*** (hereafter referred to as UNFC-2009) that created a three-dimensional model based on the following criteria: economic and social viability, field project status and feasibility, and geological knowledge.

In recent years, various stakeholders have developed or proposed documents with codes, protocols, guidelines, and frameworks to classify a range of subjects associated with geothermal resource potential. Although these documents serve different primary purposes, they all seek to quantify and/or categorize geothermal energy resource potential and, thus, to provide useful thermal and electrical power for the global community. Relevant documents include the following:

- Canadian Geothermal Reporting Code (2010)
- The Future of Geothermal Energy and Its Challenges (L. Rybach, 2010)
- Australian Geothermal Reporting Code, Edition 2 (November 2010)
- New Geothermal Terms and Definitions - by Geothermal Energy Association (November 2010)
- A Protocol for Estimating and Mapping Global EGS Potential (May 2011)
- A Resource Assessment Protocol for GEO-ELEC (November 2011)

3.3.1.2 Work Program

Graeme Beardsmore (Hot Dry Rocks Pty Ltd, Australia) has been commissioned to familiarize himself with the UNFC-2009 framework in order to interpret and to translate the terminologies of existing geothermal codes and protocols into the language of the report's classification system. With respect to the various geothermal codes and protocols, he will identify gaps, limitations, overlaps and differences in and between the terminologies as well as provide recommendations to overcome discrepancies.

Output: A report including the following will be completed by mid-2013:

- Statement for the need of a consistent geothermal terminology
- Summary of the UNFC-2009 framework
- Presentation of various geothermal reporting and classification systems
- Proposal for consistent terminology

3.3.2 Task B: Technology Crossover between Hydrothermal and EGS Technology

3.3.2.1 Introduction

Successful deployment of geothermal resources is often restricted to highly permeable zones near the boundaries of crustal plates. As a result, if geothermal reservoirs that mimic natural systems were created, it would open up a vast amount of worldwide geothermal resource potential and also address climate change.

Extensive research has been carried out on the development of EGS technologies, and a few commercial EGS plants operate around the world. During EGS reservoir creation, the direction of fluid flow paths in natural fractured media is largely controlled by magnitude and direction of in-situ stresses. However, it is yet to be determined whether similar observations are applicable to the development of hydrothermal systems.

3.3.3.2 Work Program

The US Department of Energy (DOE) has several EGS demonstration projects located near hydrothermal fields such as Desert Peak and Brady Hot Spring, two of which are managed and operated by ORMAT Technologies, Inc. IEA-GIA has commissioned Roy Baria (MIL-TECH UK Ltd) to take these two projects as a baseline in the development of ***a lessons learned document*** that would include, but not be limited to, the following:

- Natural conditions and critical parameters
- Methodology and technology to improve reservoir performance
- Evaluation of how stimulation affected performance
- Lessons learned to facilitate successful deployment and to drive future lines of research

Output: A draft document described above will be submitted to the IEA-GIA by October 2013:

3.3.3 Task D: Best Practice handbook for EGS Reservoir Evaluation

3.3.3.1 Introduction

The main objective of Annex III, Task D, will be to assemble a handbook of the current state of the art in EGS reservoir understanding, stimulation and analysis. Topics to be included are borehole measurements, well test analysis (before and after stimulation), stimulation methods, microseismic measurements, tracer studies, water management, and review of numerical models.

3.3.3.2 Work Program

This task will be lead by Doone Wyborn (Geodynamics, Australia), with plans to make this handbook available as a guide for future projects and will lead to a best understanding of reservoir properties, stimulation methods and reservoir life. As part of this study, Doone Wyborn will engage the services of Dimitra Teza (Bestec GmbH, Landau, Germany), who has expertise in borehole measurements, well testing analysis, and water management. Teza will be responsible for writing handbook chapters on these topics:

- Borehole measurements: Image logs and their interpretation, electrical logs (sonic, neutron porosity, density, gamma, spectral gamma), temperature, pressure, spinner, optical fibre techniques.
- Well test analysis: down-hole pressure measurements with build-up and draw down, pulse and hit tests, step rate test, before and after stimulation, during circulation.
- Water management: Open system, closed system, over-pressured system

Output: Three reports providing chapters relating to borehole measurements, well test analysis and water management. These reports will provide a significant contribution to the EGS development, and will be submitted to the IEA-GIA by December 2013.

3.4 References

Baria, R., Mortimer, L. and Beardsmore, G. (2012) Development of engineered geothermal systems (EGS) and its sustainability. Encyclopedia of Sustainability Science and Technology, Springer Press, New York, USA., 18 pp.

Chabora, E., Zemach, E., Spielman, P., Drakos, P., Hickman, S., Lutz, S., Boyle, K., Falconer, A., Robertson-Tait, A., Davatzes, N.C., Rose,P., Majer, E. and Jarpe, S. (2012) Hydraulic stimulation of well 27-15, Desert Peak Geothermal field, Nevada, USA. Proceedings Thirty-Seventh Workshop on Geothermal Reservoir Engineering Stanford University, Stanford, California, January 30-1 February 2012, SGP-TR-194.

Cuenot N., Frogneux M., Dorbath C. and Calo' M. (2011), "Induced microseismic activity during recent circulation tests at the EGS site of Soultz-sous-Forêts (France)", Proceedings, 36th Workshop on Geothermal Reservoir Engineering, Stanford University, California, US, 31st January – 02s February 2011.

Sanjuan B., (2011), "Soultz EGS pilot plant exploitation - Phase III: Scientific program about on-site operations of geochemical monitoring and tracing (2010-2013). First yearly progress report" BRGM/RP-59902-FR, 92 p., 16 fig., 8 ann.

3.4 Websites Related to Annex III Work

- Habanero project, Australia: www.geodynamics.com.au/IRM/content/default.htm
- Germany's Resources: www.tab.fzk.de/
- GeneSys-Project, Germany:

  www.genesys-hannover.de/Genesys/DE/Home/genesys_node.html
- EGS-PMDA promotion on: www.iea-gia.org/geothermal_information.asp
- DOE technical projects: www.eere.energy.gov/geothermal
- EGS Program Review: http://www1.eere.energy.gov/geothermal/egs_prog_review.html
- Soultz European HDR Project: www.soultz.net/

3.5 Authors and Contacts

Roy Baria
MIL-TECH UK Ltd
UNITED KINGDOM
roybaria@onetel.com

Doone Wyborn
Geodynamics Limited
PO Box 2046, Milton, Queensland
AUSTRALIA
Doone.Wyborn@geodynamics.com.au

IEA Geothermal R & D Programme

Chapter 4

Annex VII- Advanced Geothermal Drilling and Logging Technologies

Figure 4.1 *Optical fibers- development of a high temperature fiber optic transmission system.*
(For information contact Scott Lindblom at: slindbl@sandia.gov)
(Photo courtesy of Sandia National Laboratories, USA)

4.0 Introduction

The objective of advanced drilling and logging technologies is to promote ways and means to reduce the cost of geothermal drilling through an integrated effort which involves developing an understanding of geothermal drilling and logging needs, elucidating best practices, and fostering an environment and mechanisms to share methods and means to advance the state of the art. Drilling is an essential and expensive part of geothermal exploration, development, and utilization. Drilling, logging, and completing geothermal wells are expensive because of high temperatures and hard, fractured formations. The consequences of reducing costs are often impressive, because drilling and well completion can account for more than half of the capital cost for a geothermal power project.

Geothermal drilling cost reduction can take many forms, e.g., faster drilling rates, increased bit or tool life, less trouble (twist-offs, stuck pipe, etc.), higher per-well production through multi-laterals, and others. Activities in the Advanced Geothermal Drilling and Logging Technologies Task will address aspects of geothermal well construction, which include:

- Developing a detailed understanding of worldwide geothermal drilling costs;
- Compiling a directory of geothermal drilling practices and how they vary across the globe;
- Developing improved drilling and logging technologies.

The objectives of Advanced Geothermal Drilling and Logging Technologies are:

- Quantitatively understand geothermal drilling costs from around the world and identify ways to reduce those costs, while maintaining or enhancing productivity.
- Identify and develop new and improved technologies for significantly reducing the cost of geothermal well construction to lower the cost of electricity and/or heat produced with geothermal resources.
- Inform the international geothermal community about these drilling technologies.
- Provide a vehicle for international cooperation, field tests, etc. toward the development and demonstration of improved geothermal drilling and logging technologies.

Annex VII of the Geothermal Implementing Agreement has been developed to pursue advanced geothermal drilling and logging research that will address all aspects of geothermal well construction.

Participants in Annex VII are: Australia, the European Commission, Iceland, Mexico, New Zealand, Norway, and the United States.

Sandia National Laboratories (USA) is the Operating Agent for Annex VII. Stephen Bauer, of Sandia National Laboratories, is Task Leader.

Figure 4.2 *Fiber tool system.*
(For information contact Scott Lindblom at: slindbl@sandia.gov)
(Photo courtesy of Sandia National Laboratories, USA)

4.1 Tasks of Annex VII

Annex VII has three Tasks, described below. As specified in the Annex VII Charter, all Participants in the Annex are considered to participate in all Tasks.

4.1.1 Task A- Compile Geothermal Well Drilling Cost and Performance Information

(Task Leader: Stephen Bauer, Sandia National Laboratories (SNL), USA)

This activity is a compilation of drilling cost information associated with the development, construction and operation of geothermal wells. This information/data will be maintained in a single database, so that all participants can use it to identify key cost components that might be reduced by new technology or by different drilling practices. Data could include R&D cost, project cost, operation and maintenance cost, and overall cost of energy. It will include information on wells for both electricity and direct-use applications (including geothermal heat pumps), and will include information from 1990 to date. The key modification sought in this time period, based on the realization that operators do not want to openly share costs, is to collect depth-time data, from which, performance may be estimated.

4.1.2 Task B- Identification and Publication of "Best Practices" for Geothermal Drilling

(Task Leader: Stephen Bauer, Sandia National Laboratories (SNL), USA)

The Participants have identified and catalogued the technologies that have been most successful for drilling, logging and completing geothermal wells. The complete geothermal drilling handbook includes: design criteria for the drilling and completion programs, drilling practices for cost avoidance, problem diagnosis and remediation during slimhole drilling, trouble avoidance, well testing, geophysical logging, and wellbore preservation.

4.1.3 Task C- Advanced Drilling and Logging Collaboration

(Task Leader: Stephen Bauer, Sandia National Laboratories (SNL), USA)

The Participants will monitor and exchange information on drilling and logging technology development and new applications in their respective countries. The Participants will also identify activities and projects for collaboration, and then collaboration plans will be developed. For example, the Participants anticipate identifying opportunities to field test in one country a technology/system that is being developed in another participant's country.

4.2 Work Performed in 2011

4.2.1 General

Provided reports to the 25th and 26th ExCo meetings, completed written Annex VII reports, and provided Annex VII revised descriptions for the revised GIA Document.

Annex VII participants met in the spring of 2011 in Paris, France, and in the fall in London, U.K.

The following is an update of Annex VII activities presented and discussed at the aforementioned meetings which took place in 2011.

Key Points from the Annex Meetings:

- Each of the seven active participants in the Annex was represented at both meetings: Australia, the European Commission, Iceland, Mexico, New Zealand, Norway, and the United States.
- Each Task was discussed, with a view towards maintaining a substantive path forward.

4.2.2 Task A

Some new well data was added to the database in 2011. A well cost model is being developed.

4.2.3 Task B

Task B, having been completed, is being redirected.

4.2.4 Task C

Requests for collaboration have been received, discussed, and information exchanged between principal investigators. The potential for technology sharing continues.

Barry Goldstein visited Sandia National Laboratories and gave an invited lecture on Geothermal Energy in Australia.

At the fall 2011 Annex VII meeting, S.J. Bauer gave a presentation of the well cost model and example cost calculations compared to actual well costs.

The US DOE has funded numerous technical initiatives to further the advancement of geothermal energy exploration and production in the U.S. These include a high temperature seismic tool for long-term (years) monitoring and deployed/locked in a borehole at Sandia National Labs. The Type 1 tool operates at 200 °C and provides high resolution data (24 bit A:D) for periods >1,000 hours of operation. The Type 2 tool is a lower resolution tool (18 bit A:D) that operates at 240 °C for periods of years.

Other US DOE funded projects include 17 awards to industry for R&D, including: a high temperature televiewer (Baker Hughes); high temperature SiC components (GE Global Research); commercializing SNL/DOE high temperature technologies (Permaworks); high temperature pump components (Schlumberger); a downhole enthalpy meter (Stanford University); and four EGS field demonstrations that will involve drilling.

Also, the US DOE, as part of the Stimulus Funding (2-3 year projects), funded the following projects supporting technology development of high temperature tools and sensors, down-hole high temperature pumps and drill bits: a tool for detecting fractures using technology at high temperatures and depths (Baker Hughes Oildfield Operations Inc.); the development and demonstration of an electric submersible pump at high temperatures (Composite Technology Development Inc.); development of tools for measuring temperature, flow, pressure and seismicity of EGS reservoirs (GE Global Research); high temperature pump monitoring (Schlumberger Technology Corp.); extending the temperature range of electric submersible pumps to 338 °C (Schlumberger Technology Corp.); field testing of high temperature seismic tools (Sandia National Laboratories); a multi-parameter fiber optic sensing system for monitoring enhanced geothermal systems (GE Global Research); pressure and telemetry methods for measurement while drilling in geothermal wells (GE Global Research); and enhance and deliver a high temperature directional drilling instrument for geothermal (MWD Tools, Honeywell International Inc.).

4.3 Highlights of Annex Programme Work for 2011

The initiation of work on the well cost model represents the significant highlight of the Annex in 2011.

4.4 Work Planned for 2012

Increased participation in the Annex is being solicited and is anticipated. Work on the well cost model will represent a significant effort, coupled with a paper for the GRC to document its versatility.

4.4.1 Task A

The U.S. will continue to solicit drilling performance/cost data from operators. The Annex VII participants will discuss, assimilate and analyse information. An outgrowth of this work is expected to be development of a well cost data model. A report will be made to the Executive Committee.

Output: A preliminary cost model and data request.

4.4.2 Task B

This Task is ended and may be supplemented/replaced.

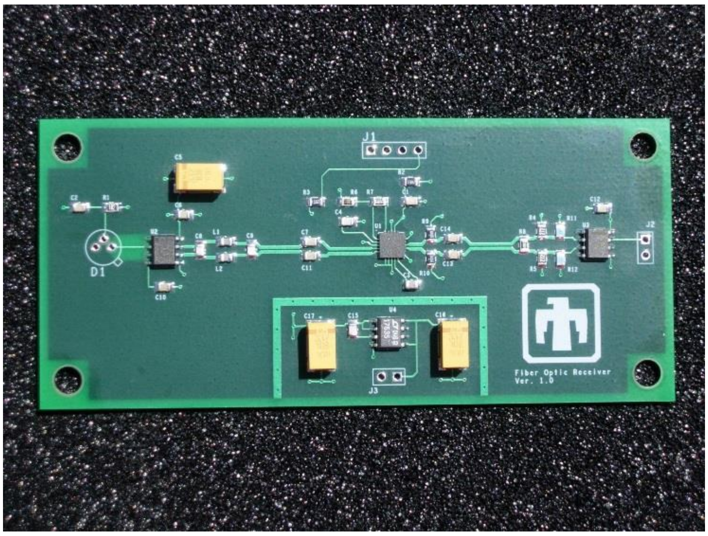


Figure 4.2 *A first generation receiver board for the uphole electronics was designed and fabricated as part of the development of a high temperature fiber optic transmission system.*
(For information contact Scott Lindblom at: slindbl@sandia.gov)
(Photo courtesy of Sandia National Laboratories, USA)

4.4.3 Task C

Solicit, coordinate, and plan international collaborations of technology sharing. Examples of such collaborations include: instrumentation demonstrations and evaluations, information exchanges through visits to foreign sites (ongoing for each year). Organize international exchange program, possibly (and in part) in association with other international travel, for information exchange and sharing.

Output: Report to Executive Committee.

4.5 Outputs for 2011

Papers and Reports

Henfling, J. A. , Atcitty, S. and Maldonado, F. (2011) Enhanced High Temperature Power Controller, 2011 HiTen Conference.

Lindblom, S., Henfling, J.A., Macrae, A., Yeung, K., Barani, K., Fong, G., Qu, J., McAuley, T., Parks, J. (2011) A High Speed, High Temperature Datalink for Geothermal Applications, Geothermal Resources Council Annual Meeting, 2011.

4.6 Websites Related to Annex Work

- http://www.sandia.gov/geothermal
- http://www.nrel.gov/geothermal/
- http://engine.brgm.fr

4.7 Author and Contact

S. J. Bauer
Dept. 6914 MS 1033
Geothermal Research Department
Sandia National Laboratories
Albuquerque, NM
UNITED STATES 87185-1033
E-Mail: sjbauer@sandia.gov

IEA Geothermal R & D Programme

Chapter 5

Annex VIII- Direct Use of Geothermal Energy

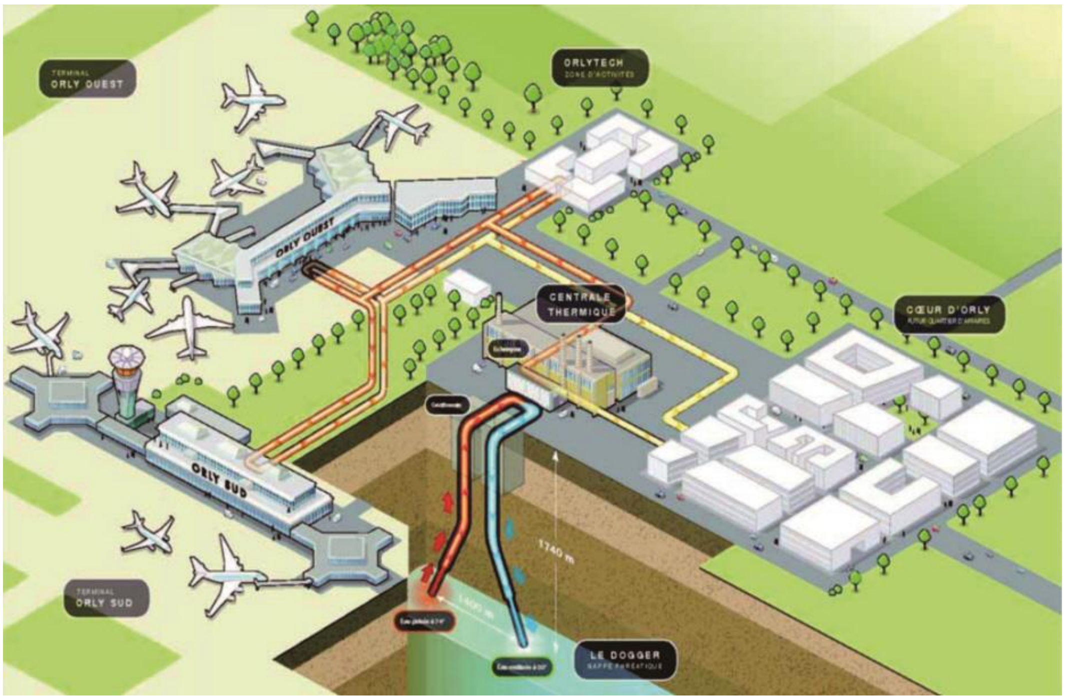


Figure 5.1 *New geothermal heating plant for Orly Airport in Paris, France. (Photo courtesy of Romain Vernier)*

5.0 Introduction

Geothermal water has been used for centuries for various applications. In earlier time the hot water was only used where geothermal water was in surface springs. It was used for bathing, cooking and for therapeutic purposes. In the past few decades, direct use of geothermal water has increased; and today, direct use of geothermal energy is possible everywhere. Today, geothermal water is used for different applications that require heat, such as heating buildings, individually or for whole towns (district heating); raising plants in greenhouses, drying crops, heating water at fish farms, snow melting, bathing and for therapeutic purposes and several industrial processes. Heating and cooling with the help of constant temperatures in the shallow subsurface (<300 m depth) through the well-known technology of ground-source heat pumps (GSHP) or geothermal heat pumps (GHP) has now become the most important form of direct use and rapidly grows in terms of capacity and also worldwide deployment.

To promote further direct use of geothermal water and to learn from each other, IEA-GIA decided to establish an Annex on this subject. The Direct Use of Geothermal Energy Annex was initiated in 2003, when the agreement entered into force

The objectives of Annex VIII are to:

- Define and characterize the direct use applications for geothermal energy, with emphasis on defining barriers to widespread application
- Identify and promote opportunities for new and innovative applications
- Define and initiate research to remove barriers, to enhance economics and to promote implementation
- Test and standardize equipment
- Develop engineering standards

Participants of this Annex in 2011 were: Australia, France, Iceland, Japan, Republic of Korea, New Zealand, Norway, Spain, APPA (Spain), Switzerland and USA.

The Operating Agent for Annex VIII is The Federation of Icelandic Energy and Waterworks, Reykjavik, Iceland, and the Annex Leader is Einar Gunnlaugsson, employee of Orkuveita Reykjavikur.

Figure 5.2 *Drilling for the new geothermal heating plant for Orly Airport in Paris, France (Figure 5.1).*
(Photo courtesy of Romain Vernier)

5.1 Tasks of Annex VIII

Six Tasks have been defined for this Annex.

5.1.1 Task A- Resource Characterization

(Task Leader: Hirofumi Muraoka, North Japan Research Institute for Sustainable Energy (NJRISE, Hirosaki University, Japan)

The aim of this task is to define the available geothermal resources in the various participating countries.

5.1.2 Task B- Cost and Performance Database

(Task Leader: Yoonho Song, Korea Institute of Geoscience and Mineral Resources (KIGAM), Republic of Korea. A new Task Leader is being sought.)

This task focuses on collecting, analyzing and disseminating the characteristic cost and performance data for installations in participating countries, with emphasis on establishing a baseline and then validating the improvements from innovative components and better designs.

5.1.3 Task C- Barrier and Opportunity Identification

(Task Leader: Yoonho Song, Korea Institute of Geoscience and Mineral Resources (KIGAM), Republic of Korea. This task has been run together with Task B)

Based on Tasks A and B, this task will define the barriers which must be overcome to gain widespread use of geothermal heat for various applications. The research activities necessary to take advantage of these opportunities will also be defined and initiated. This task has been operated together with Task B.

5.1.4 Task D- Equipment Performance Validation

(Task Leader: Tom Williams, NREL, USA)

The aim of this task is to define and test critical and innovative equipment, such as: submersible and line shaft pumps, compact heat exchangers, down-hole heat exchangers, non-metallic piping, heat pumps and other equipment to characterize performance for various applications and for various geothermal brines.

5.1.5 Task E- Design Configuration and Engineering Standards

(Task Leader: Rudolf Minder, Swiss Federal Office of Energy, Switzerland)

The work here is to develop and characterize standardized designs for various applications, with the goal of minimizing the engineering related to various applications; and to develop engineering standards for designs, equipment and controls.

5.1.6 Task F- Publication and Geographical Presentation on the Web

(Task Leader: Einar Gunnlaugsson, Orkuveita Reykjavikur, Iceland)

The aim of this task is to define suitable form to present data on direct use of geothermal water geographically on the web.

5.1.7 Expected Results

The primary results of Annex VIII will be improvements in systems and equipment, reduction in cost of delivered heat and an increase in the number of direct use applications. Cooperation among the countries and increased exchange of technical and scientific information within the field of direct use of geothermal energy will be beneficial for all partners. Specifically, the results of this Annex shall include:

- Development of an international database on direct use applications by each of the participating countries. The database will be based on standardized instruments and reporting techniques
- Reports on state-of-the-art in direct use of geothermal energy, including areas needing improvement
- Cooperative research to accomplish the needed improvements
- Participant reports on the status of research and development in new and improved technology that shall be presented in appropriate journals and meetings

5.2 Work Performed in 2011

Annex VIII meetings were held in 2011, in the form of tele-meetings on 27 April and 7 December.

A presentation describing the Annex's activities and outputs was made at the Geothermal Energy- Direct Use 2011 New Zealand Geothermal Association Seminar, held in Taupo, New Zealand (Bromley and Gunnlaugsson, 2011).

5.2.1 Task A- Resource Characterization (Temperature and Chemistry)

Evaluation of data on the temperature of the geothermal manifestations and chemistry from Korea, Iceland, Japan and USA has been made. The results show that differences in chemistry are related to the different rock types and geological environments.

5.2.2 Tasks B and C- Cost and Performance & Barriers and Opportunities

The Questionnaire for Direct Use of Geothermal Energy was first developed in 2006. It has been revised and sent to more countries than the first version. The revision was focused on barrier and opportunity identification. Answers from twelve countries have been received and compilation and analyses have been made and presented at the World Geothermal Congress in 2010. The results were used to design a section of the recently launched Annex X Trend Report and have been incorporated into it.

Figure 5.3a *A large-scale (2,100 kW) ground-source heat pump system installation for heating and cooling* supply for 1-2 zone of the new government building complex in Sejong-City, Korea. *(Photo courtesy of T-EN)*

Figure 5.3b *Pipe installation for a large-scale (2,100 kW) ground-source heat pump system for heating and cooling* supply (see Figure 5.3a) for 1-2 zone of the new government building complex in Sejong-City, Korea..
(Photo courtesy of T-EN)

5.2.3 Task D- Equipment Performance Validation

Collection of data has started. Some databases already exist in the USA. Data on groundwater heat pumps can be found but gathering and compiling that data have so far not been a priority. Some data and information are also available elsewhere (Spain, NZ, Norway and Iceland).

5.2.4 Task E- Design Configuration (Engineering Standards)

The collection of available information has begun and a list of references regarding published material is available. The list includes documents from the following countries: Germany, Austria, Sweden, France and Switzerland. Contributions from other countries are being sought.

5.2.5 Task F- Publication and Geographical Presentation on the Web

The aim of this task is to define a suitable form to present data on direct use of geothermal water geographically on the web. Tests have been made to present data in files which can be opened on the web through Google Earth. Minimum data which have to be collected to be able to show data in graphical information systems was listed for various applications. A list of basic information which is needed has been provided.

5.3 Work Planned for 2012

5.3.1 Task A- Resource Characterization (Temperature and Chemistry)

Proposed next steps:

- Define how resource characteristics are affecting direct use of the recourses
- An output for Task A is to publish An Atlas of World Hydrothermal Systems that contains a variety of diagrams and maps by the end of the third term.

5.3.2 Task B- Cost and Performance

Proposed next steps:

- Find a new Task Leader

5.3.3 Task C- Barriers and Opportunities

Proposed next steps:

- Define suggestions to remove barriers
- Develop simple concise questionnaire on case histories
- Collect good and bad case histories to be learned from
- Make a summary

5.3.4 Task D- Equipment Performance Validation

Proposed next steps:

- Collect and compile data bases which already exists in USA
- Search for data from other countries

5.3.5 Task E- Design Configuration (Engineering Standards)

Proposed next steps:

- Collection of available descriptions will continue and be listed, regardless of language
- Compile a list of engineering standards and design configurations as well as guidelines for best practice regardless of languages
- Have the first version of the list on the GIA web site

5.3.6 Task F- Publication and Geographical Presentation on the Web

Proposed next steps:

- Describe, step by step, how to convert data to formats which can be used by Google Earth
- Each country can start to collect information
- Make links available through IEA-GIA website

5.4 References

Bromley, C.J., Gunnlaugsson, E. (2011) IEA-GIA Direct Geothermal Use Research. Presentation at Geothermal Energy- Direct Use 2011 NZGA Seminar, NZ Clean Energy Centre, Taupo 12/10/2011. Presentation available at : http://www.nzgeothermal.org.nz/Publications/Upcoming_Events/3-1_Chris-Bromley-Direct-Use-Global-IEA-GIA.pdf

5.5 Authors and Contacts

Yoonho Song
KIGAM
Daejeon
REPUBLIC of KOREA
E-mail: song@kigam.re.kr

Einar Gunnlaugsson
Federation of Icelandic Energy and Water Works
Reykjavik
ICELAND
E-mail: einar.gunnlaugsson@or.is

IEA Geothermal R & D Programme

Chapter 6

Annex X- Data Collection and Information

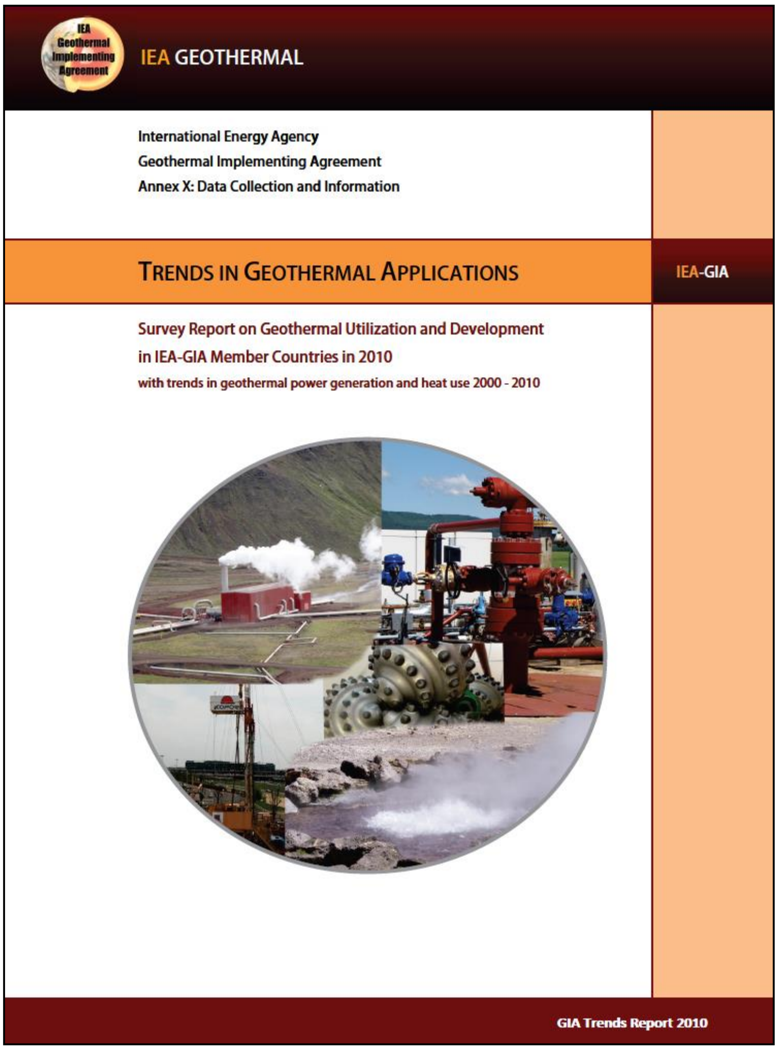


Figure 6.1 *Annex X's 2010 GIA Trend Report.*
(Photo courtesy of Britta Ganz)

6.0 Introduction

Annex X- Data Collection and Information was initiated at the end of 2010, with full activity underway in 2011. The main objective is to collect essential data on geothermal energy uses, trends and developments in GIA countries and to publish these data in an annual report called the GIA Trend Report. The objectives shall be achieved by all GIA member countries through their provision of information to the Annex Leader and by sharing the coordinated work necessary to carry out this Annex.

All Contracting Parties are obliged to participate in this Annex and Sponsors have also agreed to contribute.

The Operating Agents for the Annex X are the Leibniz Institute for Applied Geophysics (LIAG), Germany, and the Federal Office of Energy (BFE), Switzerland. The Annex Leader is Britta Ganz (LIAG, Germany).

6.1 Tasks

The task of Data Collection and Information in GIA countries developed against the background of the growing demand for data about geothermal energy uses on an international scale. Thus, it is the main objective of Annex X to collect and analyze geothermal applications data from GIA countries and to publish these data in an annual Trend Report, starting with data from 2010. The GIA Trend Report provides a brief overview of essential geothermal energy data showing the development of geothermal energy in GIA member countries. It is foreseen to extend this data collection also to non-GIA countries, if reliable data can be obtained.

6.2 Results

The data collection carried out by Annex X started in 2011 with the development and distribution of a spreadsheet with queries for data on geothermal power generation and heat uses, economic aspects, CO_2 and energy savings by geothermal energy uses, national policy, support mechanisms, and project highlights. 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 been compiled and analyzed.

6.3 Highlights and Achievements

- Development and distribution of a questionnaire to collect data on geothermal energy uses in GIA countries in a consistent form.
- Compilation and analysis of GIA data and data from other sources.
- Draft report: Trends in Geothermal Applications with data for 2010.
- Revision, completion of the first IEA-GIA Trend Report and publication on the GIA homepage in 2012.

6.4 Output

IEA-GIA 2012. Trends in Geothermal Applications - Survey Report on Geothermal Utilization and Development in IEA-GIA Member Countries in 2010, with trends in geothermal power generation and heat use 2000-2010. 38 p. (available at: http://www.iea-gia.org)

6.5 Plans for 2012 and Beyond

- Data query for 2011, data processing, and preparation of the 2011 Trend Report.
- In the future, part of the data collection should be extended to non-GIA Countries, if reliable data can be obtained. To achieve this objective, it is intended to compare the Annex X spreadsheet with data queries from other institutions, and too seek collaboration with other organizations.
- It is intended to increase the distribution of future reports by publicity in newsletters, presentations at international meetings/congresses and dissemination through other organizations and at exhibitions.

6.6 Author and Contact

Britta Ganz
Leibniz Institute for Applied Geophysics
Section 4 - Geothermics and Information Systems
Stilleweg 2
30655 Hannover
GERMANY
E-mail: Britta.Ganz@liag-hannover.de

IEA Geothermal R & D Programme

Chapter 7

Annex XI- Induced Seismicity

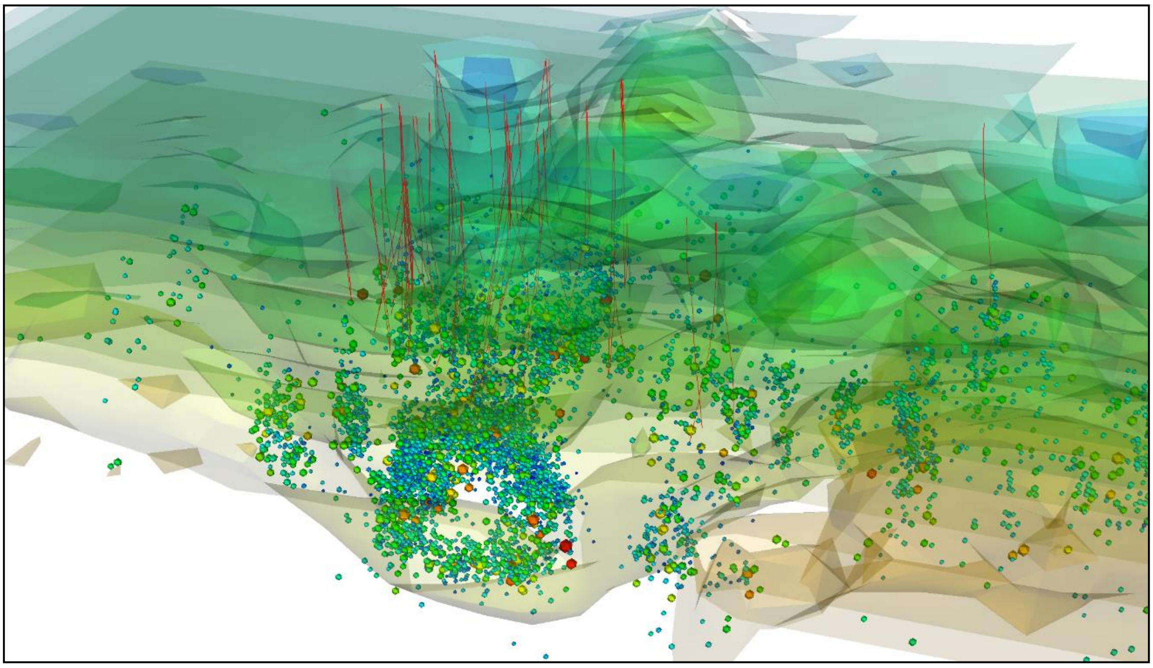


Figure 7.1 *A 3-D rendition of the seismicity at The Geysers Geothermal Field with the structure and some wells.*
(Courtesy of Ernie Majer, LBNL, USA)

7.0 Introduction

A seismic event, e.g., is an earthquake that is induced by manmade activities such as fluid injection, reservoir impoundment, mining, and other activities. In terms of EGS an induced event would occur during the EGS operations of either fluid injection and/or withdrawal. The term "induced" has been used to include "triggered seismic events" and so sometimes the terms are used interchangeably. A triggered seismic event is one that is a result of failure along a pre-existing zone of weakness e.g., fault that is already critically stressed and is pushed to failure by a stress perturbation from natural or manmade activities. The terms "induced" and "triggered" are often used interchangeably in the literature on induced seismicity and by practitioners in those fields and in the field of seismology. In terms of the process of causing a seismic event, the two terms should be used differently although admittedly it is difficult to define where an induced seismic event should be called a triggered seismic event and vice versa. In this document we use the term "induced" to include all seismic events that result from fluid injection and will only use the term "triggered" in well-defined situations.

The objective of this Annex is to encourage international cooperation to determine the steps needed to be taken to make EGS/fluid injection a safe and economic technology that is accepted by the public and useful to the industry. This includes not only steps to allow acceptance of EGS technology by the public, regulators and policy makers, but also allows induced seismicity to become a useful tool to optimize EGS applications.

Specific objectives are to reduce the uncertainty associated with both technical and public acceptability issues in order to facilitate and accelerate he development of geothermal energy by:

- Developing accepted approaches for addressing both technical and public acceptance issues that industry can use as a guide- i.e., set out the rules!!
- Developing a structure and path forward of approaches to assess risk
- Identifying areas of collaboration and cooperation
- Identifying key roadblocks and areas of technology development and research

Overall, given what we understand now about induced seismicity there is a need to specify what steps should be taken in the near future to make EGS/fluid injection a safe and economical technology that is accepted by the public and useful to the industry.

The participants in this Annex are: Australia, EC, France, Germany, Iceland, Japan, New Zealand, Republic of Korea, Switzerland and the United States of America.

The US Department of Energy, Geothermal Technologies Programme (USA) is the Operating Agent for Annex XI. Ernie Majer (Lawrence Berkeley National Laboratories) is the Annex Leader.

7.1 Tasks of Annex XI

7.1.1 Task A- Updating the Existing IEA Protocol on Induced Seismicity

Since the last protocol there has been much more experience gained with EGS and induced seismicity, both from a public acceptance standpoint and a technical standpoint on the causes and mitigation of Induced seismicity. Therefore, a revised protocol would be useful by all stakeholders to aid in the development of EGS applications.

7.1.2 Task B- Development of Best Practices Document to Address Operational Issues Associated with Induced Seismicity

This would be in addition to the protocol which expands upon the more technical aspects of the protocol. This would be used mainly by operators to meet regulatory and operational requirements.

7.1.3 Task C- Identification of Critical Research and Technology to Meet the Main Objectives of this Annex

The participants shall collect information of research needs from each participant and discuss means to leverage of a commercial EGS energy. Examples would be collecting road map exercises from different participants and relevant research groups.

7.1.4 Task D Identify Results from Field Studies that Could be Shared and Placed in a Database to Accelerated Research Results

Collect various cases of induced seismicity associated with EGS and geothermal activities as well as data to correlate with EGS parameters as heat transfer surface, rock volume, fract6ure and fault properties, injection rates, etc.

7.2 Work Performed in 2011

7.2.1 First Annex XI Meeting

On 3 May 2011, at the 25th IEA-GIA ExCo Meeting in Paris, France, Annex XI held its first meeting in a joint session with the 7th IPGT Induced Seismicity Group. Questions raised at the October 2010 IPGT meeting were addressed. The IPGT IS Working Group comprises the conveners from each IPGT country (Table 7.1)

Table 7.1 *Conveners from IPGT countries.*

Name	Organization	Country
Domenico Giardini (Leader)	Swiss Seismological Service, ETH Zurich,	Switzerland
Michael Malavazos	PIRSA	Australia
Kristján Ágústsson	ISOR	Iceland
Ernie Majer	Lawrence Berkeley National Lab	Unites States

The following people were in attendance at the joint IEA/IPGT meeting:

- Domenico Giardini – ETH Zurich, Swiss Seismological Service (Switzerland) IPGT Leader)
- Ernie Majer – Lawrence Berkeley National Lab (USA) (Annex XI Leader)
- Michael Malavazos – PIRSA (Australia)
- Chris Bromley - GNS Science (New Zealand)
- Stefan Wiemer - ETH Zurich, Swiss Seismological Service (Switzerland)
- Yoonho Song - Korea Institute of Geoscience & Mineral Resources (Republic of Korea)
- Hirofumi Muraoka - North Japan New Energy Research Center (Japan)
- Mike Mongillo – GNS Science, IEA-GIA Secretariat (New Zealand)
- Steve Bauer – Sandia National Lab (USA)
- Alexandra Long – PIRSA (Australia)
- Takatsune Ito – IEA Headquarters (Paris, France)
- Ella Thodal – SRA International in support of US DOE and IPGT Secretariat (USA)

At this meeting it was decided that:

In the next year, the IPGT and IEA-GIA would work together on 8 main issues (Table 7.2). This work will inform the IPGT white paper and comprise IEA-GIA Tasks under Annex XI. Delineation between the two groups may come in the future.

All milestones will be reviewed at the next meeting to be held in Melbourne, Australia, to coincide with the **Australian Geothermal Conference/IGA/IPGT Steering Committee Meeting**, 14-15 November 2011 (joint meeting).

Individual task members should meet whenever possible, potentially at:

- IEA-GIA ExCo Meeting; 28-30 September 2011; London, UK
- Soultz Meeting; first week October 2011
- GRC Annual Meeting; Oct 2011; San Diego, USA
- AGU; December 2011; San Francisco, USA
- Stanford Workshop; January/February 2012 (half-day meeting on test sites); Stanford, USA

The eight issues and task descriptions are presented in Table 7.2.

Table 7.2 *Annex XI Issuers, and tasks and descriptions.*

Issue	Current Action	Task	Leader
1) Terms and Definitions	Some terms defined in the US. Updated IS Protocol.	A) Circulate documents (US updated IS Protocol and IS Roadmap when publically available). B) From these create a glossary and update as necessary.	All
2) Data **Evaluate centralized data access and availability. Develop a common understanding of an open data policy**		A) Define data categories and formats. Data discussed will include waveform, magnitude, focal mechanism and metadata of induced seismicity and production/injection information. B) Identify primary data sets from past and existing experiments and develop a reference list with contact information (on a website linked between the IPGT and IEA-GIA sites).	Australia
3) Demonstration Areas **This will establish the conditions by which a site can be called a global "demonstration" site, meeting a threshold of data quality, quantity and availability adherence to protocols.**		C) Compile a list of demonstration/test areas (not necessarily public), their locations, adherence to protocols and best practices used, geologic conditions, milestones and the expected outcomes. D) Qualify each site based on threshold of data quality, quantity and availability adherence to protocols. For example, does the site meet a requirement for the ability to locate a seismic event within a certain distance?	Switzerland & US co-leads

4) Global Test Sites **Establish a suite of test sites in different representative geologic and geothermal conditions to test all aspects of geothermal science and technology and demonstrate the scalability.**		E) A) Each country should define test site conditions that they would like or may have available. This task will also look at what has been done by other scientific communities including physics (ESFRI, ICDP, EarthScope). F) B) Hold a one-day workshop to discuss wishes for a test site at the next Stanford meeting. Note that this will apply to all geothermal technologies and tools. G) C) Develop a series of international public/privately-funded test sites with common standards. These sites will bring together a large research community. Research teams will make proposals for what to do at the sites. Open to international groups as a "window of opportunity."	Switzerland & US co-leads
5) Hazard and Risk Assessment **Develop a framework for hazard and risk assessment for all phases of a project from site selection, to stimulation and operation and decommissioning.**	Existing risk assessments in all countries. List of questions from DOE/GEISER October 2010 workshop in Iceland.	H) Circulate and review the questions from the DOE/GEISER workshop. I) Develop a white paper reviewing the following: • Current actions in this area. • Methods industry uses to perform a hazard study. • Maximum possible event (is this induced or triggered?). • Standardization for hazard assessment- perhaps similar to EPRI for nuclear. • The importance/relevance of frequency. • Characterization of natural seismicity.	US, New Zealand & Switzerland co-lead

6) Mitigation Options **Develop a set of risk mitigation strategies and best practices to help project stakeholders in all phases of a project.**	Addressed in Updated US IS Protocol from technical and non-technical standpoints (education and insurance). Modelling on this topic was presented at the Stanford workshop in January 2011. GEISER is working on science behind this using modelling.	J) Review the US IS Best Practices and GEISER Work Package results as they become available. K) One year from now, re-assess with upcoming information, perhaps compiling and linking case studies. The focus will be on technical and communications aspects. It will include a synthesis of past events including cause and effect and will seek to move beyond traditional traffic light systems. Another issue that will need to be explored is how to incorporate delayed large events for stimulation and long-term operation.	US & Switzerland co-leaders
7) Website	IEA-GIA and IPGT each have a web page.	L) Create a functioning website for this group M) Link the IEA-GIA page and IPGT? N) Compile relevant search engines, references from past 5 years (including pdfs and/or links).	Mike Mongillo and Ella Thodal
8) Communication **This task will discuss what should be communicated in general and what should be communicated at what stage of a project.**	The updated US Induced Seismicity Protocol has information on this (pre-project as well).	O) The updated US Protocol will be distributed and reviewed. P) Develop a sheet on Facts and Answers on Induced Seismicity. This paper will discuss what scientists in the geothermal community agree on and what is not agreed on. Q) Submit fact sheet to the IEA's "Open Bulletin." R) Potentially develop a Wikipedia-style living document. S) Conduct interviews and report on the common experiences of induced seismicity from operators.	Revisit in 6 months at next meeting.

The progress on each of the Issues has been as follows:

Issue 1. A new protocol that has been developed by the US DOE was completed, final comments were addressed, and the final draft version will be circulated at the meeting in Australia in November 2011. A companion "best practices" (like the Protocol, but more detailed, written mainly for the industry) is in the final stages and should be out for comment by January 2012. Both of these documents contain a glossary and will be circulated at the November 2011 IPGT meeting.

Issues 2- 8. These will be discussed and reported upon at the November 2011 IPGT meeting.

General comments:

1) Domenico Giardini has stepped down as the Leader for IPGT and will be replaced by Stefan Wiemar.

2) Ella Thodal (US DOE) will step down as the IPGT Secretariat and be replaced by Matthew Deady (main contact): Matthew.Deady@ret.gov.au;
Catherine Zerger (alternate contact): Catherine.Zerger@ret.gov.au.

7.2.2 Joint IEA-GIA/IPGT Meeting in Melbourne, Australia, November 2011

In Melbourne, the joint IEA/IPGT meeting was attended by representatives from Australia, New Zealand, Switzerland, Japan, Korea, Iceland and the United States (see agenda at the end of this section). The objective was to review research and technology needs in order to strive to have induced seismicity be a tool for optimizing EGS development rather than being an obstacle. Also reviewed was progress on the tasks that were laid out at the Paris meeting in May 2011. The following people attended the meeting:

Australia: Matthew Deady (Main contact), Catherine Zerger (Alternate contact), Betina Bendall, Mike Malavazos
Iceland: Kristjan Agustsson
Japan: Hirofumi Muraoka
Korea: Yoonho Song.
New Zealand: Chris Bromley
Switzerland: Gunter Siddiqi
U.S: Ernie Majer

Results of the Meeting:

Progress was made on the following Issues:

Issue 1 (Terms and Definitions/Glossary)- Each county is to develop its own country-specific terms and come to agreement. Each country shall review current definitions (in the protocol) and prepare an evaluation of country specific terms- 3 months.
Example: EGS Enhanced versus Engineered; Triggered versus Induced; etc.

Action- Compilation of glossary, best practice and guidelines.

Issue 2 (Data)- Discussed were examples of data protocols and what could be of use by the regulators. Considered should be confidentiality issues that private companies may have, and whether others can access the data in a reasonable time frame. In Australia, the operator company must provide data to government after two months. Then, after two years, the data becomes public.

Action- Define what data should be collected. Address timelines for submission and R&D needs. Need feedback on data for safety issues as well as regulatory requirements? Only induced seismicity data? (Rather than reservoir data, injection, etc). Betina Bendall will provide draft paper for circulation.

Issues 3 and 4 (Demonstration and Test Sites)- Switzerland: European Energy Research Alliance 12 countries- Joint Program on Geothermal is pushing towards a new European demonstration site. In Switzerland, the industry is considering new demonstration sites that will be investigated jointly with Swiss research institutions. **United States:** The issue is a balance between demonstration sites versus test sites. Currently the US DOE has seven demonstration EGS sites. Jointly funded by DOE and industry, these sites only get DOE funding if industry matches funding (at least 50-50). Needed is a research agenda that would be used to select a test site. The current need is to determine what we ***don't*** know about induced seismicity that a test site could help solve.

US Action- Will try to link their projects and all the international projects at a website. Strive to have a matrix available of where data are being collected.

Issues 5, 6 and 7 (Hazard and Risk Assessment and Mitigation)- Stefan Wiemer (Switzerland) has offered to lead the drafting of the Induced Seismicity White Paper on hazard and risk/mitigation. Discussions were held on what preventative measures have been put in place to prevent an incident, (Australia, PIRSA.) Regulations are different for different countries, i.e., "fit for purpose" guidelines. The question was posed, should there be international standards for EGS projects, i.e., before we start stimulation should it be required to meet this guideline. Stefan Wiemer will provide a first draft of the white paper by March 2012 at the IEA-GIA Meeting in Oslo, Norway.

Chris Bromley and Gunter Siddiqi will submit a proposal for IEA GIA funding- a fact sheet, and how to get message across, plus some sort of response.

A more detailed task list, a white paper and agenda are now in progress. The white paper is expected to be drafted by March/April 2012. Leader for this group is currently Domenico Giardini. However, he will likely not continue with this group. Others who are involved include: Gunter Siddiqi (IPGT Steering Committee), Arno Zang (zang@gfz-potsdam.de GFZ Potsdam), Stefan Wiemer (stefan.wiemer@sed.ethz.ch, ETH Zurich), David Bruhn (dbruhn@gfz-potsdam.de, GFZ Potsdam), Hirofumi Muraoka (hiro@cc.hirosaki-u.ac.jp, Hirosaki University), Yoonho Song (song@kigam.re.kr, Korean Institute of Geoscience and Mineral Resources).

Issue 8 (Communications)- All agreed that communication is a key issue, for the public, regulators and the operators. Both the protocol and the best practices stress the importance and can act as a guide for others to follow. As experience is gained with various projects it is anticipated that the protocol and best practices will be updated.

Agenda for the Joint IEA-GIA/IPGT Induced Seismicity Working Group Meeting

14 November (9:00 AM-5:00 PM) and 15 November (8:00 AM-10:30 AM), 2011
Sebel, Albert Park, Melbourne, (Room: Sebel 2)

1. Review progress on the 8 Issues
   - Terms and Definitions – All
   - Data- Australia
   - Demonstration Areas – Switzerland and US co-leads
   - Global Test Sites- Switzerland US co-leads
   - Hazard and Risk Assessment- US, New Zealand & Switzerland co-lead
   - Mitigation Options- US & Switzerland co-leads
   - Website- Mike Mongillo and IPGT Secretariat
     - Mike Mongillo for the IEA-GIA end has added some information about the joint IEA-GIA-IPGT Induced Seismicity Working Group on the GIA website.
   - Communications
   - Add additional tasks or drop some tasks

2. Discuss content of white paper and any drafts that may exist or other work that is being done (GEISER? or similar efforts)
   - Existing DOE white papers
   - Australian drafts
   - GEISER meeting will have just finished

3. Discuss each country's efforts in Induced Seismicity
   - Road maps, etc

4. Other topics
   - Next Meeting/s
   - Website

7.3 Author and Contact

Ernie Majer
Geophysics Department
Lawrence Berkeley National Laboratory
1 Cyclotron Road MS 74-316C
Berkeley, California
UNITED STATES
E-mail: elmajer@lbl.gov

National Activities
Chapter 8
Australia

Figure 8.1 *Petratherm's Paralana 2 wellhead, located in the northern Flinders Ranges of South Australia. Paralana 2 was the first deep well to test the geothermal resource at the Paralana field. (Photo courtesy of Petratherm)*

8.0 Introduction

The use of geothermal energy for electricity generation and direct use applications is new technology to Australia and requires successful technical and commercial demonstration before gaining widespread acceptance. Nonetheless interest and activity in the geothermal sector continues to gather momentum.

8.1 Highlights and Achievements for 2011

- On 24 March 2011, the Government announced an immediate tax deduction for the exploration of geothermal energy sources from 1 July 2012. This will ensure that exploration for geothermal receives the same treatment as hydrocarbon energy sources.
- Joint Venture partners Geodynamics and Origin Energy spudded Celsius 1 well in April 2011. This was the first geothermal well in the Cooper Basin deliberately drilled to assess a Hot Sedimentary Aquifer resource in the Hutton Sandstone at about 2,416 m depth.
- In July 2011, Petratherm undertook successful fracture stimulation at their Paralana 2 deep well site in South Australia. The primary aim of the fracture stimulation, which was to create fractures in the subsurface at least 500 metres from the Paralana 2 well, was achieved and preliminary analysis suggests that the stimulated zone extends approximately 900 metres to the east of the Paralana 2 well at a depth from 3,500 to 4,000 metres.
- The Australian Government's AU$ 126 M Emerging Renewables program was launched on 8 August 2011. Around one third of this funding is expected to support geothermal projects, with AU$ 26.6 M to specifically support the geothermal industry.
- On 14 September 2011, The Australian Centre for Renewable Energy (ACRE) released three documents on the development of geothermal energy in Australia. See: http://www.acre.gov.au
- The 4th Australian Geothermal Energy Conference (AGEC) was held in Melbourne, Victoria, Australia, from 16-18 November 2011. This annual conference is the premier national forum dedicated to geothermal energy, and is jointly presented by the Australian Geothermal Energy Association (AGEA - the industry representative body for Australian geothermal companies) and the Australian Geothermal Energy Group (AGEG - representing the wider Australian geothermal energy community including industry, government and academia).

8.2 Current Status

Nationally, to the end of 2011, 56 companies have applied for 379 licence areas (covering 460,000 km^2) to progress proof-of-concept amagmatic Enhanced Geothermal Systems (EGS) and Hot Sedimentary Aquifer (HSA) projects (Figure 8.2). From 2002 to 2011, more than AU$733 million (US$758 million) has been spent on studies, geophysical surveys, drilling, reservoir stimulation and flow tests which comprise the work programs required to sustain tenure in geothermal licence areas.

8.2.1 Electricity

Geothermal energy is currently produced at one small binary power station at Birdsville, Queensland, which is supplemented by diesel powered generators. The fluid is 98 °C and derives from the Great Artesian Basin (also referred to as the Eromanga Basin) which overlies the Cooper Basin. The water is run through a gas-filled Organic Rankine Cycle heat exchanger and the partly cooled water is channelled into a pond for further cooling and reticulation into the town's water supply and lagoon. The gross capacity of the plant is 120 kW and the plant power consumption is approximately 40 kW, equating to a net output of 80 kW. Total exported power generation in 2011 was 1,933 MWh, of which 625 MWh was provided by the geothermal power plant. This equates to 32% of total exported power output, which reduced diesel consumption by about 136,000 litres and saved about 366 tonnes of greenhouse gas emissions through the year. Geothermal generation thus constitutes less than 0.001% of National Demand which is estimated at 252,619 GWh (BREE, 2011).

No new developments were constructed in 2011 and one new exploration well, Celsius 1, was spud in the Cooper Basin targeting a Hot Sedimentary Aquifer resource.

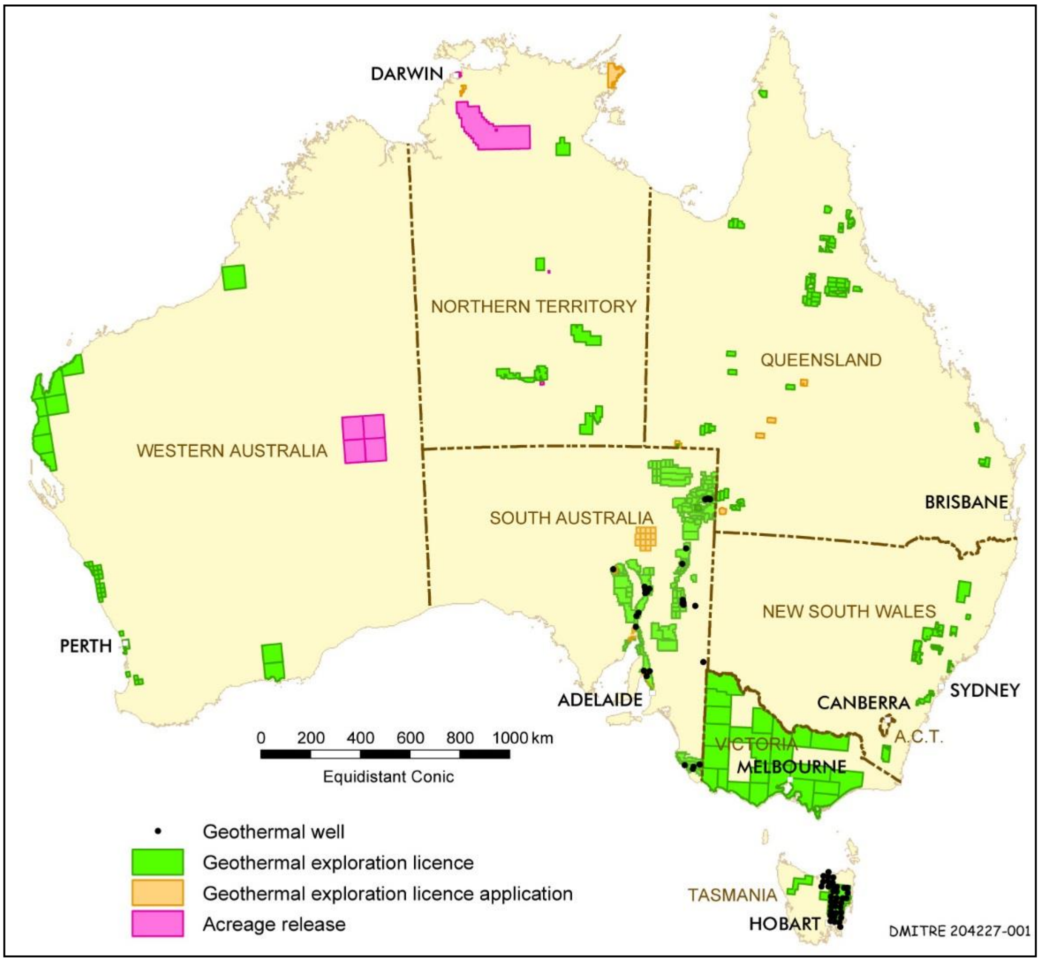


Figure 8.2 *Geothermal licences, applications and gazettal areas as at 31 December 2011.*

8.2.2 Direct Use

Australia's total installed capacity in direct geothermal applications is estimated to be 36.3 MW_{th}. This is corrected down from prior estimates due to the decommissioning of the Portland district heating system, but otherwise has increased by circa 3 MW_{th} (Lund et al., 2011). Following Lund et al. (2011), with a capacity factor of 0.22, the thermal energy used is estimated to be 254 TJ/year. Bathing and swimming installations total 7 MW_{th}; Aquaculture 2.3 MW_{th}; Ground Source Heat Pumps (GSHPs) constitute 27 MW_{th}.

8.2.3 Energy Savings in 2011

The estimated fossil fuel saving is 6,048 tonnes of oil equivalent (1 toe = 42 GJ). Using the DTI/Carbon Trust/DEFRA/Ofgem recommended figure of 0.43 kg CO_2 per kWh saved yields avoided emissions of CO_2 of 30,339 tonnes per year.

8.3 National Policy

8.3.1 Strategy

In 2011, the Australian Government introduced a comprehensive plan to move to a clean energy future. The Clean Energy Future plan will cut pollution and drive investment, helping to ensure Australia can compete and remain prosperous in the future. The plan includes introducing a carbon price, promoting innovation and investment in renewable energy, encouraging energy efficiency, and creating opportunities in the land sector. The Clean Energy Future plan will cut greenhouse gas pollution by at least 5% compared with 2000 levels by 2020, which will require cutting net expected greenhouse gas pollution by at least 23% in 2020.

On 10 July 2011, the Government announced the establishment of the Australian Renewable Energy Agency (ARENA), as a part of its Clean Energy Future plan. ARENA will commence operations on 1 July 2012, and will consolidate administration of AU$ 3.2 billion (US$ 3.31 billion) in Government support for renewable energy technology currently administered by the Australian Centre for Renewable Energy (ACRE), the Australian Solar Institute (ASI) and the Department of Resources, Energy and Tourism. ARENA's objectives are to improve the competitiveness of renewable energy technologies, and increase the supply of renewable energy.

The Emerging Renewables Program opened for applications from renewable energy technology projects on 8 August 2011. This Program commits AU$ 126 M (US$ 130.3 M) in funding toward Australian renewable energy and enabling technology projects to move them along the innovation chain. Under the Program, at least AU$ 40 M (US$ 41.3 M) will be available for developing technologies with potential to contribute to large-scale baseload power generation, such as ocean and geothermal. A further AU$ 26.6 M (US$ 27.5 M) has been allocated to assist the geothermal energy sector specifically.

The Clean Energy Future plan complements the Australian Government's Renewable Energy Target (RET) scheme, initiated in 2009 and expanded in 2010, to stimulate investment and growth in Australia's renewable energy industry, including the geothermal sector. Key goals of the RET scheme are to:

- Promote additional generation of electricity from renewable energy sources with a declared target of 20% of national electricity supply from renewables by 2020
- Achieve reductions in greenhouse gas emissions in the electricity sector.

Further details on the new RET arrangements are available in previous Annual Reports, the Enhanced Renewable Energy Target fact sheet (see: http://www.climatechange.gov.au/en/government/initiatives/renewable-target/fs-enhanced-ret.aspx) and from the Office of the Clean Energy Regulator (see: http://ret.cleanenergyregulator.gov.au/).

8.3.2 Legislation and Regulation

In Australia, legislation and regulation of geothermal exploration and development is a State and Territory government responsibility. Each of the six states (New South Wales, Queensland, South Australia, Tasmania, Victoria and Western Australia) and one territory (Northern Territory) has legislation in place to regulate geothermal exploration and development. Relevant legislation is summarised in Table 8.1.

8.3.3 Progress toward National Targets for Renewable Energy and Emissions

The Government's commitment to renewable energy is centred on the Clean Energy Future plan and the Renewable Energy Target, discussed in section 8.3.1 above. The Government has pledged to reduce emissions by 5% below 2000 levels by 2020, and has adopted a new long-term target to reduce carbon pollution by 80% below 2000 levels by 2050. The Government plans to introduce a range of complementary measures to support the transformation required to reach these targets and sustain Australia's economy.

From 1 July 2012, a carbon price of AU$ 23 (US$ 23.78) per tonne will be introduced which will create an incentive to reduce emissions, drive investment in renewable and low emissions technologies, provide greater certainty for business investment.

The expanded 20% by 2020 Renewable Energy Target (RET) introduced in 2010, is accelerating the widespread commercial deployment of renewable energy technologies. With a carbon price, the RET is expected to drive around AU$ 20 billion (US$ 20.7 billion) in private sector investment by 2020. Due to the timeframes of the development of the technology however, it is unlikely that geothermal will meet a significant amount of the RET.

Table 8.1 *Summation of the applicable legislation currently governing geothermal exploration activities in the various Australian states.*

State or Territory Government	Applicable legislation for geothermal exploration	Description
South Australia	*Petroleum and Geothermal Energy Act 2000*	Regulates licensing and activity approvals for upstream petroleum, geothermal, gas storage and petroleum pipeline projects. An 'over the counter' system, where explorers can apply for those areas desired. Licences can co-exist with existing or future minerals and petroleum exploration titles.
Victoria	*Geothermal Energy Resources Act 2005*	Regulates large-scale commercial and sustainable exploration and extraction of geothermal energy resources.
New South Wales	*Mining Act 1992*	Governs geothermal exploration, which is considered as Group 8 - Geothermal Substances. Application for a Group 8 geothermal exploration licence requires the Minister's consent.
Queensland	*Geothermal Exploration Act 2004* *Geothermal Energy Act 2010*	Applies a competitive permit system to encourage and facilitate efficient and responsible exploration. The Act includes comprehensive legislation covering exploration and production and provides for over-the-counter applications for exploration tenure. The exploration and production provisions under the *Geothermal Energy Act 2010* and the Geothermal Energy Regulation 2012 are due to commence in March 2012 and the *Geothermal Exploration Act 2004* and the Geothermal Exploration Regulation 2005 will be repealed.
Tasmania	*Mineral Resources Development Act 1995*	Geothermal tenements are granted as a Category 6 mineral 'Special Exploration Licence' (SEL). An 'over the counter' system, where explorers can apply for those areas wanted for exploration. Licences can co-exist with existing or future minerals and petroleum exploration titles.
Western Australia	*Petroleum and Geothermal Energy Resources Act 1967*	Provides legislative coverage for the exploration and recovery of both conventional (hydrothermal) geothermal energy and EGS (hot dry rock) geothermal energy. Does not cover non-commercial uses or heat pumps.
Northern Territory	*Geothermal Energy Act 2009*	Provides for "over-the-counter" application for geothermal authorities over most of the Territory. Intent is to reserve a relatively small region around the Katherine area for later tendered release.

8.3.4 Government Expenditure on Geothermal Research and Development (R&D)

The Australian Government provides support for clean energy technology research and development through Australian Research Council grants and the Commonwealth Scientific and Industrial Research Organization (CSIRO). Additional programs have been implemented to support the development of geothermal across the innovation chain. These are discussed in section 8.6.2.

The Australian geothermal sector has also benefited from targeted policy and legislative frameworks and generous grant funding from the Australian state and territory governments in addition to Commonwealth funding. New government initiatives in 2011 to support geothermal energy research and development are summarised below, and the reader is referred to previous Annual Reports for further information on historical programs.

South Australia (SA)- Launched in 2004 by the South Australian Government, the Plan for Accelerating Exploration (PACE) initiative includes funding for collaborative exploration programs that address critical uncertainties in mineral, petroleum and geothermal exploration. In 2011, AU$ 0.5 M (US$ 0.52M) in PACE funding was awarded to the South Australian Centre for Geothermal Energy Research (SACGER) in support of innovative research. For details of successful projects supported by PACE funding, see: http://www.pir.sa.gov.au/minerals/pace/theme_2. South Australian Government support for other research organisations and programs is discussed further in Section 8.6.2 and Appendix B.

Queensland (Qld)- The Queensland Government's AU$ 5 M (US$ 5.2 M) Coastal Geothermal Energy Initiative (CGEI) aims to investigate additional sources of hot rocks for geothermal energy close to existing transmission lines. A 12 hole fully-cored shallow-drilling program commenced in November 2010 to assess the geothermal potential of a range of geological settings in Queensland. By the end of 2011, ten holes were completed with stabilised temperature data being recorded from six holes. Temperature logging will be undertaken from the remaining four holes in early 2012. Thermal conductivity measurements on core samples have been completed for ten holes with heat flow regime being determined for six holes. Final results is planned to be released by the end of 2012 to report on geothermal energy potential of the selected geological settings.

8.4 Market Development, Stimulation and Constraints

8.4.1 Development Constraints

Over the past four years, the Australian Government has committed over AU$ 200 M (US$ 212 M) to the geothermal energy sector. Approximately AU$ 13.5 M (US$ 13.96 M) only of these funds have been released to companies thus far, as recipients are required to achieve certain milestones prior to payment. The Australian Government has been working with companies to assist the progress of projects and has shown flexibility where able in accordance with the Program Guidelines.

At a broader scale, the geothermal sector is having difficulty in accessing capital for their projects in the current market. No additional companies listed on the Australian Securities Exchange (ASX) in 2011, although equity markets continued their support of the geothermal sector by participating in individual companies' capital raisings. The issues in relation to access to private sector capital have been reasoned as the:

- Lack of investor certainty on a price on carbon
- High risk nature of these particular early-stage proof-of concept projects
- Some sub-optimal results from early geothermal projects
- Need for high amounts of capital for the project
- The overall increasing cost for these projects in particular the drilling component

The Bureau of Resources and Energy Economics (BREE) have undertaken a report on Australia's long term energy production (to 2034-35), which was released in December 2011 (BREE, 2011). This followed the Treasury modelling report: *Strong Growth, Low Pollution – modelling a carbon price,* released on 10 July 2011, (The Treasury, 2011).

BREE note that Australia has large geothermal energy potential. However, these resources are currently considered sub-economic because geothermal technologies for electricity generation have not been demonstrated to be commercially viable in Australia. BREE suggest that the commercial development of the industry is dependent on the demonstration of the technical and commercial viability of harnessing geothermal energy in Australia to show an acceptable investment risk, including grid connection. Given the time expected to achieve commercial viability and the long lead time to bring a new geothermal power plant into operation, geothermal energy is not expected to play a major role in electricity generation over the projection period, although it is expected to grow to 4% of total electricity generation by 2034-35.

8.4.2 Support Initiatives and Market Stimulation Incentives

Some of the measures under the Clean Energy Future Plan announced on 10 July 2011 which are relevant for geothermal include:

Carbon Price- From 1 July 2012, a carbon price of AU$ 23 (US$ 23.78) per tonne will be introduced which will create an incentive to reduce emissions, drive investment in renewable and low emissions technologies, provide greater certainty for business investment and begin the adjustment of our economy to a cleaner energy future.

ARENA- A new independent agency, the Australian Renewable Energy Agency (ARENA), will be established in 1 July 2012 incorporating measures currently managed by the Australian Solar Institute (ASI), the Australian Centre for Renewable Energy (ACRE), and the Department of Resources, Energy and Tourism. ARENA will manage a total of AU$ 3.2 billion (US$ 3.31 billion) in funding, with AU$ 1.7 billion (US$ 1.76 billion) in uncommitted funding to be invested in renewable energy and enabling technology projects between now and 2020.

Clean Energy Finance Corporation- The Government will establish a AU$ 10 billion (US$ 10.34 billion) commercially oriented Clean Energy Finance Corporation to invest in businesses seeking funds to get innovating clean energy proposals and technologies off the ground. A variety of funding tools will be used to support projects, including loans on commercial or concessional terms and equity investments. The CEFC will invest in energy efficiency and low emissions technologies, as well as the manufacturing businesses that provide inputs for these sectors (for example, manufacturing wind turbine blades).

The Australian geothermal sector benefits most directly from targeted programs currently administered under the Australian Centre for Renewable Energy (ACRE), which will transfer to the Australian Renewable Energy Agency (ARENA) in 2012. Programs with direct relevance to the sector are the Geothermal Drilling Program (GDP) and the Renewable Energy Demonstration Program (REDP). Additionally, under the Emerging Renewables Program around one third of the available AU$ 126 M (US$ 130.3 M) in funding is expected to support geothermal projects, with AU$ 26.6 M (US$ 27.5 M) to specifically support the geothermal sector.

8.4.3 Costs

Other than the Ergon Energy Birdsville Plant discussed in Section 8.2.1, no commercial scale Engineered Geothermal Systems (EGS) and Hot Sedimentary Aquifer (HSA) units have yet been commissioned in Australia; hence, there are no data available to assess development cost trends. Due to the more speculative nature of EGS and HSA technology at this time, cost discussions have focussed on a discussion of the technology status and cost trends as opposed to more detailed cost and performance estimates.

8.5 Status of Geothermal Industry

At this point the Australian Geothermal Industry remains largely at a pre-competitive exploration stage. At 31 December 2011, a total of AU$ 3,154 M (US$ 3,262 M) in work program investment is forecast for the period 2002 to 2015. An estimated AU$ 733 M (US$ 758 M) of this forecast was invested in the term 2002 to 2011. These forecasts are based upon current proposed exploration work programs and exclude capital expenditure associated with demonstration power plants. However, not all projects are expected to continue to timelines or to the completion of their tenure. An overview of Australian geothermal companies and their projects is presented in Appendix A.

8.6 RD&D Activities

8.6.1 Focus Topics

The Australian geothermal sector recognises that coordinating local research efforts with those of the wider international geothermal community is important, and to this end considerable alignment exists between identified Australian research priorities (DRET, 2008a and 2008b) and international research imperatives (e.g., DoE, 2008; ENGINE, 2008; IPGT, 2008) including the GIA Research Annexes (GIA Work Program), but with a focus on EGS technologies. Coordination is largely achieved through the efforts of the Australian Geothermal Energy Group (AGEG) and the Geothermal Research Initiative (GRI).

The AGEG is a whole-of-sector body comprised of members from industry, government and academia, including key research institutions, interested in the use and development of geothermal energy. It provides financial and intellectual support for Australia's membership in the IEA-GIA via its 12 Technical Interest Groups (TIGs) (Appendix B, Table 1) which are designed to facilitate coordination of Australia's research effort, and foster national and international sharing of information, expertise and research into improved technologies and techniques. For more information, visit http://www.pir.sa.gov.au/geothermal/ageg and see Appendix B.

Established in August 2010, the Geothermal Research Initiative (GRI) is a group of university, CSIRO and Geoscience Australia researchers who have agreed to collaborate on the research and development of geothermal energy resources across a broad range of technologies and geographical locations in Australia. The GRI's aim is to perform research that supports the development of commercial and sustainable large scale geothermal power generation (electricity and heat) in Australia.

GRI's members are the CSIRO, Geoscience Australia, The Queensland Geothermal Energy Centre of Excellence, The Western Australian Geothermal Energy Centre of Excellence, The South Australian Centre for Geothermal Energy Research, The Melbourne Energy Institute, The Priority Research Centre for Energy (University of Newcastle), and the Institute for Earth Sciences and Engineering (University of Auckland). Research topics include, but are not limited to: drilling technologies for deep, high pressure and temperature environments; environmental impacts (such as induced seismicity and efficient water use); pre-drill prediction and characterisation of geothermal reservoir potential; and innovative power generation solutions. See Appendix B.

8.6.2 Government Funded Research

Geoscience Australia- Australia's Onshore Energy Security Program- In 2011, as part of the Australian Government's five year (2006-2011) Onshore Energy Security Program, key activities of Geoscience Australia's geothermal energy project included release of new heat flow determinations as the first results generated by a new data acquisition capability, and development of 3-D thermal modelling work flows including their application to regional geothermal energy assessments. Acquisition of seismic, MT, gravity, magnetics and geochemistry data continued in areas with energy potential. For more information see: http://www.ga.gov.au/energy/geothermal-energy-resources.html

Commonwealth Scientific and Industrial Research Organisation (CSIRO)- CSIRO's research capabilities in the geothermal arena are broad, due to the organisation's research diversity and ability to integrate multidisciplinary skills. CSIRO's activities in geothermal are through its contribution to WAGCOE's research (see below) for HSA resources and in reservoir stimulation for EGS resources as well as directly into the areas of hydraulic fracturing, reservoir engineering, well bore stability, rock petrophysics and microseismic monitoring. For more information, visit www.csiro.au/org/geothermal.

South Australia (SA)- The South Australian Centre for Geothermal Energy Research (SACGER) was established in 2009 through funding from the South Australian Government's Renewable Energy Fund. In 2011 the Centre was granted an additional AU$ 2 M (US$ 2.1 M) of funding from the Department for Manufacturing, Innovation, Trade, Resources and Energy, State

Government of South Australia. A further AU$ 1 M (US$ 1.03 M) of funding to SACGER researchers was provided by the Australian Research Council and the South Australian Premier's Science and Research Fund. SACGER's research areas complements research programs of other national centres and focus on: electrical imaging of crustal fluids, regional geothermal assessments, fracture mapping using seismic tools and well logs, reservoir fracture and flow modelling, fluid-rock interactions, crustal stress, reservoir quality and productivity, thermodynamic modelling of geothermal power plants. For more information see: www.adelaide.edu.au/geothermal/ and Appendix B.

Western Australia (WA)- The Western Australian Geothermal Centre of Excellence (WAGCOE) is a collaborative venture between three of Western Australia's leading research institutions: CSIRO, The University of Western Australia, and Curtin University of Technology. WAGCOE is charged with leading the exploration and exploitation of geothermal energy in Western Australia, and is focussing initially on direct heat use technologies (e.g., geothermal powered air conditioning and desalination) for use in population centres where there is shallow groundwater of moderate temperature. For more information, visit: http://www.geothermal.org.au/ and Appendix B.

Queensland- The Queensland Geothermal Energy Centre of Excellence (QGECE) is based at the University of Queensland and commenced operations in January 2009 with a five year program designed to fill gaps in the national and international geothermal research effort. The Centre's focus is on new tools for precompetitive exploration of high heat producing granites and above ground technologies, with the aim of accelerating large-scale utilisation of geothermal energy in Australia in collaboration with other national and international research groups and the industry. For more information, visit: www.uq.edu.au/geothermal and Appendix B.

New South Wales (NSW)- Geothermal research at the University of Newcastle focuses on novel power generation cycles and the concept of CO_2 thermosiphon concept for Engineered Geothermal Systems (EGS). The study of power cycles is regarded as a key area for major technological improvements since many of the problems associated with power generation from geothermal sources are underpinned by inefficient, and often unsuitable, heat exchange processes within power cycles. This is partly due to the fact that most power cycles currently in use were originally designed for large-scale power production from fossil fuels, where higher temperature sources are available for heat exchange. For more information see Appendix B.

The University of New South Wales' School of Petroleum Engineering (SCOPE) has undertaken a research program aimed at helping the geothermal industry to pick up the critical momentum and overcome the key problems in achieving commercial viability. The primary goal of the program is to triple the flow through classical Enhanced Geothermal Systems (EGS) production and injection wells. This will be achieved by delivering a step change for stimulation technology. In view of this SCOPE has assembled an integrated work program investigating simulation of fluid flow and heat transfer, reservoir stimulation and flow assurance. For more information see Appendix B.

Victoria- The Melbourne Energy Institute, located at the University of Melbourne, has a number of geothermal projects including the Victorian Geothermal Assessment Report, which intends to address critical issues for the successful development of geothermal power capability in Victoria. For more information, visit: http://www.energy.unimelb.edu.au.

8.6.3 Industry Expenditure on Geothermal R&D

Australian geothermal sector field expenditure is considered as research and totalled AU$ 88 M (US$ 91 M) in 2011.

8.7 Geothermal Education

8.7.1 Postgraduate education

A Master's level course in Advanced Energy Systems was introduced in 2009 at the University of Newcastle to cover a range of topics including geothermal power generation.

8.8 Future Outlook

Key activities scheduled for 2012 include the drilling and stimulation of Habanero 4 well and subsurface connection of the Habanero 1 and 4 doublet at Geodynamics' Innamincka EGS Project in the Cooper Basin of South Australia.

8.9 References

Henfling, J. A. , Atcitty, S. and Maldonado, F. (2011) Enhanced High Temperature Power BREE (2011) Australian energy projections to 2034–35. BREE report prepared for the Department of Resources, Energy and Tourism, Canberra, December, 2011. Accessible online at: http://www.bree.gov.au/documents/publications/aep/Australian-Energy-Projections-report.pdf

Lund, J. W., Freeston, D. H. and Boyd, T. L. (2011) Direct utilization of geothermal energy: 2010 worldwide review. *Geothermics,* 40, Issue 3, 159-180.

The Treasury (2011) *Strong Growth, Low Pollution – modelling a carbon price*. Commonwealth of Australia, Canberra. Accessible online at: http://carbonpricemodelling.treasury.gov.au/carbonpricemodelling/content/default.asp

8.10 Websites

http://www.pir.sa.gov.au/geothermal
http://www.pir.sa.gov.au/geothermal/ageg

Acknowledgements

AGEG and AGEA Members are thanked for their input to this report.

8.11 Authors and Contacts

Betina Bendall
Energy Resources Division
Department of Manufacturing, Innovation, Trade, Resource and Energy (DMITRE)
GPO Box 1264
Adelaide, South Australia 5001
AUSTRALIA
E-mail: Betina.Bendall@sa.gov.au

Barry A Goldstein
Energy Resources Division
Department of Manufacturing, Innovation, Trade, Resource and Energy (DMITRE)
GPO Box 1264
Adelaide, South Australia 5001
AUSTRALIA
E-mail: Barry.Goldstein@sa.gov.au

National Activities

Chapter 9

European Commission

9.0 Introduction

The EU is supporting geothermal energy through its Framework Programmes for Research and Innovation. The Energy Theme of the current 7th Framework Programme (FP7) publishes annual calls for proposals. Topics concerning geothermal energy, both shallow and deep, are included in most of these calls. On the political side, the EU has launched the Strategic Energy Technology Plan (SET-Plan), designed to be the technological pillar of EU energy policy.

9.1 Major Highlights and Achievements for 2011

In the 2011 call, an ERANET for geothermal energy was called. ERANETs are the Commission's tool for co-ordinating the research activities of Member states. One proposal was received dealing with the creation of a European geothermal database. The co-ordinator is Orkustofnun from Iceland. The proposal was positively evaluated and proposed for funding. By the end of 2011 the negotiations were not yet completed.

In 2011, the ongoing projects are:

- GEISER (contact: David Bruhn, dbruhn@gfz-potsdam.de) dealing with mitigation of seismic risk in EGS wells
- GROUND MED (Co-ordinator: CRES, Greece; contact: Dimitri Mendrinos, dmendrin@cres.gr) dealing with ambient heat stored at shallow depths representing the essential component of energy-efficient heating and cooling systems in buildings
- GEOCOM (Co-ordinator GEONARDO, Hungary; contact Gabor Kitley, gabor.kitley@geonardo.com) aiming to demonstrate best available technologies in the use of geothermal energy combined with innovative energy-efficiency measures in three different pilot sites in Hungary, Slovakia and Italy

The past decade has seen a very steep increase of the deployment of heat pumps. There is today a real new need for improved buildings integration of low temperature heating/cooling; we intend to cover these issues through Private-Public Partnerships. A topic on heat pumps is planned for the 2012 call.

The European Technology Platform for Renewable Heating and Cooling (RHC-ETP) gathers all main renewable heating sources and stakeholders (biomass, solar thermal and geothermal) and deals with strategic issues for growth, competitiveness and sustainability.

The structure of this platform has been approved by the board and the next important objectives are to elaborate a shared/common vision about the development of the market by 2020 - 2030 with the preparation of the related Strategic Research Agenda.

9.2 EU-Policy

9.2.1 Strategy

The SET-Plan comprises six European Industrial Initiatives (EEI), unfortunately none on geothermal energy, and the European Energy Research Alliance (EERA). The geothermal EERA was officially launched in 2010 and is busy with programming research needs for geothermal energy until 2030.

9.2.2 EU Expenditure on Geothermal R&D

EU-support for geothermal energy RTD adds up to over 7 million € in FP7 until 2010 included. The new ERANET is not yet included because the grant agreement is not yet signed.

9.3 Authors and Contacts

Erich Nägele
European Commission DG Research
CDMA 5/173
B-1049 Brussels
BELGIUM
E-mail: Erich.Naegele@ec.europa.eu

Sylvain de Royer-Dupré
European Commission DG Energy
DM 3/124
B-1049 Brussels
BELGIUM
E-mail: Sylvain.De-Royer-Dupre@ec.europa.eu

National Activities

Chapter 10

France

Figure 10.1 ***View of BO-5 and BO-6 production wells of the Bouillante geothermal plant (Guadeloupe, West Indies): the production line has been adapted at the very end of 2010 and reinforced to resist to major seismic events.***
(Photo *©CFG Services - Géothermie Bouillante*)

10.0 Introduction

France has developed the various types of geothermal energy for a long time, especially after the two oil crises that happened at the end of the 1970s:

- Many operations of direct use of geothermal energy have been realised since 1961: the larger part of the wells have been drilled in the beginning of the 1980s, in the Paris sedimentary basin and also in Aquitaine. A renewed interest for these operations has emerged since 2007.
- The single French geothermal power plant has been installed in Bouillante (Guadeloupe, French West indies) in 1986. A second unit in Bouillante was started in 2004. There have been several surface exploration studies and exploration drillings in the French West Indies and in La Reunion island.
- The development of ground-source heat pumps is more recent and still weak.

A new policy has been implemented since 2005, mainly due to the '*Grenelle de l'environnement*' process which aimed to redefine the French policy for sustainable development and which was based on discussions with various stakeholders: industry, environmental associations, local authorities, state services, unions and experts.

This ambitious policy suggests a new development of every type of geothermal energy nowadays in France. Geothermal heat is expected to increase by a factor of 5 between 2006 and 2020, and an amount of 80 MW of geothermal electricity is expected to be installed in the overseas department in 2020.

10.1 Highlights and Achievements

10.1.1 Implementation

New geothermal operations for direct heat use have been realised since 2007 in the Paris basin. Three deep geothermal projects were finished in 2011. A totally new 11 MW geothermal plant harnessing the Dogger was inaugurated in December 2011. It will provide 85% of the thermal needs of the heating network of Lognes and Torcy (East of Paris). Moreover, two old geothermal doublets in the Paris basin, drilled in the very beginning of the 1980s, were rehabilitated in 2011: one in La Courneuve, transformed in a triplet (a new geothermal production well was drilled and the two existing wells are now injection wells with a reduced diameter;, and one in Coulommiers, where the old doublet was replaced by two totally new wells.

Figure 10.2 *Drilling operation on-going in Coulommiers.*
(Photo © CFG Services)

Two exploration permits were issued in Alsace (East of France), in Lauterbourg and Wissembourg. The geothermal resource that is expected there in the Rhine graben is more than 150 °C, in order to build a combined heat and power plant. Ten other applications for exploration permits have been registered in 2011: six in Alsace, two in Aquitaine basin, one in the Massif Central area and one in the Paris basin.

In the overseas department, three important actions have been carried out in 2011:

- Additional surface exploration has started in Martinique island.
- The Interreg project "Caribbean Geothermal" has been funded and is coordinated by the Guadeloupe regional authorities. This 8.5 M€ project aims to accelerate the development of geothermal energy in the whole Caribbean region.
- The French Agency for Development funded exploration drilling in Dominica island, the island located between Guadeloupe and Martinique. The expected potential is so important that it exceeds the local consumption and that an electric interconnection with surrounding islands is studied.

10.1.2 R&D Achievements

A significant R&D project has been Geostocal, funded by ANR and ended in 2012. It studied the feasibility of an inter-seasonal storage of excess heat (from a waste incinerator) in a deep aquifer in terms of financial sustainability, well design, geochemical behaviour, etc. The conclusions were positive and an industrial demonstration operation will perhaps be implemented in the following years.

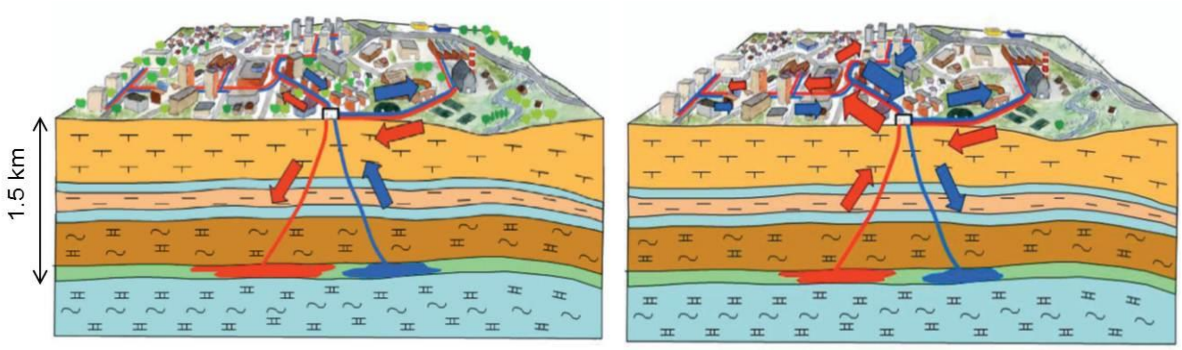


Figure 10.3 *Presentation of the Geostocal concept: in the summer (figure to the left), the heat produced by the waste incinerator (to the right) excesses the heat demand of the district heating (to the left) and is stored in the deep saline aquifer; in the winter, as the heat demand is much higher, the heat produced by the incinerator and the heat produced by the underground storage is consumed by the district heating.*
(Figure © BRGM)

10.1.3 Industry Successes

The French geothermal industry is now structured in a professional association named AFPG and organises a yearly event.

10.1.4 Funding to Industry

A renewable heat fund has subsidised deep and shallow operations since 2009. It is a very useful tool to develop these operations, as well as the feed-in tariff put in place in 2010. Moreover, the risk mitigation schemes for deep and shallow heat projects, which have existed for many years now, are very efficient too. They should be extended for electricity.

10.1.5 Funding to R&D

In 2011, a call for deep geothermal demonstration projects for heat and/or power generation has been published, based on a strategic roadmap published the same year. It will fund innovative industrial projects.

10.2 Current Status of Geothermal Energy Use

The 2011 status of geothermal energy use in France is briefly presented in Table 10.1 below.

Table 10.1 *Status of geothermal energy use in France for 2011*
(na = data not available)

Electricity	
Total Installed Capacity (MW_e)	17,7
Contribution to National Capacity (%)	na
Total Generation (GWh)	56,6
Contribution to National Demand (%)	0,01%
Direct Use	
Total Installed Direct Use (MW_{th})	345
Total Heat Used (PJ/yr) [GWh/yr]	3.8 [1,058]
Total Installed Capacity for Heat Pumps (MW_{th})	1,671
Total Net Heat Pump Use (PJ/yr) [GWh/yr]	9.1 [2,535]

Figure 10.4 *View of Bouillante reinjection: a partial reinjection has been put in place to maintain the pressure in the reservoir.*
(Photo ©CFG Services - Géothermie Bouillante)

10.2.1 Electricity Generation

The French installed capacity still consists of the two power plants described in the 2010 GIA Annual report, namely the Bouillante power plant in Guadeloupe (French West Indies) and the EGS pilot plant in Soultz-sous-Forêts (Alsace). The Bouillante power plant began operations again in April 2011, following a period of technical problems and improvement works performed on the wells and pipes during a significant part of 2010 and the beginning of 2011. Partial reinjection has been put in place and started.

Even if this electricity production is negligible compared to the national demand, it is important to note that the installed capacity in Guadeloupe represents around 6% of the need for electricity of the island.

No new wells were drilled in 2011; exploration drilling is being considered in another part of the Bouillante concession and, even though it is less mature, on the Martinique Island.

Figure 10.5 *Overview of the Montagne Pelée in Martinique (French West Indies): the western slope of the volcano is one of the most promising geothermal areas of the island. (Photo © BRGM)*

10.2.2 Direct Use

The direct use of geothermal energy is quite developed in France, compared to similar countries without magmatic resources. The installed thermal power is estimated at 345 MW_{th} and comprises about 50 plants. Most of them are used for district heating.

The Paris basin is remarkable as it incorporates 36 geothermal doublets (one production well, one injection well) linked to 31 heating networks. These doublets are exploiting the Dogger Aquifer, which is located at depths between 1,600 and 1,900 m; the temperature of the pumped water is between 60 and 80 °C.

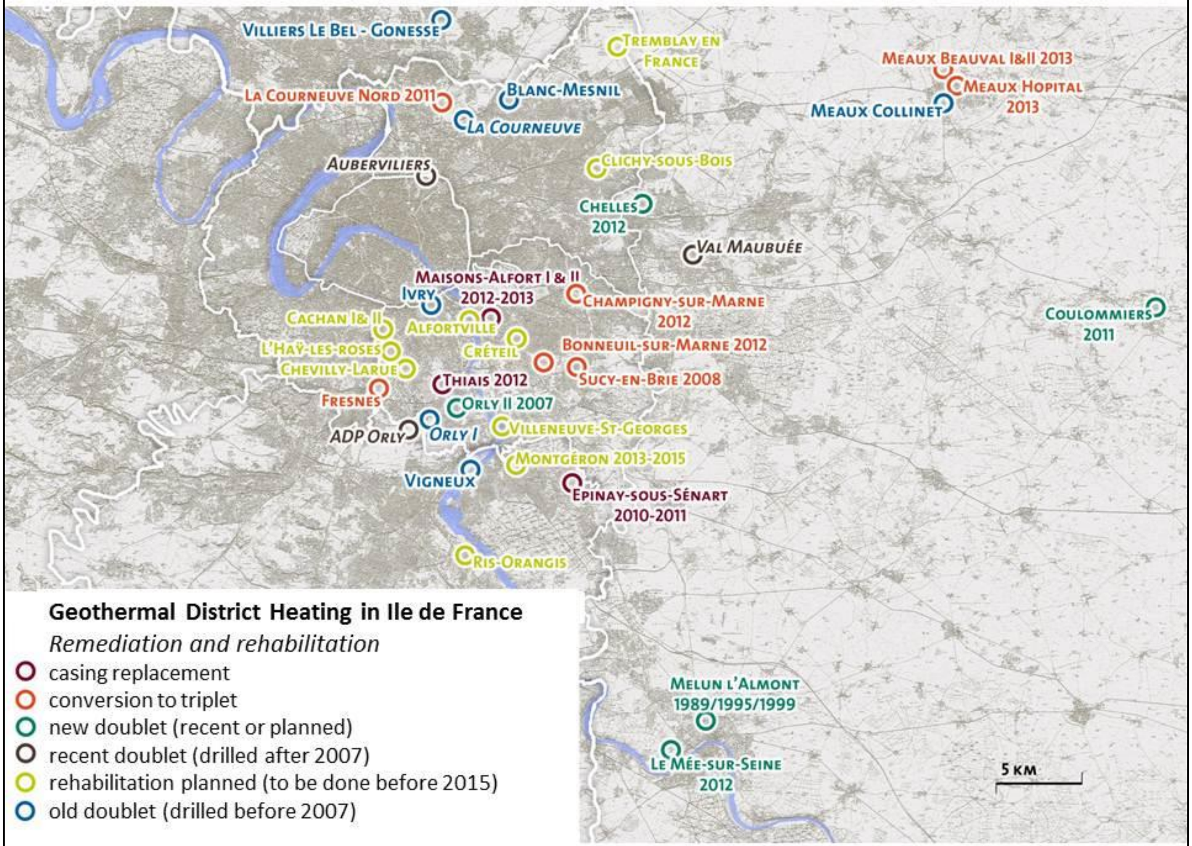


Figure 10.6 *Overview of the geothermal plants running in the Paris basin.*
(Figure © BRGM)

The second location in France for direct use is Aquitaine (south-west France), with around 10 single production wells. These operations were realised in the beginning of the 1980s and this technical option was chosen as the pumped water is not highly saline and can be discharged to the surface. The regional geology is, moreover, quite complicated, so that the drilling of reinjection wells is not easy. In addition, the temperature is lower than in the Paris basin which makes the profitability of a doublet harder to achieve.

The geothermal heat pump market is still weak, especially for individual housing. The number of installed heat pumps decreased in 2011; with a decreasing market since 2008 and the beginning of the economic crisis that limits the investment capacity of households. This general figure hides a more flourishing market for office buildings, encouraged by the integrated heating and cooling applications, and for collective public housing, motivated by the stability of costs throughout the years.

10.2.3 Energy Savings in 2011

The geothermal installed capacity in France represents an equivalent saving of 470,000 tonnes of oil and around 1,470,000 tonnes of CO_2 per year.

10.3 France National Programme

10.3.1 Strategy

In 2009, France decided on a target of 23% of renewable energies in its energetic mix by 2020. This means that an additional yearly amount of 20 million toe of renewable energies has to be produced in 2020. To reach this objective, the contribution of every type of renewable energy has been determined. 50% of the additional energy production is expected from renewable heat and 50% from renewable electricity.

The objectives for geothermal heat in 2012 and 2020 were defined in 2009, and they are shown in Figure 10.7 below:

- Direct use: from 1.5 TWh in 2006 to 2.3 TWh in 2012 and 5.8 TWh in 2020.
- Geothermal heat pumps: from 1.0 TWh in 2006 to 3.9 TWh in 2012 and 6.6 TWh in 2020. That means notably an objective of two million households using ground-source heat pumps in 2020.

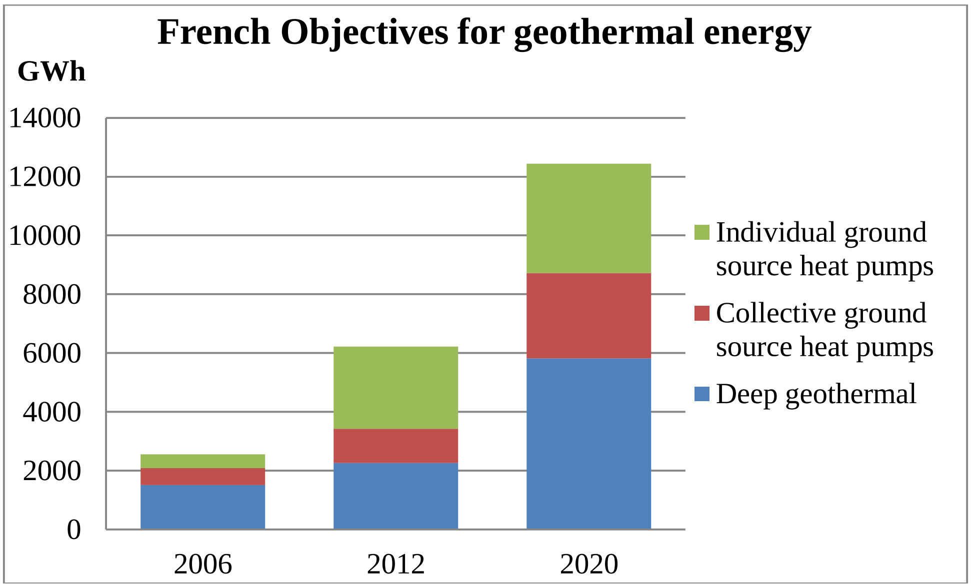


Figure 10.7 Objectives for future development of geothermal heat in France.

Geothermal heat is thus expected to increase by a factor of 5 between 2006 and 2020, whereas, the general objective for renewable heat is a factor of 2.

Geothermal electricity is expected to reach 80 MW in France in 2020. There are two main issues with this objective:

- Provide French islands (French West Indies and La Réunion) with a decarbonized energy, replacing the actual thermal electricity production, at a reasonable cost; moreover, the 2020 objective for these islands is 50% of renewables instead of 23% at a national level, because the current production is mainly from fossil fuel.
- Acquire good experience in EGS projects to develop this energy in a larger way by 2050.

In terms of the reduction of energy demand, one main measure was to set the new standard for energy consumption in new buildings at a level of 50 kWh/m^2/year. This requires replacing electric heating by Joule effect, with, e.g., heat pumps.

In 2011, a strategic geothermal roadmap was published by ADEME (the French Agency for Environment and Energy). Written with the help of a committee of experts, it describes the challenges and issues of the geothermal sector and gives a 2020 vision. It identifies the technical and scientific barriers to define the R&D priorities and the needs for demonstration operations.

10.3.2 Legislation and Regulation

The implemented measures to reach these objectives were above all designed to build an adequate economic context for the development of renewable energies: these financial measures, including the renewable heat fund, are described in section 10.4.2.

The major need in terms of regulation is a clarification of the one which is applicable to ground source heat pumps. The regulatory scheme was written at the end of the 1970s and focused on deep geothermal projects for direct use or electricity. The procedures for shallow geothermal projects are unclear at the moment: according to the way the law reads, they can be either very onerous, or non-existent. In addition to these unclear procedures, the environmental requirements are also not defined.

For these reasons, some work is being done on regulatory procedures, professional standards and the certification of drillers.

10.3.3 Progress towards National Targets

The progress differs significantly from one type of geothermal to another:

- In terms of electricity, many projects are emerging on the mainland (combined heat and power); but many fewer projects are planned in the overseas regions, due to a less favourable framework (notably, the feed-in tariff).
- In terms of direct use, a few installations are made each year in the Paris basin, which is encouraging but not sufficient. To reach the objective, it will be necessary to increase the number of installations made in the Paris basin and also to have projects in a huge variety of aquifers and geological contexts.
- In terms of ground source heat pumps, the installed capacity is increasing but the pace must be accelerated to reach the target.

10.3.4 Government Support/Incentives for R&D

The main part of the national R&D budget for geothermal energy is managed by ADEME. A part of the upstream research is also funded by ANR (national agency for research).

At the end of 2011, the French government organized a call for projects to fund innovative deep geothermal demonstration operations for heat and/or power generation, based on the strategic roadmap mentioned in section 10.2.1. The results will not be known before the end of 2012.

10.4 Market Development, Stimulation and Constraints

10.4.1 Development Constraints and Issues Affecting Growth

The major existing constraints apply to the heat pump market. Two major facts can be raised here:

- The relatively low cost of gas affects the profitability of shallow geothermal projects, above all, for heat only applications (housing).
- The new regulatory scheme for energy efficiency in buildings is based on primary energy and does not take into account the emitted greenhouse gases; a coefficient of 2.58 is applied to electricity (1 electrical kWh equals to 2.58 thermal kWh) so that heat pumps are less competitive than what they could be. A more balanced approach will surely be put in place in the future standard.

10.4.2 Support Initiatives and Market Stimulation Incentives

A 'Renewable Heat Fund' ('*Fonds chaleur renouvelable*') was put in place in 2009 to fund projects related to industry, collective housing and commercial buildings. Around € 1.2 billion was allocated to cover the 2009-2013 period, for all renewable energies. The principle is to fund the difference between a project using renewable heat and a reference solution (generally using gas). It is also funding the development of heating networks and subsidizing for feasibility studies.

After a slow start in 2009, the funding of geothermal projects is now well established, as shown in the Table 10.2 below.

Table 10.2 *Status of geothermal energy use in France for 2011.*

	Number of funded projects			Quantity of renewable energy produced by the funded projects (toe/yr)	Amount of the subsidy given by ADEME (k€)
	2009	2010	2011	2010	2010
Deep geothermal	1	4	4	10,044	11,966
Shallow aquifers	4	32	33	2,066	3,427
Borehole heat exchangers	10	35	34	325	2,544
Waste water	1	6	16	448	2,983
TOTAL	**16**	**77**	**87**	**12,883**	**20,920**

In addition to this fund, several measures to develop heating networks were implemented in 2010 and were presented in the previous annual report. A system of energy saving certificates also encourages energy suppliers to promote energy savings to their customers.

There is a 36% tax reduction in place for individual housing, covering the heat pump and the geothermal heat exchanger. The 2012 rate will, nevertheless, be 26% because all the existing tax reductions for investments related to renewable energies have been decreased.

An important incentive for the development of geothermal projects is an appropriate risk mitigation scheme. Two public schemes exist in France, one for deep geothermal (managed by 'SAF Environnement') and one for shallow (covering only operations on aquifers and called Aquapac). Both of them cover the short term risk (initial flow rate and temperature) and the long term risk (exploitability of the resource over 20 years). The reason to create two separate funds is that the insured amount of money is very different between the deep projects (€ 4.2 M) and the shallow ones (€ 115 k). These two funds are supported jointly by public authorities and by the project owners. They work thanks to the mutualisation and the public funding. However, these schemes do not currently apply for electricity.

For electricity, the main measure in 2010 is the new feed-in tariff put in place in July 2010. The geothermal electricity is now bought at an increased price of 130 €/MWh in the overseas departments (instead of 100 €/MWh) and 200 €/MWh on the mainland. A bonus is given if the co-produced heat is also used.

10.4.3 Comment on Costs

There have not been enough deep projects to be able to provide statistics. A geothermal doublet in the Dogger aquifer of the Paris basin amounts typically to 12-15 M € for 10-11 MW. The number of projects per year is increasing, so that one or two drilling rigs will hopefully stay in the Paris basin or at least in France in the coming years. This could decrease the project costs in the future.

Figure 10.8 *The Stage Costume National Center in Moulins (CNCS). Since temperature and humidity must be kept stable to preserve the 10,000 pieces of the collections, CNCS uses a 4-tube network fed by a heat pump using geothermal groundwater; this monitored installation presents an annual average coefficient of performance of 3.78, a cost per MWh produced of € 21/MWh and reduced CO_2 emissions by 77% compared to a conventional solution (gas boiler and chiller). (Photo © CNCS)*

10.5 Status of Geothermal Industry in France

10.5.1 General Description of the Geothermal Industry

The French industry covers all the activities needed for geothermal (turbine and heat pump manufacturers, surface and subsurface engineering companies, drillers, etc.). In 2010, most of them chose to gather into a national association dedicated to geothermal, called AFPG, in addition to the existing SER which represent all renewable energies. In December 2011, the association organised "les Journées de la Géothermie", a two-day conference and exhibition.

Thanks to the feed-in tariff, many companies emerged to manage deep geothermal projects and answered the call for demonstration projects mentioned in section 10.3.4.

10.6 RD&D Activities

10.6.1 Focus Areas

The French research activities cover every type of geothermal energy. France works especially on EGS, using, in particular, the pilot plant Soultz-sous-Forêts. The 3rd phase of Soultz R&D programme is on-going, focusing on the site exploitation and monitoring, and trying to determine the life time of such geothermal projects.

Some R&D is also being conducted on conventional high enthalpy, notably around the geothermal site of Bouillante. Research on low enthalpy consists of resource characterization and modelling.

Some R&D work is done on ground source heat pumps and geothermal exchangers, using different R&D platforms; with the aim to optimising the whole system and testing some innovative concepts, such as the combination of various renewable energies or underground thermal energy storage.

10.6.2 Government Funded

R&D is mainly funded by ADEME, with a budget of a few million euros. ANR also funds some research, which is more often upstream or focused on energy storage.

10.6.3 Industry Funded

Some research work is being done on equipment (thermodynamic cycles, pumps, etc.). Another important part of the investment is dedicated to geothermal exploration. The amount of the French industrial effort for R&D is however unknown.

Several national technological clusters have been put in place to develop collaborative R&D projects between industry and the research institutions:

- Avenia, based in Aquitaine, deals notably with deep geothermal applications.
- Synergile aims at developing renewable energies in the overseas department.
- Dream (Orléans), is focused on water and environmental impacts.
- S2E2 (Orléans) deals with smart buildings.
- Advancity for smart cities, Tenerrdis for several renewables, Derbi for heat storage.

10.7 Geothermal Education

The major part of the educational programs deal with ground source heat pumps, as this sector will hire the majority of the people involved in geothermal energy. Initial training is being developed by universities. ADEME funds a part of these continuous training programmes.

10.8 Future Outlook

For 2012 and beyond, several major events can be expected for a further development of geothermal energy in France:

- The number of deep operations for direct heat use will surely keep on increasing on the mainland.
- In particular, an operation will be performed in Rittershoffen, in Alsace, to produce industrial heat (more than 150 °C) for industrial processes (Roquette factory in Beinheim).
- Many other permits for geothermal exploration will surely be delivered, especially for electricity or CHP production in the mainland.
- The selection and actual funding of the deep geothermal demonstration projects will give new references to the French industry and open new perspectives.
- The exploration drilling in Dominica will surely be followed by a project of a geothermal plant.
- The regulatory framework for shallow geothermal projects will be clarified.

Figure 10.9 Grand Soufrière Sulphur Springs, Dominica.
(Photo © BRGM)

10.9 Publications, Reports and Books

Boissier, F., Desplan, A., Laplaige, P. (2010) France Country Update. Proceedings World Geothermal Congress 2010. Bali, Indonesia.

La Géothermie en France n°12 (2012) BRGM-ADEME, 2012.

Reports

Strategic geothermal roadmap (2011), ADEME, 2011.

Books

Etat des énergies renouvelables en Europe (2011) édition 2011, EUROBSERV'ER, 2011.

La géothermie en France (2012) Etude du marché en 2011, AFPG, 2012.

10.10 Websites

ADEME (French Agency for Energy and Environment) and BRGM (France's leading public institution in Earth Science field) have put in place a general website dealing with all types of geothermal energy in France: www.geothermie-perspectives.fr

The list of valid high temperature geothermal permits is published on the following website: http://www.developpement-durable.gouv.fr/Les-titres-miniers-en-cours-de.html

10.11 Authors and Contacts

Romain Vernier
Geothermal Energy Department
BRGM
3, Av. Claude Guillemin
BP36009-45060 ORLEANS
Cedex 2
FRANCE
E-mail: r.vernier@brgm.fr

Philippe Laplaige
ADEME
Centre de Sophia Antipolis
500 route des Lucioles
06560 Valbonne
FRANCE
E-mail: philippe.laplaige@ademe.fr

National Activities
Chapter 11
Germany

Figure 11.1 *Geothermal power plant, Bruchsal, Germany.*
(Courtesy of BMU, Germany)

11.0 Introduction and Overview

In Germany, there are three regions particularly well positioned to use geothermal energy: the North German Basin in the northern third of Germany, the Upper Rhine Graben in the south-west, and the Molasse Basin in southern Germany. As a general rule, the temperature of the geological subsurface, or geothermal gradient, rises by an average of 3 K per 100 m as the depth increases, although temperature gradients vary by region. In the regions cited, it is particularly high, and in some places, temperatures may rise by up to 10 K per 100 m.

Overall, by the end of 2011, there were some 120 sites operational in Germany with a drilling depth of 400 m or more (information supplied by www.geotis.de). These sites also included spas with thermal water extraction, for example. According to the German Geothermal Association (GtV), there were 21 geothermal-supplied heating plants in operation in Germany in 2011 which supply households, companies and public buildings with thermal energy via district heating networks. To date, three sites have been developed for electricity production: Landau (Rhineland-Palatinate, 2007), Unterhaching (Bavaria, 2008/2009) and Bruchsal (Baden-Württemberg, 2009). Five further geothermal projects for electricity production are currently under construction: Insheim (Rhineland-Palatinate), Kirchstockach, Kirchweidach and Sauerlach (Bavaria) and Oberhaching (also Bavaria, electricity as secondary use only) (www.geotis.de).

According to the GtV (as per the first quarter of 2010), Germany ranks 5th in the world for the use of geothermal energy in heating, with an installed thermal output of around 2,485 MW. The world leader is the USA (12,611 MW), followed by China (8,898 MW), Sweden (4,460 MW) and Norway (3,300 MW). These statistics include both deep and shallow geothermal systems.

11.1 Highlights

The highlights of geothermal projects in Germany are extensively described in the "Innovation Through Research 2011- Annual Report on Funding in the Renewable Energies Sector" report published by BMU (page 14, 46-57). This document can be downloaded at: http://www.erneuerbare-energien.de/files/english/pdf/application/pdf/broschuere_innovation_forschung_2011_en_bf.pdf.

The brochure can also be ordered as hardcopy at: http://www.bmu.de/english/publication/content/35028.php?detail=2079#6201

11.2 Research Activities

Despite becoming more widely used, there is still an extensive need for research into and optimization of deep geothermal systems. However, the signs are encouraging. Drilling work at the geothermal project in Kirchweidach, Bavaria, in December 2011, was completed with very good results. Once the power plant has been built by GEOenergie Kirchweidach GmbH, it will produce electricity as well as supplying heat to the Kirchweidach community.

However, the exploration risk remains high. One important research priority, as specified in BMU's latest funding announcement, is therefore to develop exploration methods for the selection of further potential sites. Above all, this will make the costs calculable for investors, and therefore facilitate more projects in the long term. Another priority area is to increase acceptance of geothermal projects. By improving the information available to the general public on the technologies used and the benefits of this form of energy, we can pave the way for additional projects. Above all, however, the cost of projects needs to be further reduced to allow the technology to be cost effectively used. Technological advancement throughout all the different project phases will contribute to this: at the planning and exploration phase, the drilling/construction/assembly phase, as well as the test and operational phase.

In particular, drilling needs to become less expensive and faster, since this activity currently accounts for the bulk of investment costs. Once completed, plant operation must be efficient, low-maintenance and reliable. Last but not least, research projects must help lay the foundations to make geothermal suitable for nationwide use.

In the field of geothermal research, in 2011, BMU approved a total of 42 new projects with a total funding volume of around 24.1 M Euros (2010: 30 new projects and 15.1 M Euros). A t the same time, 11.6 M Euros went to ongoing research projects (Figure 11.2) (2010: 9.9 M Euros).

11.3 Financial Support

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) and by offering subsidies towards drilling costs. Since the amendment to the EEG was adopted by the Bundestag (Lower House of Parliament) in late June 2011, the framework conditions for promoting geothermal energy will be improved starting the beginning of 2012. In order to mitigate the current high risks for investors, the subsidy for geothermal electricity will be increased to 25 euro-cents per KWh. The use of enhanced geothermal system (EGS) techniques will also attract a subsidy of 5 euro-cents per KWh as of 2012. With these new rates, the Government is hoping to encourage further advancement of geothermal energy, since construction of new capacity has fallen short of expectations to date. In order to set a realistic time frame for the commissioning of projects, while at the same time pushing for fast implementation, the reduction of subsidy rates has been postponed until 2018.

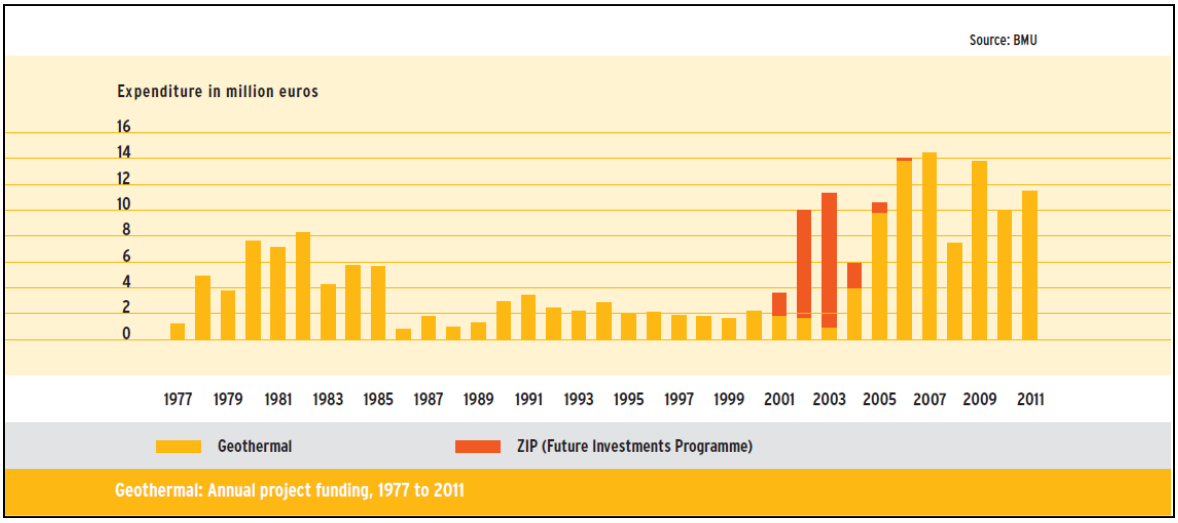


Figure 11.2 *BMU funding for geothermal research.*

11.4 Further Information

An official source for more detailed information about renewable energies can be found at: http://www.bmu.de/en/service/publications/downloads/.

The Working Group on Renewable Energies- Statistics (AGEE-Stat) annually publishes renewable energy statistics. In 2011, the brochure: ***Renewable Energy Sources in Figures- National and International Development*** presented data current to 2010; it is available at: http://www.erneuerbare-energien.de/fileadmin/ee-import/files/english/pdf/application/pdf/broschuere_ee_zahlen_en_bf.pdf

11.5 Author and Affiliation

Dr. Lothar Wissing
Forschungszentrum Juelich GmbH
Project Management Organisation Juelich
Department of Renewable Energies (EEN)
D-52425 Juelich
GERMANY
E-mail: l.wissing@fz-juelich.de

National Activities
Chapter 12
Iceland

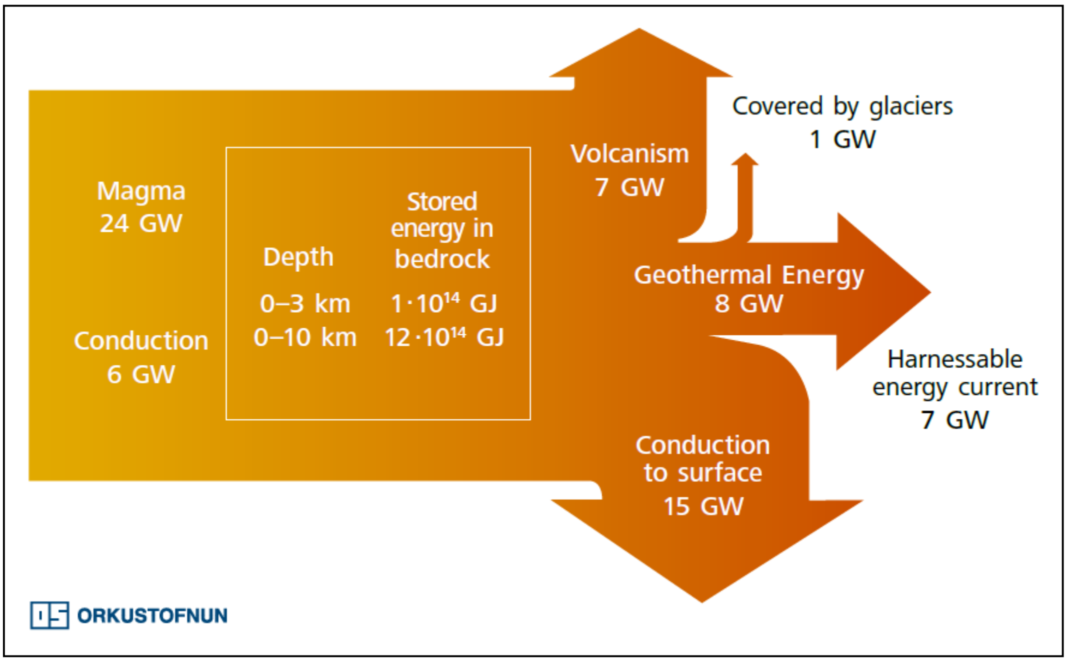


***Figure 1:** Terrestrial energy current through the crust of Iceland and stored heat (Orkustofnun, 2010).*

12.0 Introduction

Practically all stationary energy and 85% of primary energy in Iceland is derived from indigenous renewable sources with a carbon-free electricity generation. This is the result of an effective policy in making renewable energy a long-term priority in Iceland. Geothermal primary energy use contributed 66% in 2011, equivalent to 156 PJ. Nowhere else does geothermal energy play a greater role in providing a nation's energy supply.

The energy current for Iceland has been estimated to be about 30 GW as can be seen in Figure 12.1 of which 7 GW is estimated to be harnassable. Above 10 km depth the energy stored is estimated to be $12 \cdot 10^{14}$ GJ of which it is thought to be technically and economically possible to install 4,300 MW_e of geothermal power at current electricity prices in Iceland and generate about 30 TWh of electricity without taking environmental concerns into account.

12.1 Highlights for 2011

Currently, seven geothermal power plants, of total estimated 625 MW_e installed capacity, are under formal consideration as can be seen in Table 12.1 of which 45-170 MW_e is predicted to be installed in 2012-2014. In Figure 12.2 primary energy use (indigenous production) is plotted against time from 1940-2011. In Figure 12.3 installed capacity and electricity generation in Iceland is shown for 2010 and 2011.

Table 12.1 Installed and planned electric capacity in December 2011 (Orkustofnun, 2012).

Geothermal Field [MWe]	2005	2006	2007	2008–2010	2011	Licenced	Licensing	EIA Completed
Bjarnarflag	3	3	3	3	3	-	-	90
Krafla	60	60	60	60	60	-	-	150
Þeistareykir								250
Húsavík	2	2	2	2	2	-	-	-
Hengill area	120	210	243	333	423	-	-	135
Svartsengi	46	46	76	76	76	-		-
Reykjanes		100	100	100	100	80	-	-
TOTAL	*232*	*422*	*485*	*575*	*665*	*80*	*0*	*625*

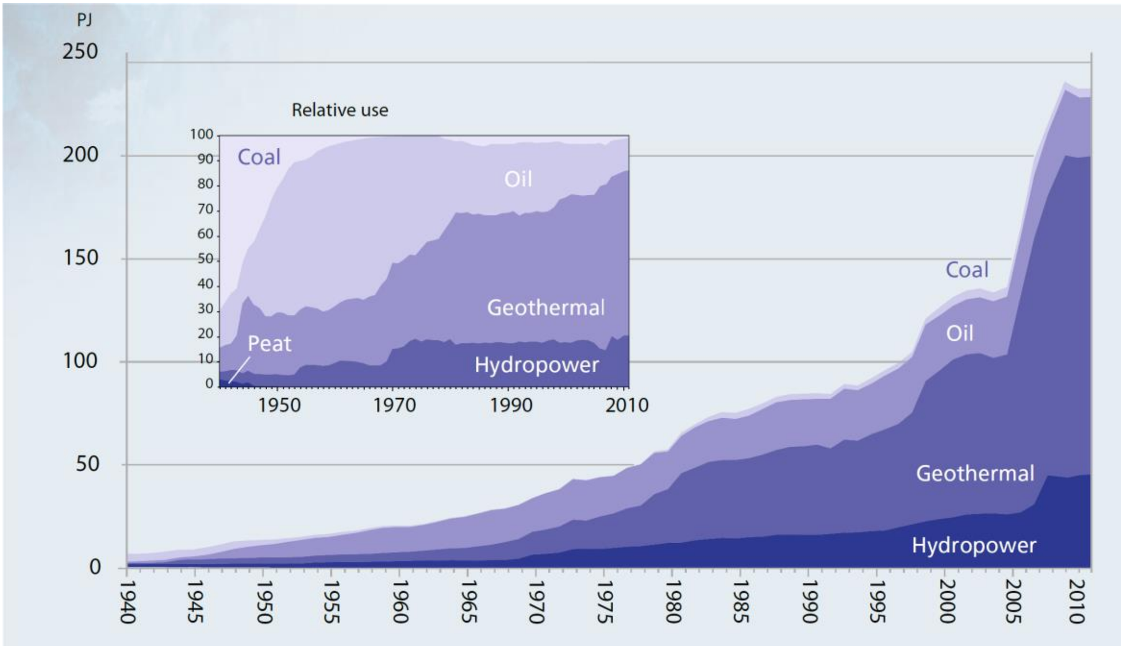


Figure 12.2 *Primary energy use in Iceland 1940-2011 (Orkustofnun, 2012).*

12.2 National Policy

It is the policy of the Government of Iceland to increase the utilization of the renewable energy resources further for the power intensive industry, direct use and transport sector in harmony with the environment. A broad consensus on conservation of valuable natural areas has been influenced by social opposition, increasing over the last decade, against large hydropower and some geothermal projects. The Icelandic Government decided in 1997 to develop a Master Plan for potential power projects. All proposed projects have been evaluated and categorized on the energy efficiency and economics but also on the basis of the impact that the power developments would have on the environment. The Master Plan has been presented to the Icelandic Parliament and the final ranking for projects will be done in 2012. There has also been a governmental effort to search for geothermal resources in areas where geothermal energy has not yet been found. A map of Iceland with identified and anticipated geothermal resources is illustrated in Figure 12.4.

Installed capacity in power plants at the end of the year

	2011		2010	
	MW	%	MW	%
Hydro	1.884	70,6	1.883	73,0
Geothermal	663	24,8	575	22,3
Fuel	120	4,5	121	4,7
Total	**2.668**	**100,0**	**2.579**	**100,0**

Electricity production

	2011		2010	
	GWh	%	GWh	%
Hydro	12.507	72,7	12.592	73,8
Geothermal	4.701	27,3	4.465	26,2
Fuel	2	0,0	2	0,0
Total	**17.210**	**100,0**	**17.059**	**100,0**

Figure 12.3 *Generation of electricity in Iceland in 2011 and 2010 (Orkustofnun, 2012).*

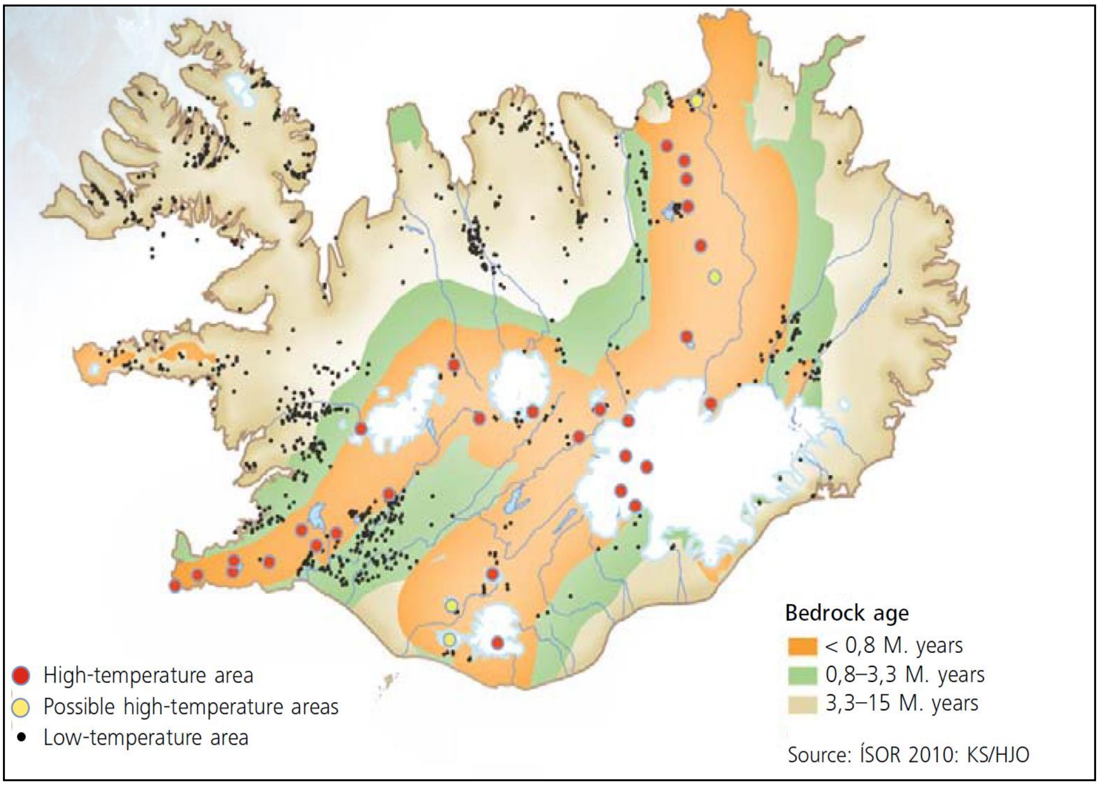


Figure 12.4 *Location of high temperature geothermal fields in the volcanic zones of Iceland and clusters of low temperature springs on the flanks of the volcanic zones. Iceland is located on both a hotsport and the Mid-Atlantic Ridge, which runs right through it. This combined location means that geologically the island is extremely active (Orkustofnun, 2012).*

Three major amendments were made in 2011 to the energy legal framework in Iceland that effect geothermal exploration and utilization: (1) As of end of 2011, The National Energy Authority is the licensing authority for research, utilization and power plant licences for resources in the ground. Before, the institution issued the licenses on behalf of the Minister of Industry. (2) Act No. 48/2011 for the utilization and protection of energy resources was passed which sets up the legal framework for the Master Plan described above. (3) Act No. 36/2011 on Administration of the Matters of Water, which transposes the European Water Framework Directive into Icelandic Law.

12.3 Current Status of Geothermal Energy Use in 2011

12.3.1 Electricity Generation

As a result of a rapid expansion in the power intensive industry in Iceland the demand for electricity has increased considerably. This has partly been met by increased geothermal electricity generation. Total installed electric capacity of geothermal power plants was 665 MW_e at the end of 2011 and 575 MW_e at the end of 2010. Electricity generation from geothermal power plants was 4,701 GWh in 2011 (Figures 12.3 and 12.5). In the near future, electricity generation is estimated to double as can be seen in Table 12.1. Orkustofnun issued two licenses in 2011 for a 90 MW_e expansion at Hellisheiði and a 40-80 MW_e expansion at Reykjanes.

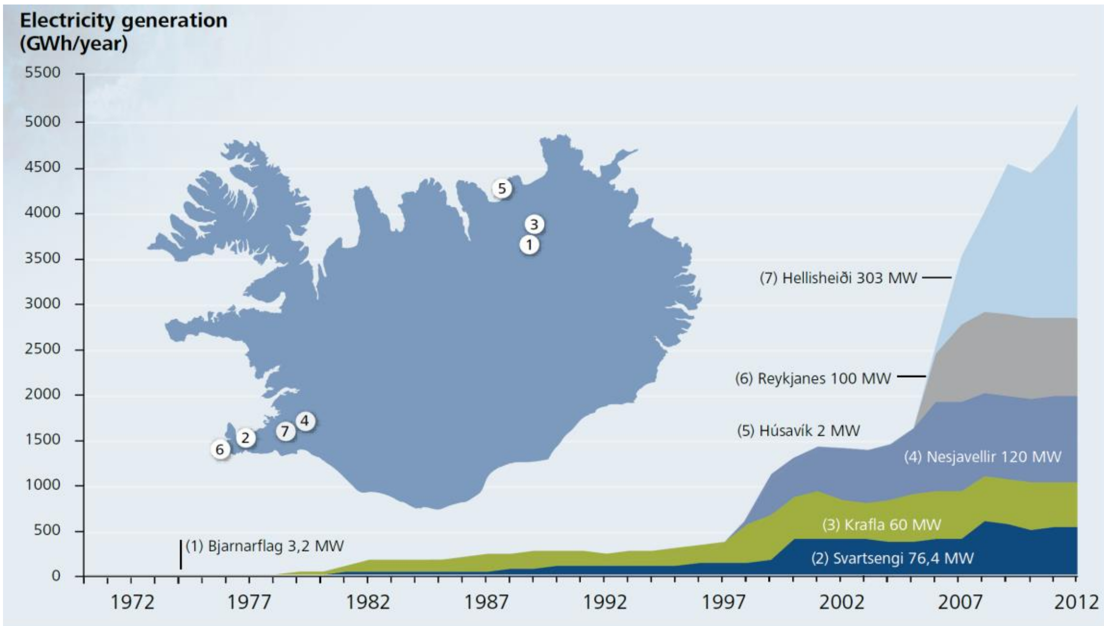


Figure 12.5 *Electricity generation by geothermal power plants in Iceland 1969-2012 (Orkustofnun, 2012).*

12.3.2 Direct Use

The total direct use of geothermal energy in 2011 is estimated to be 25.3 PJ, of which 18.8 PJ is for space heating. Currently, 90% of houses are heated with geothermal energy. The share of oil for heating continues to decrease and is, at present, at about 1%. The share of electric heating is about 9% but one third of that comes from heating plants where electricity is used to heat water for district-heating systems. Heating of swimming pools is also one of the most important types of geothermal utilization in Iceland and the one with the longest tradition. Currently, there are more than 163 geothermal swimming pools in Iceland at 134 sites with a total surface area of 37,550 m^2.

Snow melting on pavements and parking lots has been common in Iceland for the past 15-20 years, and the total area covered is about 1,200,000 m^2. There has been no increase in direct industrial uses of geothermal energy in Iceland during the last???. A seaweed processing plant at Reykhólar, W-Iceland, uses about 250 TJ/a for drying. A plant for the commercial production of liquid CO_2 has been in operation at Haedarendi, in SW-Iceland, since 1986. Geothermal water is also used for heating greenhouses and for small scale timber and fish drying. The direct use of geothermal energy in Iceland is shown in Figure 12.6.

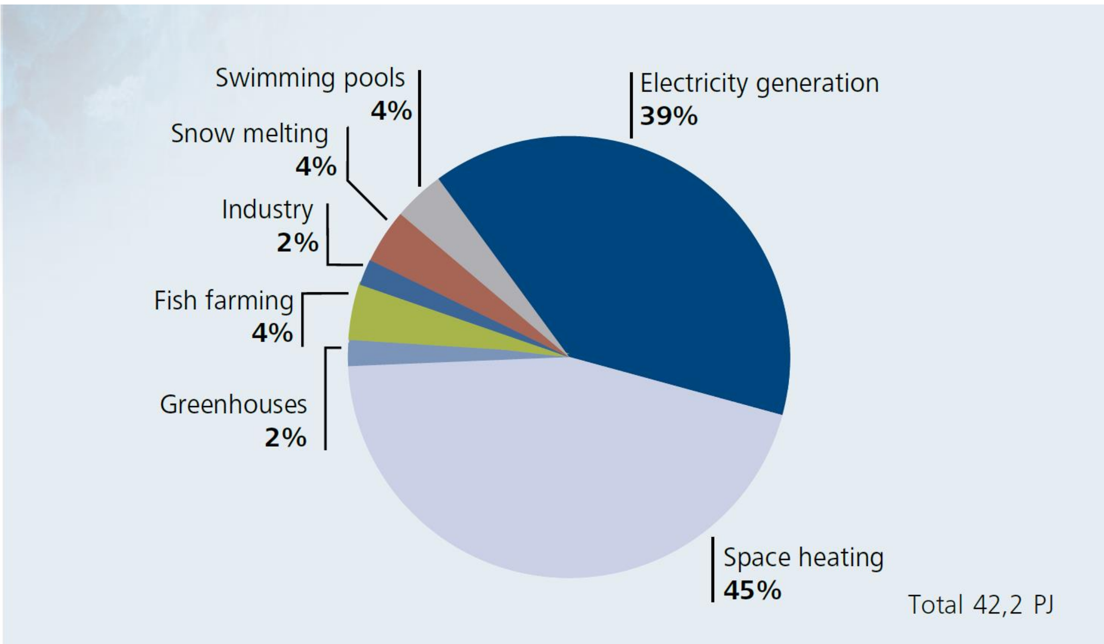


Figure 12.6 Direct use of geothermal energy and electricity generation in 2011 (Orkustofnun, 2012).

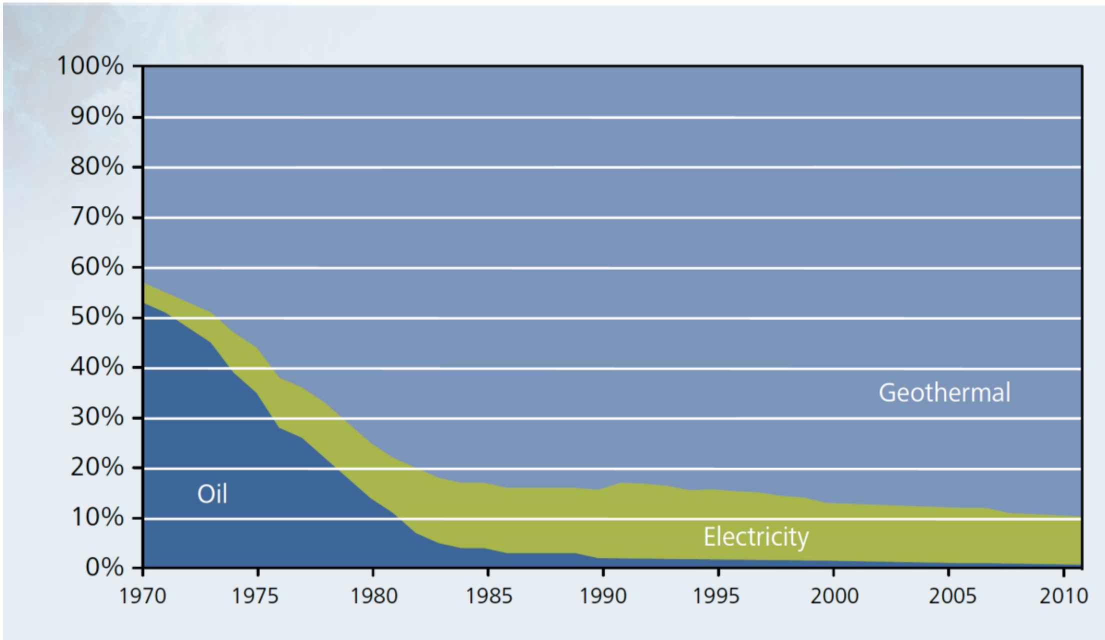


Figure 12.7 Space heating by source from 1970-2011 (Orkustofnun, 2012).

12.3.3 Energy Savings

In 2010, the total CO_2 emission from geothermal power plants was 168,293 tonnes, as can be seen in Table 12.2. Historical development can be seen in Figure 12.8.

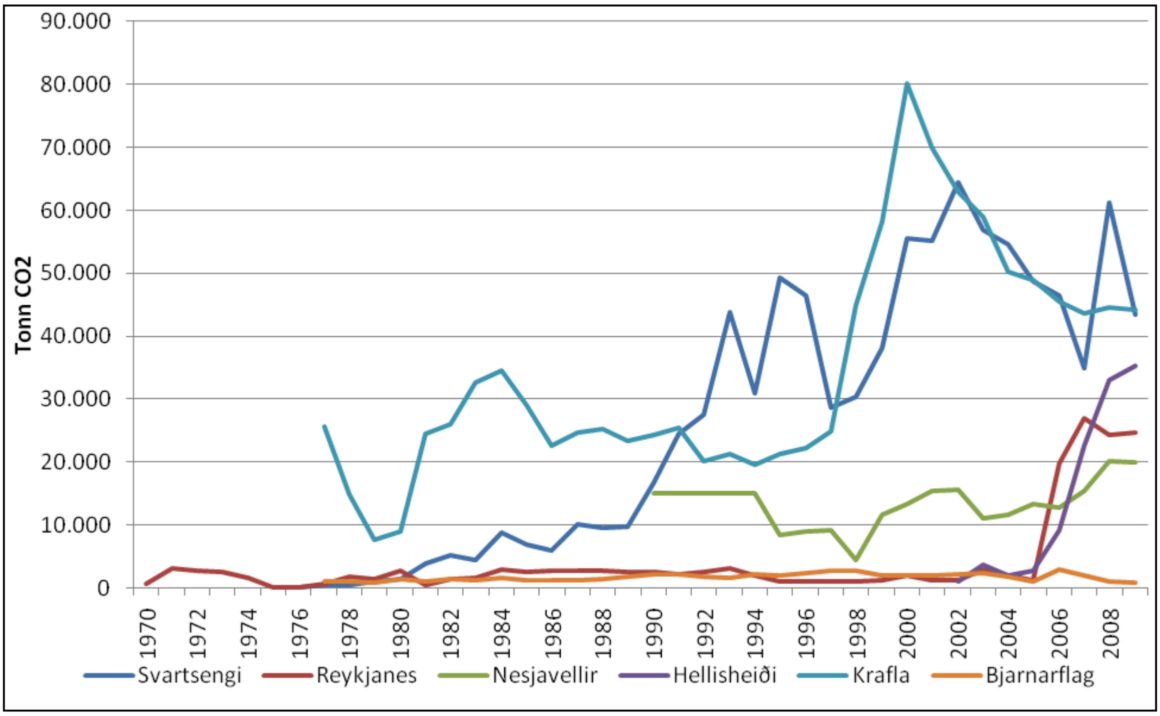


Figure 12.8 *Historical release of Carbon Dioxide from geothermal power plants in Iceland (Orkustofnun, 2011).*

Table 11.2 *Emission of CO_2 in 2010 per electric production* (*Orkustofnun, 2011*).

Geothermal Field	Emission (tonnes/a)	Emission per Electricity Production (g/kWh)
Reykjanes	24,651	28
Svartsengi	43,427	83
Hellisheiði	35,325	21
Nesjavellir	14,800	5.7
Námafjall	826	53
Krafla	44,145	92
TOTAL	*168,293*	*Weighted average: 50*

12.4 Market Development and Stimulation

The high demand for electricity for power intensive industry resulting from the favorable prices of electricity has resulted in large-scale geothermal power development in Iceland. The power intensive industry consumed about 80% of the total consumption in 2011. Due to the success in Iceland, the geothermal industry has been increasingly exporting the know-how to other countries both as consultants and as investors at the feasibility stage. The government gives grants to various projects with emphasis on finding usable geothermal water for space heating in areas where resources have not yet been found. A cluster for stimulating the market development has been formed by all the major players in the industry.

12.5 Development Constraints

Development constraints are mostly due to environmental issues and low electricity prices in Iceland, though geothermal energy was looked upon more positively than hydropower in a recent national review. Local issues do place constraints on drilling sites and access to them. As well, the visual impact of geothermal power plants is becoming increasingly important. Another development constraint is the governmental subsidies, amounting to 1,143 M ISK in 2011, to communities where there is no access to geothermal water for space heating (see Figure 12.9). The subsidies, although effective for regional development, can decrease interest in search for geothermal resources.

Figure 12.9 *Comparison of energy prices for residential heating in mid year 2011 (Orkustofnun, 2012) in kr/kWh (10 kr/kWh is equivalent to 80 USD mills/kWh).*

12.6 Economics

Geothermal power is competitive with hydro in Iceland; providing reliable base load, green energy and favorable prices; 13 ISK/kWh + VAT for 3,750 kWh/a in populated areas but can get considerably lower for the power intensive industry due to very high load factor. For residential heating see Figure 12.9. It is estimated that the installation cost of a relatively large geothermal power plant is around 3.0-3,5 million USD/MW, with about 2% annual maintenance and operational cost.

12.7 Research Activities

12.7.1 Focus Areas

The Iceland Deep Drilling Project (IDDP) 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 from hydrothermal systems at supercritical conditions. The drilling at Krafla was initiated in 2008 with intermediate casings set at 90 m, 300 m and 800 m. In March 2009, the largest drill rig in Iceland, Týr, continued drilling with a 12 ¼" bit with the aim of placing the next casing at 2,400 m. In the depth interval of 2,000 to 2,100 m, the rig ran into repeated trouble which turned out to be due to veins of molten lava. Superheated steam rich in HCl entered the well and turned corrosive when mixed with liquid water. The well was then completed with a casing cemented down to 2,000 m. The well is now believed to be the hottest well in the world with a measured enthalpy of 3,400 kJ/kg. Fluid handling and evaluation along with pilot plant testing started in 2011. Wet scrubbing has been tested with good success. The measured temperature of the fluid in December of 2011 was around 445 °C. The estimated possible power output after losses with wet scrubbing is in the order of 25-35 MW_e. The decision on where to drill the next well has not yet been taken but IDDP-2 is likely to be in Reykjanes. For the Master Plan, research is ongoing in high temperature geothermal areas. In addition, geothermal areas are being searched for near districts that do not have geothermal space heating and Orkustofnun is involved in a few heat pump installations.

In the Master Plan for hydro and geothermal energy resources projects has been evaluated on the basis of the environmental, social and economic impact the projects will have and thus categorized to be developed, protected or to be further considered as seen in Table 12.3. The Parliament in Iceland is now reviewing the results and good amend the final decision before it will be enforced in the law on the Master Plan.

Table 12.3 *Projects in the Master Plan for hydro and geothermal energy resources have been evaluated on the basis of the environmental, social and economical impact the projects will have and thus categorized to be developed, protected or to be further considered.*

Potential Power	Hydro TWh/a	Geoth. TWh/a*	
Existing	13	5	26%
To be developed	3	10	20%
To be protected	8	18	39%
To be considered	6	3	14%
Total	**31**	**35**	

Fluid handling and evaluation along with pilot plant testing started in 2011. Wet scrubbing has been tested with good success. The measured temperature of the fluid in December of 2011 is around 441°C. The estimated possible power output after losses with wet scrubbing is in the order of 25-35 MW_e. The decision on where to drill the second well has not yet been taken, but IDDP-2 is likely to be in Reykjanes. For the Master Plan, research is ongoing on high temperature geothermal areas. In addition, geothermal areas are being searched for near districts that do not have geothermal space heating and Orkustofnun is involved in a few heat pump installations.

In the Master Plan for hydro and geothermal energy resources projects have been evaluated on the basis of the environmental, social and economical impact the projects will have and thus categorized to be developed, protected or to be further considered as seen in Table 12.3. The Parliament in Iceland is now reviewing the results and could amend the final decision before it will be enforced in the law on the Master Plan.

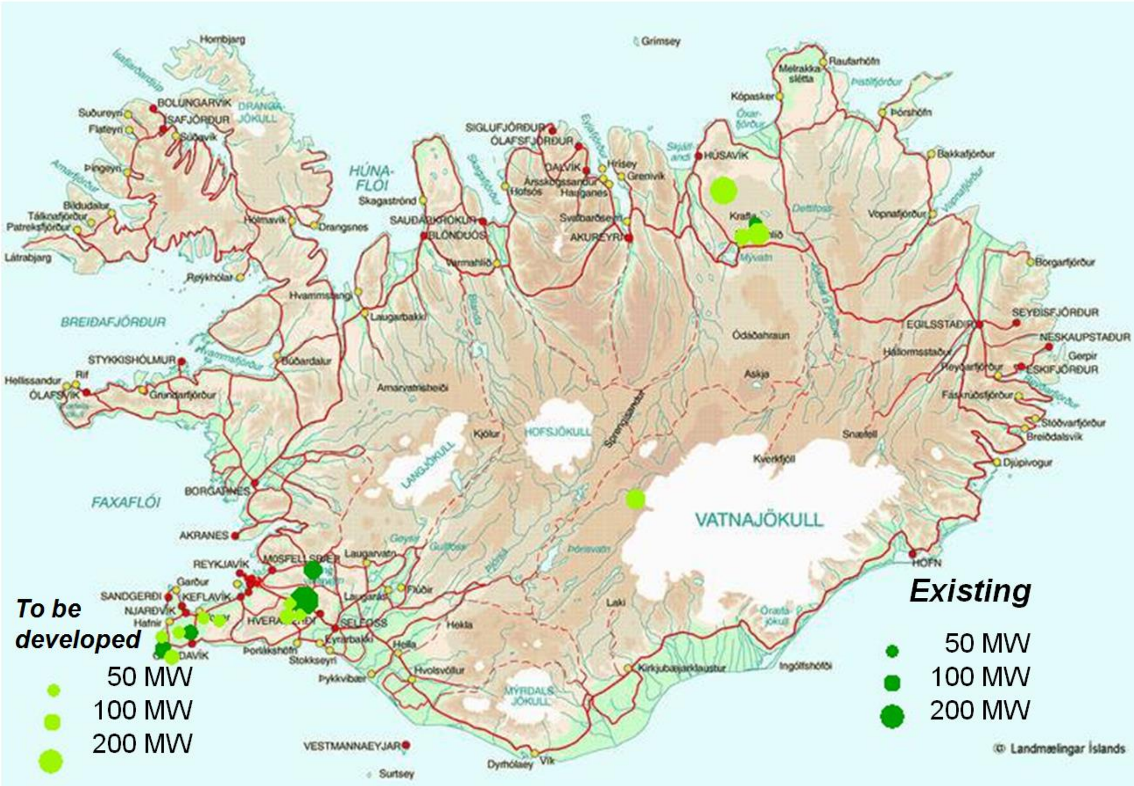


Figure 12.10 *Geothermal power plants to be developed according to the Master Plan.*

12.7.2 Government Funded Research

The international GEOthermal Research Group (GEORG) was launched in 2009, with participation of all the major power companies, research institutions and authorities. GEORG is financially supported by the Science and Technology Policy Council in Iceland, RANNÍS, with up to 70 million ISK annual contribution for seven years. The Energy Fund granted in total 27.4 M ISK to 15 projects in 2011. Orkustofnun represents the government on a steering committee of the IDDP. The total amount from Orkustofnun will be a maximum of US$ 4.6 M. For a few years, the Ministry of Industry has been running a program to encourage geothermal exploration for domestic heating in areas where geothermal resources have not been identified. For the period 2007-2009, 172 M ISK were granted for exploration in 29 places, of which the total cost is estimated to be 300 M ISK. The Icelandic International Development Agency (ICEIDA) is involved in stimulating geothermal utilization in developing countries like, e.g., countries in the East African Rift Valley. The project is in cooperation with the UN Environmental Programme, the KfW Bank in Germany and the Global Environment Fund, along with other donors relating to the research and use of geothermal energy in the northern reaches of the East African Rift.

12.7.3 Industry Funded Research

The three major power companies in Iceland each grant US$ 1.4 M for R&D of the IDDP. The power companies are also responsible for drilling down to 3.5 km depth at their geothermal areas with an estimated cost of around US$ 13.9 M per well. The energy fund of Landsvirkjun granted, in 2011, 56 M ISK to 21 projects.

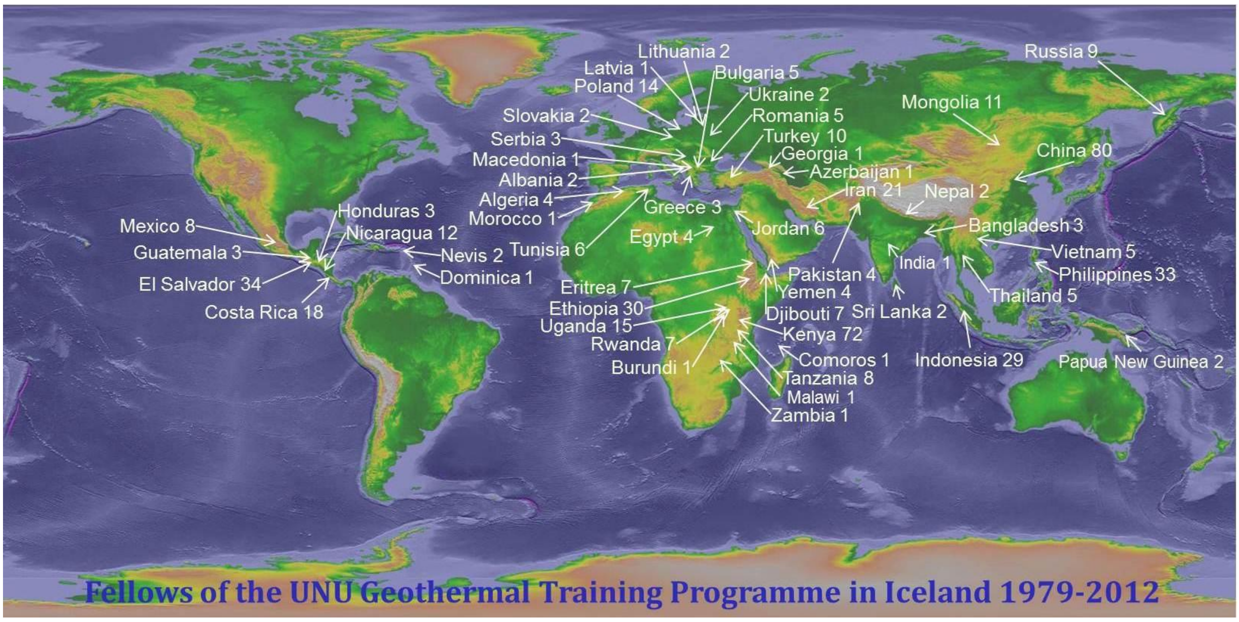


Figure 11 Fellows of the UNU Geothermal Training Programme in Iceland 1979-2012 (*Orkustofnun*).

12.8 Geothermal Education

The United Nations University-Geothermal Training Programme (UNU-GTP) has been operating in Iceland since 1979, with the aim to assist developing countries with significant geothermal potential to establish groups of specialists in geothermal exploration and development. An MSc programme was started in 2000 in cooperation with the University of Iceland. UNU-GTP receives its funding from the government of Iceland, US$ 5 M/a. Since 1979, 482 scientists have graduated from 50 countries. They have come from countries in Asia (41%), Africa (30%), Latin America (16%), and Central and Eastern Europe (13%). Amongst these have been 89 women (18%).

Reykjavik Energy Graduate School of Sustainable Systems (REYST) started its first academic year in 2008 offering education in the field of renewable energy, emphasizing geothermal. REYST graduated three students in 2011.

12.9 International Cooperative Activities

Orkustofnun has made a concerted effort in recent years to foster cooperation amongst entities involved in energy research and the coordination of research projects between countries through administration and active participation within organizations, including the International Partnership for Geothermal Technology (IPGT), the International Energy Agency- Geothermal Implementing Agreement (IEA-GIA), Energy Development in Island Nations (EDIN), the World Energy Council (WEC), the International Hydropower Association (IHA) and the Scandinavian Simulation Society (SIMS).

Through its international efforts in the fields of geothermal and hydro, Orkustofnun aims to foster the efficient utilization of available resources with minimal environmental effects. There has been a variety of outcomes from this effort, which include the development of assessment criteria on the sustainability of hydro and geothermal utilization, and the publication of handbooks and articles within IEA-GIA and IHA, white papers on geothermal technology for IPGT and the mapping of research projects among member states. Regarding the EDIN project, the development of sustainable energy sources for the island of Dominica, in the Caribbean, is underway and Iceland Drilling, in cooperation with Iceland GeoSurvey, is scheduled to complete drilling test wells in the Wotten Waven area in 2012.

Orkustofnun will lead cooperation efforts between seven European countries within the ERA-NET project for geothermal which run on grants from the European Union. The ERA-NET project is aimed at coordinating geothermal research in Europe and fostering cooperation and coordination in the allocation of European geothermal grants.

Orkustofnun will assume the role of Donor Programme Partner (DPP) within the EFTA Development Fund for Hungary, Portugal and Romania on the development, execution and supervision of projects supported by the fund in the field of renewable energy. The focus will be on the utilization of geothermal according to project plans, especially regarding the construction and development of district heating systems with utilization and re-injection wells. It is estimated that over 20 million Euros will be invested in relation to these three programmes.

Iceland has a great deal of know-how and experience in the harnessing of geothermal sources, both for space heating and electricity generation. The Icelandic firms offer technical and investor know-how to maximise the profitability of investment in geothermal projects world-wide: Iceland GeoSurvey, Landsvirkjun, Mannvit, Verkís, Efla and Iceland Drilling Company take part in international cooperative activities.

12.10 References

Orkustofnun, Energy Statistics 2012 (Accessable on the website www.os.is)

Sveinbjörn Björnsson, Inga Dóra Guðmundsdóttir and Jonas Ketilsson. *Geothermal Development and Research in Iceland.* Orkustofnun. 2010. (Accessable on the website www.os.is)

12.11 Author and Contact

Jonas Ketilsson
Orkustofnun
Grensasvegi 9
ICELAND-108
E-mail: jonas.ketilsson@os.is

National Activities

Chapter 13

Italy

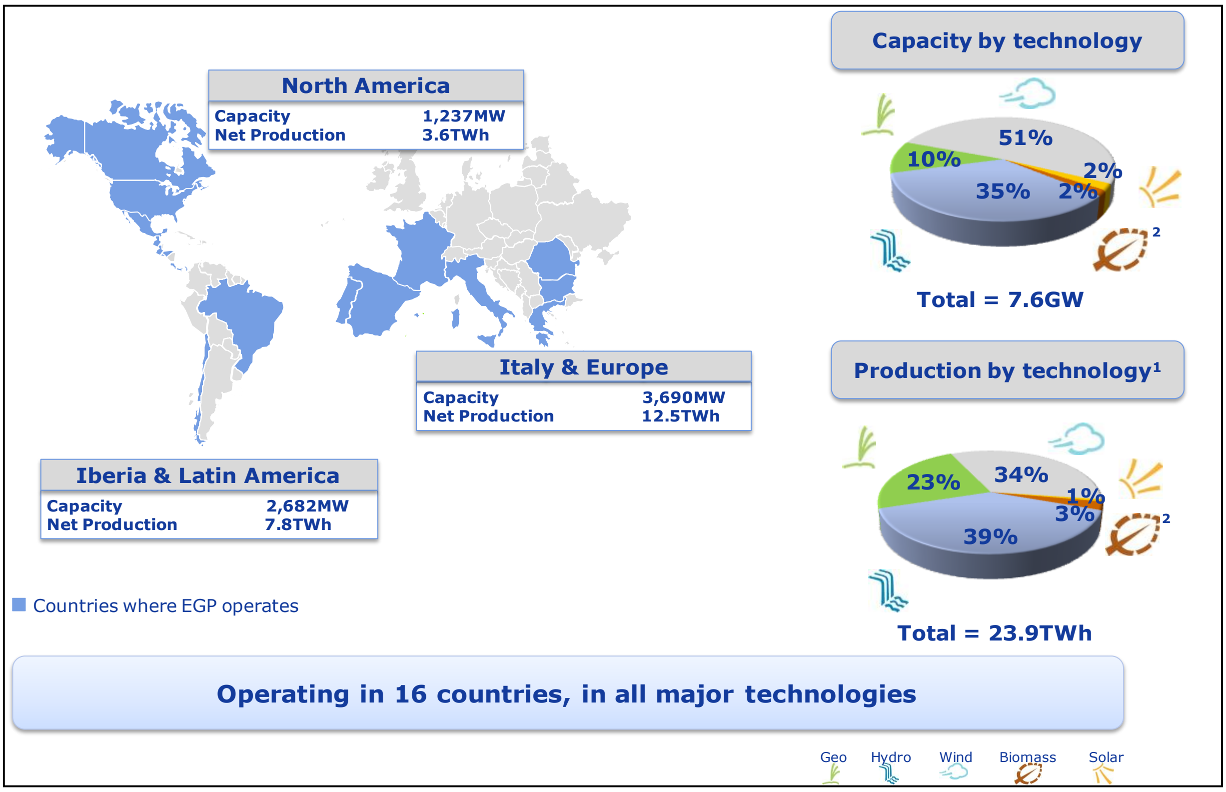


Figure 13.1 *Enel Green Power world wide presence.*

13.0 Introduction

13.1 The Electricity Market in Italy

In Italy, geothermal electricity generation is only in Tuscany, whereas direct uses are scattered all along the country, mainly for bathing and district heating purposes. An overview of the activity carried out in 2011 is presented in this chapter.

The total installed capacity reached the historical maximum of 882 MW_e, with 35 units and the production of 5,315 GWh_e. The heat delivered to direct uses is 3,500 GWh_{th} from 1,000 MW_{th}, half of the installed capacity being used by heat pumps. A new Incentive Law has been approved for the remuneration of the geothermal electricity.

13.1.1 Enel Green Power

The Enel Green Power company is a fully renewable energy producer, owned and controlled by the Enel Group, with a relevant presence in sixteen countries, and a portfolio of geothermal, wind, small hydro, biomass and solar plants. The installed capacity per country and technology is given in Table 13.1 and Figure 13.1.

Table 13.1 Enel Green Power renewable portfolio.

COUNTRY	WIND	HYDRO	GEOTHERMAL	SOLAR	OTHER	TOTAL
Italy	**623**	**1,513**	**722**	**86**		**2,944**
Rest of Europe	**699**	**19**		**28**		**746**
Bulgaria	42	-				42
France	166	-				166
Greece	199	19		28		246
Romania	292					292
Total Europe	**1,322**	**1,532**	**722**	**114**		**3,690**
Iberia	**1,674**	**57**		**13**	**107**	**1,851**
Spain	1,548	57		13	42	1,660
Portugal	126				65	191
Latin America	**98**	**733**				**831**
Brazil		93				93
Chile		92				92
Costa Rica	24	31				55
Mexico	74	53				127
Panama		300				300
Guatemala		164				164
Total Iberia & Latin America	**1,772**	**790**		**13**	**107**	**2,682**
USA	727	313	47	26		1,113
Canada	103				21	124
Total North America	**830**	**313**	**47**	**26**	**21**	**1,237**
WORLD TOTAL (MW_e)	**3,924**	**2,635**	**769**	**153**	**128**	**7,609**

The total number of plants in operation or planned reached the installed capacity of 7.6 GW_e with the production of about 24 TWh_e, making Enel Green Power one of the world leaders in renewable electricity generation. About 1.4 GW_e of new projects are under construction.

13.2 Current Status of Geothermal Energy Use

13.2.1 Electricity Generation

All the geothermal plants in operation are located in Tuscany, in the two productive areas of Larderello/Travale and Mount Amiata (Figure 13.2). All the plants are owned and operated by Enel Green Power.

As of 31 December 2011, the following figures were achieved:

- Wells in operation: 308 for production, 69 for reinjection and 107 as reserve or field control; 96 wells have depths greater than 3 km
- Gathering systems: 207 km of steam lines, 298 km of reinjection pipes
- Power plants: 35 power units, 4 of 60 MWe, 3 in the range 20-40 MWe, 4 old units below 15 MWe, and the majority (24) is with the standard unified design of 20 MWe
- Capacity: the installed capacity of 882 MWe is unevenly split in the two area: Larderello/Travale with 794 MW_e of dry steam units, and Mount Amiata, where in the water dominated field 88 MW_e of flash plants have been installed. The total operating capacity is 728 MW_e, achieving a production of 5,315 GWh_e in 2011.

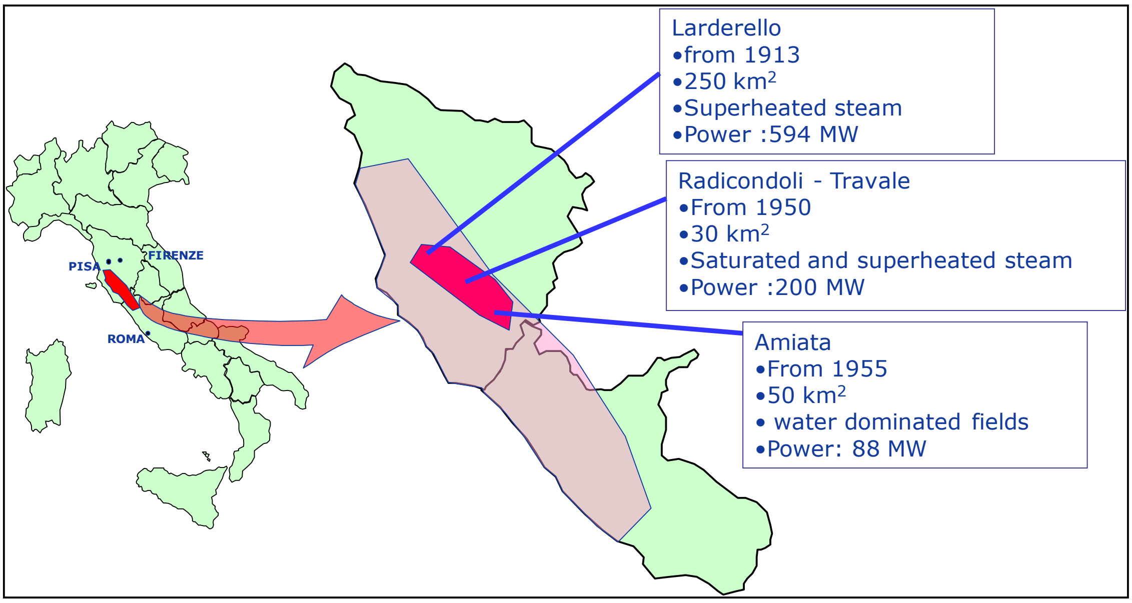


Figure 13.2 *Geothermal areas in Italy.*

The Enel Green Power business plan for Italy is strongly focused on the geothermal development on Tuscany, with several new projects, as highlighted in Figure 13.3: a new 40 MW plant in Bagnore with an additional small binary unit (under construction) on the separated water stream; exploration in the new leases, surrounding the Larderello and Mount Amiata areas, aimed to identify an exploitable geothermal fluid with temperatures suitable for binary power plants.

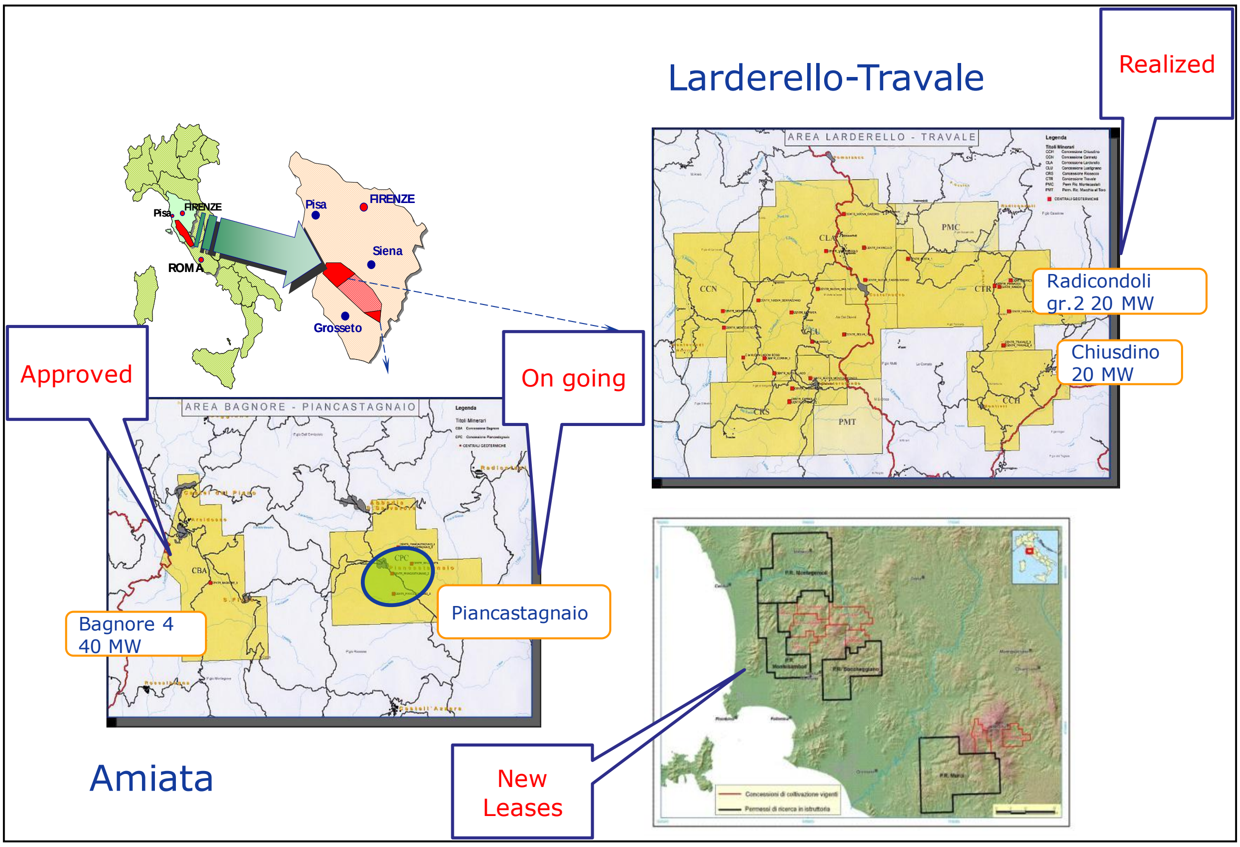


Figure 13.3 *Planned Enel Green Power activities.*

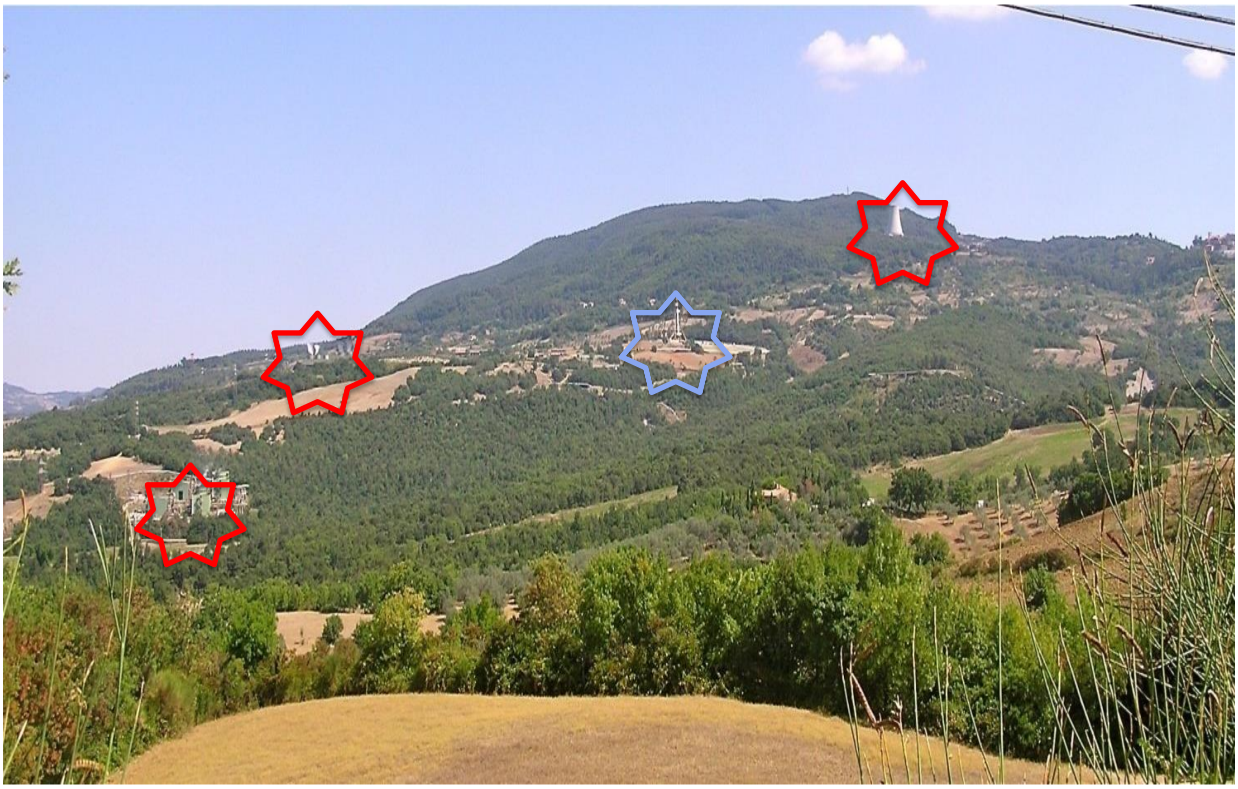


Figure 13.4 *90 MW_e in a snapshot: Carboli, San Martino & Monte Rotondo and a new well in drilling phase.*

13.2.2 Drilling activities

In the 2012, the following drilling activities have been carried out in Tuscany by Enel Green Power drilling unit:

- Four new wells, with depth 2.1 km, 3.9 km, 4.3 km and 4,4 km
- Two piezometric wells of 200 m each
- Seven work-over/deepening

The total number of meters drilled in 2012 in all the wells was 16 km.

13.2.3 Direct Uses

In Italy, besides electricity generation, geothermal energy is used for direct uses, mainly bathing and district heating, in several regions of the country.

There are in operation 14 major district heating networks (in Northern and Central regions), for an aggregated capacity of 98 MW_{th}, and a heat delivery of 550 GWh_{th}. All the other minor heating systems add up to 53 MW_{th}, for a heat production of about 300 GWh_{th}.

The spa systems are very large and present in almost all the country, with a long exploitation history, dating back to Etruscan and Roman times. The total number of classified natural geothermal bathing systems comprises 12 main thermo-mineral districts, as shown in Figure 13.5, with about 500 hot springs or thermal manifestations. The number of locations with temperatures above 40 °C is 42, with a total hot water utilization of 52 million m^3 per year. The total thermal capacity is 180 MW_{th}, and the heat utilization is about 1,200 GWh_{th}.

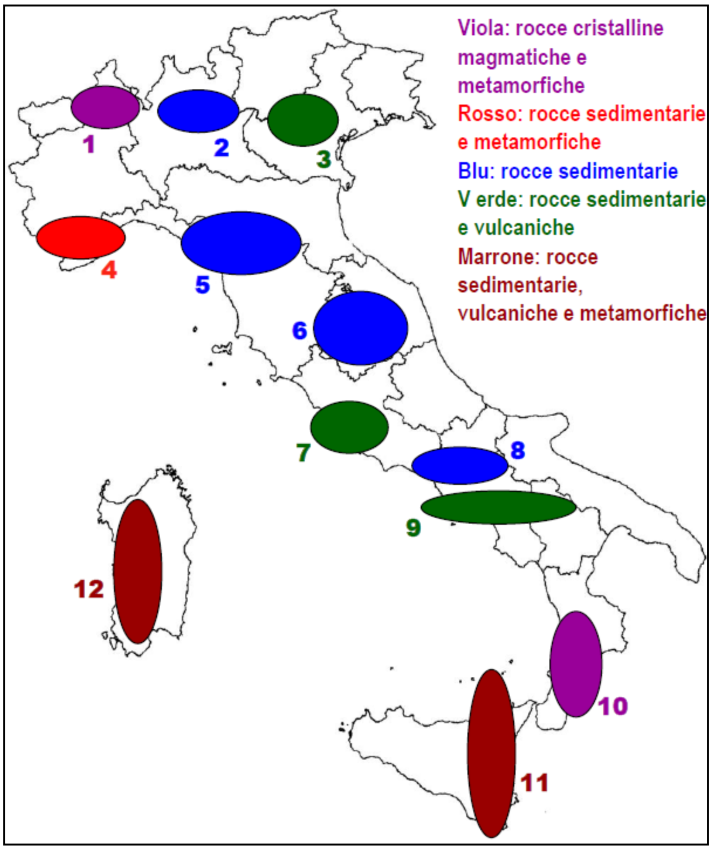


Figure 13.5 *Main thermo-mineral districts in Italy.*

The estimated total installed capacity for heat pumps is about 500 MW_{th}, with an energy production of 470 GWh_{th}. The pie chart in Figure 13.6 shows all the relative utilizations of direct uses in Italy.

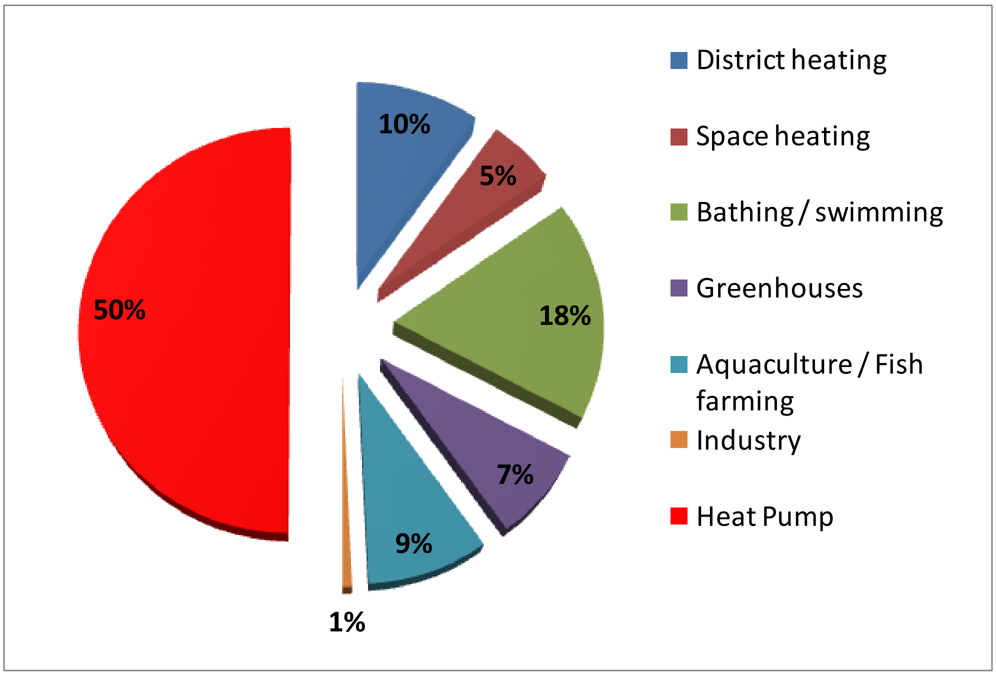


Figure 13.6 *Percentage of Direct Utilizations*

The total installed capacity is 1,000 MW_{th}, with half accounted for by heat pumps. The total heat delivered in 2012 was about 3,500 GWh_{th}, with 470 GWh_{th} from heat pumps and the remaining 3,030 Gwh_{th} from all the other applications.

13.2.4 Avoided Emissions

The contribution of geothermal energy to the fossil fuel saving in Italy is not negligible (Table 13.3).

Table 13.3 *Saving factor of geothermal energy in Italy (2011 data).*

Geothermal Energy Produced	GWh/yr	Savings Factor [toe/ GWh]	Fossil Fuel Savings [toe]
Geothermal power produced	5,315	253	1,346,821
Geothermal heat produced	3,500	127	443,437
TOTAL	**8,815**		**1,790,258**

The avoided emission of carbon dioxide is highlighted in Table 13.4.

Table 13.4 *Avoided CO_2 emissions (2011 data).*

Description	GWh/yr	Total CO_2savings by substitution of gas/oil/coal in tonnes [t CO_2]
Geothermal power produced (Table 13.3)	**5.315**	
CO_2 savings for natural gas [kg/MWh]	193	**1,025,795**
CO_2 savings for oil [kg/MWh]	817	**4,342,355**
CO_2 savings for coal kg/MWh]	953	**5,065,195**
Geothermal heat produced in 2011 (Table 13.3)	**3.500**	
CO2 savings for natural gas [kg/MWh]	97	**339,490**
CO2 savings for oil [kg/MWh]	409	**1,431,459**
CO2 savings for coal kg/MWh]	477	**1,669,452**

13.2.5 Environmental Acceptability Aspects

The strong interaction occurring between geothermal activities and the territory of Tuscany, a region so important for its landscape and tourist attractions, has placed a serious hindrance to developing new high enthalpy projects, especially in the Mount Amiata area.

As an important investment for reducing the odor emissions from H_2S of the Italian power plants, Enel Green Power installed 20 abatement systems (AMIS plant, Figure 13.7), of patented original design, with very good results in improving the local acceptance of the geothermal development.

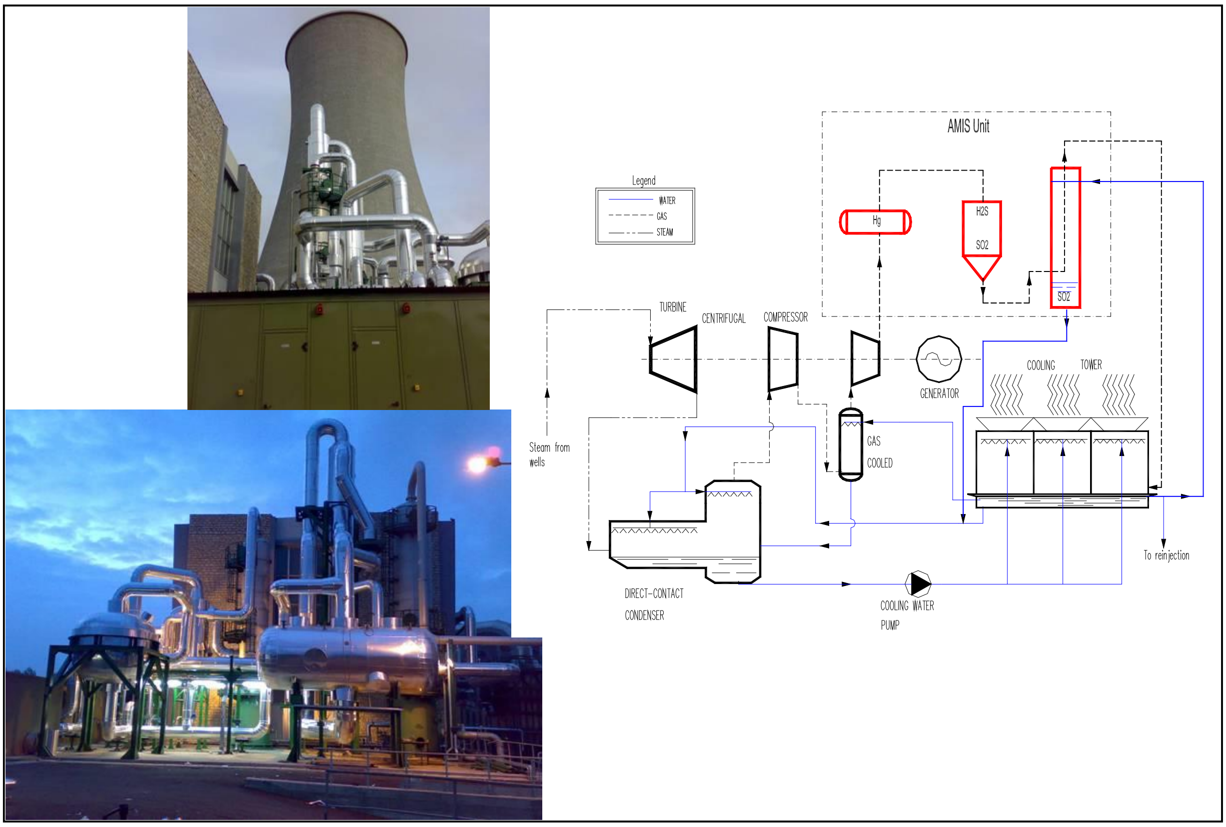


Figure 13.7 *The Enel Green Power AMIS system.*

13.3 Market Development and Stimulation

13.3.1 New Law for Geothermal Energy Tariff

Geothermal energy is included in the national energy strategy to reduce greenhouse gas emission.
The Italian policy gives support to the development of renewable resources using a different approach, in terms of a tariff, according to the size of the plants, through a new law on incentives for renewable electricity, in force since July 2012.

The incentives will apply only to a limited number of plants, to be officially shortlisted. It is possible to bid for lower incentives in order to enter into the RES quota. However, in the case of a great number of plants asking for the incentives, this process can result in penalties, but it is unlikely to foresee this problem in the near future for geothermal.

For a plant acknowledged as fully innovative, with a non-commercial technology, it is recognized with an all inclusive tariff of 200 €/MWh up to the fluid temperature of 150 °C. The incentive will be reduced accordingly to a linear formula from 200 €/MWh at 151 °C down to 137 €/MWh at 235 °C.

The standard tariff (Figure 13.8) is in three levels: plants below 1 MW receive 135 €/MWh; plants between 1 MW and 20 MW receive 99 €/MWh; and other plants receive 85 €/MWh.
An additional premium is given to plants with special technologies:

- 30 €/MWh for a total reinjection plant (zero emission)
- 30 €/MWh for the first 10 MW installed in a new area, without existing plants
- 15 €/MWh for plants with H2S and Mercury abatement of at least 95% of the emission

Allegato 1 – Vita utile convenzionale, tariffe incentivanti e incentivi per i nuovi impianti

Fonte rinnovabile	Tipologia	Potenza	VITA UTILE degli IMPIANTI	tariffa incentivante base
		kW	anni	€/MWh
Eolica	On-shore	1<P≤20	20	291
		20<P≤200	20	268
		200<P≤1000	20	149
		1000<P≤5000	20	135
		P>5000	20	127
	Off-shore (1)	1<P≤5000	25	176
		P>5000	25	165
Idraulica	ad acqua fluente (compresi gli impianti in acquedotto)	1<P≤20	20	257
		20<P≤500	20	219
		500<P≤1000	20	155
		1000<P≤10000	25	129
		P>10000	30	119
	a bacino o a serbatoio	1<P≤10000	25	101
		P>10000	30	96
Oceanica (comprese maree e moto ondoso)		1<P≤5000	15	300
		P>5000	20	194
Geothermal source		1<P≤1000	20	135
		1000<P≤20000	25	99
		P>20000	25	85

> **Additional premiums**
>
> **30 €/MWh for the first 10 MW in each new area**
>
> **30 €/MWh in case of total reinjection and zero emission**

Figure 13.8 *The standard incentive for geothermal electricity.*

13.4 Royalties

The royalties for exploitation leases are about 1.2 K€/km^2. In addition, it should be noted that, by law, additional royalties are due to municipalities and districts proportional to the produced energy and "one-off" at the commissioning of a new power plant.

13.5 Liberalization

A new Law liberalized access to the geothermal market, opening the possibilities for new players to enter into the geothermal business and asking the regional authority for concessions for "exploration leases". In the past couple of years only several new leases have been requested, in many different Italian regions, as shown in Figure 13.9.

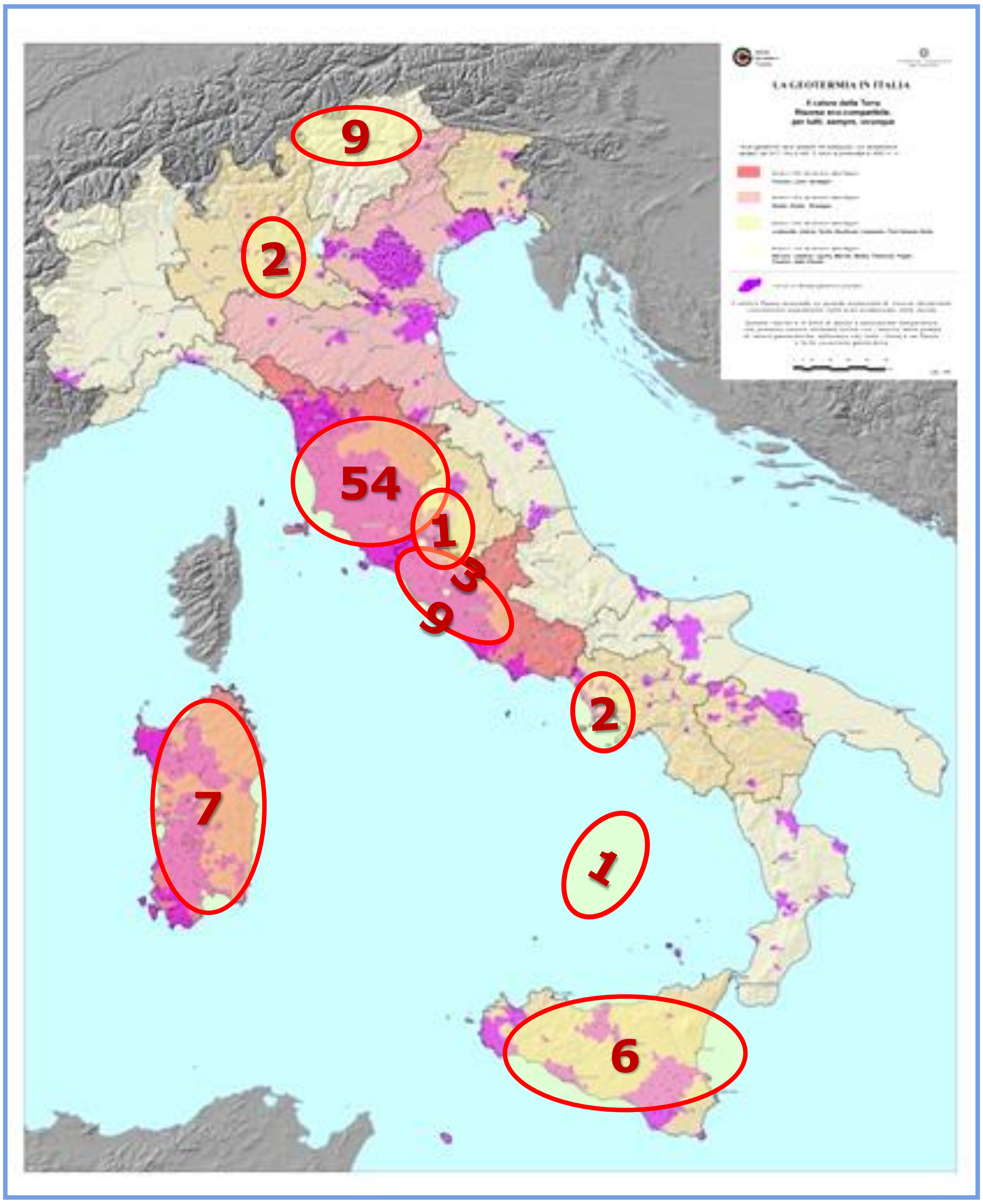


Figure 13.9 New geothermal leases in Italy.

13.6 Author and Contact

Paolo Romagnoli
Enel Green Power
Via Andrea Pisano 120
56100 Pisa
ITALY
E-mail: paolo.romagnoli@enel.com

National Activities

Chapter 14

Japan

Figure 14.1 *The Yuzawa geothermal power plant with a 42 MW-class capacity is under development in Yuzawa City, Akita Prefecture, since the Hachijojima geothermal power plant was lastly installed in 1999.*
(Photo courtesy of H. Muraoka on 11 May 2010)

14.0 Introduction

Japan's first geothermal power generation of 1.12 kW was experimentally performed in Beppu, Oita Prefecture, Kyushu, in 1925. The practical use of geothermal power commenced in 1966, with the installation of the first plant, the Matsukawa Geothermal Power Plant of 9.5 MW_e (23.5 MW_e at present and sustainably working for 45 years), Iwate Prefecture, in northern Honshu.

Japan, as a volcanic country, is blessed with potential geothermal resources for development. However, the construction of geothermal power plants has been restricted due to factors such as the restrictions in National Parks and huge numbers of hot spring resort areas. At the end of the 1980s only nine plants were operating, with a total capacity of about 215 MW_e.

Since the two oil crises, the government rapidly promoted research and development in several areas of geothermal exploration and technology throughout the 1980s. As a result, geothermal development in several areas in the Tohoku and Kyushu Districts attained a construction rush in the early 1990s, more than doubling the total capacity to about 534 MW_e.

Immediately after the rush, Japan faced a deflation economy stage in the late 1990s, and the lines of incentive policies were withdrawn from geothermal energy, thus freezing the geothermal market. No new geothermal power plants have been constructed since the late 1990s, except for small-scale plants such as the Kuju Kanko Hotel of 2 MW_e in 1998, the Hachijojima geothermal power plant of 3.3 MW_e in 1999, the Hatchobaru geothermal binary power plant of 2 MW_e in 2006, the Suginoi Hotel of 1.9 MW_e in 2006 and the Kirishima geothermal binary plant of 0.22 MW_e in 2006.

This pessimistic trend will soon be changed by the dynamic market force in the international geothermal sector.

The Japanese fiscal year starts in April and ends in March. Most of Japanese statistical data on the electric power generation are compiled on each fiscal year and tend to be published in one fiscal year later (e.g., Thermal and Nuclear Power Engineering Society, 2012). Therefore, the following electric statistics are mostly obtained from the Japanese fiscal year 2010 that started in April 2010 and ended in March 2011. However, events such as highlights are described on those of the calendar year 2011.

14.1 Highlights for 2011

The year 2011 was marked by several highlights:

- Japan faced the Great East Japan Earthquake on 11 March 2011 and it was immediately followed by the Fukushima Unit-1 Nuclear Reactor Disaster.
- These disasters completely changed a consensus of the energy policy from the nuclear energy option to the renewable energy option.
- The operation of many of the 50 nuclear reactor units was gradually terminated in 2011, resulting in Japan facing the risk of an electric power shortage.
- The effect of the change of the energy policy was, however, very slow due to the economic recession caused by the Great East Japan Earthquake and almost annual change of the Cabinet.
- Some Japanese turbine makers such as Fuji Electric Co., Ltd., Kawasaki Heavy Industries, Ltd. and Kobe Steel Ltd. initiated manufacturing of binary cycle power generation systems.

14.2 Current Status of Geothermal Energy Use

14.2.1 Electricity

The installed geothermal power capacity is 540.09 MW_e and the geothermal power generation is 2652.2 GWh/yr in the fiscal year 2010, from April 2010 to March 2011.

The new investigation company, Yuzawa Geothermal Co., Ltd., was established and provided with capital investments by Electric Power Development Co., Ltd., Mitsubishi Material Co., Ltd., and Mitsubishi Gas Chemical Company, Inc., and began the relevant procedures for an environmental impact assessment in November in order to construct a plant producing 42 MW_e at Wasabizawa and Akinomiya areas in Tohoku district.

During 2011, 5 production wells were drilled at 5 power stations (Sumikawa, Matsukawa, Uenotai, Yanaizunishiyama and Ogiri), and 3 reinjection wells were drilled at 3 power stations (Kakkonda, Otake, and Hatchobaru).

The contribution of geothermal power generation to national demand is 0.2 % in the installed capacity base and 0.3 % in the power generation base.

14.2.2 Direct Use

Although updated statistical data are only obtained on the year 2006 (Sugino and Akeno, 2010) and the installed capacity of direct use without geothermal heat pumps is 2,086.2 MW_{th}. Bathing is traditionally a major category for geothermal direct use in Japan.

Although updated statistical data are only obtained on the year 2006 (Sugino and Akeno, 2010) and the installed capacity of direct use for geothermal heat pumps is 13.4 MW_{th}.

Table 14.1 *Status of geothermal energy use in Japan for 2011.*

Electricity	
Total Installed Capacity (MW_e)	540
Contribution to National Capacity (%)	0.02
Total Generation (GWh)	2,652
Contribution to National Demand (%)	0.03
Direct Use	
Total Installed Direct Use (MW_{th})	2,086
Total Heat Used (PJ/yr) [GWh/yr]	102.2 [28,383]
Total Installed Capacity for Heat Pumps (MW_{th})	13.4
Total Net Heat Pump Use [GWh/yr]	21

14.2.3 Energy Savings in 2011

Energy savings in 2011 are 2,652 GWh by geothermal power and 7,141 GWh by geothermal direct use.

14.3 National Policy

14.3.1 Strategy

After the Great East Japan Earthquake on March 11, 2011, the current Basic Energy Plan was under discussion toward reviewing for promoting renewable energy and geothermal energy is expected to be included because of Japan's abundant geothermal resources.

14.3.2 Legislation and Regulation

De-regulation was under discussion for binary cycle power generation systems.

14.3.3 Progress towards National Targets

National targets for geothermal development are not clearly projected.

14.3.4 Government Support and Incentives for RD&D

The Ministry of Economy, Trade and Industry (METI) announced Japan's Feed-in Tariff scheme for renewable energy will be started from 1 July 2012.

14.4 Market Development, Stimulation and Constraints

14.4.1 Development Constraints and Growth Issues

De-regulation was under discussion for geothermal development in the National Parks.

14.4.2 Support Initiatives and Market Stimulation

The "Geothermal Development Promotion Survey" programme conducted by NEDO was decided to be demolished in 2010, because geothermal development in Japan has been suspended for more than 10 years, as the result of the review of projects administered by METI. Based on the result of the surveys in 2010, geothermal development surveys were carried out directly by METI in 2011 in the two areas of higher priority Komonomori and Kijiyama-Shitanotai in the Tohoku district. Surface surveys and environment surveys, with a subsidy ratio of 100%, were carried out in these two areas.

A serious energy shortage, because of the influences of the Great East Japan Earthquake of 11 March 2011 and the subsequent accident at the Fukushima nuclear power plants, makes renewable energy, including geothermal energy, in Japan more expected to be developed.

METI will utilize new industrial investment of 15 billion yen in 2011 to establish subsidy systems for ground studies, lending systems for exploratory activities, and loan guarantee systems for drilling of production wells. METI will study the building of a development support structure for geothermal resources that utilizes, to the maximum extent, possible know-how and networks of Japan Oil, Gas and Metals National Corporation (JOGMEC) for the development of fossil fuels, metals, minerals, and other natural resources.

There are two types of subsidies for companies developing power plants, one aimed at the drilling of exploration wells, with a subsidy ratio of 50%; and the other for the construction of production and reinjection wells, and facilities above the ground, with a subsidy ratio of 20%. The project was transferred from NEDO to New Energy Promotion Council (NEPC) of private organizations in April 2011, as the result of the review of projects administered by METI. The actual subsidy record by NEPC for FY 2011 is that 5 production wells and 3 reinjection wells were drilled and new pipe was laid at 2 power plants.

Actual subsidy record for FY 2011:

- 5 Production wells were drilled at: Sumikawa, Matsukawa, Uenotai, Yanaizunishiyama and Ogiri
- 3 Reinjection well were drilled at: Kakkonda, Otake, and Hatchobaru
- 2 Power Plant Facilities: new pipe laid at Sumikawa, and Yanaizunishiyama

14.4.3 Comment on Costs

The costs data are seldom available.

14.5 Industry Status

Some Japanese turbine makers such as Fuji Electric Co., Ltd., Kawasaki Heavy Industries, Ltd. and Kobe Steel Ltd. initiated manufacturing of binary cycle power generation systems.

14.6 Research, Development and Deployment Activities

14.6.1 Focus Areas

The Ministry of Economy, Trade and Industry (METI) terminated full-scale national projects on geothermal R&D since April 2003.

The Ministry of the Environment (MOE) adopted two geothermal RD&D projects for three years starting from April 2010 in the competitive research grant application round on March 2010. One project is conducted by AIST, Tokyo Electric Power Services Co., Ltd. (TEPSCO), Nittetsu Mining Consultants Co., Ltd. and Hirosaki University and aims at the geothermal reservoir management technology for the coexistence with hot springs. Another project is conducted by GERD, GREEN, AIST and Hirosaki University and aims to demonstrate the hot spring power generation system that is a 50 kW_e class Kalina-cycle project.

Many universities and institutes are investigating geo-heat pumps, hydrochemistry, geothermal reservoir engineering, rock mechanics, and other topics; and conducting geothermal assessments and geothermal exploration.

14.6.2 Government Funded

The budget of two geothermal RD&D projects by MOE was approximately 10 million Yen each in FY2011.

14.6.3 Industry Funded

The data are not easily obtained.

14.7 Geothermal Education

Geothermal education has been mainly conducted at Kyushu University, Tohoku University, Hokkaido University, Akita University and Iwate University, at both undergraduate and graduate levels for many years. The University of Toyama recently initiated geothermal education at both undergraduate and graduate levels since October 2010. Hirosaki University founded the North Japan Research Institute for Sustainable Energy in Aomori City in October 2010. This Institute includes a geothermal research group and is preparing to open the graduate course from April 2013. The Geothermal Research Society of Japan holds a forum on geothermal energy for its enlightenment and dissemination to citizens once a year.

14.8 Future Outlook

The Great East Japan Earthquake on 11 March 2011 and the following Fukushima Unit-1 Nuclear Reactor Disaster have completely changed the previous government's energy policy that had depended on nuclear power generation. A public opinion poll made by NHK (a semi-governmental TV station) on 27 August 2011 showed that 76.8% of people expressed a will to reduce nuclear powers in the very near future. Although geothermal development has been stagnant in Japan for the last 15 years, it might soon be revived in a few years.

14.9 References

Agency for Natural Resources and Energy (2012) The Energy White Paper 2011. http://www.enecho.meti.go.jp/topics/hakusho/2012/index.htm, 259 p (in Japanese).

Thermal and Nuclear Power Engineering Society (2012) The Present State and Trend in Geothermal Power Generation of Japan in the Fiscal Year 2010 and 2011. 99 p (in Japanese).

Sugino, H. and Akeno, T. (2010) 2010 Country Update for Japan. Proceedings of World Geothermal Congress 2010 (CD-ROM), Bali, Indonesia.

14.10 Authors and Contacts

Hirofumi Muraoka
North Japan Research Institute for Sustainable Energy (NJRISE)
Hirosaki University
2-1-3 Matsubara, Aomori 030-0813
JAPAN
E-mail: hiro@cc.hirosaki-u.ac.jp

Asahiko Tokuoka
New Energy Technology Department
New Energy and Industrial Technology Development Organization (NEDO)
18F Muza Kawasaki Building, 1310, Omiya-cho, Saiwai-ku
Kawasaki, Kanagawa 212-8554
JAPAN
E-Mail: tokuokaash@nedo.go.jp

National Activities

Chapter 15

Republic of Korea

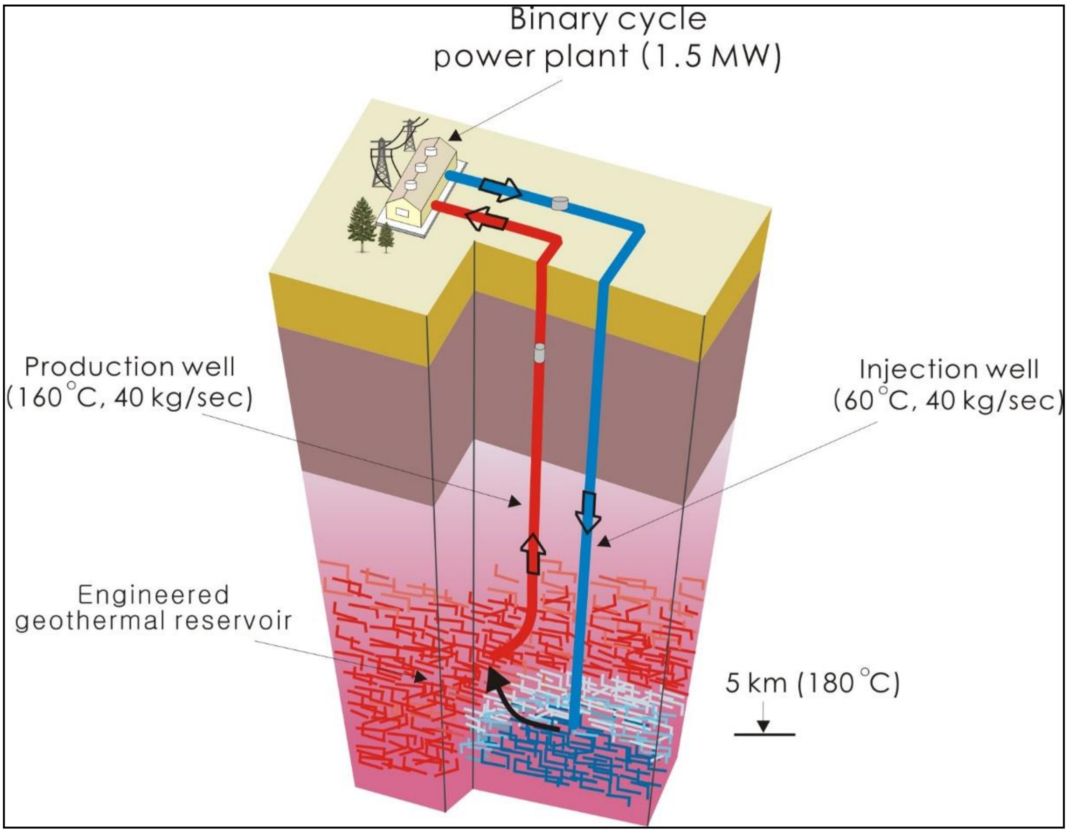


Figure 15.2 *Conceptual model of the Korean EGS pilot plant project.*
(Figure courtesy of Yoonho Song)

15.0 Introduction

Direct use of geothermal heat in Korea has been quite active for the last eight years, especially for geothermal heat pump (GHP) installation. The rapid increase of GHP is mainly due to active government subsidizing programs and a special "Mandatory Act" for renewable energy deployment. An additional special subsidy program for GHP installation for greenhouses, launched in 2010, became the main driver for fostering GHP installation, which amounted to 75 MW_{th} in 2011.

The first geothermal power generation project through enhanced geothermal system (EGS) is on-going from its official launching at the end of 2010. There were numerous preparation activities in 2011, including: site preparation, well design and micro-seismicity network design and starting installation. The first phase will comprise drilling of the first well down to 3 km depth, with subsequent measurements and exploration work in 2012. Successful completion of the well down to 3 km and confirmation of a bottom hole temperature higher than 100 °C will result in the project moving to the second phase, which includes completion of a doublet system and construction of binary power plant by the end of 2015.

15.1 Highlights and Achievements for 2011

15.1.1 Implementation

The total installed capacity of geothermal heat pumps exceeded 400 MW_{th} in 2011, with new installations amounting to 184.7 MW_{th} in terms of total capacity.

15.1.2 R&D Achievements

We have started installation of the micro-seismicity monitoring network around the planned EGS drilling site, which is the first attempt in Korea. There will be nine stations equipped with three-component borehole accelerometers, 24 bit digitizers, and high speed internet connections. This network will be used for monitoring and controlling reservoir growth created by hydraulic stimulation in the EGS project.

15.1.3 Funding to R&D

Table 15.1 *Geothermal R&D expenditure for the period 2006-2011. (Expenditure in* US$ 1,000s; US$ 1.00 = 1,000 KRW until 2009; 1,227 KRW for 2010; and 1,146.5 KRW for 2011)

	2006	2007	2008	2009	2010	2011
Government	6,943	7,792	6,914	7,760	8,750	8,294
Industry	1,148	1,800	1,383	1,800	2,000	4,554
Total	8,091	9,592	8,297	9,560	10,750	12,828

15.2 Current Status of Geothermal Energy Use

Table 15.2 *Current status of geothermal direct use and energy savings in Korea as of December 2011.*

Use		**Installed Capacity (MW_{th})**	**Annual Energy Use (TJ/yr [GWh/yr])**	**Capacity Factor**	**Fossil Fuel Saving (toe/yr)**	**Reduced CO_2 (tonne)**
Other than heat pumps*	Space heating	8.66	53.43 [8.7]	0.20		
	District heating	2.21	31.28 [14.8]	0.45		
	Greenhouse heating	0.17	1.33 [141.0]	0.25		
	Bathing/Swimming	32.56	507.61 [0.4]	0.49		
	Sub total	43.7	593.7 [164.9]		20,942	78,657
Geothermal Heat Pumps**		299.1	1,646.5 [457.4]	0.19	58,090	218,180
Total		342.8	2,240.2 [622.3]		79,032	296,837

* 2010 data.
** Pure geothermal contribution (estimates based on subsidies).

15.3 National Policy

15.3.1 Strategy

In 2008, the Korean government proclaimed 'The First National Energy Master Plan (2008-2030)' according to 'The Energy Law' passed in 2006, and amended in 2008 under the slogan of "*low-carbon, green-growth*". There are four basic strategies: a low-carbon and energy-conscious society, increased clean energy supply, green-driven growth, and affordable energy for all. This plan also emphasizes balancing of the 3-Es; energy security, energy efficiency, and environmental protection.

According to the master plan, 'The Third Basic Plan on New & Renewable Energy Technology Development, Utilization and Diffusion (2009-2030)' has been set up aiming at a new & renewable energy's share of 11% of total primary energy supply and of 7.7% of electricity generation by 2030. The target for geothermal energy is 3.8% of the total new & renewable energy contribution by 2030, which means only 0.42% of the total primary energy. However, the geothermal community expects that much higher portion can be provided by geothermal; more than 1% of the total, considering the current rapid increase of GHP installations.

Among the new & renewable energies, photovoltaic (PV), wind, and hydrogen/fuel cell are the three major sources on which government policy and investment are focused. For renewable energy deployment, an ambitious deployment project named 'One Million Green Homes by 2020' has also been launched. This is to be fulfilled by developing the 'Smart Energy System' that combines various renewable sources such as PV, solar, geothermal, wind, and fuel cell. This project will help GHP installation continue to increase in the future.

15.3.2 Legislation and Regulation

From 2004, the "Mandatory Public Renewable Energy Use Act" (Mandatory Act) came into effect, and it states that "in construction of all public buildings bigger than 3,000 m^2 in area, more than 5% of the total budget must be used to install renewable energy equipment." According to the Act, GHP installation plans amounting to a total of 78 MW_{th} in 2010 and 114 MW_{th} in 2011, were reported, and will be installed within two or three years (sometimes more) after planning, considering the construction period.

15.3.3 Progress Towards National Targets

The total primary energy consumption at the end of 2011 reached around 271.346 M tonne of oil equivalent (toe), while geothermal provided 53,505 toe (2,240.2 TJ), which covered 0.020% of the total primary energy consumption. The status and prospect of geothermal energy in relation to the national target is still very small. Fortunately, however, the importance of geothermal utilization is being acknowledged by the government and the public sector, and geothermal's share of the market stimulating incentive has become significant. Therefore, we can see some remarkable progress in GHP installations in recent years.

Increases in GHP installations and energy uses are presented in Figure 15.1. The values are based on officially reported installations, though the actual number of installation is expected to be larger than reported.

15.3.4 Government Support/Incentives for R&D

The Korean Government set up the New and Renewable Energy Program according to the Master Plan. The Ministry of Knowledge Economy funds R&D through an agency, the Korea Institute of Energy Technology Evaluation and Planning (KETEP), and the total budget for 2011 reached US$ 362 M. R&D funding is generally based on industry matching except for small academic research projects. Geothermal R&D is mainly funded by KETEP, while the Korea Institute of Geoscience and Mineral Resources (KIGAM) funds projects through the Basic Program which was US$ 5.2 M in 2011. See Table 15.1 for funding trends.

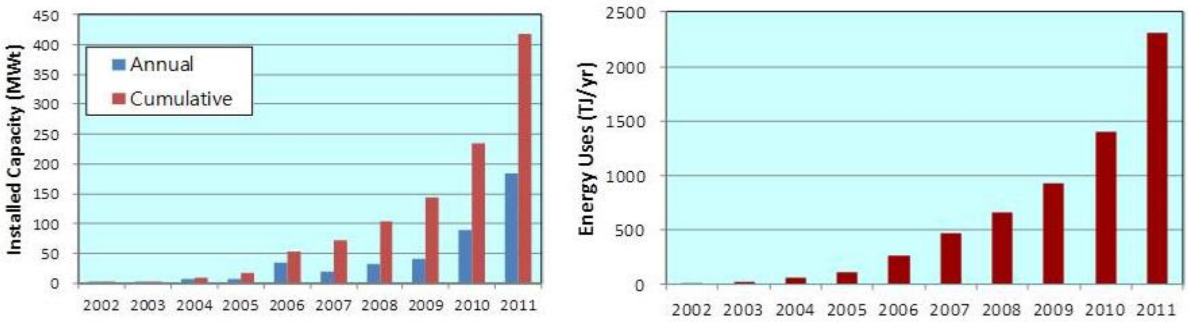


Figure 15.1 Increasing trend of GHP installation (left) and annual energy uses (right). (Data from Korea Energy Management Corporation; estimates for 2011 are based on the amount of subsidy and plan reported according to the 'Mandatory Act'). Note that 'Energy Uses' accounts for total energy from GHPs.

15.4 Market Development, Stimulation and Constraints

15.4.1 Development Constraints

A barrier to progress of GHP deployments from technical and scientific points of view may be explained by the relative negligence of importance of accurate information on the thermal properties of subsurface materials and lack of scientific knowledge on hydrological conditions influencing heat extraction/injection rates. Such technological drawbacks often lead to over-design of systems and thus weaken economical competitiveness. Although there are huge amounts of alluvial groundwater resources in agricultural areas and towns, utilization of groundwater thermal energy is still quite limited because of the unnecessary concern about running out of the water resources resulting from the lack of understanding of the natural water cycle.

There is increasing concern for geothermal power generation with low-temperature geothermal water through deeply-extended fractures and/or enhanced geothermal systems. But, insufficient understanding of low-temperature power generation technology available at temperatures even lower than 100 °C and lack of deep drilling experience are technical barriers. Lack of a legal framework supporting deep geothermal development is also a major barrier: deep geothermal water in Korea is dealt with only in the Hot Spring Law, which states that warm water must be firstly used for hot springs. For that reason, there is no risk guarantee or insurance framework for deep drilling.

15.4.2 Support Initiatives and Market Stimulation Incentives

The Korean Government offers long-term low-interest loans, tax benefits and government/public funds for those using renewable energy. Subsidies for geothermal installations through various renewable energy spreading programs amounted US$ 76.8 M in 2011 (Table 15.3). A special subsidy program for supporting economic competitiveness of greenhouse started in 2010.

15.4.3 Comments on Costs

There is no cost data available for well drilling; however, the total installation cost for GHP is around US$ 1,474/kW.

Table 15.3 *Subsidy for geothermal heat pump installations for the period 2008-2011*.*
(In US$ 1,000s; 1 $ = 1,000 KRW until 2009, 1,227 KRW for 2010, and 1,146.5 KRW for 2011*)*

	2008		2009		2010		2011	
	Capacity (MW)	Subsidy (US$ 1,000)	Capacity (MW)	Subsidy (US$ 1,000)	Capacity (MW)	Subsidy (US$ 1,000)	Capacity (MW)	Subsidy (US$ 1,000)
Deployment Subsidy Program	14,11	7,689	6.83	4,153	5.11	2,498	8.51	4,137
Rural Deployment Program	89.55	73,728	14.39	9,093	11.08	4,702	6.16	3,356
1 Million Green home Program	-	-	5.02	3,868	13.82	9,905	16.39	10,464
Greenhouse Subsidy Program**	-	-	-	-	41.7	41,750	75.1	58,853
Total	103.66	81,417	26.24	17,114	71.7	58,855	106.7	76,810

* Note: Data correspond to year of subsidy support, so actual operations are one or two years later.
** 80% (central government 50% + local government 30%) of total costs are subsidized, while for
the other programs 50% are covered by government.

15.5 Status of Geothermal Industry

The geothermal industry in Korea has mainly focused on GHP design and installation. According to official reports, there are more than 100 small GHP businesses; however, among them, fewer than 20 companies are active with more than 50% market share. There are two industry associations: Korea Geothermal Energy Association (registered with the Ministry of Knowledge Economy) and Korea Groundwater and Geothermal Energy Association (registered with the Ministry of Land, Transport and Maritime Affairs), both of them are for GHP installation.

Several engineering companies and construction companies have recently participated, or are preparing to participate, in geothermal power generation through domestic projects or overseas business. Although the overall status is still immature, we expect that some companies will be active in geothermal power generation in next five years.

15.6 RD & D Activities

15.6.1 Focus Areas

Almost all of the research activities in Korea are initiated by government funding. R&D activities can be categorized into two main fields: 1) shallow geothermal utilization using various GHP types, and 2) deep geothermal exploration and exploitation. For shallow geothermal utilization, there were several successful R&D projects such as sampling and measurement of subsurface thermal properties for borehole heat exchangers resulting in a large database, and simulation of T-H-C coupled behaviour, with borehole heat exchangers under groundwater flow.

There is also research on the efficiency of borehole heat exchanger types and on utilizing groundwater thermal energy along with aquifer thermal energy storage (ATES).

For deep geothermal, there is on-going research on exploration and exploitation of low-temperature geothermal water for district heating; and characterization and assessment of geothermal resources is also an important research topic. There has been increasing interest in geothermal power generation among decision makers and industries as well as researchers, especially in enhanced geothermal systems (EGS). This has resulted in the launch of the first EGS pilot plant project at the end of 2010.

15.6.2 Government Funded R&D

R&D and RD&D programs on geothermal are mainly funded by the Korea Institute of Energy Technology Evaluation and Planning (KETEP), a government R&D funding agency under the Ministry of Knowledge Economy. In 2011, a total of nine R&D projects, including three new ones, were granted for geothermal developments; amounting to a total budget of US$ 6.1 million. Bigger RD&D projects are to be led by industry as the prime contractors, while research organizations and universities are to be involved as participants.

R&D in geothermal investigation, exploration and exploitation has been led by the Korea Institute of Geoscience and Mineral Resources (KIGAM), the only government funded research institute in the geoscience field in Korea. The Geothermal Resources Department of KIGAM is leading a government funded R&D program called Development of Geothermal Resources for Combined Heat and Power Generation. KIGAM is also playing an important role in the newly launched EGS pilot plant project.

The EGS pilot plant project (Figure 15.2, beginning of Chapter) is the first attempt to realize geothermal power generation in Korea. It is a five-year term, government funded and industry matching project. The target area is Pohang field of higher heat flow, located in the south-eastern part of the Korean Peninsula (see 2006 Annual Report). Long-term monitoring at exploration well BH-4 in Pohang showed a temperature of 91 °C at the depth of 2 km, which suggests at least 180 °C at the planned depth of 5 km. Two small businesses, a big industrial company, two research organizations and a university are participating in this project, with a small business as prime contractor.

The project consists of two phases: 1) site characterization: to drill a 3 km deep well and to confirm a temperature higher than 100 °C, within two years, and 2) extending the 3 km deep well down to 5 km to make it an injection well, hydraulic stimulation and reservoir creation; and drilling a production well of 5 km and completing a doublet system; and installing a 1.5 MW binary power plant, in another three years (Figure 15.2).

By the end of 2011, site characterization was done, including re-evaluation of existing surface and well data, and stress measurement along a survey borehole of 1 km depth. The drill site has been selected at Heunghae-eup, Pohang-city, which is the only region in Korea covered by Tertiary sediments. The basic design of the well is done down to 5 km, while the upper 3 km section will be finished by the end of the first phase (November, 2012).

Installation of the micro-seismic monitoring network, which is centred on the drill site, was started in November 2011, aiming for completion of the total nine stations by March 2012. Three-component borehole accelerometers equipped with piezoelectric transducers are to be deployed down to 100-130 m depth, with one deeper at the drill site. Figure 15.3 shows the location map of the micro-seismicity monitoring stations and Figure 15.4 shows a schematic diagram and photo of the first station.

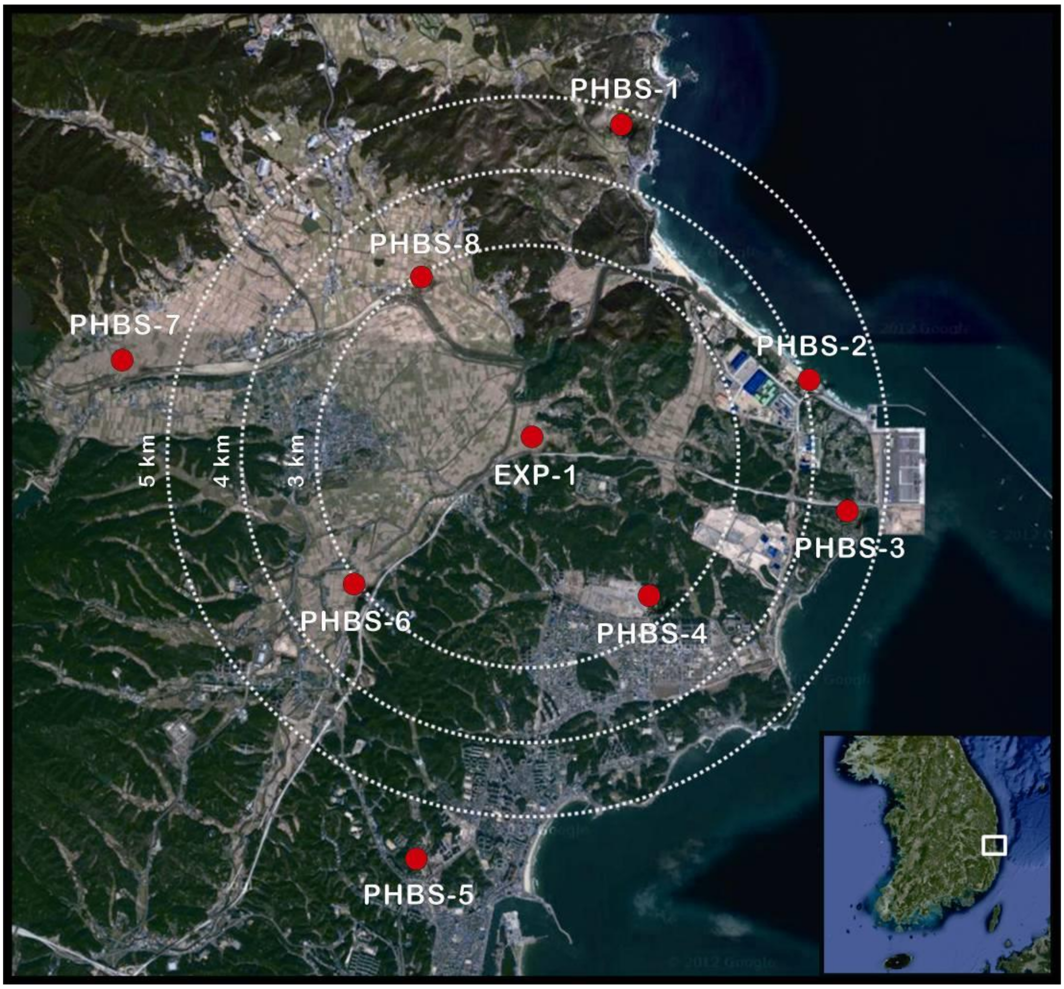


Figure 15.3 Location map of the micro-seismicity monitoring network. PHBS-6 is the first station installed in November 2011 and other will be completed by March 2012. (Map courtesy of Yoonho Song)

15.7 Geothermal Education

There have been regular geothermal courses at Seoul National University, both at undergraduate and graduate levels, from 2009. Public recognition of geothermal is increasing; and there are special training courses for HVAC and architectural engineers to introduce general geothermal topics and state-of-the-art heat pump technologies, and for training in the design and proper installation of GHP. Also, there are many small seminars about general geothermal topics and geothermal power generation reflecting increasing public recognition.

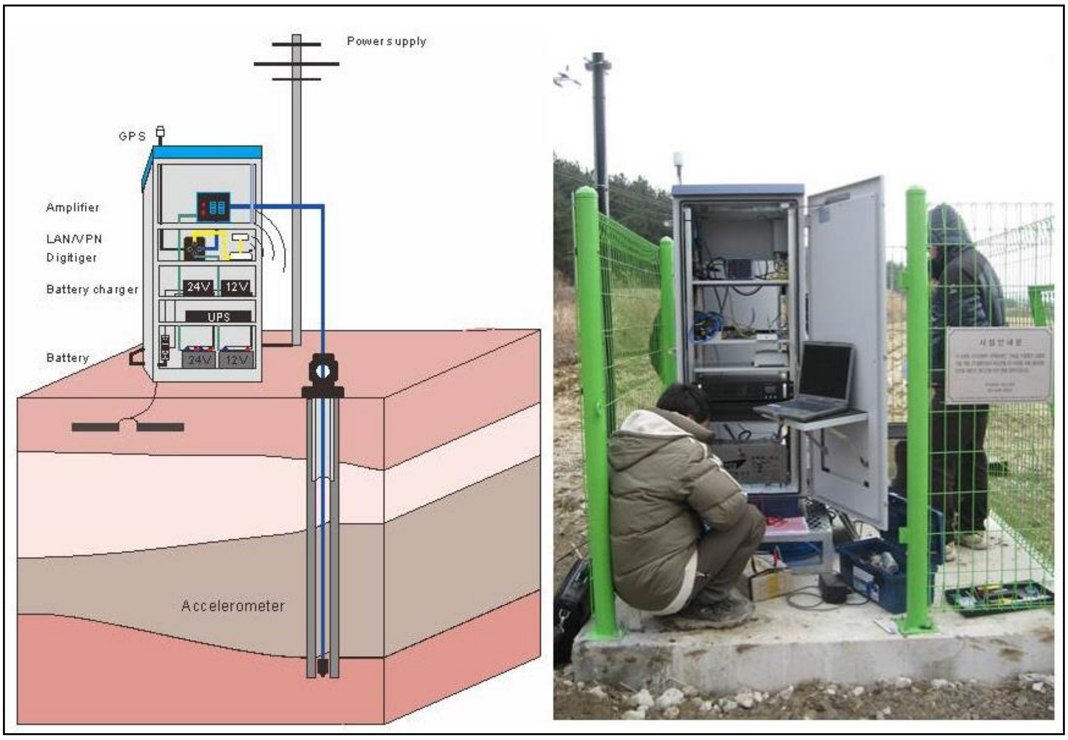


Figure 15.4 Schematic diagram of the micro-seismicity observatory (left) and photo of the first station (right).
(Figure and photograph courtesy of Yoonho Song))

15.8 Future Outlook

Geothermal utilization, in terms of GHP installation, will continue to rapidly increase for the next five years: 50-100 MW_{th}, or more, annually. This is due to active subsidy programs and the special Mandatory Act. There are concerns about low performance or the malfunctioning of GHP systems due to bad installations without proper design and performance validation that can accompany rapid market growth. Long-term performance modelling and validation are other important tasks to keep GHP installations growing, especially for large systems (bigger than 1 MW_{th} capacity).

The EGS pilot plant project will lead to the initiation of other R&D projects related to geothermal power generation, such as induced seismicity, hydraulic stimulation and binary power generation cycles. These will draw more attention from industry, which in turn would make geothermal industry more active in the power generation business, both domestically and overseas. We expect successful cases of domestic development and overseas investment in the next five years.

15.9 References and Websites

Geothermal Resources Department, KIGAM: http://geothermal.kigam.re.kr

15.10 Author and Contact

Yoonho Song
Geothermal Resources Department
Korea Institute of Geoscience and Mineral Resources (KIGAM)
Gwahang-no 124, Yuseong-gu, Daejeon 305-350
REPUBLIC OF KOREA
E-mail: song@kigam.re.kr

National Activities

Chapter 16

Mexico

Figure 16.1 *Cerro Prieto 7, Mexico.*
(Courtesy David Nieva)

16.0 Introduction

Geothermal and wind are the most important non-conventional renewable energy sources utilized in Mexico. Although there is some tradition for direct uses of geothermal energy, mainly related to balneology, the most important use is for electricity generation.

Geothermal development for electricity generation started in Mexico in 1959, with the commissioning of the first commercial plant in the Pathé field (central Mexico). In December 2011 the geothermal-based installed capacity for electricity generation was 958 MW_e.

16.1 National Policy

About 76.3% of the installed capacity for public-service electricity generation belongs to the government-owned utility, namely the Comisión Federal de Electricidad (CFE). The other 23.7% belongs to private-owned companies who must sell their power to the CFE. CFE has developed and manages all geothermal fields and is responsible for all electricity generated with geothermal steam. This primary energy source has been utilized for decades for power generation; the technology is considered mature for conventional (hydrothermal, high temperature) resources, and it is set to compete on the same basis as fossil-fuel, conventional hydro and nuclear technologies.

16.2 Current Status of Geothermal Energy Use

16.2.1 Electricity Generation

16.2.1.1 Installed Capacity

The net installed capacity at the end of 2011 was 958 MW_e distributed among the geothermal fields as follows: Cerro Prieto (720 MW_e), Los Azufres (188 MW_e), Los Humeros (40 MW_e) and Las Tres Vírgenes (10 MW_e). It is worth mentioning that the running capacity in 2011 was 883 MW_e, since the two oldest units in the Cerro Prieto field, of 37.5 MW_e each, were out of operation.

16.2.1.2 Total Electricity Generated

The total electricity generation with geothermal steam in 2011 was 6,524 GWh.

16.2.1.3 New Developments in 2011

One new 25- MW_e condensing (flash) unit was practically completed by the end of 2011, and another of the same type and capacity was at 60%, both at the Los Humeros geothermal field. Units were being constructed and installed by Alstom through an EPC contract, and will be operated by the CFE. Some additional geologic surveys were conducted in the Chichonal Volcano geothermal zone. International bidding for construction and installation of a new condensing (flash) unit was about to be launched in the Los Azufres geothermal field.

16.2.1.4 Number of Wells Drilled and in Operation

There were, on average, 238 production wells and 26 injection wells in the four operating fields. These wells were distributed as follows: Cerro Prieto: 172 production and 16 injection wells, Los Azufres: 29 production and 6 injection wells, Los Humeros: 29 production and 3 injection wells, and Las Tres Vírgenes: 4 production and 1 injection wells.

16.2.1.5 Contribution to National Demand in 2011

Electricity generation from geothermal sources represented around 2.4% of total electric generation for public service in Mexico. In 2011, the geothermal contribution to electricity generation was 1.4 times higher than its contribution to the installed capacity (1.7%), reflecting a high capacity factor of geothermal electric plants.

16.2.2 Direct Use

The most recent estimate (2008) of installed thermal power in Mexico: is 156 MW_{th}, mainly for balneology.

Direct use for balneology occurs at around 165 sites distributed in 19 states.

16.3 Market Development and Stimulation

At present, there are no economic incentives for geothermal development in Mexico.

16.4 Development Constraints

As mentioned above, power generation with geothermal energy is considered conventional in Mexico, and thus it is set to compete on the same basis as fossil-fuel, conventional hydro and nuclear technologies. Therefore, it is fair to say that the main constraint for further geothermal development in this country is its economic disadvantage against modern fossil-fuel generation technologies.

16.5 Economics

16.5.1 Trends in Geothermal Investment Foreseen

Both new power units in Los Humeros are delayed, expecting to be commissioned in late 2012 or early 2013. When they are running, three of the current 8 backpressure units, 5 MW_e each, in operation are planned to be dismantled, and then the net additional capacity in this field will be 35 MW_e, to reach 75 MW_e. CFE continues working on the development of 25 MW_e in Cerritos Colorados. It is expected to start construction of another new unit in Los Azufres by late 2012. The first private geothermal power development is under way in the western part of the country, with no public information disclosed on it.

16.5.2 Trends in the Cost of Energy

The price of electricity in Mexico has been subject to gradual upward adjustments to cover the corresponding increases in the cost of operation of the public power system, and in order to reduce the level of subsidy. This trend is expected to continue. Currently, most power prices to final consumers are subsidized at different levels by the federal government.

16.6 Research Activities

Most geothermal research activities in Mexico are focused on the development and exploitation of resources for power generation. Specifically, they are aimed to improve the knowledge of the fields and thus the ability to predict their behaviour under continued exploitation. Some effort is spent in exploration of new areas with geothermal potential. Practically all geothermal research is funded by the federal government, although some interest to explore new areas has been expressed recently by private enterprise.

16.7 Geothermal Education

In the past, CFE trained some of their engineers through the geothermal programs offered by Iceland (the United Nations University), New Zealand (the Geothermal Institute of the University of Auckland) and the Baja California University (UABC). During the last years CFE has sent young engineers for training to Japan, under an agreement between JICA and the Mexican Government. For the most part, mechanical, electrical, chemical and geological engineers are trained on the job, as part of their professional development in CFE and at the Instituto de Investigaciones Eléctricas (IIE). Periodic professional meetings (congresses, seminars, etc.) provide a basis for continued education of geothermal personnel.

16.8 International Cooperative Activities

Mexico, through IIE and CFE, participated in the activities of Annex VII (Advanced Geothermal Drilling Technologies) and Annex X (Data Collection and Information) of the IEA Geothermal Implementing Agreement.

16.9 Authors and Contacts

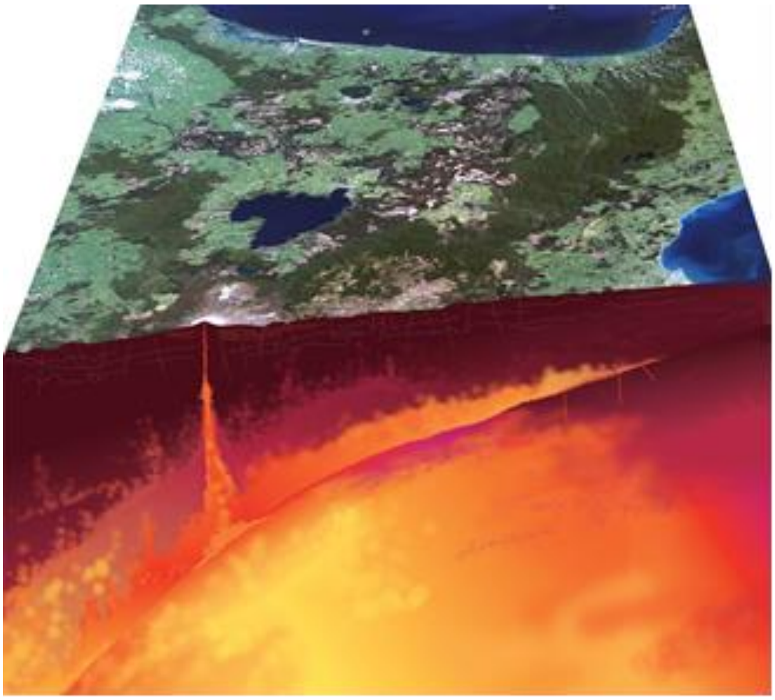
R. Maya and L. Gutiérrez-Negrín
Comisión Federal de Electricidad
MEXICO

D. Nieva
Instituto de Investigaciones Electricas (IIE)
Av. Reforma N°113, Col. Palmira
62490 Temixco, Mor.
MEXICO
E-mail: dnieva@iie.org.mx

National Activities

Chapter 17

New Zealand



"Hotter and Deeper" research initiative to explore beneath the Taupo Volcanic Zone to depths of 3-5 km and temperatures> 400 ^{0}C.

17.0 Introduction

In New Zealand, electricity demand growth stalled after 2008. This was due to a slump in demand following the global financial crisis. From 2010, growth in domestic electricity demand was steady at the long-term average rate of about 1.5% per annum, but this was offset by reducing demand from industrial and manufacturing consumers of electricity and heat. Despite this stalling of total demand, growth in geothermal generation has been sustained at a relatively high rate. The reason has been the construction and commissioning between 2008 and 2010 of several new large baseload geothermal power stations. This has helped to improve security of supply. Details regarding this geothermal growth spurt are contained in the previous New Zealand country report (2010). The level of exploration and production drilling and activities related to planning and resource consent applications has also remained buoyant. This is because of the long lead time required before commissioning of new power plants.

For reference purposes, a location map of major New Zealand geothermal resources is shown in Figure 17.1. For more details and background information refer to the 2010 New Zealand Annual report.

Approximately 400 MW_e of potential capacity increments remains in the planning phases, with activities focussed on exploration and consenting. The objective of this development strategy is to shorten the lead-time for future power plant construction when and if the economic indicators become more favourable for the investors, owners and power-plant operators.

Construction began in 2011 on two new power plant projects (Ngatamariki and Te Mihi) with commissioning anticipated in 2013. Further significant increases of installed geothermal capacity (after 2013) are likely to be dependent on the local economic situation regarding supply and demand of electricity and process heat. Both of the two largest geothermal operators (Mighty River Power and Contact Energy) have indicated that their geothermal expansion plans are likely to remain on hold for several years, that is, until the demand situation improves, or retirements of older thermal generating plant are advanced, or the duty of gas-fired plants is changed from baseload to peaking operation.

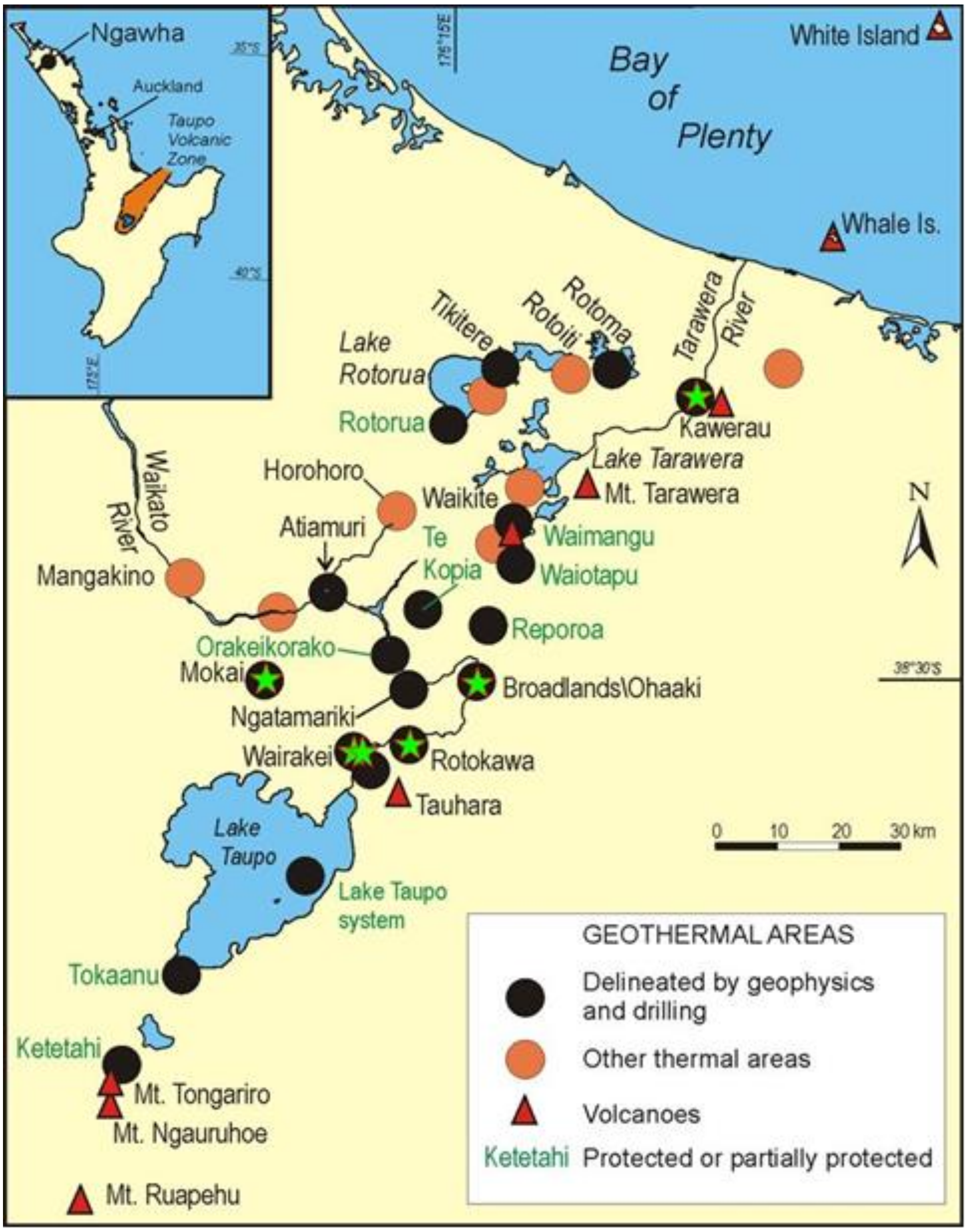


Figure 17.1 Map of New Zealand high temperature geothermal fields. Stars identify operating geothermal systems in the Taupo Volcanic Zone. Taheke, a newly explored system, is located north of Tikitere. Ngawha is an operating geothermal system located in Northland, north of Auckland.

Despite these statements, the Ministry of Business, Innovation & Employment (MBIE), formerly the Ministry of Economic Development (MED), has projected encouraging 20 year forecasts of new capacity growth. An additional 900 to 1200 MW_e of base-load geothermal capacity is anticipated to be constructed in New Zealand within the next 20 years if future demand growth averages about 1% per annum. If such a growth rate in geothermal occurs, it would place New

Zealand in a relatively high ranking internationally for its percentage of total electricity generation provided by geothermal energy (growing from 13.4% in 2011 to over 25% by 2030).

It should be noted that there have been other periods when the market did not appear highly favourable but when investment in smaller scale geothermal development continued anyway. These investments were led by land developers (farmers and Maori Trusts) and lines companies that were able to see niche opportunities for assets on their land. Similar groups, together with a large direct-use industry located on the Kawerau field are looking at new opportunities, so further growth is expected in the short term.

Geothermal heat pumps have a considerable future growth potential in New Zealand. They are slowly becoming established, especially in colder climate regions (e.g., the South Island).

Several industrial-scale, direct-use applications have been commissioned or are in the planning/ construction stages. These include paper manufacture, timber drying and milk drying. The New Zealand Government remains committed to accelerating the use of renewable low-emission energy (including geothermal energy) and reducing fossil fuel consumption.

17.1 Major Highlights and Achievements for 2011

17.1.1 Implementation

- No new power plants or large scale direct use heating plants were commissioned, but annual electricity generation increased as operation from 2010 installations contributed a greater share of total base-load power.
- All geothermal power plants are running at full capacity (average 90% capacity factor), with the exception of Ohaaki, which is operating at about 50% of its installed capacity.
- Exploration drilling success (using 3 slim holes to about 1 km depth) was achieved at Taheke, a green-field development north of Tikitere.
- Construction commenced on two new power plant projects: Ngatamariki (82 MW_e) and Te Mihi-Wairakei (166 MW_e). Note that Te Mihi will allow partial retirement of some Wairakei units.

17.1.2 R&D Achievements

- Research into novel direct use projects focussed on economic and social aspects and culminated in publication of a number of case studies, ranging from large industrial process heat applications to residential space heating (http://www.gns.cri.nz/earthenergy).
- New research was initiated into “Hotter and Deeper” drilling and geophysical exploration with an objective of exploring to 4-5 km depth in the high temperature Taupo Volcanic Zone. This zone, at 3-5 km depth range and >400 °C, has the potential to add at least 10 GW_e to the existing 4 GW_e estimated shallower geothermal resource potential.
- Research efforts to better understand the causes and mechanisms of subsidence at Wairakei and Tauhara were completed, and work has been continuing on a range of applied research including high temperature geothermal cements.

17.1.3 Industry Successes

- Establishment of a new ground-source heat pump association (GHANZ) within New Zealand is expected to assist with dissemination of information on technology suitable for New Zealand settings, and to address any issues regarding installation best practices and quality assurance (http://www.ghanz.org.nz).

- Drilling activity has remained at a relatively high level (17 deep boreholes completed) and a relatively high success rate of about 90% was achieved.
- Construction started on a novel biological treatment facility for Wairakei Power Station steam condensate to remove most of the dissolved H_2S in the cooling water (from direct contact condensers) before discharge to the Waikato River.
- The Miraka Dairy Factory at Mokai was formally opened; it uses about 270 TJ/yr of heat from clean steam (stripped of contaminating gases using a novel process) to process about 210 M litres/yr of milk into milk powder for export (at a rate of up to 8 tonnes/hr).
- A tourism facility at Wairakei Terraces, that uses hot water from the nearby reinjection pipeline, was enhanced through construction of an outdoor spa bathing facility.

17.1.4 Funding

- Funding for geothermal research and development amounts to about NZ$4.6 million from the government. Additional support comes from sponsorship of student thesis work by companies such as Mighty River Power, and applied research grants and co-funding of research for specific problem solving by companies such as Contact Energy.

17.1.5 Funding from the New Zealand Government

- Funding was also announced for 25 new scholarships for overseas students to enrol at the annual Geothermal Institute Diploma Course held at Auckland University (50% of these scholarships are targeted for Indonesian graduate students).

17.2 Current Status of Geothermal Energy Use

No new power plants were commissioned in 2011, so the total geothermal power operating capacity in New Zealand remained at 758 MW_e throughout the year, generating at an average effective capacity factor of 87%. The gross installed capacity remains at 792 MW_e (including 34 MW_e of decommissioned capacity at Ohaaki). Without Ohaaki, which is limited in generation by a steam supply shortfall, the capacity factor would be 90%. About 200 MW_e (net, taking into account planned turbine retirements) of additional geothermal generation was also under construction, with a planned commissioning date of mid-2013.

17.2.1 Electricity

- Total installed capacity was 792 MW_e, and operating capacity was 758 MW_e
- Net generation was 5770 GWh/yr
- No new power-plants were commissioned in 2011
- 17 new deep geothermal wells were drilled (that is, completed)
- The contribution of geothermal to national electricity demand for 2011 was 13.4 %
- Fugitive gas emissions (mostly CO_2) were estimated to be 0.8 Mt CO_2-e/yr

17.2.2 Direct Use

- Installed capacity was 987 MW_{th} and total heat used was 9.9 PJ/yr (2764 GWh/yr)
- Categories of use include : process heat for pulp and paper manufacture, timber drying, milk powder manufacture, aquaculture, horticulture, space heating, bathing, and tourism

- Geothermal heat pumps increased by about 10% to 0.45 MW_{th} (mostly heating of commercial buildings in colder climate settings, such as the South Island)
- The Miraka milk treatment plant was officially commissioned in 2011
- Increased direct use for industrial plants (e.g., SCA clean-steam tissue plant at Kawerau) and plans developed for future expansion.

These data are presented in Table 17.1 and Table 17.2 alongside the values for 2010 for comparison.

Table 17.1 *Status of geothermal energy use in New Zealand for 2010 and 2011.*

Electricity		2010	2011
Total Installed Capacity (MW_e)		794	794
Total Operating Capacity (MW_e)		758	758
Contribution to National Capacity (%)		8	8
Total Generation (GWh)		5,550	5,770
Contribution to National Demand (%)		12.8	13.4
Direct Use			
Total Installed Direct Use (MW_{th})		962	987
Total Heat Used (PJ/yr) [GWh/yr]		10.1 [2,810]	9.9 [2,764]
Total Installed Capacity for Heat Pumps (MW_{th})		4	4.5
Total Net Heat Pump Use [GWh/yr]		11	12

Table 17.2 *Categories of direct use: estimates of heat energy used in GWh/yr.*

Category	2010	2011
Industry: paper, timber, milk	1730	1646
Cascaded use (prawns, timber)	225	233
Bathing/tourism	480	495
Space heating	250	284
Greenhouses (horticulture)	105	105
Other	20	1

17.3 National Programme

17.3.1 Strategy

The New Zealand government has set targets for renewable energy including 90% of total electricity by 2025 and 9.5 PJ/yr of additional direct use geothermal or renewable biomass by 2025 relative to 2005. Background to national policy and regulations is given in the 2010 country report.

17.3.2 Legislation and Regulation

Other than a cost of carbon (currently defaulting to NZ$12.5/tonne of CO_2 equivalent) under the New Zealand Emissions Trading Scheme (http://www.climatechange.govt.nz/emissions-trading-scheme/), which is applied to all industrial emitters, there are no government-imposed regulations or fiscal incentives for renewable energy, such as feed-in tariffs, quota obligations (RPS), tradable renewable energy credits, subsidies, grants, or tax rebates.

Regulation of geothermal resource utilization is achieved through the Resource Management Act, and administered by Regional Councils (local government) through granting and monitoring of "Resource Consents". The purpose of these is to facilitate participation of local inhabitants, and to avoid, remedy or mitigate adverse environmental effects, while ensuring sustainable development. Both the Waikato and Bay of Plenty Regional Councils (where most of the geothermal resources are hosted) undertook a public review of their policy statements with respect to geothermal in 2011.

17.3.3 Progress towards National Targets

The growth of geothermal (which doubled in 6 years), is helping achieve the desired trend towards the target of 90% renewable electricity generation by 2025. In 2011, renewable electricity generation reached 77%, having grown from 65% in 2006. Progress towards the target in direct use is less impressive, but steady.

17.3.4 Government Support/Incentives for R&D

The principal government support for geothermal R&D comes through the award of research grants. Up until 2010 these were awarded through competitive bid to research organizations. From 2011, the bulk of the funding is considered "core" research and is exempt from regular competitive re-bidding. Examples of providers include GNS Science, University of Auckland, University of Canterbury, other Crown Research Institutes (e.g., Industrial Research Ltd (IRL), later the Callaghan Innovation) and specialist contactors.

The government also part-funded the 'New Zealand Clean Energy Centre' www.cleanenergycentre.co.nz which was completed in 2011 at Taupo. The venue was used to host some geothermal seminars, focussing particularly on direct use.

The Energy Efficiency and Conservation Agency (EECA) have launched feasibility study grants to businesses that are considering a specific energy efficiency or renewable energy project, but require further assessment of the technical and financial feasibility before deciding to proceed or not. The grant amount is up to 40% of the feasibility study costs, with a maximum of NZ$ 20,000. EECA also offers grants to support industrial and commercial energy efficiency or renewable energy projects including energy management and building design.

In 2011, the government approved New Zealand joining the IPGT (International Partnership for Geothermal Technologies) for collaborative research in specific topic areas. NZ Trade and Enterprise (NZTE) also launched *Geothermal New Zealand* (www.geothermalnewzealand.com), a collaboration that exports diverse geothermal skills and expertise to countries exploring their geothermal potential. The New Zealand government, through funding participating organizations and companies, such as GNS Science, SKM and PB Power (NZ), has been offering geothermal expertise overseas for regional aid projects since the 1970s (e.g., Kenya, Chile, Mexico, Indonesia and the Philippines), and has signed a number of bilateral and multilateral agreements which include energy. Recent geothermal energy examples are:

- ASEAN–NZ : geothermal expertise for infrastructure development in Brunei, Indonesia, Malaysia, Philippines, Singapore, Thailand, Vietnam, Laos, Myanmar, and Cambodia;
- Mexico-NZ: clean energy agreement; and
- Chile-NZ: joint statement on clean energy cooperation.

17.4 Market Development, Stimulation and Constraints

17.4.1 Development Constraints/Issues Affecting Constraints

- In New Zealand, constraints to development include proximity to electric grid infrastructure. A potential bottleneck in HV transmission through the central North Island, where much of the potential geothermal resources occur, is currently being addressed by the transmission planners. Another issue is the potential re-distribution of transmission costs amongst power producers which could adversely affect the economics of geothermal generation.

- Environmental factors are also a significant constraint. Currently, approximately 40% of the estimated resource potential is protected by Regional Councils, through policy designed to protect systems from energy utilisation. This is intended to protect the most-prestigious, highly-valued or outstanding systems from possible adverse effects on the surface environment that might adversely reflect on their tourism value, cultural value, scientific value or aesthetic appeal.

- The single biggest factor affecting growth is the issue of flat demand, but there are other market drivers. An example is the possibility of de-commissioning of a large aluminium smelter at Bluff in the South Island which would release approximately 14% additional power from hydro-electric sources into the marketplace, thereby depressing spot wholesale power prices and potentially leading to the retirement of the country's only coal-fired station.

- Despite efforts on the part of research groups and industry associations, many developers are still unaware of the availability of competitive geothermal energy options for process heat from high temperature geothermal fields, or domestic and commercial use from geothermal heat pumps. Effort is going in to raising the profile of these options.

17.4.2 Support Initiatives and Market Stimulation Incentives

One of the biggest market incentives has been the relatively low-risk drilling in recognised geothermal fields (~90% success rate in recent years). This has been achievable because of applied research, and historic knowledge from government-funded, exploration surveys and drilling activity.

17.4.3 Costs

According to analysis by independent government planners (MBIE, www.med.govt.nz) the cheapest Long Run Marginal Cost (LRMC) option for the next 1 GW_e (or 8TWhr/yr) of new generation is for geothermal base-load power at about NZ$ 64-74/MWh (or US$ 52-60/MWh at average 2012 exchange rates). This assumes 8% discount rate and NZ$ 25/tonne long-term carbon-charge, but no other subsidies or feed-in tariffs. [Gas baseload and wind options are more expensive by about 25 to 45%].

Total project capital costs, as published, for recent geothermal power station construction, are:

- Kawerau (100 MW_e flash, 2008) ~NZ$ 3.0 M/ MW_e
- Te Huka- Tauhara (23 MW_e binary, 2010) ~NZ$ 3.4 M/ MW_e
- Nga Awa Purua- Rotokawa (140 MW_e flash, 2010) ~NZ$ 3.6 M/ MW_e
- Te Mihi- Wairakei (166 MW_e, flash, constructing) ~NZ$ 3.8 M/ MW_e

17.5 Status of Geothermal Industry in New Zealand

The status of the geothermal industry in 2011 is similar to that described in the 2010 New Zealand Country report. In summary, the industry is still in a growth stage, with seven companies participating in major electricity generation projects on known geothermal systems, and several continuing their exploration and investigation efforts on 'greenfield' prospects.

17.6 RD&D Activities

17.6.1 Focus Areas

Principal focus areas for research funded through the Ministry of Science and Innovation (MSI) are similar to 2010, and include the following:

- Potential development from deeper and hotter resources
- Resource delineation and geophysical exploration methods (especially MT and micro-seismicity)
- Improved simulations of sustainable reservoir performance (modelling)
- Managing geochemical scaling and production chemistry
- Avoidance of adverse environmental effects (subsidence, induced seismicity, hot spring effects)
- Geothermal ecosystems including extremophiles (thermal bacteria)
- Rock-fluid interactions at high temperature and pressure
- Cements for extreme environments
- Enhancement of knowledge about resources and technologies suitable for direct use

17.6.2 Government Funded Research

Approximately NZ$ 4.3 M per year in research funding for geothermal comes from the MSI. Business innovation and investment research continues to support funds (50:50) for firms to undertake innovative geothermal projects, student internships, capability building and R&D strategy reviews.

17.6.3 Industry Funded

The two largest companies (MRP and Contact Energy) have indicated an intention to spend NZ$ 3-4 billion over the next decade (2010 to 2020). However, this is likely to be concentrated in 2011-2013, during committed power-plant construction activities, and 2018-2020, based on current expectations of demand growth and retirement plans for other thermal generation. Part of this funding is committed to applied research.

17.7 Geothermal Education

Auckland University continues to offer through the Geothermal Institute an annual post-graduate training program (July to November) leading to a diploma in geothermal technology, along with short-term specialist courses, and also organises an annual New Zealand Geothermal Workshop, usually held in November. The University of Canterbury in Christchurch has consolidated its geothermal programme concentrating on Masters and PhD students. The New Zealand Geothermal Association (NZGA) runs an annual geothermal seminar on particular topics of interest. GNS Science and other consulting companies run commercial geothermal training seminars on various topics, for both New Zealand and international participants.

17.8 Future Outlook

Future prospects for 2012 and beyond are encouraging for continued growth in both electricity and industrial heat developments. Over 2012-2013 construction of Ngatamariki (82 MW_e) and Te

Mihi (166 MW_e, net 124 MW_e) power plants will continue. Exploration of Taheke will also continue with new consent applications anticipated by about 2014 (perhaps totalling 50 to 100 MW_e). Exploration drilling and power plant planning is anticipated at Tikitere (perhaps 45 MW_e by 2017). A project amounting to at least 35 MW_e is anticipated at Rotoma-Tikorangi, and several power and direct use expansion projects are anticipated at Kawerau (NST: 25 MW_e, NTGA: 20 MW_e & ~200 MW_{th}, Te Ahi O Maui: 15 MW_e).

Although consents have been granted for a 250 MW_e development at Tauhara II, near Wairakei, a target commissioning date is anticipated to be delayed to about 2018 to 2020 because of the current slow demand growth. Another complication is that surplus hydro-electric power at Manapouri (14% of NZ's total generation) from possible decommissioning of the Bluff aluminium smelter by about 2018, may dampen short-term enthusiasm for building new base-load generation elsewhere in New Zealand.

Despite the anticipated lag in new project commissioning, growth preparations are expected to continue. Projections by energy planners in the New Zealand government foresee construction of significant new geothermal capacity (~1 GW_e) being required for base-load generation (because it is the lowest cost option in terms of long-run marginal costs) from 2020 to 2050. The planners expect geothermal to contribute 25% of total generation by 2030. Hydro is expected to contribute 52% and wind 9% by 2030, making a total of 86% from renewable sources. The planner's most likely scenarios predict that greenhouse gas (CO_2 eq.) emissions from power generation will drop to about 4.5 MT/yr by 2025, then stabilize at approximately 50% of their 2005 peak value.

Growth in geothermal could be accelerated ahead of this timeframe if other options for expanded use of the renewable geothermal resource, such as through export by HVDC cable to Australia, local increase in energy-intensive industries, or wide-spread vehicle fleet electrification, are realised.

17.9 References and Websites

Ministry of Economic Development, (2011) New Zealand Energy Strategy 2011-2021 Developing Our Energy Potential, August 2011, Available at: www.med.govt.nz/energy-strategy, ISBN 978-0-478-35894-0 (PDF).

White, B. (2011) Case for New Zealand Membership of the International Partnership for Geothermal Technology. Available at www.nzgeothermal.org.nz.

White, B., and contributors (2011, 2012) NZGA Newsletters Available at www.nzgeothermal.org.nz

Websites

- www.med.govt.nz/sectors-industries/energy/energy-modelling/modelling/new-zealands-energy-outlook-electricity-insight/interactive-electricity-generation-cost-model
- www.med.govt.nz/sectors-industries/energy/energy-modelling/technical-papers/2011-nz-generation-data-update
- www.ghanz.org.nz
- www.climatechange.govt.nz/emissions-trading-scheme/
- www.nzgeothermal.org.nz
- www.geothermalnewzealand.com
- www.gns.cri.nz/earthenergy
- www.cleanenergycentre.co.nz
- www.iese.co.nz/geothermal-institute

17.10 Authors and Contacts

Chris Bromley
GNS Science Limited
Wairakei Research Centre
Private Bag 2000
Taupo 3350
NEW ZEALAND
E-mail: c.bromley@gns.cri.nz

Brian White
Executive Officer
New Zealand Geothermal Association
PO Box 11-595
Wellington 6142
NEW ZEALAND
brian.white@eastharb.co.nz

National Activities

Chapter 18

Norway

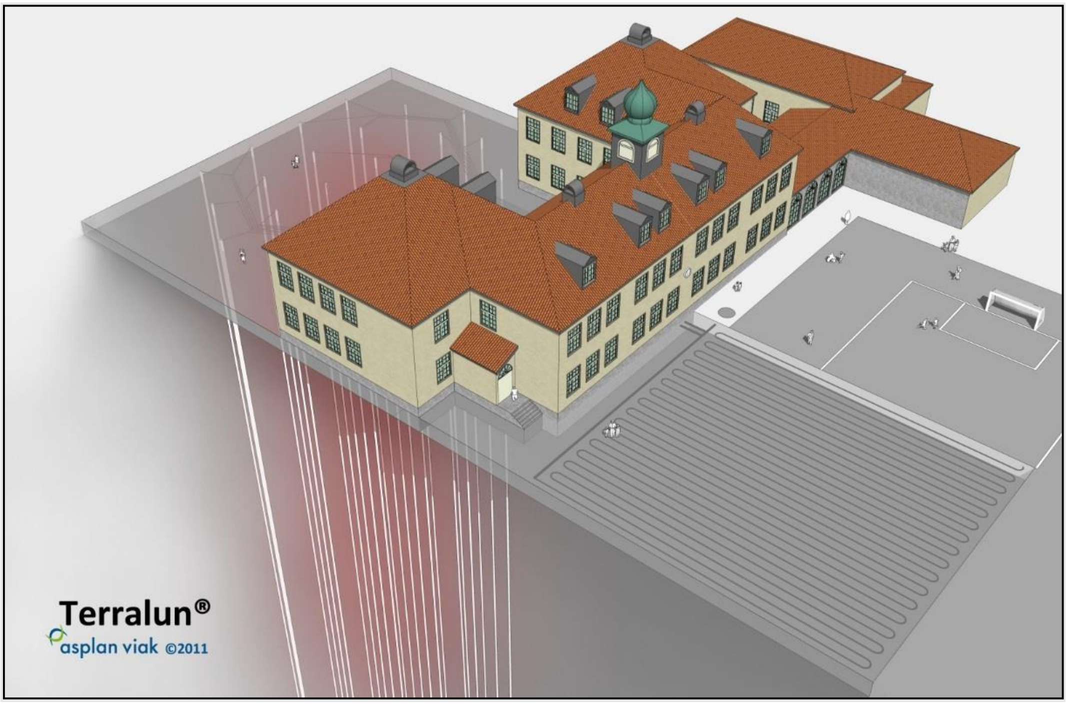


Figure 18.3: *Illustration of the BTES system at Ljan School in Oslo with integrated solar collectors in the asphalt in the schoolyard.*
(Figure courtesy Jiri Muller)

18.0 Introduction

This is the second country report since Norway joined the IEA-GIA in 2010. Detailed background about Norwegian energy status is described in more detail in the corresponding section in the country report for 2010.

Norway is an important energy nation with abundant hydrocarbon off-shore resources and extensive access to cheap and clean hydropower. Though there is a strong political will in Norway to make use of renewable energy sources (wind, biomass, ocean waves, sun), from the practical point of view, they contribute only marginally to Norway's energy consumption.

Geothermal energy is considered as a highly significant alternative for the future, but not yet a subject of great interest for the Norwegian society in general, including funding agencies and industry. To promote, cooperate and develop deep geothermal energy the Norwegian Centre for Geothermal Energy Research (CGER) was established in 2009, which, at the beginning of 2011, had over 20 partners from universities, colleges, research institutes, and industry.

The Norwegian industry and research establishment has valuable experience and know-how in off-shore technologies, which include amongst others drilling, geochemistry (corrosion, scale, tracer technology) and thermal modelling. This valuable knowledge is readily transferable to geothermal industry, both in Norway and overseas. However, for successful application, these technologies need to be adapted for geothermal settings, which include harder (crystalline) rocks and higher temperatures than those found in classical hydrocarbon settings found in off-shore Norway.

18.1 Highlights and Achievements

18.1.1 Implementation

CGER organised a successful national conference on geothermal energy in Bergen "GeoEnergi 2011" attended by Norwegian academia, industry, funding agencies and distinguished guests from abroad.

IFE organised a well-established international conference TRACER 6 in Oslo, where one of the sessions was, for the first time, devoted to geothermal energy.

18.1.2 R&D Achievements

The Energi21 initiative launched by Norwegian Government, which aims at designing a broad-based, collective R&D strategy for the energy sector, continued its work and was revised. One of its working prioritised areas entitled "Sub-Committee for Renewable Thermal Energy" was changed to "Working Group for Geothermal Energy" (WGfGE). This group had the mandate to contribute to the future governmental white papers on issues related to strategy for the Norwegian energy sector. Though the WGfGE worked actively, deep geothermal energy was not given priority in the final report.

Conclusions drawn in Energi21: "In the area of heat pumps and shallow geothermal the necessary technical solutions are largely available. The obstacles to more extensive use lie elsewhere and are related to need for more information and knowledge among users and for economic incentives.

Regarding deep geothermal there are a few areas of synergy between petroleum activities and geothermal energy production. Norwegian players with roots in the oil and gas industry have the potential to supply a deep geothermal energy market, but this market is not yet well developed.

There are still major unutilised resources for shallow geothermal energy and it may be assumed that it will be more cost-effective to draw upon these first. It is therefore unlikely that a large Norwegian market for deep geothermal heating will emerge in the short and medium term. "

18.1.3 Industry Success

Green Energy Group AS (GEG) is a Norwegian company established in 2008, which manufactures and commissions prefabricated modular geothermal power plants. Their concept reduces the time from successfully drilled geothermal well to power online. In 2009, GEG signed a R&D contract with KenGen, the national power company of Kenya, to deliver the first 5 MW wellhead power plant. In 2011, GEG raised a combined NOK 87 M in equity. The first modular power plant began operation in Kenya in January 2012.

18.2 Status of Geothermal Energy Use

18.2.1 Energy Use

Norway is a young nation when it comes to utilisation of geothermal energy. So far there is no electrical production from geothermal resources; geothermal use is now dominated by the deployment of heat pumps. This is graphically illustrated in Figures 18.1 and 18.2. The yearly variation reflects the prices of electricity, where 2003 was a dry year with low hydro power production, and 2005 wet year. There is a clear trend with increasing interest in geothermal ground source heat pumps- GSHPs (water/water, air/water heat pumps), but the Norwegian heat pump market is still dominated by air/air heat pumps as reflected in Figure 18.1. The latter are not considered GSHPs, and therefore do not contribute to geothermal energy technology and its statistics.

Today, more than 350 larger GSHP systems for public and commercial buildings, and multi-family dwellings are installed, including some of Europe's largest GSHPs with borehole heat exchangers (BHE) (see IEA-GIA Annual Report 2010). These installations are borehole thermal energy storage (BTES) systems providing a balanced combination of both heating and cooling.

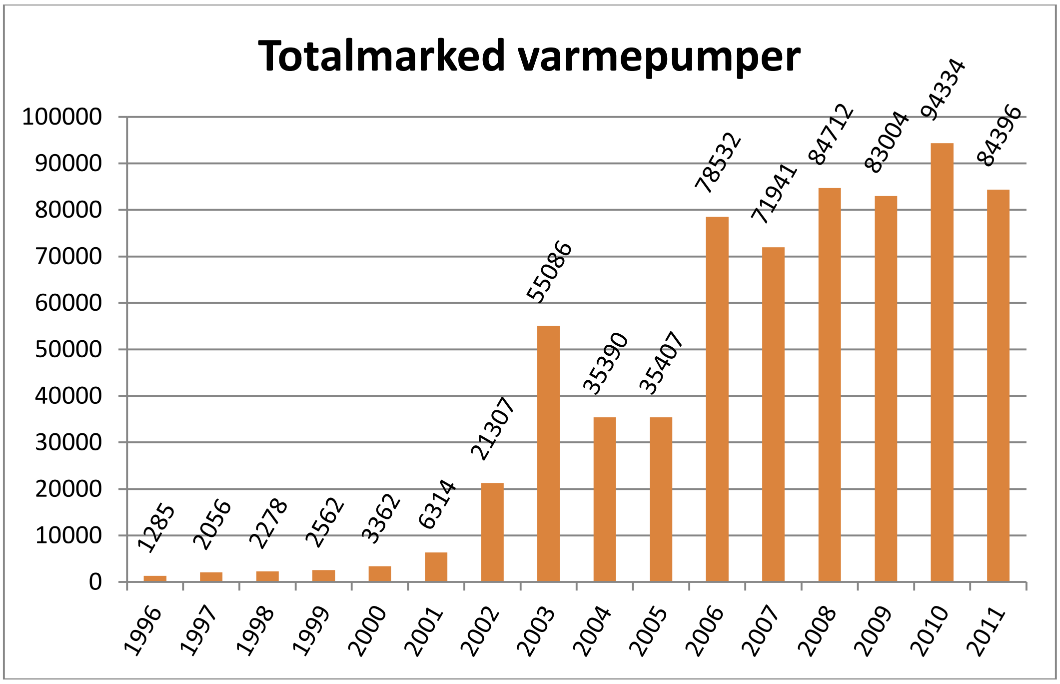


Figure 18.1 *Annual installation of all types of heat pumps in the period 1996-2011.*

Table 18.1 *GSHP data for Norway.*

Electricity Generation	
Total Installed Capacity (MW_e)	0
Contribution to National Capacity (%)	0
Total Generation (GWh)	0
Contribution to National Demand (%)	0
Direct Use (only estimates are given)	
Total Installed Direct Use (MW_{th})	na
Total Heat Used (PJ/yr) [GWh/yr]	na
Total Installed Capacity for Heat Pumps (MW_{th})	2,000
Total Net Heat Pump Use [GWh/yr] (water/water and water/Air)	6,000

na = data not available

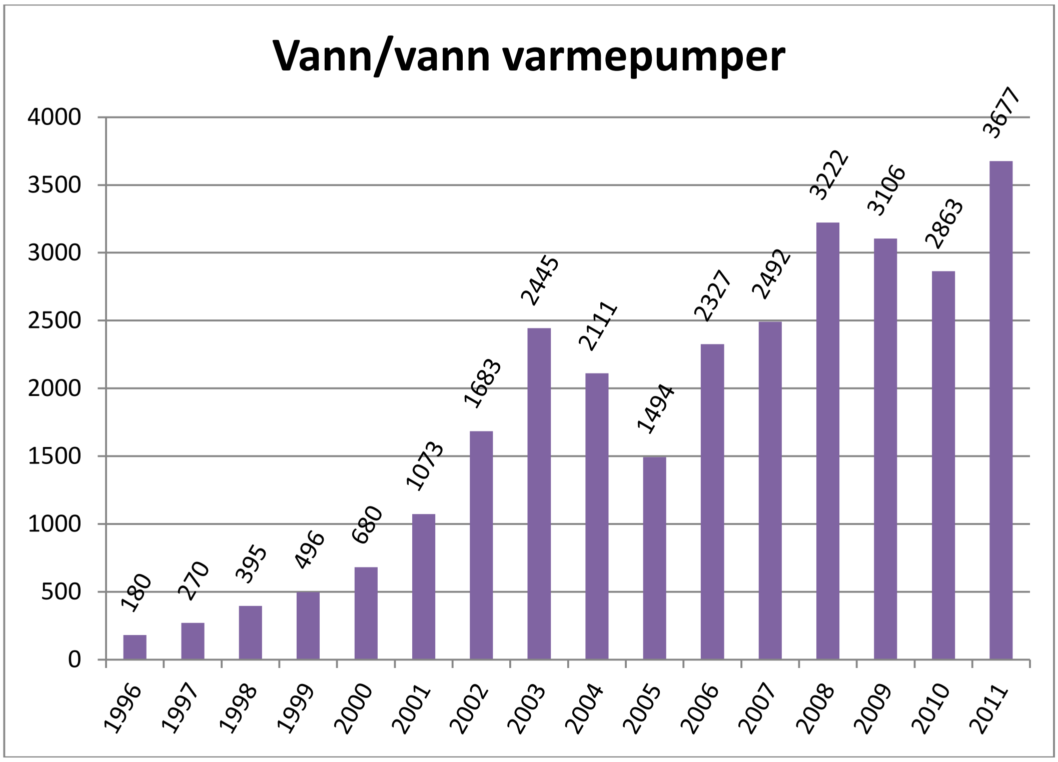


Figure 18.2 *Annual installation of water/water heat pumps in the period 1996-2011(Statistics for air/water heat pumps are similar).*

18.2.2 Energy Savings

Though the Norwegian market is dominated by air/air heat pumps (see Figure 18.1), there is an increasing tendency to invest in GSHPs. 3677 water/water heat pumps were sold in Norway in 2011, which resulted in an energy savings of 434.4 GWh. 2914 air/water heat pumps were sold in Norway in 2011, which gave energy savings 183,7GWh.

The total number of reported energy wells for the period from 2000 to 2010 is 13,832.

18.3 National Programme

18.3.1 Strategy

See Sections 18.1.2 and 18.8 for more details.

18.3.2 Legislation and Regulation

Energy wells or boreholes for shallow geothermal energy (heat pumps) are presently regulated by The Law for Water Management ("Vannressursloven"), and must be reported into the National Database of Groundwater administrated by the Geological Survey of Norway (NGU). See Table 18.2. The share of energy wells compared to drinking water wells has been increasing over the last decade. The numbers in the database are considered as incomplete however they have an increasing credibility during the recent years. The growing number of energy wells compared with drinking water wells gives probably the best indication of the increasing trend in development of energy wells.

*__Table 18.2__ Statistics from the National Database of Groundwater at NGU. *Due to lag in the data input, the numbers for 2011 are estimates. The numbers refer to new energy wells reported in each year.*

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Number of energy wells	210	265	470	956	978	1095	1473	1864	2033	1982	2506	3100*
Energy wells in % of total	28	27	32	42	43	33	42	43	45	47	54	58*

There has been an issue on whether a borehole drilling has to be applied for in relation to the Law for Planning and Building Regulations ("Plan- og bygningsloven") as interference in the terrain surface. In response to this, the Government has made a declaration which states that boreholes do not have to be applied for in advance.

However, Oslo municipality has introduced a duty to report borehole drilling in advance due to the possibility of polluting water systems via spill of silty water from the drilling into the water drain system. This can happen for boreholes with high water flows. In these cases, proper handling of silty drill water in containers might be insufficient, and with permission from the municipality, the drill water can be discharged into the drain system. After finishing the borehole drilling, the drain system has to be flushed properly to avoid cementation in the water drain pipe. Oslo municipality practices this scheme as owner of the drainage water and sewage pipes.

18.3.3 Progress towards National Targets

See section 18.1.2 (Energi21 document).

18.3.4 Government Support/Incentives for R&D

This is discussed in more detail in Section 18.4 below, where the government agency Enova plays a central role. Enova's main mission is to contribute to environmentally sound and rational use and production of energy, relying on financial instruments and incentives to stimulate market actors and mechanisms to achieve national energy policy goals.

18.4 Market Development, Stimulation and Constraints

Enova SF is a public enterprise owned by the Ministry of Petroleum and Energy. Enova's objective is to strengthen the work in transforming energy consumption and generation into more sustainable forms, while simultaneously improving supply security. Enova is financed via funds allocated from the Energy Fund. The Energy Fund is financed via a small additional charge to electricity bills (1 øre per kWh), which has been charged since 2004 and which amounted to NOK 788 M in 2010 (100 øre = 1 NOK= US$ 0. 18). In addition, the Energy Fund has been allocated the proceeds from the Green Funds for Renewable Energy and Energy Efficiency Measures. The Green Fund capital is NOK 25 billion. No deep geothermal project has been funded from the Energy Fund. In general, the governmental organisation Enova supports private homes with up to US$ 2,000 in funding per installed brine to water heat pump. Larger installations are supported on a case by case basis in the Enova programme "Local Energy Centres". Many of the shallow geothermal installations established in 2011 obtained funding from Enova.

Sørlandssenteret, a shopping mall in the city of Kristiansand, established a shallow geothermal system of 90 boreholes to 200 m, received NOK 2.4 M from Enova. The energy saving is estimated to be 3.2 GWh.

A potential study of "Ground source heat in Norway- mapping of economic potential" initiated by the Norwegian Water Authorities (NVE) in 2011, concluded that almost the entire heating and cooling demands of Norwegian buildings can be covered by the use of ground source heat pumps. The unit price of heating and cooling, based on the ground source heat pump technology for middle sized to large installations, is competitive with other energy alternatives. For the household segment, profitability is lower, but still interesting. The study does not include the indoor heating and cooling distribution system, but covers the heat pump, energy well and installations costs. The relatively high thermal conductivity of the crystalline bedrock makes Norway well suited for energy wells with closed loop collector systems. Some locations in Norway can also utilize groundwater resources in superficial deposits.

Open systems utilizing shallow groundwater resources have gained popularity in the municipality of Elverum. The ground source heat potential in the city centre of Elverum, based on direct use of groundwater from superficial deposits, was mapped by the Geological Survey of Norway in 1998-99. Now, the municipality of Elverum has ground water based heat pump systems in 5 of their public buildings. For this effort, the municipality got the "municipality of heat pumps-award" of 2012.

As a result of a competition for an innovative heating system solution organized by Undervisningsbygg, the school building owner in Oslo municipality built a BTES system at Ljan School in Oslo (Figure 18.3, start of this Chapter). Here the ground is used in conjunction with solar heat collected in the asphalt of the schoolyard. The solar collector is integrated into the asphalt and used to heat the brine for the heat pump during spring, summer and autumn, and maybe during some sunny and warm days throughout (late) winter. Excess heat from the solar collector in the summer is used for "charging" the energy wells.

There are currently no serious environmental issues in connection with geothermal energy in Norway. This is discussed in more detail in 2010 IEA-GIA Annual Report.

18.5 Status of Geothermal Industry

Statoil has an ambition to gradually build a position in renewable energy production. In addition to the established interest in offshore wind, geothermal has been identified as a potential business area for further growth. The aim of Statoil is to build upon its core expertise from oil and gas, such as geology, drilling and reservoir management, in order to realize the full potential of geothermal power in markets where the company already has a presence.

There are emerging small SME companies who are interested in penetrating the geothermal market, especially within drilling; two examples are:

- Norwegian Hard Rock Drilling AS, NORHARD (www.norhard.no), is a company for development of technology and production/operation of equipment for long distance drilling (Figure 18.4). Further development for drilling of geothermal wells and for oil and gas applications are ongoing, and
- Resonator (www.resonator.no) is now developing a powerful electric hammer for improved percussion drilling, based upon a new proprietary technology (Figure 18.5). This work takes place at the University for Life Sciences (UMB) south of Oslo. Demonstration of the technology is planned to take place in about 2 years.

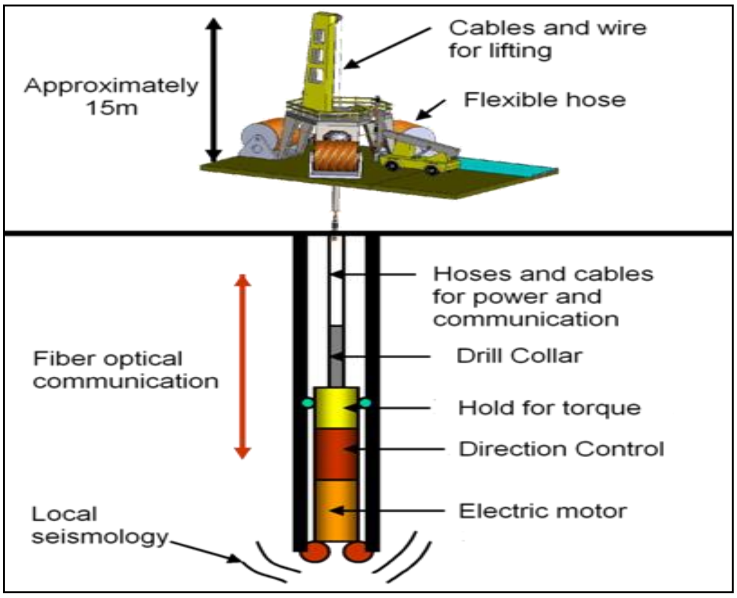


Figure 18.4 Sketch illustrating NORHARDs innovative technology. (Photo courtesy NORHARD)

Figure 18.5 Photo from RESONATORs laboratory showing some of its equipment. (Photo courtesy RESONATOR)

18.6 RD&D Activities

18.6.1 Focus areas

The focus area is a transfer of research competence from highly developed hydrocarbon activities in the North Sea and tunnel drilling in hard rocks to the geothermal research.

18.6.2 Government Funded

The following projects have been funded by The Research Council of Norway in 2011:

- Game Changing Drilling Technology (Norhard AS).
- UiB/PGP project on modelling and simulation (University of Bergen).
- Sustainable exploitation of geothermal energy in the North Western Indian Himalayas (INDNOR-India/Norway collaboration pre-project).

18.6.3 Industry Funded

Industry, in many cases, co-funds government funded research. There is no direct industry funded geothermal research in Norway.

18.7 Geothermal Education

There are presently no specific courses and degrees at Norwegian universities and technical high schools related to geothermal energy. However, students attending courses in petroleum sciences (which are of high standard in Norway) are well qualified to enter the geothermal market. The Norwegian educational establishment, however, is ready to prepare more specifically tuned courses to geothermal subjects provided that the government gives green light to such a move which includes funding.

CGER has continued to run its members mini-workshops on topics which are relevant to geothermal energy; and the Workshop on drilling was run by IRIS in Stavanger in 2011.

18.8 Future Outlook

Shallow geothermal energy (heat pumps) is a widely used in Norway. However, deep geothermal energy is a relatively new concept for the Norwegian establishment, in particular, for the public, politicians, funding agencies, the press (media), industry and also research organizations.

"Working Group for Geothermal Energy" prepared a road-map for the government body Energi21, which deals both with shallow and deep geothermal energy. Energi21 has, however, given deep geothermal energy low priority in its strategic plan, which effects government short term and long term funding of geothermal. Despite this setback, CGER continued its lobby activity to promote geothermal energy amongst politicians and the public with the hope that this negative trend will be reversed. While this report was being written in 2012, it was announced that the Norwegian Parliament has mentioned specifically geothermal energy as one its priorities in its White Paper dealing with energy and climate.

18.9 References and Websites

- www.rcn.no
- www.cger.no
- www.enova.no
- http://www.energi21.no/
- www.novap.no
- www.ngu.no

18.10 Authors and Contacts

This report was written and compiled by Jiri Muller with valuable contributions from, amongst others, Kirsti Midttømme and Randi Kalskin Ramstad.

Jiri Muller (corresponding author)
Institute for Energy Technology
PO Box 40
No-2027 Kjeller
NORWAY
E-mail: jiri@ife.no

Kirsty Midttømme
Christian Michelsens Research AS
P.O Box 6031
Bergen
NORWAY 5892
E-mail: Kirsti.Midttomme@cmr.no

Randi Kalskin Ramstad
Asplan Viak AS
Postboks 6723
7490 Trondheim
NORWAY
E-mail: RandiK.Ramstad@asplanviak.no

National Activities

Chapter 19

Spain

Due to unforeseen circumstances, Spain was unable to submit a country report for 2011.

National Activities

Chapter 20

Switzerland

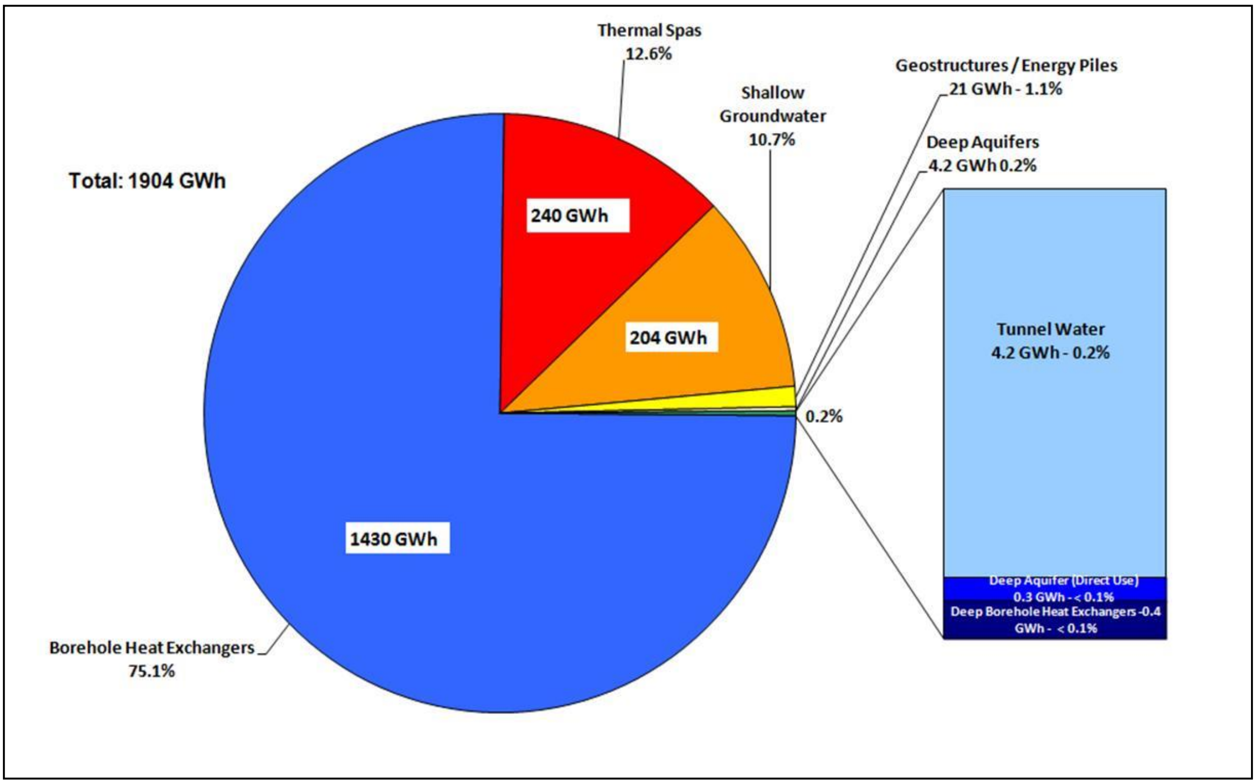


Figure 20.2 *Utilization of geothermal heat in Switzerland in 2011.*
(Source: Imhasly et al., 2012)

20.0 Introduction

Switzerland's national energy program, SwissEnergy (http://www.bfe.admin.ch/energie/index.html?lang=en), and corresponding cantonal programs which have run until the end of 2010, provide the framework for the uptake of measures related to energy efficiency and renewable energy. The program has been in operation for nine years and continues to have a substantial and measurable impact. In terms of greenhouse gas emissions, Switzerland is on track to reach the targets according to the CO_2-law and the Kyoto Protocol (Figure 20.1). While the Swiss CO_2 law focuses on CO_2 emissions arising from fuels utilized in the heating and transportation sector, the Kyoto Protocol also includes CO_2 emissions from the process industry, and other greenhouse gases.

In response to recent trends in Switzerland's emissions the federal government has decided that the subsequent phase of Switzerland's national energy program will ramp up activities related to energy savings and emission reduction in the areas of mobility, electric equipment, industry and services and ramp down activities related to renewable energy and buildings. Cross-cutting initiatives related to urban agglomeration, training and education and managing the national energy program will be increased. Federal budgets continue to be under pressure owing to the Swiss people's 2001 decision not to permit unsustainable public finances and maintain stable debt ratios of the federal government during an economic cycle.

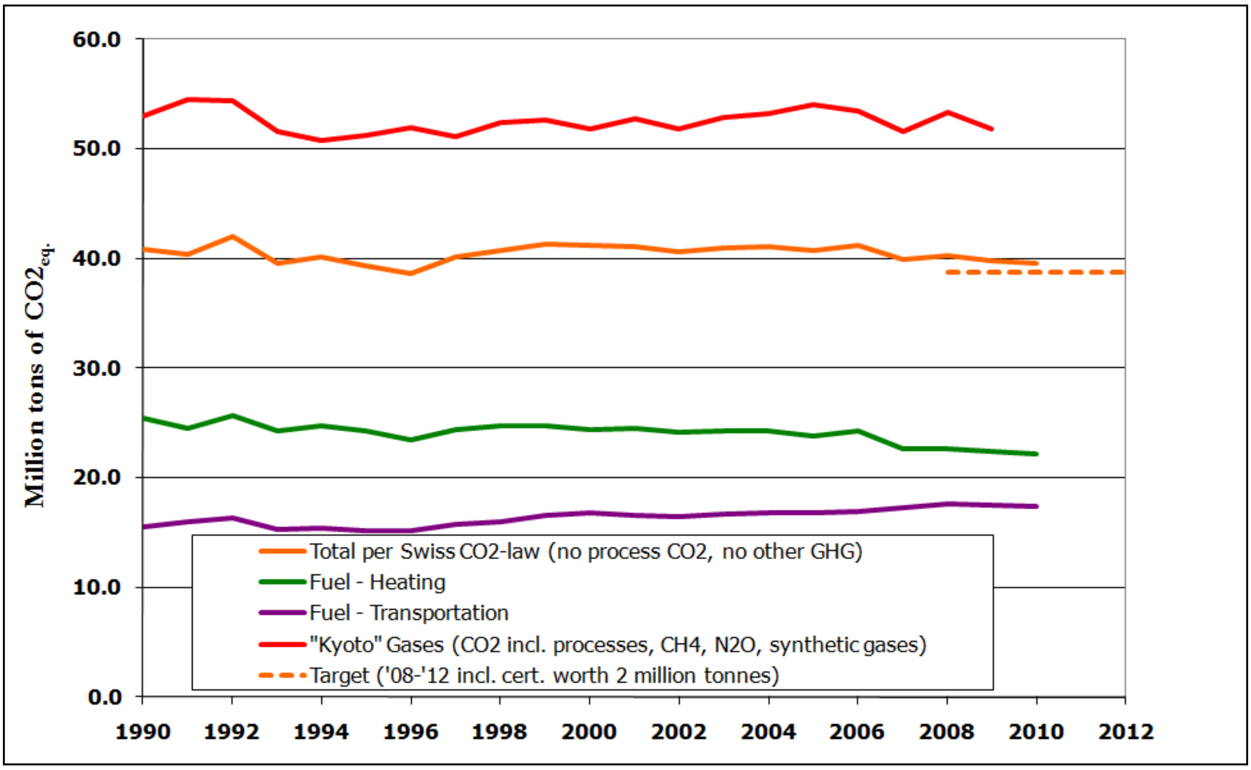


Figure 20.1 *Development of CO_2-Emissions in Switzerland. Geothermal installations substitute by and large fossil fuel for heating purposes, some 0.7 million tons of CO_2 have not been emitted, approximately 1/3 is a reduction due to replacement and 2/3 have been avoided.*

20.1 Major Highlights and Achievements

20.1.1 Implementation

The steady growth of geothermal direct use, mainly due to continued uptake of geothermal heat pump systems, continues in unabated fashion. Notably, they are increasingly replacing fossil fuelled boilers in the course of renovating old building stock. This trend emerges by inspecting the total length of borehole drilled for ground source heat pumps for new when compared to renovated building stock: in 2010 some 950 km had been drilled in the course of building renovation and 1,400 km for new buildings compared to the year 2006 when 350 km and 640 km, respectively, had been drilled.

20.1.2 R&D Achievements

Major progress has been achieved in the analysis of data sets generated in the EGS Basel Project within the framework of the GEOTHERM research project led by ETH Zurich. Based on microseismic data obtained in the course of the massive hydraulic stimulation at Basel, significant progress has been made to adapt Epidemic Type Aftershock Sequence (ETAS) models to derive a 6-hr forecast of the seismicity to come, and use the forecast to develop a time-varying evolution of the seismic hazard during hydraulic stimulation.

20.1.3 Industry Success

The city utility of St. Gall, in charge of the development of the St. Gall deep hydrothermal combined heat and power project, has utilized an extensive 3-D seismic data acquisition campaign to successfully image a deep regional fault structure thought to be hydraulically conductive. The fault structure and the surrounding damage zones are the prime exploration target for a well to be drilled in 2013.

20.1.4 Funding to Industry

There are no statistics available that capture industry funding for geothermal research, development and deployment (RD&D). Estimates made by the Swiss Federal Office of Energy indicate approximately US$ 20-25 M in RD&D expenses by commercially operating entities.

20.1.5 Public Funding to RD&D

Government (federal, cantonal and community) level support for geothermal RD&D comprises some US$ 5 M of federal funds, and approximately US$ 2-3 M at the cantonal and community level.

20.2 Status of Geothermal Energy Use

20.2.1 Electricity Generation

There was no power production from geothermal resources in 2011. A number of hydrothermal projects are in the planning phase, which, if suitable resources are encountered, may eventually lead to power production from hydrothermal or enhanced geothermal systems. Significant stimulus is provided by the success of hydrothermal systems in related play concepts of Southern Germany, the possibility to obtain attractive feed-in tariffs, a federal risk guarantee scheme and the obligation of several local utility companies to explore and, if possible, develop geothermal resources.

Table 20.1 *Status of geothermal energy use in Switzerland for 2011.*

Electricity	
Total Installed Capacity (MW_e)	0
Contribution to National Capacity (%)	0
Total Generation (GWh)	0
Contribution to National Demand (%)	
Direct Use	
Total Installed Direct Use (MW_{th})	1238.5
Total Heat Used (PJ/yr) [GWh/yr]	6.9 [1910]
Total Installed Capacity for Heat Pumps (MW_{th})	1205.2
Total Net Heat Pump Use [GWh/yr]	1664

20.2.2 Direct Use

The Swiss Geothermal Association (www.geothermie.ch) publishes annual statistics on the use of geothermal energy in Switzerland. In 2011, some 2.6 TWh of heat was produced from geothermal systems (Table 20.1), of which 1.9 TWh are directly attributable to geothermal energy (Figure 20.2, start of this Chapter). Compared to 2010, 2011 marks a 4% decline which due to an unusually mild winter. The compound annual growth rate since the year 2000 has been a highly satisfactory 9%, attesting to the maturity of the technology, the uptake in the market place and the popularity among consumers. Noteworthy is the continued very high uptake of borehole heat exchanger coupled systems. Together with groundwater heat pumps they have a total share of some 86% of heat production and continue to enjoy high growth rates both in terms of installed capacity and heat produced. Thermal spas continue to contribute around 240 GWh of produced heat in Switzerland (Figure 20.2).

20.2.3 Energy Savings

Some 182,500 tons of oil equivalent have been saved in 2011, and emissions of around 580,500 tons of CO_2 equivalent with respect to emissions from heating oil have been avoided.

20.3 National Policy

20.3.1 Strategy

The governmental energy program SwissEnergy provides the general strategic framework for meeting the goals on CO_2 emissions, to slow the growth of electricity consumption and to advance the use of renewable energies. Five focus areas were identified for the period of 2006-2010; the modernization of Switzerland's building stock, the use of renewable energy, efficiency gains in equipment and engines, efficient energy and waste heat use in industrial sectors, and energy efficient and low emission mobility. SwissEnergy mainly works through voluntary agreements with trade and industry, and with information campaigns to improve public awareness.

20.3.2 Legislation and Regulation

The energy article of the Swiss Federal Constitution, the Energy Act, the CO_2 Act, the Nuclear Energy Act and the Electricity Supply Act are all integral parts of a sustainable and modern Swiss energy policy. In addition to these legal instruments, energy policies of the federal government and the cantons are based on the availability of future energy supply and demand scenarios as well as on strategies, implementation programs and the evaluation of energy-related measures at community, cantonal and federal levels.

Since 1990, all cantons have been drawing up their energy legislation and regulations, and with the enactment of the Federal Energy Act and the Federal Energy Ordinance on 1 January 1999, the Federal Council has complied with the mandate conferred by the Energy Article of the Swiss Federal Constitution. A CO_2 Act entered into effect on 1 May 2000, in which Switzerland defined binding targets for the reduction of the greenhouse gas, CO_2. The targeted reduction is primarily to be achieved through voluntary measures on the part of companies and private individuals, as well as measures relating to energy, environment, transport and financial policy. The revised version of the CO_2 Act will take effect in 2013. In the wake of the major incident at one of the Fukushima (Japan) nuclear power stations, both government and parliament have decided on a phased exit from nuclear energy in 2011. This decision, probably subject of a referendum in 2014, has led to an ongoing major revision of the Energy Act (and other relevant acts) and the drafting of a wide-ranging catalogue of measures to enable the transformation.

Since ownership and regulations of geothermal resources fall under the remit of each of the 26 cantons of Switzerland, legislation and regulations governing the utilization of geothermal resources are heterogeneous. There is, however, increased activity at the cantonal level to start regulating the use of the deep subsurface, including geothermal resources. Further information may be obtained from the Swiss Federal Office of Energy.

20.3.3 Progress Towards National Targets

National targets comprise:

- In accordance with the CO_2law, the goal of Switzerland's climate policy is to reduce CO_2emissions by 10% over a period of 2008-2012 and to stabilize other greenhouse gas emissions compared to their values of 1990. This translates into an 8% reduction in greenhouse gas emissions according to the Kyoto Protocol.

- The reduction of the rate of growth of electricity consumption (at most 5% more consumption in 2010 compared to 2000).
- More uptake of renewable energies for electricity production (+0.5 TWh in 2010 compared to 2000) and heat production (+3 TWh in 2010 compared to 2000).

Owing to a 14.1% rise in the consumption of transportation fuels, Switzerland's CO_2 emissions (calculated according to the CO_2 law) have, at the end of 2011, only declined by 2.8 million tons, from 40.8 million tons in 1990 to 38.0 million tons in 2011. In 2011, Switzerland's electricity produced amounted to 217,494 TJ (60.4 TWh) compared to the year 2000, when 188,640 TJ (52.4 TWh) were produced. In 2011, new renewable energy sources (excluding large hydropower) contributed to an electricity production of approximately 5,766 TJ or 2.7% of the total. The latter figure compares to 847 GWh for the year 2000. For the year 2011, a total of 43,764 TJ (12,157 GWh) of heat were derived from renewable energy sources compared to 8,915 GWh in the year 2000.

20.3.4 Government Support/Incentives for R&D

Switzerland's primary government incentive for research, development and deployment is administered through a topical research program into geothermal energy by the Swiss Federal Office of Energy. The research program operates within the framework of the Energy Research Concept developed by the Federal Commission for Energy Research for the period 2008-2012. In addition, the Swiss Federal Institutes of Technology (e.g., ETH Zurich, EPF Lausanne, Paul Scherrer Institute, Empa, and others) and the Universities of Applied Sciences also undertake project-oriented research into geothermal energy. In addition, basic research is funded via the Swiss National Science Foundation. Industry-targeted research is funded by the Commission for Technology and Innovation CTI. Finally, cantonal funds are available for the (cantonal) universities in Switzerland, notably, the University of Neuchâtel through the Canton of Neuchâtel.

Although not a member state, Switzerland has a range of bilateral agreements with the European Union (EU) that includes research activities and allows cooperation with and integration into EU-wide R&D activities.

20.4 Market Development and Stimulation

20.4.1 Development Constraints

Geothermal heat pump systems have a high market penetration for new buildings, and are increasingly considered for larger systems (>100 kW capacity). At times, the high density of buildings poses accessibility constraints if geothermal heat pump systems are planned for building stock undergoing renovation. Currently there are a number of hydrothermal projects (direct use of hot aquifers and, if suitable, power production) in the planning stage. Since there has been no recent experience in designing and building a hydrothermal project in Switzerland, project maturation is comparatively slow. The adverse publicity caused by the felt induced seismicity of the Basel EGS Project causes project developers to involve a wide range of stakeholders and pursue a long-term, sustained communication and consultation process. Concern about potential hazards associated with induced seismicity in drilling and geothermal operations, and environmental concerns about water are some of the key obstacles to speedy execution and operation of planned projects. Another fact which makes the development of deep geothermal projects difficult and risky is the lack of underground data in large parts of the country. Finally, the overall level of experience in Switzerland's geothermal industry involved in planning, designing, constructing and operating geothermal energy projects is limited.

There are currently no EGS projects in the construction or execution phase, but private developers are planning new projects.

20.4.2 Support Initiatives and Market Stimulation Incentives

During the years 2000-2011, borehole heat exchanger systems have been deployed mostly in newly constructed real estate. However, as most of Switzerland's building stock is old and the heating systems are in need of renovation (also because of increasing environmental restrictions), the rate of deployment in renovated building stock has correspondingly accelerated over the last few years. This trend is accelerated by support programs in a number of Switzerland's 26 cantons where home owners are given financial incentives to install ground source heat pumps /borehole heat exchangers.

To ensure the wide-spread uptake of geothermal energy utilization, the Swiss Geothermal Association (www.geothermie.ch) provides educational activities at universities, colleges and technical colleges, and further education seminars on a regular and as-needed basis. A few hundred technical and engineering professionals have taken part in these activities. In addition, the Swiss Geothermal Association was instrumental in the revamped industry standard for borehole heat exchanger coupled systems (SIA 384/6) and contributed to the development and implementation of quality standards and certificates for the Swiss geothermal industry.

The Electricity Supply Ordinance and the revised Energy Ordinance detail the implementation of the legal provisions for liberalization of the electricity market for large consumers as well as the introduction of compensatory feed-in tariffs. Since 1 January 2009, an annual charge of 0.45 Swiss-cents per kWh has been levied on high-voltage grid transmission costs. Revenues from the surcharge feed up to CHF 320-340 M per year of funds available for feed-in tariffs and a CHF 150 M fund to underwrite a risk guarantee scheme for geothermal power projects.

Table 20.2 *Feed-in Tariffs for electricity produced from geothermal resources. The tariffs apply to net production of the facility. Tariffs decrease by 0.5% per year from 2018 on (1 USD ≈ 1 CHF).*

Nominal capacity (MWe)	Tariff (CHF/kWh)
≤5	0.40
≤10	0.36
≤20	0.28
>20	0.227

Source: http://www.admin.ch/ch/d/sr/7/734.71.de.pdf

In addition to the feed-in tariffs, there exists a "commitment to guarantee" subsurface risk for finding commercially viable geothermal resources. The purpose of this instrument is to encourage potential investors in geothermal projects by sharing the risk of finding suitable subsurface resources. If boreholes fail to deliver agreed targets, a maximum of up to 50% of the total subsurface costs may be reimbursed. The costs include, for example, well pad construction, drilling and completion for production, injection and observation wells, borehole geology, logging and instrumentation, production, injection and circulation tests, reservoir stimulation, chemical testing, etc. The process is described in detail in attachment 1.6 of the Swiss electricity supply ordinance (http://www.admin.ch/ch/d/sr/7/734.71.de.pdf). So far, 2 projects have received the risk guarantee.

20.4.3 Comment on Costs

As in prior years, the installation costs of geothermal systems did not significantly decrease in 2011. Geothermal systems are perceived to be local in nature, and thus contribute to energy supply security. Energy Contracting for geothermal heat pump systems is increasingly popular (the local electric utility builds, owns, and operates the system and the building owner receives monthly bills for heating, cooling and warm water). Neither unit technical costs nor retail prices are known.

20.5 Status of Geothermal Industry

Most geothermal industry players are small and medium sized enterprises active in the field of shallow geothermal energy. A number of utility companies are engaged in developing and building hydrothermal and EGS combined heat and power projects. The lack of domestic oil and gas and mining industries is most likely the principal contributing factor to Switzerland's hydrothermal and EGS industry being dominated by downstream actors in the geothermal energy value chain migrating upstream. Accordingly, barriers and risks are perceived and managed somewhat differently given prevailing business models.

20.6 RD and D Activities

20.6.1 Focus Areas

Shallow geothermal energy has proven to be successful in the market place and is therefore deemed less of a general priority in terms of federal government sponsored R&D. Instead, special topics are pursued; such as design specifications of energy piles that account for coupling of mechanical and thermal loads, borehole heat exchanger fluids and failure investigations. Most of federally administered funds for research and development are increasingly focused on advancing hydrothermal systems for direct use and power, and on pursuing further research into enhanced geothermal systems (EGS).

20.6.2 Publicly and Government Funded R&D

Only a subset of publicly funded R&D activities is listed in this section. A number of smaller research projects focus on measurement campaigns associated with large and complex geothermal ground source heat pump systems, and establishing best practice manuals regarding the use of borehole heat exchangers both for heating and cooling. Figures for 2011 are not yet available, with the exception of funds that have been provided by the Swiss Federal Office of Energy: for Research and Development some CHF 1.0 M (US$ 1.1 M), for pilot and demonstration projects some CHF 0.6 M (US$ 0.6 M), and for support of the Swiss Geothermal Association to promote the uptake of geothermal energy some CHF 0.5 M (US$ 0.6 M).

A large scale R&D program, GEOTHERM (www.cces.ethz.ch/projects/nature/geotherm), is devoted to Engineered (or Enhanced) Geothermal Systems. The development of this technology to maturity would allow geothermal to make a significant contribution to the global energy mix. GEOTHERM comprises five modules: reservoir geomechanics, microseismicity studies of the permeability creation process and seismic hazard, development of a hydro-thermal-mechanical-chemical coupled numerical code for reservoir simulation, fluid-rock interaction, and optimal use of geothermal resources in an urban environment. Safe and successful EGS reservoir creation by massive hydraulic stimulation will ensure that operators retain their "license to operate" and become adept at engineering the reservoir to optimize subsequent heat extraction while reducing exposure and risks to a level as low as reasonably practicable (ALARP). Owing to the installation of a highly sophisticated microseismic monitoring system, the operators of the Basel EGS Project have collected a data set that illuminates the processes operating during a massive hydraulic stimulation. Within the framework of the GEOTHERM project, ETH Zurich's Bettina Goertz-Allmann and colleagues have analyzed P-wave spectra of about 1,000 seismic events to estimate stress drops and their spatial variation throughout the stimulated reservoir. The estimated median stress drop is 2.3 MPa, with values varying over 2 orders of magnitude. Small stress drops of around 1 MPa occur close to the casing shoe with higher magnitude events progressively further away from the injection zone, with a maximum at 300 m distance away. A hydraulic diffusivity model accounts for locally observed transport properties and reveals a close correlation of the spatial distribution of stress drops with a modeled pressure perturbation. The result confirms that pore pressure distribution during, and in the wake of a hydraulic stimulation, and observed stress drops are very good proxies. Some important insights into possibilities of designing and executing hydraulic stimulation operations have been made in a recently published study. ETH Zurich's Corinne Bachmann, in collaboration with Germany's GFZ

Potsdam, have analyzed statistical features of the induced seismicity sequence at Basel and show that the sequence is well modeled with the Omori–Utsu law following the termination of water injection. Based on this model, the sequence will last 31(+29/−14) years to reach background levels of seismicity. Bachmann et al. (2011) use Epidemic Type Aftershock Sequence (ETAS) models to successfully derive a 6-hr forecast of the seismicity to come, and use the forecast to develop a time-varying evolution of the seismic hazard during hydraulic stimulation. Such a model may in future serve as a valuable tool for designing probabilistic alarm systems for EGS experiments and govern operations in an increasingly controlled manner. Whereas Mohr-Coulomb failure criteria are commonly employed, Bachmann et al. (ibid.) relate their observations to modern rate and state variable friction laws. Thus, new approaches to designing and executing hydraulic stimulations may be developed based on mechanical rate effects, mechanical aging effects, hydrothermal effects on strength, and hydrothermal effects on fluid flow.

The Swiss Seismological Service (SED) is implementing the GeoBest project on behalf of the Swiss Federal Office for Energy (SFOE) to provide cantonal and federal authorities with guidelines on how to handle seismic hazard in the framework of the environmental risk assessment. Within GeoBest, selected pilot projects in Switzerland will be supported in the necessary seismic monitoring of natural and induced seismicity. GeoBest supports the pilot project in the first two years, which are most critical with respect to the financial risk, by providing seismological instrumentation from the GeoBest instrument pool, and through partial financial support for the installation and operation of the seismic monitoring network. In return, the pilot projects grant SED access to project data needed for seismic hazard assessment and the development of best practice guidelines.

For more information on the R&D program of the Swiss Federal Office of Energy please refer to http://www.bfe.admin.ch/forschunggeothermie/02484/index.html?lang=de

In addition, Swiss universities and small and medium-sized enterprises participate in R&D programs that are publicly funded by foreign jurisdictions (e.g., GEISER funded by the European Commission's 7th EU Framework Program, and R&D related to EGS funded by the US Department of Energy).

20.6.3 Industry Funded R&D

In many instances, utility industry R&D funds are co-mingled on a corporate basis and include all energy related R&D. Actual expenditures (including those for exploratory work) for 2011 are likely to range from CHF 20-25 M (US$ 22-27 M); the funds derive mostly from (1) Switzerland's principal project developers, (2) major Swiss utility companies and their joint research vehicle ("swiss*electric* research"), (3) member funds used for Switzerland's Laboratory for Geothermics based at the University of Neuchâtel, (4) funds that small and medium sized enterprises contribute, and (5) funds from semi-private regional and local utility companies.

20.7 Geothermal Education

A large part of geothermal education in Switzerland continues to be managed by the Swiss Geothermal Association (www.goethermie.ch). Continuing education courses have been held at a large numbers of universities and technical colleges in the German, French and Italian-speaking regions of Switzerland. At university level, the ETH Zurich offers courses in geothermal energy as part of an Earth Sciences degree course. Importantly, the University of Neuchâtel's Center for Hydrogeology and Geothermal Energy has initiated a joint Master's program in Hydrology and Geothermal Energy and now offers university-level courses related to geothermal energy. Also a first course leading to a Certificate of Advanced Studies in deep geothermal systems (CAS DEEGEOSYS) was run by the University of Neuchâtel.

20.8 International Cooperative Activities

Since Switzerland perceives geothermal energy (and EGS in particular) to be an increasingly important energy source in the coming decades, Switzerland strives for international cooperation in developing geothermal resources and geothermal technology. On a policy level, and on issues related to Switzerland's federally sponsored and coordinated geothermal activities, the Swiss Federal Office of Energy now aims for a tight cooperation and integration into the IEA's Geothermal Implementing Agreement. Similarly, Switzerland strives to pursue the development of its geothermal resources and on research and development within the European Union. Switzerland has continued to contribute to the EGS Project in Soultz-sous-Forêts (France) and to European research projects funded by the European Commission and member states (e.g., GEISER, EGS related R&D in Germany and France, GEOTHERMAL ERANET) and the US Department of Energy.

The International Partnership for Geothermal Technology (IPGT), comprising the USA, Iceland, Switzerland, Australia and New Zealand, is an important vehicle to pursue further research into EGS (http://internationalgeothermal.org). The IPGT working groups have the following areas of focus: (1) Lower Cost Drilling, (2) Zonal Isolation/Packing, (3) High Temperature Tools, (4) Stimulation Procedures, (5) Modeling, (6) Exploration Technologies, and (7) Induced Seismicity. In light of the EGS Basel project experience, the areas "Stimulation Procedures" and" Induced Seismicity" are of particular interest for Switzerland.

20.9 Future Outlook

Changes in Switzerland's energy policy due to the planned phased exit from nuclear energy are expected to lead to increased attention to Switzerland's geothermal resources. Substantial support measures are being developed to enable the utilization of geothermal energy. Revised legislation will be debated in the Swiss parliament in 2013 and 2014, and a possible referendum held in late 2014.

The entry of new geothermal players suggests an increasingly dynamic pace of geothermal industry development, in particular, with respect to direct use and geothermal power generation. A crucial step will be the success of the two major Swiss projects, AGEPP in Lavey-les-Bains (Canton of Vaud) and St Gallen (Canton of St Gall).

20.10 References and Websites

- Website of the Swiss geothermal research program: http://www.bfe.admin.ch/forschunggeothermie/02484/index.html?lang=de

- Website of the Swiss geothermal association: www.geothermie.ch

- Website of GEOTHERM: http://www.cces.ethz.ch/projects/nature/geotherm/

- Website of Project GeoBest: http://www.seismo.ethz.ch/research/groups/spec/projects/ProjectGeoBest

- Website of the St Gall Geothermal Project (in German): http://www.geothermie.stadt.sg.ch/aktuell.html

Bachmann, C.E., Wiemer, S., Woessner, J. and Hainzl, S. (2011) Statistical analysis of the induced Basel 2006 earthquake sequence: introducing a probability-based monitoring approach for Enhanced Geothermal Systems. Geophysical Journal International, 186, 793-807.

Imhasly, S., Signorelli, S., Rybach, L. (2012) Statistik der geothermischen Nutzung in der Schweiz. Ausgabe 2011.
http://www.geothermie.ch/data/dokumente/miscellanusPDF/Publikationen/Geothermiestatistik%20Schweiz%202011.pdf

20.11 Authors and Contacts

Gunter Siddiqi and Rudolf Minder
Swiss Federal of Energy
Department of the Environment, Transport, Energy and Communication
Swiss Federal Office of Energy
CH-3003 Bern
SWITZERLAND
E-mail: gunter.siddiqi@bfe.admin.ch and rudolf.minder@bluewin.ch

National Activities

Chapter 21

United Kingdom

Figure 21.1 *Drilling of the Science Central Borehole in the centre of Newcastle-upon-Tyne. (Credit BGS)*

21.0 Introduction

2011 was a momentous year for the UK as it formally rejoined the IEA-GIA in September. The UK was a founder member of the IEA-GIA in 1997, but left in 2004. The contracting party is the UK Department for Energy and Climate Change (DECC). The Executive Committee Member is Dr Penny Dunbabin from DECC (penny.dunbabin@decc.gsi.gov.uk) and the Alternate Member is Dr Jon Busby from the British Geological Survey (jpbu@bgs.ac.uk). The UK is participating in three Annexes; Annex III- Enhanced Geothermal Systems, Annex VIII- Direct Use of Geothermal Energy and Annex X- Data Collection and Information.

After an active geothermal research programme in the 1970s and 80s that assessed the potential of the deep saline sedimentary aquifers and Hot Dry Rock there was little, if any geothermal exploration in the UK. The only deep geothermal project was in the City of Southampton where one of the legacy boreholes from the research programme was developed to provide a geothermal contribution to a district heating scheme.

The UK Government is committed to providing 15% of energy from renewables by 2020. The UK Renewable Energy Strategy was launched in 2009 with a lead scenario of more than

30% of electricity and 12% of heat generated from renewable sources. Part of the strategy was grant aid of £ 5.1 M capital for deep geothermal exploration. This was distributed via the Deep Geothermal Challenge Fund in two rounds. In round one, in 2009, £ 3.5 M was divided between two large Cornwall-based EGS projects to purchase capital equipment for use when drilling begins. The other £ 0.5 M went to a heat-only project in Eastgate, County Durham. In the second round, in 2010, the funding was allocated for the preliminary drilling of a heat only borehole in the centre of the city of Newcastle, a proposed heat only borehole on Keele University campus (never spudded) and a refitting of the pump to the borehole at Southampton. In 2011, the UK Renewable Energy Roadmap was published which identified deep geothermal as a contributor to renewable electricity and heat, introduced the Renewable Heat Incentive for non-domestic ground source heat pumps and the Renewable Heat Premium Payment (grant aid) for eligible domestic scale ground source heat pumps.

21.1 Major Highlights and Achievements

- During 2011, a geothermal borehole was drilled in the centre of Newcastle-upon-Tyne on a brown field site that is to be developed for university, commercial and residential buildings. The intention is that deep geothermal heat will be used to provide a renewable energy option for space heating. The borehole development was led by Professor Paul Younger from the University of Newcastle with funding from the University, DECC, Newcastle Science City, Newcastle City Council, Northumbrian Water and the British Geological Survey. The borehole, referred to as the Science Central Borehole, was drilled to a depth of 1,821 m, but the calculation of true vertical depth awaits a deviation log. The borehole intersected the Carboniferous Fell Sandstone Formation (the target geothermal reservoir) between 1,480-1,796 m depth. It is hoped that fracture permeability, associated with the nearby Ninety Fathom Fault System, will have enhanced the natural permeability of the sandstone and may have allowed the migration of warmer water to flow from the Wearedale Granite located to the west. A temperature of 47.7 °C was logged at a depth of 968 m indicating a geothermal gradient of 3.9 °C /100 m. A shale bridge at 969 m depth created a temporary blockage, postponing further logging and pump tests to 2012.
- The second round of the Regional Growth Fund run by the UK Department of Business Innovation and Skills (BIS) awarded a grant of £ 6,050,000 to Geothermal Engineering Ltd to support the drilling and construction of the UK's first deep geothermal power plant and establish a Centre of Research Excellence for Geothermal Energy with Exeter University.
- The Microgeneration Certification Scheme released the draft MIS 3005 which defines the standard practice required of installers of ground source heat pump systems. The final version (3.1a) was released in March 2012.
- The Environment Agency released a good practice guide entitled 'Environmental Good Practice Guide for Ground Source Heating and Cooling'. It covers the environmental good practice that should be followed for both open and closed loop systems.
- The Ground Source Heat Pump Association released a guide for 'Closed Loop Vertical Borehole, Design, Installation and Material Standards'.
- The Engineering and Physical Sciences Research Council is funding 4 research projects into ground engineering and heat and mass transfer. The total budget is £ 1,000,000.

21.2 Current Status of Geothermal Energy Use

Geothermal development in the UK remained at low levels despite government targets for renewable energy and carbon emissions reduction. This was due to a number of factors including;

- The economic downturn reducing public and private sector finance.
- Uncertainties over subsidy levels and feed-in-tariffs for geothermal electricity and heat.
- Lack of a publicly funded exploration risk insurance scheme for deep geothermal drilling.
- Lack of acceptance of geothermal which is perceived as a new, risky, technology.
- Lack of a legal framework (licensing scheme) for deep geothermal energy.

New installations and total installed capacity are summarized in Table 21.1.

21.2.1 Electricity

There is no geothermal electricity generation in the UK. Two commercial projects based in Cornwall in southwest England have planning permission to commence drilling. These projects aim to install a combined generation capacity of ~14 MW_e.

Table 21.1 Status of geothermal energy use in the UK for 2011.

Electricity	
New capacity installed in 2011 (MW_e)	0
Total Installed Capacity (MW_e)	0
Direct Use	
New capacity installed in 2011 (MW_{th})	0
Total Installed Direct Use (MW_{th})	2.76
Total Heat Used (TJ/yr) [GWh/yr]	72.55 [20.2]
Ground Source Heat Pumps	
New capacity installed in 2011 (MW)	63
Total Installed Capacity for Heat Pumps (MW)	295
Total Net Heat Pump Use [GWh/yr]	480*

* 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.

21.2.2 Direct Use

The only direct uses of geothermal heat in the UK are the spas at Bath and Buxton and the geothermal borehole at Southampton that contributes heat to a district heating scheme. No new installations were added in 2011. A borehole was drilled in the centre of the city of Newcastle-upon-Tyne with the intention of supplying geothermal heat to a new university, office and housing development (see section 21.1).

A total of 2,736 ground source heat pumps were installed in 2011 (Table 21.2).

Table 21.2 Number and type of ground source heat pumps installed in 2011 (Source: BSIRA, UK).

Small Domestic (up to 10kW)	1,301
Large Domestic (10.01-20kW)	1,054
Commercial (above 20kW)	381
Total	2,736

21.3 National Policy

21.3.1 Strategy

The UK Renewable Energy Strategy was launched in 2009 with a target of 15% of energy from renewable by 2020. It also aims to reduce the UK's carbon dioxide emissions by over 750 million tonnes by 2030. The lead scenario envisages more than 30% of electricity generated from renewables, 12% of heat generated from renewables and 10% of transport energy from renewables. Most of this will be wind, biomass, biofuels and electric vehicles, but with a significant input to domestic heating from ground source heat pumps. Geothermal electricity is expected to have a minor role.

The UK Renewable Energy Roadmap was published in 2011 and identified 8 technologies that have the greatest potential for the UK to meet its renewable energy targets. One of those identified was ground source and air source heat pumps. Incentives introduced included the Renewable Heat Incentive for non-domestic ground source heat pumps, the Renewable Heat Premium Payment (grant aid) for eligible domestic scale ground source heat pumps and the collection of data on how best to improve heat pump performance and raise the technical abilities of installers by tightening standards of training under the Microgeneration Certification Scheme (see above).

21.3.2 Legislation and Regulation

The Renewables Obligation (RO) is currently the main financial mechanism by which the UK Government incentivises the deployment of large-scale renewable electricity generation. Support is granted for 20 years. The RO places a mandatory requirement on licensed UK electricity suppliers to source a specified and annually increasing proportion of electricity they supply to customers from eligible renewable sources or pay a penalty. The scheme is administered by Ofgem who issue Renewables Obligation Certificates (ROCs) to electricity generators in relation to the amount of eligible renewable electricity they generate. Generators sell their ROCs to suppliers or traders which allows them to receive a premium in addition to the wholesale electricity price. Suppliers present ROCs to Ofgem to demonstrate their compliance with the obligation. Where they do not present sufficient ROCs, suppliers have to pay a penalty known as the buy-out price, which was set at £ 36.99 in 2011. Geothermal electricity was eligible for 2 ROCs per MWh in 2011, although there was no generation.

The Feed-in Tariffs (FITs) scheme was introduced on 1 April 2010. Through the use of FITs, DECC hopes to encourage deployment of additional small-scale (less than 5 MW) low-carbon electricity generation. There was no geothermal electricity generation in 2011.

The Renewable Heat Incentive (RHI) was introduced in July 2011 and pays a tariff for renewable heat for non-domestic installations. This includes deep geothermal heat as well non-domestic ground source heat pumps. The tariff pays 4.7 p/kWh_{th} for projects < 100 kW_{th} and 3.4 p/kWh_{th} for projects > 100 kW_{th}. Domestic scale ground source heat pumps are eligible for a Renewable Heat Premium Payment (RHPP) of £ 1,250 to help cover the purchase price.

21.3.3 Progress towards National Targets

- Up to August 2012, there were 6 accredited ground source heat pump installations receiving the RHI with a combined installed capacity of 0.105 MW_{th}. Eligible heat generated (since July 2011) was 54,881 kWh_{th}.
- Between August 2011 and April 2012, 1,033 ground source heat pump installations received the Renewable Heat Premium Payment.

21.3.4 Government Support/Incentives for R&D

- The Engineering and Physical Sciences Research Council is funding 4 research projects into ground engineering and heat and mass transfer. The total budget is £ 1,000,000.
- The British Geological Survey received £ 82,000 in 2011 from the Natural Environment Research Council to conduct geothermal research.

21.4 Market Development, Stimulation and Constraints

Development of geothermal projects remains at a low ebb, mainly because:

- The geothermal industry would like to see the Renewable Obligation increase the number of ROCs from 2 to bring subsidy rates for geothermal electricity more in line with those in continental Europe.
- There is no publicly funded deep drilling insurance scheme as exists in several countries. Developers have found private insurance rates to be too high.

21.5 Status of Geothermal Industry

The geothermal industry is likely to be slow to take off in the UK until one or two pilot plants are operational and the subsidy regime becomes more attractive. This may change for heat only projects when new levels for the Renewable Heat Incentive are published in September 2012. For electricity projects, an entirely new system of subsidies will be outlined in 2013 (Electricity Market Reform).

21.6 Research and Development Activities

Geothermal research in the UK is at a low level when compared to research into other renewable technologies. The government has been supporting technologies such as wave and tide, where it sees the UK can develop a commercial advantage that can be exported. The majority of UK geothermal research is largely related to resource estimations and utilisation of the resource.

21.6.1 Government Funded

Government funding for early stage research is distributed through the Research Councils. Additional funding may also be available from the European Commission and is included here. Table 21.3 lists projects that are presently funded, but this is not an exhaustive list.

Table 21.3 *Government funded research projects.*

Institute	Industrial partner	Project title	Subject area	Funder*
Cambridge University	Arup	Numerical modelling of EGS reservoir development	Deep geomechanics	EPSRC
Newcastle University	Cluff Geothermal Ltd	A conceptual hydrogeological model for fault-related geothermal energy resources in northern England	Geothermal potential of northeast England	NERC
Reading University		Ground coupled heat pumps: mitigation potential for current and future climate predictions	Impact of climate change on horizontal GSHP	NERC
De Montfort University	Earth Energy Ltd	Modelling of robust and adaptable geothermal heating and cooling systems	Single borehole heat exchanger performance	NERC
Southampton University		Performance of ground energy systems installed in foundations	Energy piles performance	EPSRC
Cardiff University		SEREN – Ground Source Heat	Improve the performance and uptake of GSHP	WEFO

* EPSRC – Engineering and Physical Sciences Research Council
NERC – Natural Environment Research Council
WEFO – Welsh European Funding Office

In addition the Scottish government has funded a project to assess the deep geothermal potential of Scotland.

21.6.2 Industry Funded

Funding from industry is not always publicised as it may be commercial-in-confidence. Projects being undertaken within the university sector (not an exhaustive list) are provided in Table 21.4.

Table 21.4 *University sector geothermal research projects.*

Institute	Project title
Durham University	Multiphysics simulation of geothermal engineering
Durham University	Geothermal potential of low enthalpy deep sedimentary basins

21.7 Geothermal Education

There are no specific higher education courses devoted to the exploration and exploitation of geothermal energy in the UK. However, earth science and renewable energy university courses will often have modules on aspects of geothermal energy.

During 2011, the Ground Source Heat Pump Association (GSHPA) organised a number of educational seminars around the UK in order to provide instruction on the application of the Microgeneration Certification Scheme (MCS) MIS 3005 standard for the installation of ground source heat pumps. The British Drilling Association (BDA) organised 6 seminars around the UK on Standards, Quality and Improvements to Ground Source Heat Pump Installations. In addition, the GSHPA organised 2 Technical Seminars in 2011 for the dissemination and discussion of the latest research into ground source heat and its exploitation and utilisation.

21.8 Future Outlook

There is still optimism that the first deep EGS borehole will start drilling during 2012/13 in Cornwall, in the southwest of England. It is generally believed that if one borehole can prove the resource and the viability of EGS in the UK then funding further boreholes should be much easier.

There is an increasing awareness of deep geothermal heat and its potential for district and agricultural heating. On 29 March 2012, the UK Government set out its vision for heating homes, businesses and industry in the decades ahead in a publication titled: 'The Future of Heating: A Strategic Framework for Low Carbon Heat in the UK' see: Heat - Department of Energy and Climate Change. This strategic framework for low carbon heat sets out the possible ways in which the supply of heat can be decarbonised to meet the UK's renewables and emissions reduction targets. Heat networks which can be supplied by deep geothermal heat form a key element of the strategic framework.

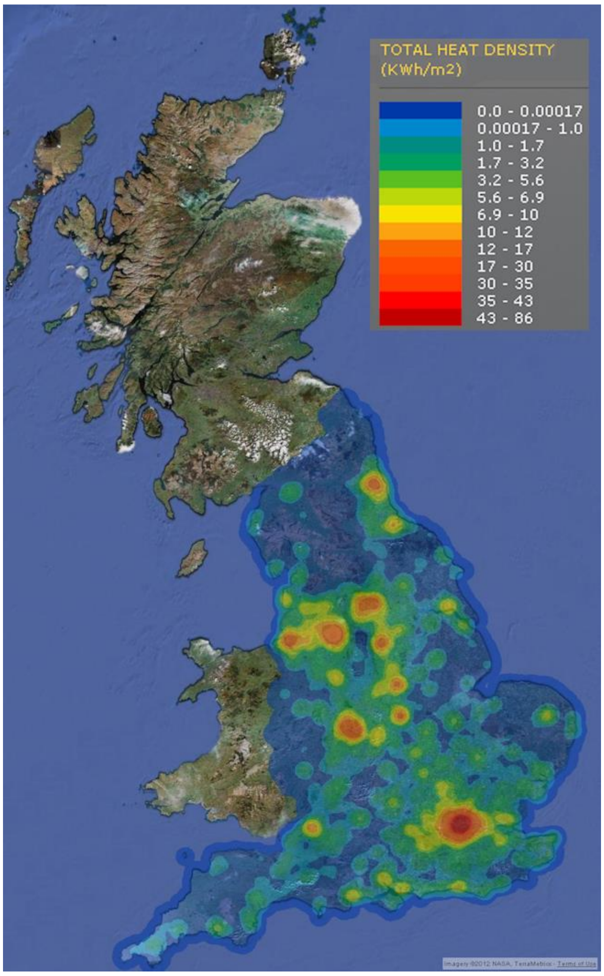


Figure 21.2a *Heat demand map.*
(http://ceo.decc.gov.uk/nationalheatmap/)

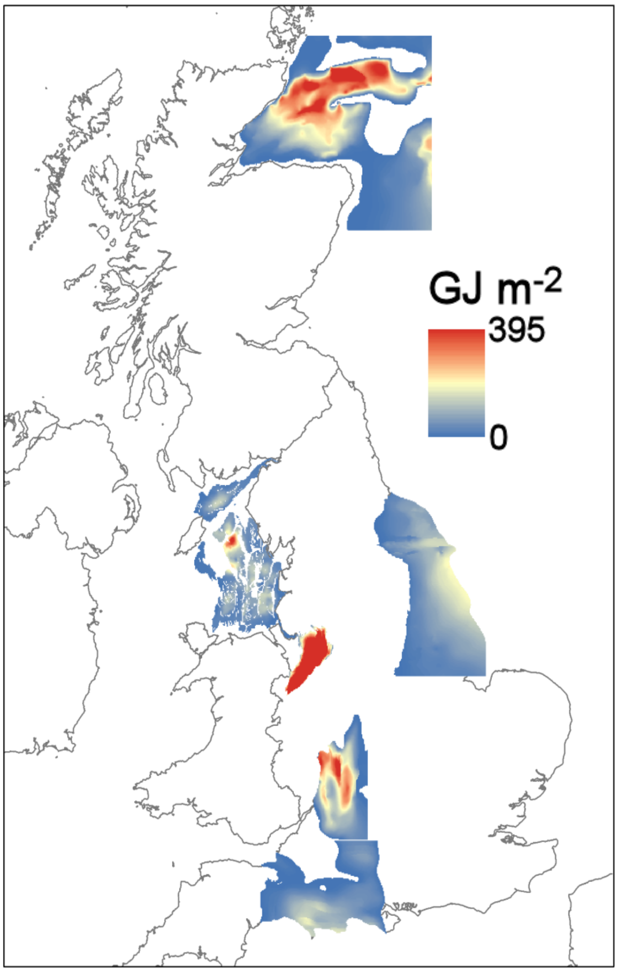


Figure 21.2b *Heat in place in Sherwood Sandstone.*

Several local authorities are considering geothermal whilst developing sustainable energy plans. The potential of mine water heat has also received publicity and several preliminary resource assessments have, or are about to be made. Of particular note is Glasgow, in Scotland, where it is estimated that the geothermal resource to a depth of 300 m amounts to 2 000 GWh km^{-2}, which could be exploited at 22 GWh km^{-2} per year, which could provide 40% of the heating demand for at least 100 years.

The UK Department for Energy and Climate Change (DECC) has published, in 2012, a heat demand map. It consists of series of electronic maps showing heat demand from buildings across England. The intention is to help developers and planners identify priority areas for low carbon heat projects. The map above (Figure 21.2a) shows the heat demand density in kWh m^{-2} per year for all sectors and building types. It is possible to zoom and sub-select for residential, commercial, industrial and public buildings. Also shown in Figure 21.2 is the Heat in Place for the Triassic Sherwood Sandstone (Figure 21.2b) illustrating that deep geothermal heat could meet some of the heat demand.

The UK Government are also in the process of introducing the Green Deal that will enable householders to upgrade their homes with energy efficiency and carbon reduction improvements with loan finance from The Green Deal Finance Company. Unlike most loans, the repayment is made through the property's energy bill and hence the financial obligation remains with the bill payer if the ownership of the property changes. Ground source heat is 1 of 45 improvements that are covered by the Green Deal.

21.9 References and Websites

- Office for Renewable Energy Deployment

  www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/ored/ored.aspx

- Renewables Obligation

  www.ofgem.gov.uk/Sustainability/Environment/RenewablObl/Pages/RenewablObl.aspx

- Renewable Heat Incentive

  www.decc.gov.uk/en/content/cms/meeting_energy/renewable_ener/incentive/incentive.aspx

  www.energysavingtrust.org.uk/Professional-resources/Funding-and-finance/Renewable-Heat-Incentive

- Renewable Energy Association Deep Geothermal Group

  www.r-e-a.net/member/deep-geothermal

- Ground Source Heat Pump Association

  www.gshp.org.uk/

21.10 Author and Contact

Jon Busby
British Geological Survey
Keyworth, Nottingham
NG12 5GG
UNITED KINGDOM
E-mail: jpbu@bgs.ac.uk

Penny Dunbabin
Climate & Energy, Science & Analysis
Area 6A
Department of Energy & Climate Change
3-8 Whitehall Place
London, SW1A 2AW
UNITED KINGDOM
E-mail penny.dunbabin@decc.gsi.gov.uk

National Activities

Chapter 22

United States of America

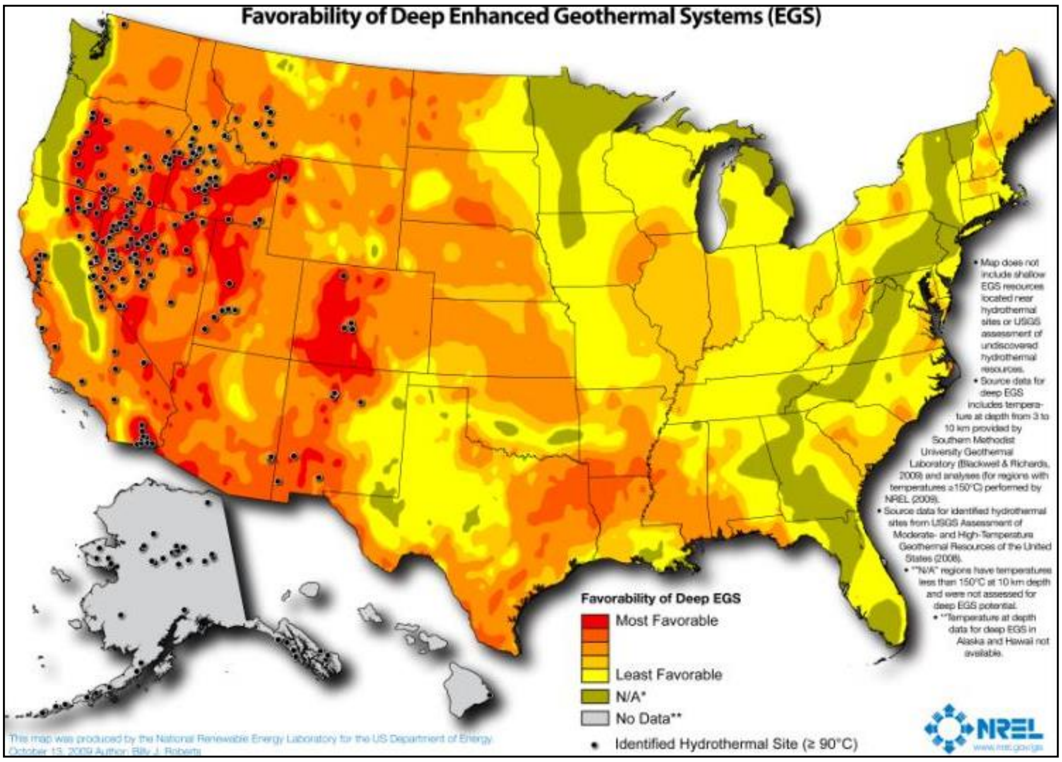


Figure 22.1 *EGS favorability map across the United States.*
(Source: NREL)

22.0 Introduction

Geothermal energy in the United States represents a largely untapped energy alternative with an estimated 30 GW of undiscovered hydrothermal resources in the western states (USGS, 2008). Given greater success rates in exploration and confirmation activities, it is likely to contribute a significant amount of electricity to the United States renewable energy portfolio. Although newly installed capacity was relatively low in 2011, a recent surge in binary systems over the last several years is encouraging. The United States Government played a key role in advancing the industry, with tax incentives through the Treasury Department, competitive leasing through the Bureau of Land Management, and comprehensive geothermal resource assessment surveys carried out by the United States Geological Survey. Research initiatives implemented by the Department of Energy (DOE) indicate promise for the development of "blind" hydrothermal resources as well as the validation of Enhanced Geothermal Systems (EGS). Continued progress with co-produced, low temperature technologies could lead to expansion into states that currently lack utility-scale systems such as Colorado and Texas.

22.1 Highlights and Achievements

- **DOE Finalizes $ 96.8 M Loan Guarantee for Oregon Geothermal Project- February 2011**
  A $96.8 million America Recovery and Reinvestment Act (ARRA) loan guarantee was granted to U.S. Geothermal, Inc. to construct the 23 MW Neal Hot Springs geothermal power in Malheur County, Oregon. The project was estimated to create 150 construction jobs, over a dozen permanent jobs, as well as jobs along the supply chain that spanned several states including Texas, California and Ohio.
- **$70 M to Advance Technology and Reduce Cost of Geothermal Energy- June 2011**
  DOE awarded up to $70 million for geothermal energy over a three-year period. Funding will target key research areas such as innovations in exploration technologies, improvements in resource characterization, drilling, and reservoir engineering techniques.
- **$38 M to Advance Technology and Reduce Levelized Cost of Electricity- September 2011**
  DOE announced $38 million over three years for projects to accelerate the development of geothermal energy technologies. Thirty-two projects in 14 states will address issues such as locating geothermal resources, improving resource characterization, advanced drilling methods, and reservoir engineering techniques.
- **DOE Awards Up To $11 M to Advance Innovative Geothermal Energy Technologies- June 2011**
  Eight projects in five states—California, Connecticut, Louisiana, Texas, and Utah—were selected to receive up to $11.3 million of Department of Energy funding to advance innovative energy technologies. During Phase I of each project, feasibility studies were conducted that included technical and economic modelling and, if selected for Phase II after a Go/No-Go Decision, projects will validate their respective designs in real-world environments.
- **Secretary Chu, Senator Reid Announce Department of Energy Conditional Commitment for a Loan Guarantee for Nevada Geothermal Project- June 2011**
  DOE announced a conditional commitment for a loan guarantee for a 122 MW geothermal project in Nevada. The project, sponsored by Ormat Nevada, Inc., will benefit from a partial guarantee for a $350 million loan. Ormat estimated the project will create approximately 330 construction jobs and nearly 65 permanent jobs.
- **Nevada's Beowawe Geothermal Plant Generates Clean Energy- April 2011**
  The Beowawe Geothermal Plant in Eastern Nevada, developed by Terra-Gen Power and TAS Energy, added a 1.9 MW binary cycle system to its existing nameplate capacity of 17.7 MW. The project received a $2 million America Recovery and Reinvestment Act grant from DOE's Geothermal Technology Program and $4 million in private sector investments.

22.2 Current Status of Geothermal Energy Use

The United States remains the global leader in geothermal installed capacity. The last several years have seen a resurgence in geothermal power due to technology advancements coupled with government incentives.

22.2.1 Electricity Generation

Installed geothermal capacity in 2011 was approximately 3,111 MW (GEA, 2012) which supplied an estimated 16.7 TWh of electricity (USEIA, 2012). Geothermal energy represented approximately 2% of renewable energy demand and 0.4% of total national energy production (ibid.). In 2011, two newly developed geothermal facilities added 9.9 MW of nameplate capacity. The plants included the 8 MW Puna Extension binary facility located in Hawaii and the 1.9 MW Beowawe flash steam facility in Nevada (GEA, 2012). Installed capacity spanned eight states with over 95% concentrated in California and Nevada.

The United States Geothermal Energy Association (GEA, 2012) identified 123 developing projects and 170 total confirmed projects and prospects over 15 states (ibid.). Between 4,116-4,525 MW were represented for confirmed resources in development, and a potential of 4,882-5,366 MW when including unconfirmed projects in resource development. Advantaged-stage planned capacity additions, which refer to facilities in permitting/initial development as well as resource production/power plant construction, ranged from 949-956 MW, with the largest additions in California (559 MW) and Nevada (295 MW).

Two separate Bureau of Land Management (BLM) lease sales occurred across 25 parcels of land. In March, 17 parcels in Nevada generated $ 456,353 in revenue, while in May, 8 parcels in Idaho totalled over $ 53,000 in revenue (USBLM, 2011a). For Fiscal Year 2011, 10 geothermal wells were started (8 Nevada, 1 California, 1 Utah) and 6 wells completed (3 Nevada, 2 Oregon, 1 California) (USBLM, 2011b), versus the previous year when 16 wells were started and 7 were completed.

22.2.2 Direct Use

Based on a 2010 study, the combination of direct heat use and geothermal heat pumps produced approximately 56,552 TJ/yr from an estimated installed capacity of 12,611 MW_{th} (Lund et al., 2010).

On its own, direct heat use accounted for 9,152 TJ/yr from an estimated 611 MW_{th} which were distributed between the following categories: aquaculture (34%), bathing and swimming pools (28%), individual space heating (15%), greenhouses (9%), district heating (8%), agricultural drying (3%), industrial process heating (2%), cooling (1%), and snow melting (<1%).

Geothermal heat pumps accounted for approximately 81% of overall use and, over the last five years, exhibited a 13% annual growth rate, with an estimated 100,000-120,000 12 kW_{th} geothermal heat pumps were installed. Overall, approximately 70% of units were residential, whereas 30% were commercial or institutional.

22.2.3 Energy Savings in 2011

Geothermal power produced in 2011 was estimated to have energy savings of 18,987 GWh/y, divided among power (16,700 GWh/yr) and heat (2,287 GWh/yr) (note: the geothermal heat value was calculated based on 2010 geothermal applications). As far as CO_2 savings by geothermal power production, total savings was 32,782,100 tons CO_2, which was averted from a combination of natural gas (3,223,100 tons CO_2), oil (13,643,900 tons CO_2), and coal (15,915,100 tons CO_2).

22.3 National Program

22.3.1 Strategy

The DOE's Geothermal Technologies Program (GTP) continued in its role to support RD&D that will guarantee the cost competitiveness of geothermal energy. For hydrothermal resources, a broad portfolio of projects included rapid reconnaissance on a regional scale to locate prospects, improve performance of existing exploration technologies, and develop tools capable of reducing the cost and risk of exploration. For EGS, GTP funded seven demonstration projects to prove technical feasibility of reservoir creation. Given commercial implementation, a vast amount of energy might be captured across the United States (Figure 22.1).
The National Geothermal Data System (NGDS) is being developed as a distributed, interoperable network of geothermal data repositories, or nodes. NGDS will provide a gateway to access content-rich data for the purpose of broadening the pool of knowledge that will advance discovery and development of commercial-scale geothermal energy. The system will be fully operational in 2014.

The National Academy of Sciences funded a draft protocol for induced seismicity that included all DOE-funded EGS demonstrations, with an updated protocol released for comment in June

2011. Projects were funded to enhance scientific understanding of the causes and mitigation of induced seismicity.

GTP undertook a detailed lifecycle water-use study as well as an investigation of air-cooling and the use of CO_2 as a geofluid to reduce water consumption. Since geothermal resources are primarily located in western states where water can be scarce, an evaluation of plant types was intended to estimate plant level incidence on water supplies.

22.3.2 Legislation and Regulation

The Federal Production Tax Credit (PTC) was established at 2.2 cents/kWh for geothermal projects with a placed-in-service date of 31 December 2013 for the first 10 years of operation. In addition, the Treasury Department's 1603 Program "Payments for Specified Energy Property in Lieu of Tax Credits" allowed geothermal property owners to apply for cash grants in lieu of PTCs or Investment Tax Credits (ITCs). Two businesses received approval for cash grants worth a total of $ 67,421,657: NGP Blue Mountain, LLC ($ 65,741,725) and Beowawe Binary, LLC ($ 1,679,932) (USDOT, 2012).

22.3.3 Progress Towards National Targets

Geothermal energy played a role in President Barack Obama's goal to double renewable energy under his administration. Between his inauguration in January 2009 and 31 December 2011, geothermal installed capacity grew by approximately 210.7 MW (Figure 22.2).

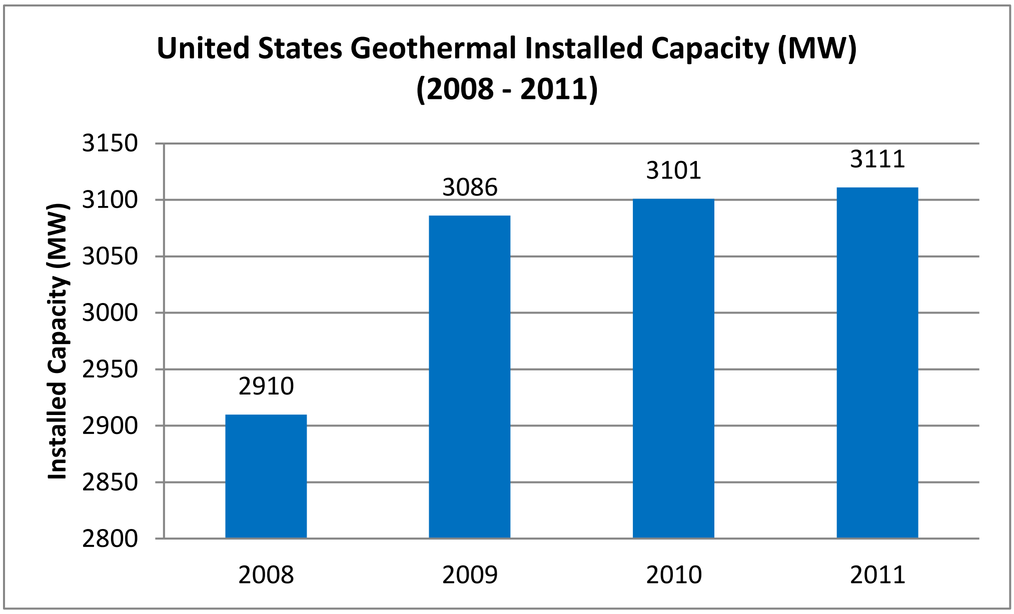


Figure 22.2 *United States geothermal energy installed nameplate capacity between 2008 and 2011.*
(Source: GEA)

22.3.4 Government Support/Incentives for R&D

For the purpose of clean energy development and job creation, the America Recovery and Reinvestment Act directed $ 16.8 billion to DOE's Office of Energy Efficiency and Renewable Energy (EERE), of which almost $ 400 M was awarded to geothermal energy. For 2011, RD&D initiatives continued to draw upon ARRA grants or GTP's $ 38 million operating budget. For 2011, GTP's projected ARRA payment was $ 89,941,767 (Figure 22.3).

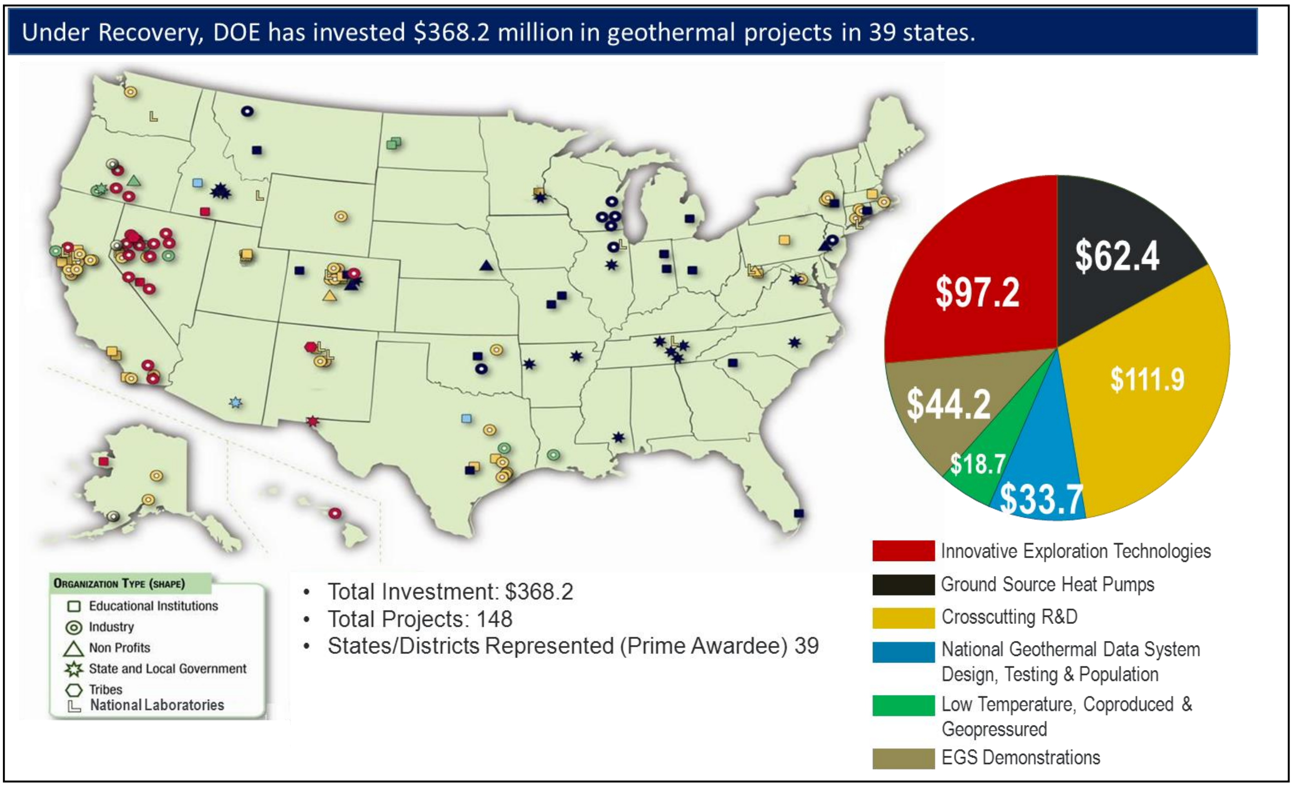


Figure 22.3 GTP's ARRA investment of $ 368.2 M in 39 states.

22.4 Market Development, Stimulation and Constraints

Geothermal development continues to be affected by high upfront costs and exploration risks that pose a challenge to project financing. Since many geothermal companies operate with limited financial resources, government support might be necessary to accelerate the growth of the industry in the near- to mid-term. Developing tools and techniques to discover additional resources remains key to uncovering "blind" hydrothermal resources. Permitting also continues to affect market development given the time and costs associated with environmental oversight agencies and competing land interests.

While EGS has an enormous resource potential, there are challenges associated with reservoir engineering, permeability enhancement, and sustainability. An understanding of the key mechanisms controlling the development of EGS reservoirs is critical before widespread commercialization can take place. Despite the advantages of EGS as a baseload renewable energy source, environmental concerns exist and must be addressed to reduce public concern and to ensure that developers operate safely and sustainably.

For EGS, water availability and the potential for contamination are primary issues of public concern. Since water is required to "stimulate" reservoirs and re-open existing fractures, the location of the project may serve as an impediment in areas where water is scarce. However, strategies for reducing fresh water consumption are in place in existing geothermal fields such as The Geysers. Increased hydraulic fracturing for shale gas has created public concern with regard to groundwater/aquifer contamination, although significant differences exist between the technologies.

The perception of induced seismicity as a hazard requires public engagement in order to better explain the nature of seismicity, listen to concerns, and promote safety. Developers must evaluate risk by assessing the history and potential for seismicity in the local area based on their injection plan and the proximity to active faults. In order to assure all stakeholders that EGS development will be engineered to minimize induced seismicity risks and to ensure that resources are developed in a safe manner, the DOE initiated a protocol in 2004 with the international community to address technical and public acceptance issues surrounding EGS induced seismicity. As a result, an International Energy Agency- Geothermal Implementing Agreement (IEA-GIA) protocol for Induced Seismicity was published in 2009 and recently updated by the United States in 2011 (http://esd.lbl.gov/files/research/projects/induced_seismicity/egs/EGS-IS-Protocol-Final-Draft-20110531.pdf).

22.5 Industry Status

According to a 2010 GEA report, direct employment in the geothermal industry was approximately 5,200 full-time jobs, which increased to 13,100 when adding indirect and induced impacts of the industry (GEA, 2010). The report also identified 39 different states that supply goods and services associated with geothermal resource development.

According to the Bloomberg New Energy Finance database, in 2011 capital expenditure for geothermal was $ 554,150,000, which is a value that might be higher if not all projects were accounted for (Bloomberg, 2012).

22.6 RD&D Activities

GTP divided its RD&D activities into the following subprograms:

- Hydrothermal & Resource Confirmation- Included funding for 24 projects of innovative exploration technologies, 15 demonstrations of low temperature, and various geophysical and geochemical exploration tools.
- Enhanced Geothermal Systems- Included funding for 7 demonstration projects, as well as various projects for high temperature tools, reservoir modelling, stimulation methods, and zonal isolation. A description of EGS demonstration projects is included in Table 22.1.
- Systems Analysis- Included resource assessment and classification, National Geothermal Data System, techno-economic analysis, workforce development, international collaborations, and communications and outreach.

22.7 Geothermal Education

22.7.1 Geothermal Energy Association

Geothermal Energy Association (GEA) is the 501(c)6 non-profit trade association for the United States geothermal industry. Located in Washington, DC, GEA engages in advocating public policies that promote development and utilization of geothermal resources, providing a forum for the industry, encouraging research and development, presenting industry views to governmental organizations, providing assistance for the export of geothermal goods and services, compiling statistical data about the industry, and conducting education and outreach projects.

22.7.2 Geothermal Resource Council

Geothermal Resources Council (GRC) is a non-profit organization with members in more than 40 countries. As an international platform, GRC focuses on the professional development of its members through outreach, information sharing, and education. Annual meetings attract industry leaders and stakeholders from around the world.

Table 22.1 *Description of DOE Geothermal Technology EGS projects.*

	DOE Geothermal Technologies Program EGS RD&D Projects		
Recipient	**Project Site**	**Site Information**	**2011 Update**
Ormat Technologies, Inc.	Desert Peak, NV	Adjacent to existing hydrothermal sites	Completed a 4 stage stimulation
Geysers Power Company, LLC	The Geysers, CA	Two existing well will be reopened and deepened for injection and stimulation	Developer intends to begin stimulating in the near future
University of Utah	Raft River, ID	Improve the performance of the existing geothermal field	NEPA approval granted July 7 for well rework, stimulation, and monitoring
Ormat Technologies, Inc.	Brady Hot Springs, NV	Improve the performance of the existing geothermal field	Developing a structural model to develop a stimulation plan
AltaRock Energy, Inc	Newberry Volcano, OR	High potential in an area without existing geothermal development	Submitted Environmental Assessment package to BLM
TGP Development Co.	New York Canyon, NV	Adjacent to hydrothermal sites with high temperatures at shallow depths	Drilling continues in Coyote Canyon
NakNek Electric Association	Naknek, AK	Located in remote location in AK without existing geothermal development	Evaluating the condition of well in order to determine a path

22.7.3 National Geothermal Academy

In 2010, GTP announced the creation of an annual, 8-week intensive summer course for undergraduate and graduate students. The course, hosted by the University of Nevada, Reno, covers all aspects of geothermal energy. DOE provided merit-based financial assistance for up to 20 students from across the nation. The course is a collaborative effort among faculty from various institutions such as the University of Nevada, Stanford University, Cornell University, Oregon Institute of Technology, University of Utah, Southern Methodist University, University of Massachusetts, Dartmouth, and West Virginia University.

22.8 Future Outlook

Geothermal energy is expected to increase substantially in the near- to mid-term with an estimated total planned capacity between 1,622 and 1,673 MW across fifteen states (Figure 22.4).

In the long-term, success of the geothermal industry will rely on the ability to achieve significant cost reductions and thus compete with more conventional forms of electricity. To this end, the DOE Geothermal Technologies Program aims to reduce geothermal levelized cost of electricity (LCOE) for newly developed hydrothermal facilities to 6 cents/kWh by 2020 and for EGS facilities to 6 cents/kWh by 2030. Successful demonstration and cost-competitive deployment will help to ensure that geothermal electricity makes a significant contribution to the United States renewable energy portfolio.

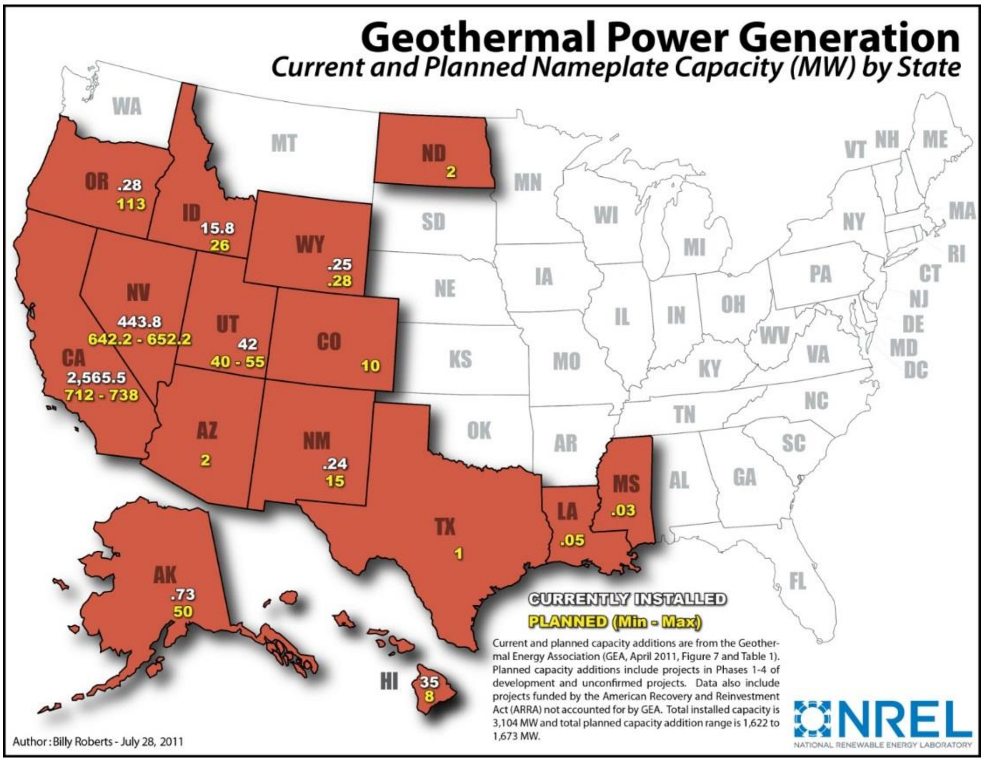


Figure 22.4 Current and planned geothermal energy capacity.
(Source: GEA and NREL)

22.9 References

Bloomberg (2012) Bloomberg New Energy Finance Database, 2012. Accessed:. 29 Jul. 2012, http://www.bnef.com/bnef/.

GEA (2012) Annual U.S. Geothermal Power Production and Development Report 2012. Geothermal Energy Association. Accessed: 8 Nov. 2012, http://geo-energy.org/reports/2012AnnualUSGeothermalPowerProductionandDevelopmentReport_Final.pdf.

GEA (2010) Green Jobs Through Geothermal Energy. Geothermal Energy Association. Accessed: 8 Nov. 2012 http://geo-energy.org/pdf/reports/GreenJobs_Through_Geothermal_Energy_Final_Oct2010.pdf

Lund, J.W., Gawell, K., Boyd, T.L., Jennejohn, D. (2010) The United States of America Country Update 2010. *Proceedings World Geothermal Congress*. 2010, Bali, Indonesia, 25-29.

USBLM (2011a) *Geothermal Energy*. United States Bureau of Land Management 2011. Accessed: 7 November 2012. http://www.blm.gov/wo/st/en/prog/energy/geothermal.html.

USBLM (2011b) New Oil, Gas and Geothermal Activities on Federal Lands, Fiscal Year 2011. United States Bureau of Land Management. Accessed: 10 August 2012, http://www.blm.gov/public_land_statistics/pls11/pls3-16_11.pdf.

USDOT (2012) *Recovery Act.* United States Department of Treasury. Accessed: 7 Nov. 2012, http://www.treasury.gov/initiatives/recovery/Pages/1603.aspx.

USEIA (2012) Electric Power Monthly, February 2012. United States Energy Information Administration. Accessed: 29 July 2012, http://www.eia.gov/electricity/monthly/current_year/february2012.pdf.

USGS (2008) Assessment of Moderate- and High-Temperature Geothermal Resources of the United States 2008. United States Geological Survey. Accessed: 8 Nov. 2012, http://pubs.usgs.gov/fs/2008/3082/pdf/fs2008-3082.pdf.

22.10 Authors and Contacts

Steven CJ Hanson
SRA International
For:
U.S. Department of Energy
Geothermal Technologies Program, EE-2C
1000 Independence Ave, SW
Washington DC, 20585
UNITED STATES
E-mail: steven.hanson@ee.doe.gov

Jay Nathwani
U.S. Department of Energy
Geothermal Technologies Program, EE-2C
1000 Independence Ave, SW
Washington DC, 20585
UNITED STATES
E-mail: jay.nathwani@ee.doe.gov

Sponsor Activities

Chapter 23

Canadian Geothermal Energy Association

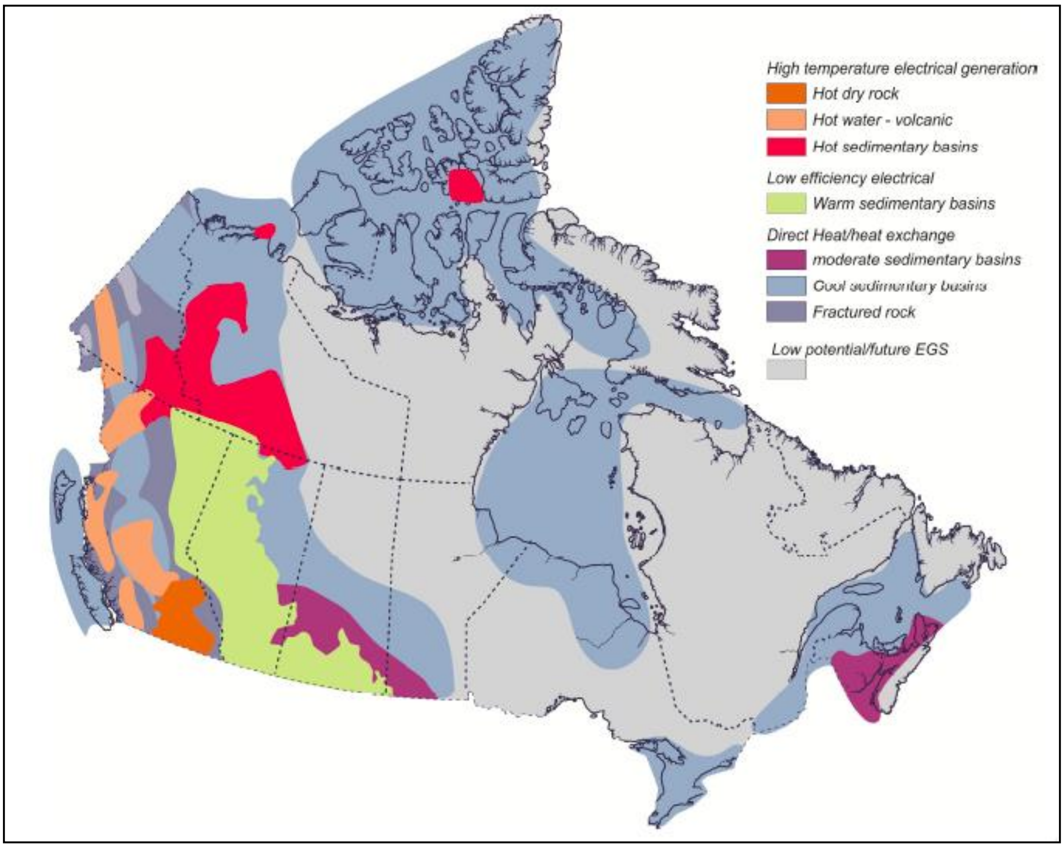


Figure 23.1 *Map illustrating the geothermal energy development potential for Canada. (Courtesy: the Geological Survey of Canada)*

23.0 Introduction

Canada's conventional geothermal energy potential has routinely been estimated at more than 5,000 MWe geothermal. Enhanced geothermal systems (EGS) multiply this estimate by several times and place geothermal energy in close proximity to nearly all Canadians. The Canadian Geothermal Energy Association (CanGEA) and its members believe that as much as 5,000 MW_e of conventional geothermal power could be brought online as soon as 2025.

According to a report released by the Geological Survey of Canada (GSC) in 2011, Canada has "enormous geothermal resources that could supply a renewable and clean source of power." It further states that the "high capacity factor of geothermal makes it particularly attractive" as a renewable base load energy supply.

For the most part, Canada's accessible geothermal resources are located in Western Canada. The geological conditions defined by the long mountain ranges of the Canadian Cordillera grant access to Canada's only hydrothermal resources. This region is akin to the tranche of geothermal resources located in the Western United States, Alaska, and Mexico. Other geothermal opportunities exist in the petroleum producing areas of Canada, such as the Northwest Territories, Alberta, Saskatchewan, Ontario, Newfoundland, Nova Scotia and New Brunswick where hot to moderate sedimentary aquifers may be found. The interior of Canada, on the other hand, is comprised of deep crustal granitic rocks with low geothermal gradients referred to as the Canadian Shield which make high-temperature geothermal resources harder to access.

The map below, compiled by the GSC, illustrates the potential for geothermal energy development across the country. The most favourable regions for development include Alberta, British Columbia, Saskatchewan and the Yukon and Northwest Territories – all located in the western third of Canada. In these regions the resource is both significant and relatively accessible, further exemplified by the abundant hot springs and pools visible at the surface. These regions also have gained extensive geological knowledge from a long history of mineral and oil & gas exploration activities. Information and data collected from these activities provide a foundation for geothermal exploration, even in the absence of government support for geosciences and resource mapping.

23.1 Highlights and Achievements

23.1.1 Implementation

In 2011, there was some increase in activity and significant progress only on small projects. These smaller projects, also mentioned in section 1.2., are the Ft. Liard project by Borealis GeoPower and Acho Dene Koe First Nation in the Northwest Territories, the Swan Hills project by Borealis GeoPower in Alberta and the Rafferty project by DEEP Earth Energy Production in the province of Saskatchewan.

CanGEA hosted two successful conferences in September and November 2011 that demonstrated strong international representation. These conferences included the Annual Geothermal Conference & Investment Forum in Toronto, which commenced with the opening of the TSX by CanGEA members, and the Annual Geothermal Power Forum in Calgary where many oil & gas companies were present. CanGEA also presented at the Opening Session of the GRC Annual Meeting in October 2011 and intends to host a Technology Information Session on the Canadian Geothermal Power & Direct Use of Heat Technology Roadmap and Implementation Plan in early 2012. Initial funding has been secured for the first steps of the work on the roadmap, while remaining funding is being sought with government and corporate sponsors.

Additionally, CanGEA is finalizing interviews with industry players and assessing the state of the present supply chain and preparing a sector overview with an emphasis on power, direct use and co-produced fluids market opportunities. Both of these reports will be released late 2012.

23.1.2 R & D achievements

The Canadian geothermal energy industry continued to promote investor confidence with its Canadian Geothermal Code for Public Reporting. The Code provides a minimum set of requirements for the public reporting of Exploration Results, Geothermal Resources and Geothermal Reserves. Furthermore, the Code provides a basis for transparency, consistency and confidence in the public reporting of geothermal information. CanGEA has also begun work on preparation of data sets for a national geothermal database, starting with the province of Alberta. This is based on an international protocol for assessing geothermal resource data and the Canadian Geothermal Code for Public Reporting. Partial funding from Alberta Innovates – Energy and Environment Solutions and through an industry champion has already been secured.

23.1.3 Industry successes

In spite of the continued low level of support for geothermal development in Canada, the Canadian Geothermal Energy Association (CanGEA) has maintained a wide membership consisting of approximately 45 members. These members include geothermal developers, equipment manufacturers and utilities, to firms specializing in the consulting, engineering, construction, financial, and legal aspects of geothermal energy. Canadian geothermal developers listed on the Toronto Stock Exchange (TSX) and Toronto Venture Exchange (TSX-V) currently represent about one fourth of the geothermal power generation capacity in the United States despite witnessing an "annus horribilis" in stock prices in 2011. They also contributed to substantial growth in international development.

23.1.4 Funding to industry

In 2011, the industry continued to face substantial challenges in attracting investment to push the development of geothermal power projects.

23.1.5 Funding to R & D

The year of 2011 saw very little funds invested in geothermal research and development. Some funds were provided to the GSC for their national report and mapping efforts. Most of the other funds were provided to smaller tranches of the Clean Energy Fund for geothermal pilot projects.

23.2 National Programme

23.2.1 Strategy

In 2011, there was little progress made by the Federal government in regards to geothermal policy. Funding for a Geothermal Technology Roadmap, however, is under review and if approved, could quite possibly provide a push forward for development of geothermal energy in Canada.

Geo-exchange applications have seen continuous support from the Federal government, while support for the geothermal power sector remained unrecognized. Due to Canada's rich energy resources, including vast amounts of hydroelectric, fossil fuel, and nuclear power, the impetus to explore new alternative energy sources has not been sought to the same degree as other nations seeking energy independence.

23.2.2 Legislation and Regulation

Currently only one jurisdiction (British Columbia) has legislation governing the exploration and development of geothermal resources but other provinces and territories are considering adopting similar legislation. CanGEA remains active in the consultation process to expedite the prudent development of these resources.

At the Federal level, geothermal energy development remains a lower priority in the context of other energy resources such as oil & gas, hydroelectric, wind, and solar power. Through active policy work and advocacy, CanGEA is making headway in attracting interest and progressive policy to advance the industry.

23.2.2.1 British Columbia

The Province of British Columbia is in some ways the most progressive jurisdiction in terms of policy and administration for geothermal energy development. The Province recently held a tenure permit auction in 2011, in addition to the two auctions held in 2010. However, they failed to meet their own guidelines governing the issuance of multiple tenure permits enabling geothermal exploration and development. Nonetheless, this latest auction reflects a renewed interest and ability for geothermal to meet the clean energy demands of the Province.

The Province has also been undertaking industry consultation to modernize its legislation and regulations for the geothermal industry and announced a new Clean Energy Act in 2010. The new Act was expected to provide greater Ministerial authority in advancing clean energy projects while streamlining certain processes to expedite project development. While no improvements have been made thus far, the industry is hopeful that the new Act will usher in geothermal resource exploration and development and provide the needed government support to attract further investment in the industry.

23.2.2.2 Alberta, Yukon and Northwest Territories

The remaining Western Canadian jurisdictions with strong geothermal resources are also keenly looking at ways to advance the development of their geothermal resources. In Alberta, where electricity generation is largely governed by other legislation such as oil & gas and mineral exploration and extraction, policy reform still needs to be developed and remains a goal. A provincial agency has recently put forth funding for a co-produced fluids geothermal project which would provide local financial incentives of $15 per tonne of CO_2 equivalents removed or negated in the power production market (or $9.75/MWh based on current guidelines) in place. This, in addition to Federal incentives, has drawn interest to the geothermal sector in Alberta – especially for co-produced fluids projects that are symbiotic to the oil & gas and mining industries. In the Northern Territories, there is similar interest in developing geothermal resources for electricity production and for residential and commercial heating. Many of these northern and remote communities have relied upon fossil fuel and food imports, which are both costly and environmentally damaging. Geothermal energy represents a comprehensive solution to these issues and is an ideal alternative worth consideration. The Federal government has sponsored one geothermal power pilot project and one geothermal heating project in the Northwest Territories. Additionally, Saskatchewan showed interest in the geothermal industry in early 2011 with support for a Hot Sedimentary Aquifer (HSA) project. Any of these projects, including the Alberta project, has potential to be Canada's first geothermal power plant to generate electricity from the earth's energy.

23.2.2.3 Other Canadian Provinces and Territories

Many other jurisdictions in Canada are pursuing aggressive plans to initiate and develop alternative and renewable means of energy production. Quebec and Ontario, similar to British Columbia, have each adopted progressive energy policies that promote renewable electricity and heat production. Geothermal energy has largely been left out of these programs, as the geothermal resource potential is low in these regions and may require non –conventional technology development such as EGS. The opportunity, however, for co-produced fluids, geo-pressured, and direct use applications is still an option for other regions throughout Canada and is further being examined by CanGEA.

23.2.3 Progress towards National Targets

The Canadian Federal Government initiated a target of deriving 90% of Canada's power production from "non-emitting" sources by 2020 instead of the 70% current being generated today. Over 50% of Canada's total power production is derived from hydroelectric generation. It has been made clear through Canadian geothermal interests that geothermal energy could contribute materially towards this national goal. CanGEA, which represents the high-temperature geothermal industry in Canada, maintains that with proper legislation and support, 5,000 megawatts of geothermal power could be harnessed feasibly by 2025 – roughly 7% of Canada's current electricity consumption.

23.2.4 Government Support/Incentives for Research and Development

Federal support for geothermal power production has been limited to indirect research and mapping of the heat resources of Canada. Research efforts and further collection of hydrological and rock permeability data is necessary for development of geothermal power projects. While the GSC has played a major role in the collection of this data in the past, current Federal budget cuts will likely lead to the suspension of their current geothermal program.

23.3 Status of Geothermal Energy Use

23.3.1 Electricity Generation

Canada's geothermal industry is largely focussed on projects outside of Canada's borders. The TSX and TSX-V hosts geothermal developers and service companies from around the world. In 2011, there were no new listings, and all companies have seen a sharp decline in their stock price following news of project challenges and general market trends. The Canadian Geothermal Code for Public Reporting supports the industry and the investment community by bringing transparency and accountability to the industry and further supports investor confidence in the geothermal energy sector. There is currently no geothermal electricity produced in Canada and six active projects under development (Table 23.1).

Table 23.1 *Current active projects in Canada.*

Project	Developer	Province/ Territory	Status
Swan Hills	Borealis GeoPower	Alberta	Co-produced fluids project of 2MW
Canoe Reach	Borealis GeoPower	British Columbia	Feasibility phase
Lillooet	Alterra Power/ 2149749 Ontario Inc.	British Columbia	3 permits
South Meager	Ram Power	British Columbia	Suspended
Ft. Liard	Borealis GeoPower	Northwest Territories	Feasibility for 1MW pilot project
Rafferty	Deep Earth Energy Production Corp.	Saskatchewan	Feasibility

23.3.1.1 New Developments during 2011

While interest in Canada's geothermal industry has seen some increase, the only significant progress has been made on small projects in the Northwest Territories and Alberta by Borealis GeoPower, as well as in Saskatchewan by DEEP Earth Energy Production.

23.3.1.2 Number of Wells Drilled

Canada has yet to see the completion of a full-scale production/injection well system but does, however, have a number of test, slim-hole, and production wells. In addition, Canada has many active, retired, and abandoned oil & gas wells that are currently being evaluated for co-produced fluids and/or direct use applications. At the Meager Creek complex, some of the eight wells that were drilled may be productive and suitable as injection wells. The status of these wells, however, remains commercially unproven and inactive in any material capacity. Canada's oil & gas and mineral extraction industries have also left behind a legacy of wells that can provide accurate estimates of temperature gradients, subsurface formations and compositions that can now be employed for geothermal energy development. The Rafferty project of DEEP Earth Energy Production in Saskatchewan also looks at utilizing old oil & gas wells for development of a geothermal project in the province.

23.3.1.3 Contribution to National Demand

It is estimated that Canada has a near-term potential of 5,000 MW_e of conventional geothermal resources (hydrothermal and HSA). With EGS technology, the potential may be two to three times greater. Unfortunately, geothermal power did not contribute to the national energy supply in 2011 and power production remains at nil.

Figure 23.2 *Drilling at Meager Creek, British Columbia.*

23.3.2 Direct Use

There continues to be no current data available on direct use geothermal resources in Canada. CanGEA continues to encourage the GSC to undertake this study.

In recent years, Canada has steadily embraced heat pump technology. It is estimated that up to 50,000 residential and 5,000 commercial systems are currently installed (Thompson, 2010). The cost of installing these units, especially in building retrofits, is often prohibitive for the average consumer; however, federal and local subsidies have encouraged the adoption of such systems. The growth rate is estimated at 13% per year, with recent rates being as high as 50%. More information can be found with the Canadian GeoExchange Coalition (CGC), a non-profit industry association representing this technology (www.geo-exchange.ca).

Heat pump technology has also been used in abandoned mines, starting as early as 1989 at the Springhill Mine of Nova Scotia. Geothermal fluids from the abandoned mines used for heating and cooling of several commercial and residential building in Springhill provided an estimated cost savings of C$45,000/yr. The City of Yellowknife in the Northwest Territories commissioned a similar study in 2007, using heat pump technology to generate heat from an abandoned gold mine. The project recently received federal funding in the amount of C$10 million and would provide an estimated savings of C$13 million/yr. Apart from the abandoned mine projects, there are twelve hot springs currently developed in Western Canada with a total installed capacity of 10-15 MWth, plus a number of naturally occurring hot springs that are being used for recreational purposes (Lund et al., 2005).

With no available data on the various uses of direct use geothermal in Canada, we estimate a total of 1,100 MWt and 8,487 TJ/yr using the following: a COP in the heating mode of 3.5 for heat pumps, 3,000 full load heating hours per year, an average residential size of 12 kW, and commercial size of 100 kW. An estimate of 11 MWt and 26 TJ/yr is generated from mining waters (Jessop, 1995) and 15 MWt and 360 TJ/yr for the twelve developed hot springs. This gives us a total of 1,126 MWt and 8,873 TJ/yr.

There are two additional projects being proposed in the Northwest Territories, see below.

Table 23.2 *Proposed projects for the Northwest Territories, Canada.*

Project	Developer	Province/ Territory	Status
Ft. Liard	Acho Dene Koe First Nation, Borealis GeoPower	Northwest Territories	Feasibility stage
Con Mine	City of Yellowknife	Northwest Territories	unknown

23.4 Market Development, Stimulation and Constraints

23.4.1 Development Constraints

Currently, there are a number of constraints to the development of Canada's geothermal energy resources. Perhaps most notable is the lack of education and awareness for the geothermal power sector, which remains somewhat of a foreign concept to both Canadian citizens and politicians. Unlike other nations who have embraced geothermal energy for decades, the industry is still new to Canadians and holds a lower priority in the context of rich fossil fuel and hydro resources, or other renewables such as wind, run of river and solar energy sources. Transmission and power purchase agreements will likely also be a major concern for project development and project financings. CanGEA is working to pave the way for progressive policies in transmission access and clean power calls to enable the development of geothermal resources.

23.4.2 Support Initiatives and Market Stimulation Incentives

Presently, financial incentives exist in Canada for the installation of low-temperature heat pump systems in homes and businesses, however there have been no measures aimed at stimulating growth in high-temperature geothermal power projects.

In an effort to improve the efficiency of heating older buildings, a homeowner or small business may qualify to have up to 25% of the cost of a heat pump system reimbursed by the Federal Government, to a maximum of C$50,000. Several Canadian financial institutions also offer favourable loan programs to finance the installation of heat pump systems, in consideration of the amount of time required to recuperate the initial investment cost.

Several federal and provincial government programs have been conducted in recent years to subsidize the production of electricity from renewable sources. Qualified producers of wind power for example, were eligible to receive a $10/MWh direct subsidy from the Federal Government, which granted C$254 million between 2002 and 2007. As of 2011, geothermal power had not been recognized in any of these subsidy programs, making the establishment of equal subsidy for geothermal power a priority initiative in the Canadian geothermal community. To date, the wind, run of river and solar industries have received in excess of $1.3B in government funding, via $10/MWh subsidies, while proportional support for geothermal energy is yet to be seen.

23.4.3 Development Cost Trends

The prices for energy continue to vary widely across Canada ranging from 7-30 cents (US$) per kilowatt-hour ($70-$300/MWh). The top end of this range represents isolated power grids in Northern Canada where fossil fuels are flown in for power generation and heat. In other regions such as Labrador there is an overwhelming excess of power generation, much of which is exported to other provinces and/or the United States. The average price per kilowatt-hour in Canada is roughly 11 cents (US$) per kilowatt-hour ($110/MWh). No information is available on the cost of geothermal energy.

23.5 Status of Geothermal Industry

While Canada can build upon a strong natural resources sector (mining, oil & gas), geothermal development hasn't picked up in Canada as a result of more favourable market conditions in countries like the United States, Iceland, Philippines, Indonesia, Chile, Africa and even the Caribbean. With an increasing overlap in mining and geothermal activities, there are now several Canadian companies either in early stages of geothermal activities, e.g. in countries such as Serbia, Guatemala, Chile and elsewhere, or in actual joint venture cooperation further advanced, e.g. in the United States. Most of the larger technology providers in the geothermal sector are represented in Canada through subsidiaries and any development – despite the current small size – is monitored closely. With the right incentives and political support, the market could see a sudden spur in interest at any moment.

Many of the leading geothermal energy producing countries required significant time and effort to get to where they are today. Canada has the potential to move forward and adapt much more quickly to geothermal development, given the country's strong natural resources heritage and industry infrastructure.

23.6 RD & D Activities

23.6.1 Focus areas

To date much of the research focus has been on heat resources of Canada with little attention paid to other factors such as hydrological or rock composition criteria, which may be crucial to resource development. Going forward, the geothermal industry will need to work closely with governments and focus their efforts on prominent areas of research that will benefit the industry's growth.

23.6.2 Government Funded

Canadian governments, both provincial and federal, have intermittently supported geothermal resource development for over 100 years. The first such projects supported through government initiatives date back to the late 1800s with direct use applications of hot springs along the Canadian western railroad. As the railroad progressed west, several naturally occurring hot springs were discovered and subsequently developed into world renowned tourist attractions and national parks. For much of the 20th century, the focus would remain on developing hot springs for direct use applications for recreational and therapeutic use.

In the early 1980s, as energy prices soared, governments turned their attention to finding new and renewable sources of energy. As such, the Canadian Federal Government, through the Ministry of Natural Resources and the GSC, initiated studies to explore Canada's geothermal energy potential for electricity production. Unfortunately, as energy prices returned to affordable levels, this early exploratory work was abandoned and no formal report was published. For the most part, Canada's geothermal power sector lay dormant for much of the following two decades while interest in the industry continued to grow outside of Canada's borders.

Today, governments of all levels are slowly becoming interested in examining the many benefits of adopting geothermal energy to meet increasing power and heating demands across the country. Four geothermal projects have recently received government funding for pilot demonstration projects and research initiatives.

23.6.2.1 Ft. Liard, Northwest Territories

The Ft. Liard community-based geothermal demonstration project is a collaborative effort supported by the Federal Government, the Acho Dene Koe First Nation, and Borealis GeoPower Inc. The project is the first of its kind in Canada and is funded through the Natural Resources Canada Clean Energy Fund. Using existing well data from nearby abandoned oil & gas projects, the project aims to generate both heat and power for the community and its roughly 600 residents. This project will demonstrate how a northern community can use a geothermal resource to generate electricity and heat, thereby reducing the entire community's fossil fuel demand and energy costs. A successful demonstration will provide a model for other northern and First Nations communities with available geothermal resources. Federal project funding is in the amount of $10–$20 million.

For additional information: http://www.nrcan.gc.ca/media/newcom/2010/201001a-eng.php

23.6.2.2 Yellowknife, Northwest Territories

Figure 23.3 *Yellowknife, location of a planned heating system using hot water from a deep gold mine.*

The Con Mine project continues forward on extensive preliminary studies that were conducted in 2007 to provide heat from the abandoned Con Gold Mine to the nearby city of Yellowknife. The City of Yellowknife, with support from the Federal Government is moving forward with the project and is now in the advanced stages of project engineering and planning. Using the relatively hot thermal resource of the deep mine, the city plans to install a district heating system that will greatly reduce dependence on fossil fuel imports for residential and commercial heating. The project will be instrumental in paving the way for similar projects utilizing deep ground source and aquifer thermal resources to provide heat for the surrounding community. Federal project funding is in the amount of $10–$20 million.

For additional information: http://www.nrcan.gc.ca/media/newcom/2010/201001a-eng.php

23.6.2.3 Swan Hills, Alberta

The Swan Hills project is a collaborative effort between Borealis GeoPower, Free Energy, and the Alberta government. The project goal is to research the effective utilization of geothermal energy from deep oil & gas wells in the Canadian Foothills for the production of electrical power. Relatively hot fluids being extracted from the well are sent through a heat exchanger to harness the thermal energy of the well to generate electric power. The Alberta Energy Research

Institute (AERI) has contributed $2.6 million to the project under the Clean Air and Climate Change Technology and Innovation Program. This pilot project could have major benefits for Alberta's many active and retired oil & gas wells, as well as the oil sands.

For additional information: http://www.borealisgeopower.com/expertise/details/co-production-geothermal-from-waste-water/

Figure 23.4 *Swan Hills project aims to generate electricity using deep oil & gas wells.*

23.6.2.4 Whitehorse, Yukon Territory

Yukon Energy, a crown corporation, and the City of Whitehorse have initiated a project to examine the potential for geothermal energy exploration and development for the City and Territory. Funded in part by the Yukon Cold Climate Innovation Centre and Yukon Energy, the project will look at opportunities to utilize the surrounding natural hot springs and reservoirs to provide heating and/or power for the community of Whitehorse. The project will test the use of remote sensing satellite imagery and infrared thermal sensors to find sites where geothermal resources exist. This research will help narrow the search for the best possible drill sites and most economically feasible projects which could result in major cost savings for the City and the Territory in the future.

For more information: http://www.yukonenergy.ca/news/releases/archive/77/

23.6.3 Industry Funded

The balance of funds for the Swan Hills and Fort Liard projects are provided by Borealis GeoPower. The Rafferty project is funded by DEEP. The Canoe Reach project is funded by Borealis GeoPower.

While progress is being made internationally by Canadian geothermal players, Canada has yet to see this progress being made at home. With many developments occurring in the United States and South America, the expenditure – in part supported by the U.S. Department of Energy's Geothermal Technologies Program – is done outside of Canada, but could easily be applied to the Canadian context. While some oil & gas players have taken steps towards some R&D efforts in the geothermal industry, these efforts are for the most part, marginal. On behalf of its members, CanGEA worked on several industry reports in 2011 which may be downloaded from their website (www.cangea.ca) in early 2012. These reports include the Canadian Geothermal Project Overview 2012 and Unlocking Canada's geothermal potential: CanGEA 2012-2014 Funding Drive. These reports identify the current status of geothermal energy and direct heat developments in Canada, as well as the various R&D projects being initiated by CanGEA and its members.

23.7 Geothermal Education

The geothermal specific R&D, education and training segment in Canada is rather fragmented and underdeveloped compared to other countries in the geothermal energy market. Of the 24 major universities in Canada most, if not all of them, have undergraduate and graduate programs that could support geothermal education in one or more departments. These universities may provide an application of geothermal energy in their curriculum or strengthen geothermal R&D in Canada. Currently, however, most of the geothermal expertise is concentrated within a small number of research and academic groups. They include the following:

- The Pacific Center for Geothermal Education and Research (University of British Columbia)- http://geothermal.mining.ubc.ca
- Physical Volcanology Group (Simon Fraser University)- http://www.sfu.ca/volcanology/index.html
- The Centre for Environmental Research in Minerals, Metals, and Materials (University of British Columbia)- http://www.mining.ubc.ca/cerm3/index.html
- Helmholtz Alberta Initiative (the Helmholtz Association of German Research Centres (Germany) and the University of Alberta)- http://www.helmholtzalberta.ca
- Campus Alberta Innovation Program (University of Alberta and Government of Alberta)- http://www.campusalbertainnovatesprogram.ca
- Earth Mine Energy Research Group (Qatar, McGill and Laval Universities)

There were also recent efforts to establish a group representing the geothermal research community in Canada which led to the establishment of the Canadian Geothermal Research Council (CanGRC) in the summer of 2011, supported by CanGEA. Please visit their website for more information: www.cangrc.ca

Although geothermal expertise is concentrated within a small number of research and academic groups, Canada's leadership in geosciences and proven record of subsurface geological exploration could tie into geothermal energy resource development. Knowledge transfer from strong academic, private and public research centres and bodies for natural resources, as well as mining and oil & gas topics in Canada can help increase the level of geothermal expertise in Canada.

Some organizations and entities currently emerging into the geothermal supply chain include the following:

- CanmetENERGY (Natural Resources Canada)- http://canmetenergy.nrcan.gc.ca/home
- Alberta Innovates (Government of Alberta)- http://www.albertatechfutures.ca/Home.aspx
- Geoscience BC (not-for-profit organization)- http://www.geosciencebc.com
- Petroleum Technology Research Centre- not-for-profit organization- http://www.ptrc.ca/index.php

23.8 International Cooperative Activities

The Canadian geothermal industry was active in a number of international conferences and summits in 2011 and also hosted the Fourth Annual Geothermal Conference in Toronto in September 2011. CanGEA further hosted its national Geothermal Power Forum in Calgary in November 2011. Going forward, the Canadian geothermal industry will continue to leverage the experience and developments of more progressive nations to help foster the development of Canada's domestic geothermal resources.

CanGEA also increased its efforts to cooperate with other industry associations representing the geothermal energy industry, e.g. in the United States, Chile, Australia, the EU and other countries. This led to the creation of the International Geothermal Business Coalition in early 2011. Canada's geothermal industry works in close partnership with the International Energy Agency (IEA) and the International Geothermal Association (IGA). Furthermore, the Geothermal Reporting Code saw the Canadian and Australian industries work closely together. For more information on please visit: http://www.cangea.ca/ccpr/).

23.9 Future Outlook

With the continued lack of material interest by the Federal Government and the lack of funding, current development will continue but may lack the right incentives for larger scale geothermal projects. Pilot projects currently in development, however, could change the prospects for geothermal in Canada dramatically in the future. With the current interest from Canadian oil & gas players and geothermal development outside of Canada, development in Canada would have a solid service industry to rely upon.

The industry does not expect to reach its first milestone of bringing geothermal power to the country in 2012. However, in the near future at least one, if not two, small-scale power and combined heat power plants could come online. Development in Canada will also be dependent on the interest of the financial market. While the TSX and TSX-V have been receptive to geothermal developers raising money, 2011 saw a drop in share price between 57% and 90% for the four listed geothermal players. As well, one of the listed players, Magma Energy, acquired a renewable energy company and became Alterra Power. Alterra Power has a geothermal component that is not considered a pure play geothermal company.

While Canadian players continue to develop internationally, there is hope that there will be enough interest in utilizing the know-how and expertise in Canada to develop locally in the near future. In it anticipated that 2012 will see more progress than the current year, as several geothermal pilot projects are developed. It is further anticipated that in the near future, we will see an important milestone for geothermal development in Canada with the potential for the first geothermal power plant to come online.

23.10 References and Websites

Geological Survey of Canada (Natural Resources Canada): http://www.nrcan.gc.ca/earth-sciences/home

Canadian Geothermal Research Council (CanGRC): http://www.cangrc.ca/

Canadian Geo-Exchange Coalition (CGC): http://www.geo-exchange.ca/en/

23.11 Author and Contact

Canadian Geothermal Energy Association (CanGEA)
P.O. Box 1462, Station M
Calgary, Alberta
CANADA
T2P 2L6
E-mail: info@cangea.ca

Sponsor Activities

Chapter 24

Geodynamics

Figure 24.1 *Clean-up flow from Habanero 4; flowrate 36 kg/s at a wellhead temperature about 200 °C and climbing.*
(Photo courtesy of Geodynamics Limited)

24.0 Introduction

Geodynamics Limited is a public company limited by shares, incorporated and domiciled in Australia. It listed on the Australian Securities Exchange on September 2002. Geodynamics has a specific focus on the economic extraction of heat from hot rocks using enhanced geothermal systems (EGS) technology. Geodynamics' vision is to become a world-leading Australian geothermal energy company, supplying competitive zero-carbon energy and base-load power.

Geodynamics is Australia's most advanced geothermal energy developer. While the Company holds geothermal exploration licences in South Australia, New South Wales, Northern Territory and Queensland, the majority of efforts are currently focused on extracting heat from its geothermal tenements near Innamincka in South Australia, where high-heat-production granite buried 3.6-4 km beneath the Cooper and Eromanga Basins approaches temperatures of 280 °C at 5 km depth.

24.1 Highlights for 2011

The company spent the 2011 year planning for the drilling of a replacement well for well Habanero 3. Habanero 3 suffered a catastrophic failure in April 2009 when the three casing strings fractured in the top 6m of the well. Habanero 4 was designed to mitigate two possible causes of casing failure, (1) hydrogen embrittlement from the native granite formation water, with failure related to corrosion at low temperatures, and (2) caustic cracking from alkaline fluids likely to be present in the top of the inner annulus remaining after a less-than-perfect cement job with failure related to corrosion at high temperatures.

The drilling of Habanero 4 is scheduled to commence in early 2012.

24.2 Status of Geodynamics' Geothermal Activities in 2011

The company concentrated on the design of Habanero 4 with a reduced aim of only drilling to the existing stimulated reservoir located at a depth of 4,100-4,200m. This would allow the commencement of operations of the 1 megawatt power station originally built to operate from Habanero 3. Any deeper exploration below the current reservoir would need to await the results of the first phase of Habanero 4 drilling, stimulation and flow testing.

24.3 Planned Activities for 2012 and Beyond

Habanero 4 is to be drilled to the existing stimulated reservoir located at 4,100 to 4,200 m depth. The well will be connected by a high pressure pipeline of length 835 m to Habanero 1 via heat exchangers located next to the 1 megawatt power station adjacent to Habanero 1. After stimulation and flow testing Habanero 4 the power station will be commissioned and operated for a period of time yet to be determined. The aim is to observe any changes in the condition of the reservoir and any possible scaling and corrosion in the surface facilities.

Any up-scaling of operations, including drilling Habanero 4 to deeper levels, replacing or working over Habanero 1 to improve injectivity, or drilling additional wells into the reservoir, will depend on outcomes of the current program.

24.4 Comments on the Geothermal Market Opportunities and Constraints

24.4.1 Marketing Initiatives and Market Stimulation Incentives

Public and institutional support for geothermal projects in Australia is currently not particularly healthy. The commencement of operation of the 1 MW_e plant at Habanero after the completion of Habanero 4 could assist in this regard. The federal government is providing research and commercialisation funding of A$3.2 billion over 8 years for renewable energy projects through its new office the Australia Renewable Energy Agency (ARENA). It is expected that a considerable proportion of the funding will go to geothermal projects and research.

24.4.2 Development Cost Trends

Conventional electricity demand fell by about 3% in Australia during 2011 and this is continuing. It has been caused by increased electricity costs resulting in consumers implementing energy efficiencies, and increased use of roof-top photovoltaics.

24.5 Company's Research Activities

Geodynamics has a Geothermal Technology Plan. The focus is on:

- Drilling multiple fractures in an overpressured environment
- Stimulation of multiple fractures
- High temperature logging tools
- Well integrity
- Decreased well costs
- Increased flow rate (enthalpy)
- Temporary diverting agents

24.6 Author and Contact

Doone Wyborn
Chief Scientific Officer
Geodynamics Limited
PO Box 2046, Milton, Queensland
AUSTRALIA 4064
E-mail: doone.wyborn@geodynamics.com.au

Sponsor Activities

Chapter 25

Geothermal Group- Spanish Renewable Energy Association

Execution works of 45 geothermal exchangers (at 126 m depth) for HVAC of the Residencia Maria Santísima de la Caridad y Consolación in Jaén, Andalucia.
(Photo courtesy of PILOSUR GEOTERMIA)

25.0 Introduction

25.0.1 General Description of Organization and its Activities

The Spanish Renewable Energy Association –APPA- is a National Association that represents more than 500 producers, businesses and other associations in the Spanish renewable energy sector. Its role is to coordinate, to represent and to defend the interests of the Sector in politics, civil society and the media, as well as to participate in the development of Spanish energy and environmental policy.

APPA is composed by nine departments, covering all the renewable technologies: Biofuels: Bioethanol and Biodiesel, Biomass and Biogas, Wind Energy, Small Wind Energy, Solar Photovoltaic, Solar Thermoelectric, Hydropower, Marine Energy and Geothermal Energy (High and Low Enthalpy).

At the beginning of 2007 APPA set up the High Enthalpy Geothermal Department, and since 2008 is setting up the Low Enthalpy Geothermal Department. The creation of both departments is a result of the interest shown by private entities in the Spanish geothermal potential. Now the High Enthalpy Geothermal Department has 6 companies as members and the Low Enthalpy Geothermal Department has 30.

25.0.2 Mission Statement and Strategic Objectives

According to APPA companies these are the strategic objectives broken down for both departments:

- Low Enthalpy Geothermal Department objectives
  - To boost and to spread low enthalpy geothermal technologies in institutions
  - To coordinate the different Spanish Autonomous Regions with the aim they have similar requirements
  - To contact with other European associations
  - To normalize the different types of implementation technologies
  - To make geothermal energy attractive to electricity companies and electricity consumers
  - To contribute in a positive way to electricity demand
- High Enthalpy Geothermal Department objectives
  - To boost and to spread high enthalpy geothermal technologies among stakeholders
  - To define and propose basic exploration lines to improve the resource knowledge
  - To define and propose specific investigation support lines and financing mechanisms to increase geothermal business attractiveness in Spain
  - To propose improvements for geothermal development legal framework
  - To work along with governments and public institutions in order to achieve Spanish Geothermal 2020 objectives

25.1 Highlights for 2011

In Spain, the most important milestone and for which the Spanish industry had worked since before 2010 and has finally materialized in 2011. It has been the consideration of geothermal energy within the Spanish Renewable Energy Plan (PER) 2011-2020. As this is the first time this renewable energy is incorporated into national energy planning and the use of its potential is taken into account to contribute to its objectives. The objectives that have been established in the new PER 2011-2020 are quite far from the true potential of the generation that has both high enthalpy geothermal energy for electricity production as low enthalpy geothermal energy for heat production have in Spain. Although the sector is valued very positive that has finally been taken into account one of the most novel renewable energies in Spain, and have proposed a number of specific measures to promote its development in the coming years.

Once achieved, the industrial sector has continued working throughout 2011 to promote the progress of geothermal energy at all levels, both institutional (national and regional) and among civil society. To do this, in 2011, at the policy level, the sector has been involved in the process of revising the RITE (Regulations on Thermal Installations in Buildings) and the development of the RITE standard publication "Designing Systems Geothermal Heat Pump". It has also been involved in developing the standard of AENOR (Spanish Association for Standardization and Certification) for the design, implementation, and monitoring of shallow geothermal installation with closed loop vertical. This is going to be the first in a series of rules that will do the same with all facilities with geothermal heat exchanger associated: closed horizontal, open, etc. In Spain there is no specific regulation for this type of shallow geothermal installations that each day they are most demanded because they are capable of generating heating, cooling and DHW (domestic hot water) for 24 hours, 365 days a year with significant energy savings from the first day of operation, so it is essential to establish a regulatory framework to ensure the proper functioning of the facilities ensuring their quality.

25.2 Status of Organization's Geothermal Activities in 2011

In 2011 the APPA Geothermal Department (Low and High Enthalpy) has worked on key aspects that will enable the development of geothermal energy in Spain in agreement with the objectives considered, especially in aspects related with the legal and economic regimes that make up the regulatory framework governing geothermal energy:

- Study into the different support frameworks (subsidy type) affecting the sector and its sub- sectors in order to achieve a correct unification and homogenization of such frameworks across all Autonomous Regions.

- Study into the viability of implementing an economic compensation system for thermal energy generation that can be sustained by that already in place for the generation of electricity.

- Provide advice to the different Administrations on the development of a regulatory framework that fits and satisfies sector needs (Regulations on Thermal Installations in Buildings - RITE, Technical Building Code - CTE, Mines Act, etc.): Proposal to include aspects that are specific to the field of shallow geothermal energy in building codes and regulations (CTE and RITE), proposal to include geothermal energy in municipal urban planning, proposal to adapt and update the current Mines Act.

- Spain does not have specific technical regulations in the field of geothermal energy. Nevertheless, the development of standardization and certification activities contributes to improving the quality of companies' operations and management thereof, their products and services and to protect the environment while progressing toward society's wellbeing. Thus, it is essential to have norms of this kind that can support the development of the technology.

  Since 2011, AENOR (Spanish Association for Standardization and Certification) together with the open participation of all entities and agents that are involved as well as interested in the work carried out by this committee is immersed in the process of preparing an UNE norm (Spanish standardization) relative to the design, implementation, and monitoring of shallow geothermal installation with closed loop vertical. It is worth pointing out that it is equally important to work along these lines to expand the efforts to other sub-sectors in the field of geothermal energy.

25.3 Review of Active Geothermal Projects and Their Status

During 2011, several deep geothermal energy projects are being developed in different points of the country, such as the Canary Islands, Madrid, Aragon or Galicia. These projects are in different development stages, some of them very mature. Sadly, as in many other fields of industry, activity has been slowed during past year, and there were no significant advances.

25.4 Planned Activities for 2012 and Beyond

The APPA Geothermal Department (Low and High Enthalpy) will continue working on the key aspects that will enable the development of geothermal energy in our country in agreement with the objectives considered.

These aspects are:

- Promoting best practices during the process of implementation of shallow geothermal systems via preparation of a Code of Best Practices (linked to a quality mark) according to the models of other European texts, that is, to adapt as closely as possible to most of the singularities currently existing in Spain.

- Developing of specific technical regulations in the field of geothermal energy.

- Implementing of support measures established in the Spanish Renewable Energy Plan (PER) 2011-2020.
- Protecting the interests of geothermal sector during the development of the forthcoming new RE Spanish regulatory framework.

Also High Enthalpy APPA Geothermal Department is participating in a 30 months EU project called GEOELEC - Develop Geothermal Electricity in Europe to have a renewable energy mix. The project, coordinated by European Geothermal Energy Council (EGEC) is part of the Intelligent Energy for Europe Programme (IEE). This program is within the Competitiveness and Innovation Programme (CIP) managed by the European Commission and the Executive Agency for Competitiveness and Innovation (EACI).

The objective of GEOELEC project is to convince decision-makers about the potential of geothermal electricity in Europe, to stimulate banks and investors in financing geothermal power installations and finally to attract key potential investors such as oil and gas companies and electrical utilities to invest in the geothermal power. The project will finish in 2013

25.5 Comments on the Geothermal Market

25.5.1 Marketing Initiatives and Market Stimulation Incentives

The new Spanish Renewable Energy Plan (PER) 2011-2020 considers a number of significant measures to boost emerging renewable technologies among which is geothermal energy. The APPA Geothermal Department (Low and High Enthalpy) miss some specific measures for geothermal energy such as reducing risk in the initial phase of drilling and a greater allocation of funds to support the initial phases of the investigation. The measures established in the Plan are:

- Support frameworks: Adaptation of the remuneration for electricity generated with renewable energy so as to allow reasonable rates of return on investment.
- Economic measures
    - Measures for financial support for projects and actions.
    - Measures for funding, including major development of the new PER 2011-2020.
    - Regulatory measures: Improve administrative procedures, modification of the CTE, adaptation of RITE to renewable technologies, establishment of a certification system qualification for installers, and inclusion of renewable heating and cooling networks in energy certification systems of buildings.
- Performances in energy infrastructure: Promote the integration of renewables in energy infrastructure. Measures to achieve greater and better integration of renewable energy in the electrical system.
- Planning, promotion, information, training and other measures: 30 essential measures for the development of the Plan.

25.5.2 Development Cost Trends

The R&D research lines of the Spanish Technology Platform Geothermal (GEOPLAT) would be a breakthrough in eliminating the barriers that are impeding the progress of the sector. Implementation of these research lines will help to increase competitiveness and reduce costs. (http://www.geoplat.org/setup/upload/modules_en_docs/content_cont_URI_1267.pdf)

25.6 Organization's Research Activities

25.6.1 Spanish Geothermal Technology Platform -GEOPLAT

Regarding to R & D, in 2011, the development of the first Strategic Research Agenda of Spanish geothermal sector was completed, drafted by members of GEOPLAT - Geothermal Spanish Technology Platform. It sets the technological priorities of this sector for the coming years. Their achievement would be an important step in the learning curve of geothermal energy in Spain, making possible its transformation into a renewable energy increasingly competitive. The technological priorities are:

25.6.1.1 Deep geothermal systems

- Basic investigation
  - Development of a public database
  - Structural geological analysis
  - Geochemical exploration campaigns
  - Preparation and proposal of geological and thermo-structural models
  - Geophysical exploration campaigns
  - Geothermal gradient well drilling and thermal conductivity and temperature measurement campaigns
- Subsurface
  - Technology and costs of drilling methods
  - Investigating the level of knowledge of enhancement processes and focal microseism generation mechanisms
  - Development of three-dimensional numerical models
  - Development of prospecting instrumentation with passive micro-seismicity
  - Fluid reinjection studies
  - EGS demonstration projects
- Surface
  - Investigating efficiency improvements of thermodynamic power cycles.
  - Investigating improvements of cooling processes.
  - Investigating the hybridization of geothermal fluids with concentrated solar power technology.
  - Investigating desalination applications powered by geothermal resources.
  - Investigating cooling applications through absorption of heat from low temperature geothermal resources.
  - Investigating the production of cascade thermal energy.

25.6.1.2 Shallow geothermal systems

- Cost reduction of geothermal circuits
- Improvement of ground evaluation methods. Increasing well productivity

- Surface systems: Proposal of associated key strategic areas: increasing the efficiency of energy generation equipment, developing competitive low temperature emission systems, developing building retrofitting systems and standardization of geothermal systems in buildings, especially hybrid heating, cooling and domestic hot water (DHW) installations with other renewable energy sources.

  As consequence of the publishing and disseminate the technological priorities of the industry, Spanish federal government is becoming aware of the R&D necessities for the geothermal sector and the result is that 2011 is the first year in which the Spanish R&D national program INNPACTO, is awarding several geothermal projects in both deep and shallow geothermal projects.

  Projects granted are as follows:

  - GEOTHERCAN- project develop surface exploration techniques and 3D models to define potential geothermal reservoirs in Canary Islands. - INNPACTO subvention 2011= 187,000 €
  - INNSONDA- Development of new surface research technologies with drilling of deep boreholes and its application on CO2 stores prospection and medium and high enthalpy geothermal resources.- INNPACTO subvention 2011 = 323,567 €
  - GEOGLASS ENERGY - Design and development of models for calculation and sizing of geothermal exchange systems and active glazing for sustainable buildings.- INNPACTO subvention 2011=99,047 €
  - Thermal insulation board system based on geothermal energy (GEODUCTO).- INNPACTO subvention 2011=282,424 €
  - GEOCIM: Thermo active Foundation. Geothermal energy integration in building structures for its use in HVAC (Heating, Ventilating, Air Conditioning) and DHW (Domestic Hot Water) applications.- INNPACTO subvention 2011= 212,434 €

25.6.1.3 Key support areas for development: training and education

Geothermal energy is a growing sector whose development relies on the continuous preparation and education of individuals that can become qualified geothermal energy professionals. To this effect, it is worth noting here that a requirement already exists which calls for the setup and implementation of a geothermal installation professional certification by the end of 2012 (according to European Directive 2009/28/EC).

The main strategic areas to be considered during the investigation phase of a geothermal resource can be grouped into:

- Adapting professional profiles to the requirements of the geothermal sector and particularly to those of European Directive 2009/28/CE
- Incorporating geothermal energy content into University Curricula and Spanish's Technical and Vocational School (TVS) Curricula
- Promotion and diffusion of geothermal energy in pre-university and consumer environments

GEOPLAT also collaborates with the Spanish Ministry of Economy and Competitiveness (MINECO), through the Centre for Industrial Technological Development (CDTI), in the definition of the Spanish geothermal R&D priorities to be included in the coming 7th Framework Programme Work Programmes (2011, 2012), mainly in the Energy theme, but providing as well comments on other themes such as Environment.

25.7 Reference and Websites

- GEOPLAT- Spanish Geothermal Technology Platform: www.geoplat.org
- APPA, documentation pertinent to APPA Geothermal Department (Low and High Enthalpy)

25.8 Author and Contact

Geothermal Department of the Spanish Renewable Energy Association-APPA
Aguarón 23B, 1B
28023 Madrid
SPAIN
E-mail: margadegregorio@appa.es

Sponsor Activities

Chapter 26

Green Rock Energy

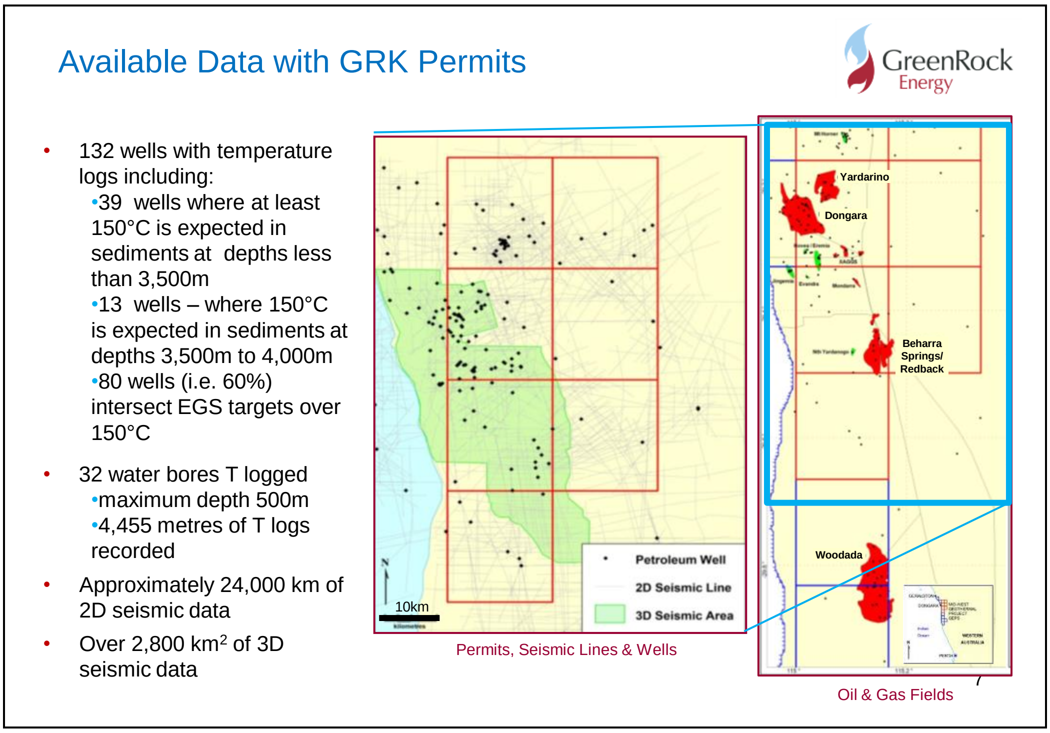


Figure 26.1 Green Rock energy permits.

26.0 Introduction

Green Rock Energy Limited is a public energy company listed on the Australian Securities Exchange with its geothermal energy focus on developing two commercial scale power projects from geothermal energy recovered from hot sedimentary aquifers. One project is in Hungary and the other in the north Perth Basin in Western Australia.

For both projects there is evidence from existing petroleum wells that suitable temperatures for commercial scale power generation can be obtained at reasonable target depths from within sedimentary formations. During the past year the Company's activities for both projects have been directed to proving there are natural permeable reservoirs with sufficient geothermal fluid flow potential to sustain commercial scale power projects. To assist in resolving these issues Green Rock Energy is participating in GIA Annexes III (Enhanced Geothermal Systems), and VII (Advanced Geothermal Drilling Techniques) and in Annex VIII (Direct Uses).

26.1 Mid-West Geothermal Power Project, North Perth Basin, Western Australia

The Perth Basin is a 1,000 kilometre long extensional rift or half graben. Green Rock holds seven geothermal Permits (known as the Mid-West Geothermal Project) occupying 2,094 km² in the north Perth Basin where data from petroleum wells shows there is good geothermal resource potential within sediments for power generation (Figure 26.1). Sediments within Green Rock's

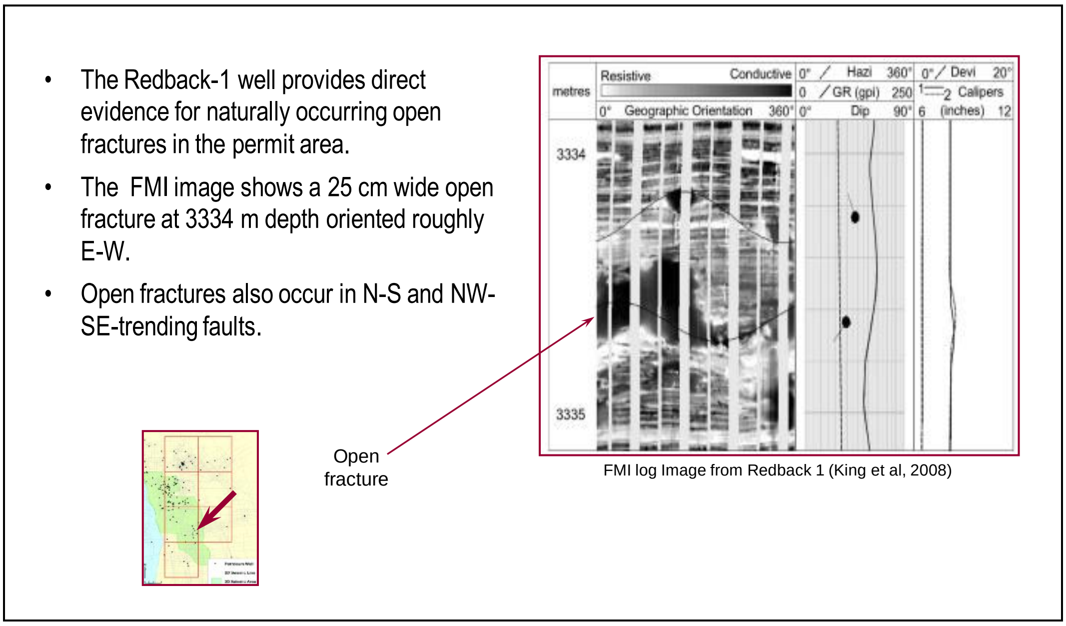


Figure 26.2 *Green Rock energy permits.*

permits are up to 6km thick. These Permits are located near producing oil and gas fields close to power infrastructure and in a region with rapid growth in power demand. The Mid West region has the fastest growing power demand in the State. Development of magnetite iron ore mining and processing will require several hundreds of MW_e and potentially over 1 GW of base-load electricity supply in the next 5-10 years.

In 2011, Green Rock and leading Australian renewable energy company Pacific Hydro entered into a binding Memorandum of Understanding to work together to develop power projects based on Green Rock's Permits in the North Perth Basin. The Company also entered into a joint venture agreement with New World Energy Limited, an unlisted company with Geothermal Exploration Permits adjacent to Green Rock in the North Perth Basin with a view to cooperating to jointly develop a project in the best locality in the area.

The primary source of geological and thermal information about the sedimentary sequences in the Perth Basin comes from petroleum wells and shallower water bores. Over 250 wells have been drilled in the NPB, reaching depths up to 4,850m, resulting in the discovery of more than 13 oil and gas fields. Most of these discoveries are located in and around the Green Rock permits and as a result the area has the highest density of petroleum wells and seismic data in the Basin.

Prior to 2011 exploration for geothermal resources was directed to mapping locations within sediments having the highest heat flows as shown by existing petroleum wells and water bores. The highest known heat flows in the Perth Basin, averaging over $90mW/m^2$, have been determined from petroleum wells in the north Perth Basin in or near producing oil and gas fields in Green Rock's and New World Energy's Permits. Five of the 132 petroleum wells in Green Rock's Permits have encountered bottom-hole temperatures greater than 150°C at depths ranging from 3416m to 4065m. Temperature and heat flow modelling for an additional 95 wells drilled in the area indicate locations where temperatures of 150°C should be reached at depths less than 3500m deep.

This year the Company concentrated on locating and mapping permeable fractured reservoirs within areas of highest heat flows near existing power transmission lines. This involved processing and analysis of 3D seismic and petroleum well image and other logs and drilling data.

In addition to conventional structural mapping, a number of volume interpretation techniques have been applied to North Perth Basin 3D seismic data, allowing 3D sub-surface features to be identified, filtered, classified and extracted quickly and accurately using an automated fracture detection process. Automated fracture extraction is based on the physical measurement of spatial variation in amplitude, phase and/or frequency content of 3D seismic data, and is as such free of bias and interpretation.

In addition to the fracture detection from 3D seismic data, interpretation of image log data from wells reveals numerous fractures are present in the Green Rock Permits. FMI logs show some fractures are electrically conductive, which suggests they may be water-filled and permeable or otherwise filled with conductive minerals (Figure 26.2). At least some of the conductive fractures have associated mud losses during drilling, suggesting they are permeable.

Determining a relationship between the orientation of conductive versus resistive fractures should help determine the most favourable orientations to target for drilling. Accordingly geomechanical analyses have been undertaken to establish those fracture orientations and dips which are most likely to be reactivated and open. The most common azimuth for the fractures detected is approximately N10°W, which is essentially perpendicular to the σ_{Hmax} orientation. When fractures with this azimuth dip 20° to 50° to the east or west, geomechanical studies indicate they are most likely to be critically stressed and therefore permeable. This suggests that the reservoir risk can be significantly reduced by targeting locations where seismic data shows the existence a high density of appropriately oriented fractures. Work continues into 2012 to correlate fractures identified from 3D seismic which have geo-mechanically favorable orientations and dips with electrically conductive fractures seen in image logs and mud losses zones in detected in wells.

Green Rock's geothermal Permit areas in the north Perth Basin are currently being actively explored by petroleum companies for unconventional hydrocarbons. This work includes fracture stimulation to recover tight gas. Recent reports indicate this work has been successful. This petroleum exploration activity may present opportunities for Green Rock to co-ordinate various activities with those companies including sharing some drill rig costs.

26.3 Hungary (Joint Venture with MOL in Hungary (50% interest))

Green Rock's initial aim in Hungary is to generate electricity from geothermal energy for distribution and sale into nearby power grids. Hungary currently has commercial scale direct heat supply from geothermal energy but does not generate electricity from geothermal energy.

Green Rock participates in Hungary through the Hungarian joint venture company Central European Geothermal Energy (CEGE) which was established in 2008 with MOL, Hungary's largest company, to explore and develop geothermal energy in Hungary and surrounding countries. CEGE is owned by MOL (50%) and Green Rock (50%).

CEGE purchased a MOL petroleum well after carrying out well tests in 2010 to determine the geothermal energy potential close to existing power infrastructure. This indicated a geothermal reservoir which should be capable of supporting several MW of power generation capacity. Since then CEGE has been waiting to be awarded the concession and formal approvals to enable it to proceed with drilling a production well into the identified naturally permeable reservoir. CEGE formulated plans to carry out a magneto-telluric survey of the area to delineate the extent of fluid saturated naturally fractured reservoirs at depth.

For more information, visit http://www.greenrock.com.au

26.4 Author and Contact

Adrian Larking
Director of Operations
Green Rock Energy
6/38 Colin Street
West Perth
AUSTRALIA
E-mail: ALarking@greenrock.com.au

Sponsor Activities

Chapter 27

Ormat Technologies, Inc.

In 2011, Ormat successfully completed the 8 MW (net) expansion of the 30 MW (net) Puna Geothermal Complex in Hawaii, which is owned & operated by Ormat. (Courtesy of Ormat Technologies)

27.0 Introduction- Ormat Technologies, Inc.

Ormat Technologies (NYSE:ORA) is a leading vertically integrated company engaged in the geothermal and recovered energy power business. The company has over four decades of ORC experience and over 25 years offering proven geothermal applications.

Ormat explores, develops, designs, builds, owns and operates clean, environmentally friendly geothermal and recovered energy-based power plants. In addition, Ormat also designs, manufactures and sells power units and other power generating equipment for geothermal and recovered energy-based electricity generation for third parties.

As of December 2011, Ormat owns and operates approximately 556 MW of geothermal and recovered energy generation (REG) facilities including approximately 503 MW of geothermal and 53MW of REG in the United States. In total, Ormat has built approximately 1,500 MW of geothermal, REG and solar installations worldwide, in 24 countries. Geothermal represents over 90% of the total installation.

In the U.S, Ormat has deployed approximately 70% of the geothermal capacity installed since 2000.

Ormat has grown to a team of more than 1,200 employees worldwide, with approximately 526 in the United States.

27.1 Status of the Company's Geothermal Activities in 2011

In 2010 and 2011 Ormat added approximately 160 MW of gross geothermal capacity worldwide to its fleet and to its clients. This capacity included two power plants, located in Nevada that demonstrate Ormat's ability to develop a successful greenfield projects which are the future of geothermal energy growth in the western United States.

The same type of ORMAT ORC power technology is used for both geothermal and REG. Examples of Power plants installed in 2011 are shown below in Figures 27.1 and 27.2.

Figure 27.1 *The 17 MW (gross) IREM Geothermal Power Plant was commissioned in 2011, one of ten geothermal plants sold in Turkey in recent years. Supplier-Ormat; Owner & Operator-Maren. (Photo courtesy of Ormat Technologies)*

Figure 27.2 *The 18 MW (net) Tuscarora geothermal power plant in Nevada; Completed in 2011. (Courtesy of Ormat Technologies)*

27.2 Revenues

In 2011, Ormat achieved strong results in the both its Electricity and Product Segments. The company completed new projects, enhanced existing plants and made considerable progress in production, development and exploration activities. Additionally, during 2011 Ormat had received a record of orders, which concluded in strong revenues and strong backlog to support high revenues in this segment also in 2012.

Total revenues increased by 17 percent to $ 437.0 million from 2010 to 2011 and product revenues increased 39 percent to $ 113.2 million, up from $ 81.4 million in 2010. Electricity revenues increased by 11 percent to $ 323.8 million, up from $ 291.8 million in 2010 (Figure 27.3).

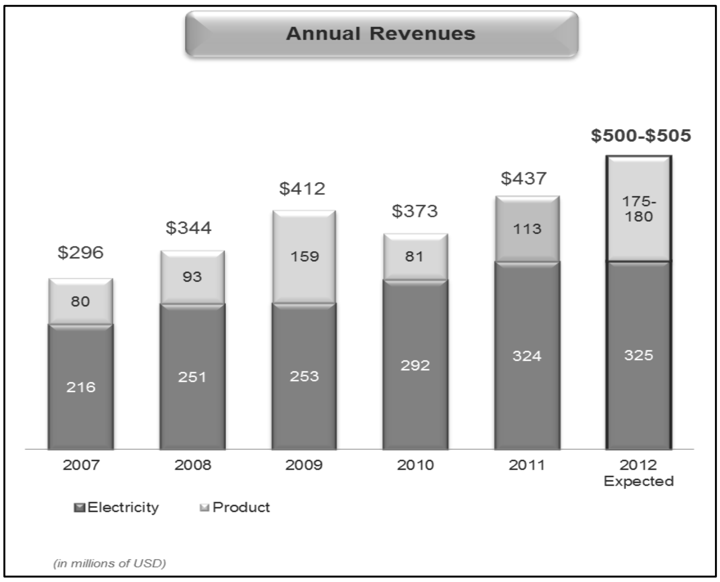


Figure 27.3 *Ormat's total revenues for 2007-2011, with estimates for 2012.*

27.3 Planned Activities for 2012 and Beyond

Ormat is well positioned for future growth and plans to continue building a geographically balanced portfolio of geothermal, recovered energy assets and remote power solutions, while maintaining its position as a leading sustainable energy manufacturer, product innovator and service provider.

As of September 2012, Ormat owns a total of 586 MW of geothermal and recovered energy generating capacity in the United States, Nicaragua, Kenya and Guatemala. By the end of 2013 Ormat is expect to bring its generating capacity to 648 MW. Additionally, Ormat has 148 MW that are currently under various stages of development.

27.3.1 Long-Term Growth Plans

Ormat is engaged in the largest effort undertaken by a single company, within the last 20 years, to categorize, map, sample and drill Greenfield prospects in the US.

Ormat has a dedicated staff of geologists, resource engineers and drilling engineers to confirm and develop new geothermal fields.

Ormat has various leases and concessions for geothermal resources of approximately 675,000 acres in 42 sites located in Alaska, California, Nevada, Hawaii, Oregon, Idaho and Utah in the United States, and in Chile, Guatemala and New Zealand.

Ormat also has an option to enter into geothermal leases covering approximately 264,000 acres of land in Oregon and Washington. Ormat started, or plans to start, exploration activity at a number of these sites that will support its future growth. We are actively pursuing additional land in these and other states where prospective geothermal resources remain untapped.

Figure 27.4 Ormat's in-house drilling company, GeoDrill, has over 100 employees and nine rigs with the capability to drill to 18,000 ft (5,500 m).
(Courtesy of Ormat Technologies)

27.4 Geothermal Market: Opportunities and Constraints

Geothermal power plants generate base-load electricity with un-paralleled reliability. This factor makes geothermal energy an invaluable contributor to the U.S. renewable energy portfolio and can reward developers and financers with lucrative PPAs and projects utilities desire.

The key to growth of the geothermal industry is successful exploration of large plots of land. Developers must achieve valid results from the exploration and development process before evaluating the geothermal reservoir size. Ormat remains committed to this process with responsible exploration and development activity performed at more than 33 sites in the U.S.

Federal and state policies have increased the risks and rewards that can be found in the renewable industry, especially in geothermal development. The American Recovery and Reinvestment Act of 2009 established valuable tax incentives along with “placed in service dates” that have made it more imperative for developers to have the technical strength and expertise in finding a resource, securing capital and getting to commercial operation on time and on budget.

An additional factor driving demand is the Renewable Portfolio Standard (RPS), renewable portfolio goals, or similar laws requiring or encouraging electric utilities to generate or buy a certain percentage of their electricity from renewable energy sources or recovered heat sources. In the United States 37 states and the District of Colombia have all adopted RPS, renewable portfolio goals, or similar laws. Twenty nine states (including California, Nevada, and Hawaii, where Ormat has been the most active in our geothermal energy development) and the District of Columbia define geothermal resources as “renewable.”

27.5 Research and Development

To date, Ormat has taken on several Research and Development (R&D) projects in various applications. Among these are EGS, innovative exploration and drilling technology, and co-production with oil wells.

These applications have been performed in multiple states, including Alaska, California, Hawaii, Nevada, Oregon and Wyoming. Ormat has worked with various institutions including universities and federal research labs. Further, Ormat is pursuing additional research opportunities through new U.S. Department of Energy (DOE) funding grants. Ormat has also sponsored and participated in technical conferences that advance R&D throughout the industry.

These activities and projects are described briefly below.

27.5.1 Enhanced Geothermal Systems (EGS)

In the field of EGS, Ormat, supported by DOE, has focused its efforts at existing operating plants at the Brady's Hot Springs and Desert Peak geothermal fields in Nevada.

27.5.1.1 Desert Peak

At Desert Peak, supported by DOE, Ormat has been working with a combination of experts from the U.S. and around the world for the past three years. The ultimate goal of the project is to increase power generation at the Desert Peak power plant by stimulating a non-productive and hydrogeologically isolated heat reservoir located more than a mile east of the developed hydrothermal system currently being utilized by the operating power plant. Through this project, the techniques successfully tested in this stimulation effort will be applied in projects throughout the globe. Ormat's U.S. partners in this project include the Geothermex, Lawrence Berkeley National Laboratory, the US Geological Survey (seismic studies), Temple University, and the University of Utah. Thus far, the project has advanced to the stimulation of fractures in an existing well within the isolated heat reservoir.

27.5.1.2 Brady

At Brady's Hot Springs, approximately four miles northwest of Desert Peak, a similar EGS project is underway. The purpose is to increase power generation at the operating Brady's power plant by stimulating a well or wells in the southwestern part of the field, along the extension of the Bradys fault south of the production area. This project is ongoing, following a similar methodology to Desert Peak, but also building from what was learned thus far at Desert Peak. Partners include Lawrence Berkeley National Laboratory, Los Alamos National Lab, the University of Nevada-Reno, and the University of Utah.

27.5.2 Innovative Exploration and Drilling

In the field of innovative exploration and technology, Ormat has advanced several of its geothermal projects through various grants.

Ormat and the DOE have collaborated on matching grants to fund exploration and drilling in Hawaii, Oregon and California. The collaboration includes: (1) acquiring, processing and interpreting high-resolution 3D seismic data that will be used for drilling activity; (2) Implementing remote sensing techniques designed to better delineate the unique geological setting, and; (3) better identify upflow zones to reduce exploration drilling risks

A $2 million grant from the State of Alaska has enabled Ormat to perform exploration and core-hole drilling at Mount Spurr, an active volcanic complex 80 miles west of Anchorage and 40 miles west of Alaska's largest generating facility (the Beluga Natural Gas plant). The grant was provided to support exploration and drilling programs during the summer of 2010 and 2011. Innovative remote sensing techniques have also been used in the exploration studies.

In the field of drilling technology, Ormat and Sandia National Lab are exploring Oil & Gas/Shale/Mining drilling technologies and operation in attempt to identify commercially available drilling technologies and drilling operation which can fit, with proper modifications, to geothermal drilling needs.

27.5.3 Co-production of Electricity at Oil and Gas Fields

Ormat, conducted a joint project with the Department of Energy (DOE) at the Rocky Mountain Oil Test Center (RMOTC), validates the feasibility of proven technology already used in Geothermal and Recovered Energy Generation (REG) for the production of commercial electricity using hot water produced during the process of oil and gas field production. This project marked the first of its kind by providing on-site fuel-free power that will increase the productivity and possibly extend the longevity of existing U.S. oil fields.

Figure 27.7 *Hot water co-produced from oil wells at the Rocky Mountain Oilfield Testing Center (RMOTC), Wyoming, U.S. (2008). (Courtesy of Ormat Technologies)*

The oil fields in the U.S. could provide an additional 200 to 5,000 MW of electricity through this technology, according to United States Senator Mike Enzi (Wyoming). The Ormat ORC unit used (Figure 21.5) is similar to the 250 kW_e air-cooled unit that has been producing electricity from 210°C geothermal water at an Austrian resort since 2001.

Additionally, there are similar units in Nevada (700 kW_e) and Thailand (300 kW_e) which have been in continuous commercial operation without overhaul since 1984 and 1989, respectively.

27.6 Corporate Responsibility

Ormat upholds a continued focus on education. From the establishment and sustained support of the primary schools in the communities surrounding our plants in Kenya and Guatemala, to extensive work with students and research initiatives in universities in the U.S.

Ormat also works at creating long-term, positive relationships with the many stakeholders who have an interest in our geothermal and recovered energy power plants. To encourage ongoing transparency, Ormat reaches out to stakeholders with an array of communications tools and initiatives which providing timely information about our operations and development plans.

Outside the U.S., Ormat also supports initiatives to improve the livelihood of the communities with support to health, community activities and local organizations. This includes ongoing activities such as access to doctors and medicine and assistance in local celebrations and special events.

Figures 27.8 (top) and 27.9 (bottom) *Primary schools Supported by Ormat in Guatemala and in Kenya. (Courtesy of Ormat Technologies)*

Figure 27.10 *Reforestation project in Amatitlan, Guatemala in 2011. (Courtesy of Ormat Technologies)*

Ormat continues to help the communities and environment surrounding Ormat's Amatitlan geothermal power plant following the 2010 Pacaya volcano eruption and Agatha storm in Guatemala near Amatitlan. Efforts were made in 2011 to create a reforestation program with the goal of planting 10,000 Cypress trees, to help restore the forested areas and minimize erosion and future landslides. Students from local schools joined with members of the Peace Corp and Ortitlan employees in the effort, which included an Ecology Drawing competition for the students to motivate and encourage their involvement.

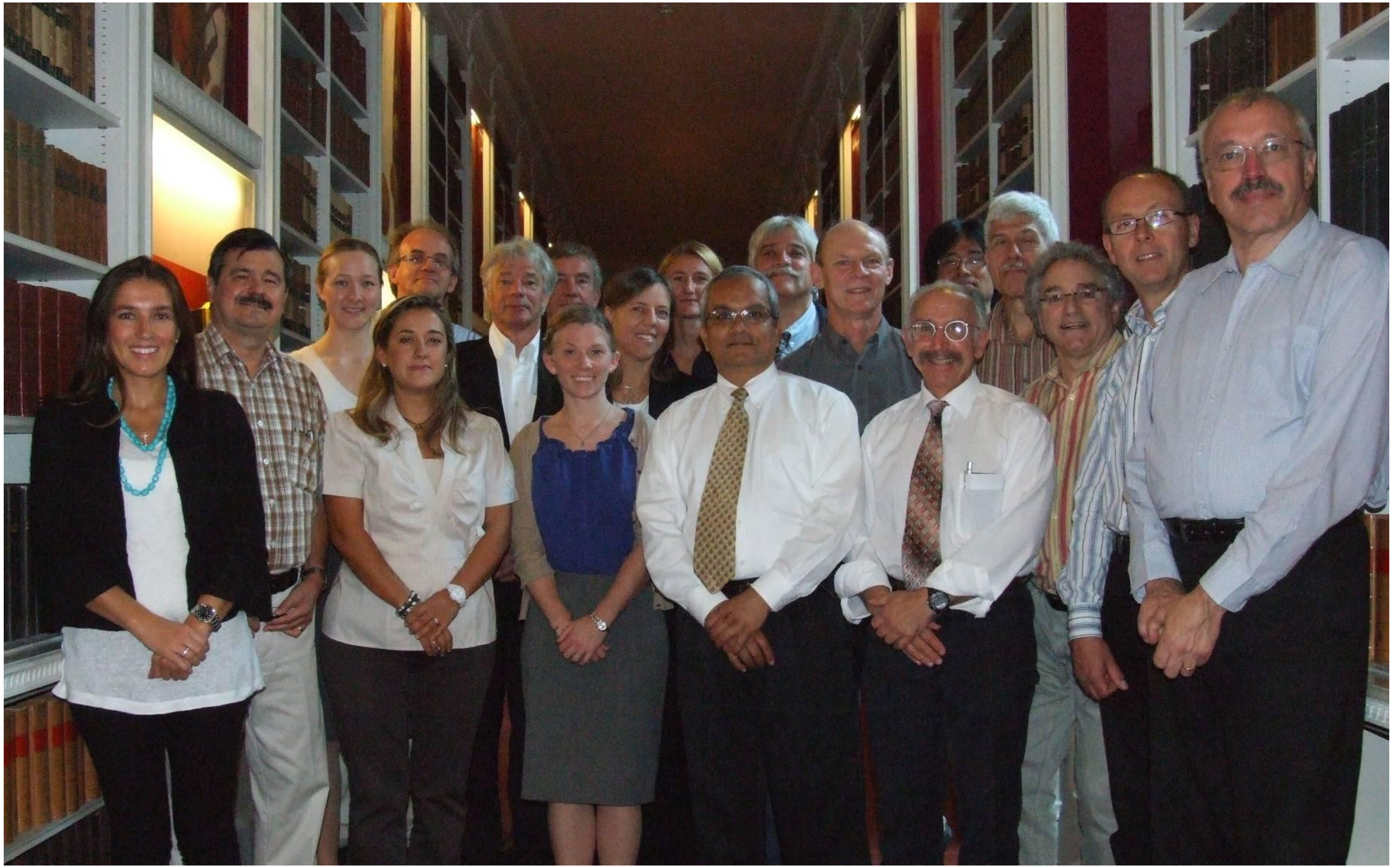
27.7 Author and Contact

Lucien Y. Bronicki
Chairman and CTO
Ormat Technologies, Inc.
Reno, Nevada 89511
UNITED STATES
E-mail: bronickily@ormat.com

Appendix A   Participants at the 25th IEA-GIA Executive Committee Meeting, Paris, France, 5-6 May 2011

(Photo courtesy of Mike Mongillo)

Appendix B Participants at the 26th IEA-GIA Executive Committee Meeting, London, UK, 29-30 September 2011



Appendix C IEA-GIA Executive Committee as of December 2011

IEA Geothermal Implementing Agreement Executive Committee

Country / Name	Delegate	Organization / address	e-mail / tel / Fax	Alternate	Address, etc. (where different)
AUSTRALIA	**Barry Goldstein** ***Vice-Chairman***	**Director** **Petroleum & Geothermal Group** **Primary Industries & Resources-SA (PIRSA)** Government of South Australia GPO 1671 Adelaide SA 5001 AUSTRALIA	barry.goldstein@sa.gov.au Tel: +61-8-8463-3200 Fax : +61-8-8463-3229	Betina Bendall	**Petroleum & Geothermal Group** **Primary Industries & Resources-SA (PIRSA)** Betina.Bendall@sa.gov.au Tel: +61-8-8463-3243 Fax: +61-8-8463-3229
CANADIAN GEOTHERMAL ENERGY ASSOCIATION (CanGEA)	**Alison Thompson**	**Executive Director** **Canadian Geothermal Energy Association (CanGEA)** P.O. Box 1462 Stn M Calgary, Alberta T2P 2L6 CANADA	Alison@cangea.ca Tel: +1-403-816-5161 Fax: +1-403-699-8139	Alexander Richter	**CanGEA** Alexander@cangea.ca
EUROPEAN UNION	**Erich Nägele**	**European Union** DG RTD K3 "New and Renewable Energy Sources" CDMA 5/173 B-1049 Brussels BELGIUM	Erich.Naegele@ec.europa.eu Tel: +32-2-296-5061 Fax: +32-2-299-4991	Sylvain de Royer-Dupré	**European Union** DG TREN New and Renewable Sources of Energy, Energy Efficiency & Innovation Rue de Mot 24, Floor 3/124 B-1049 Brussels BELGIUM Fax: +32-2-296-6261 sylvain.de-royer-dupre@ec.europa.eu
FRANCE	**Romain Vernier**	**Head** **Geothermal Energy Department** **BRGM** 3, Avenue Claude Guillemin BP 36009 45060 Orléans Cedex 02 FRANCE	r.vernier@brgm.fr Tel. +33-2-38 64 31 06 Fax +33-2-38 64 33 34	Philippe Laplaige	**ADEME** Centre de Sophia Antipolis 500 route des Lucioles 06560 Valbonne FRANCE philippe.laplaige@ademe.fr Tel: +33-4-9395-7936 Fax: +33-4-9365-3196
GEODYNAMICS Limited	**Doone Wyborn**	**Chief Scientist** **Geodynamics Limited** Level 2 23A Graham Street PO Box 2046 Milton Queensland 4064 AUSTRALIA	doone.wyborn@geodynamics.com.au Tel: +61-7-3721-7506 Fax: +61- 7-3721-7599	To be appointed	-

IEA Geothermal Implementing Agreement Executive Committee (continued)

Country / Name	Delegate	Organization / address	e-mail / tel / Fax	Alternate	Address, etc. (where different)
GEOTHERMAL GROUP- SPANISH RENEWABLE ENERGY ASSOCIATION (APPA)	**Margarita de Gregorio**	**Thermoelectric Energies Manager** **APPA – Spanish Renewable Energy Association** Aguarón, 23 B, 1ºB 28023 Madrid SPAIN	margadegregorio@appa.es Tel: +34-91-307-1761 Fax: +34-91-307-0350	Raúl Hidalgo	**Petratherm España, S.L.** Avda de Italia, nº8 1º, oficnas 4-5 37006 Salamanca SPAIN r_hidalgo@petratherm.es Tel: +34-6616-54088 Fax: +34-9230-13431
GERMANY	**Lothar Wissing**	**Forschungszentrum Jülich GmbH** Project Management Organization D-52425 Jülich GERMANY	l.wissing@fz-juelich.de Tel: +49-2461-61-48-43 Fax: +49-2461-61-28-40	Andrea Ballouk	**Forschungszentrum Jülich GmbH** a.ballouk@fz-juelich.de Tel: +49-2461-61-1596 Fax: +49-2461-61-2840
GREEN ROCK ENERGY Limited	**Adrian Larking**	**Managing Director** **Green Rock Energy Limited** 6/38 Colin Street West Perth AUSTRALIA	alarking@greenrock.com.au Tel: +61-8-9482-0482 Fax: +61-8-9482-0499	Richard Beresford	**GreenRock Energy Limited** rberesford@greenrock.com.au Tel: +61-8-9482-0405 Fax: +61-8-9482-0499
ICELAND	**Jónas Ketilsson** ***Vice Chairman***	**Orkustofnun** Grensásvegur 9 108 Reykjavik ICELAND	jonas.ketilsson@os.is Tel: +354-569-6000 Fax:	Guðni Axelsson	**Iceland GeoSurvey** Grensásvegur 9 IS-108 Reykjavik ICELAND gax@isor.is Tel: +354-528-1500 Fax: +354-528-1699
ITALY	**Paolo Romagnoli**	**ENEL Green Power** **Geothermal Production** Via Andrea Pisano 120 56100 Pisa ITALY	paolo.romagnoli@enel.com Tel: +39-050-618-5998 Fax: +39-050-618-5504	Ruggero Bertani	**ENEL Green Power** **Geothermal Production** Via Andrea Pisano 120 56100 Pisa ITALY ruggero.bertani@enel.com Tel: +39-050-618-5998 Fax: +39-050-618-5504
JAPAN	**Hirofumi Muraoka**	**Professor** **Hirosaki University** North Japan New Energy Research Center 2-1-3 Matsubara Aomori 030-0813 JAPAN	hiro@cc.hirosaki-u.ac.jp Tel: +81-17-762-7294 Fax: +81-17-735-5411	Naoki Kumazaki	**Energy and Environment Policy Department** **New Energy and Industrial Technology Development Organization (NEDO)** MUZA Kawasaki Central Tower 18F 1310 Omiya-cho, Saiwai-ku Kawasaki City Kanagawa 212-8554 JAPAN kumazakinok@nedo.go.jp Tel: ++81-44-520-5183 Fax ++81-44-520-5186

IEA Geothermal Implementing Agreement Executive Committee (continued)

Country / Name	Delegate	Organization / address	e-mail / tel / Fax	Alternate	Address, etc. (where different)
MEXICO	**David Nieva**	**Manager of Technology Transfer** **Instituto de Investigaciones Electricas (IIE)** Av. Reforma N˚113, Col. Palmira 62490 Temixco, Mor. MEXICO	dnieva@iie.org.mx Tel: +52-777-318-3811, ext. 7495 Fax: +52-777-318-9542	Alfonso García Gutiérrez	**IIE** aggarcia@iie.org.mx Tel: +52-777-318-3811, ext. 7306 Fax: +52-777-318-9542
NEW ZEALAND	**Chris Bromley** ***Chairman***	**GNS Science** Wairakei Research Centre Private Bag 2000 Taupo 3352 NEW ZEALAND	c.bromley@gns.cri.nz Tel: +64-7-374-8211 Fax: +64-7-374-8199	Colin Harvey	**GNS Science** c.harvey@gns.cri.nz
NORWAY	**Jiri Muller**	**Institute for Energy Technology** P.O. Box 40 NO-2027 Kjeller NORWAY	Jiri.Muller@ife.no Tel: +47-6380-6185	Stein Trygve Briskeby	**Statoil ASA, New Energy** Forusbeen 50 N-4035 Stavanger NORWAY stbri@statoil.com Mobile: +47-9711-6143
ORMAT Technologies, Inc.	**Lucien Bronicki**	**Chairman & CTO** **ORMAT Technologies, Inc.** 6225 Neil Road Reno, Nevada 89511-1136 UNITED STATES	bronickily@ormat.com Tel: +1-775-356-9029 Fax: +1-775-356-9039	Ezra Zemach	**ORMAT Technologies, Inc.** ezemach@ormat.com
REPUBLIC of KOREA	**Yoonho Song**	**Geothermal Resources Department** **Korea Institute of Geoscience & Mineral Resources (KIGAM)** 92 Gwahang-no Yuseong-gu Daejeon 305-350 KOREA	song@kigam.re.kr Tel: +82-42-868-3175 Fax: +82-42-868-3413	Tae Jong Lee	**KIGAM** megi@kigam.re.kr Tel: +82-42-868-3051 Fax: +82-42-868-3413
SPAIN	**Ángel Chamero Ferrer**	**Subdirección General de Planificación Energética** **Secretaría General de Energía** Ministerio de Industria, Turismo y Comercio Paseo de la Castellana 160 Madrid 28071 SPAIN	achamero@mityc.es Tel: +34-91-349-7426 Fax: +34-91-349-7555	D. Carmen Mª Roa Tortosa	**IDAE- Minihidraulic, Geothermal and Sea Energy Department** C/Madera 8 2802 Madrid Spain cmroa@idae.es Tel: +34-91-456-5009 Fax: +34-91-523-0414

IEA Geothermal Implementing Agreement Executive Committee (continued)

Country / Name	Delegate	Organization / address	e-mail / tel / Fax	Alternate	Address, etc. (where different)
SWITZERLAND	**Gunter Siddiqi**	**Swiss Federal Ministry of the Environment, Transport, Energy and Communications – UVEK Federal Office of Energy (BFE)** Division of Energy Economics/Energy Research CH 3003 Berne SWITZERLAND	gunter.siddiqi@bfe.admin.ch Tel: +41-31-322-5324	Rudolf Minder	**Program Manager, Geothermal Energy Research Program, Swiss Federal Office of Energy** c/o Minder Energy Consulting Ruchweid 22 CH-8917 Oberlunkhofen SWITZERLAND rudolf.minder@bluewin.ch Tel. +41 56 640 1464 Fax +41 56 640 1460
UNITED KINGDOM	**Penny Dunbabin**	**Senior Scientific Officer** **Department of Energy & Climate Change** Area 6D 3-8 Whitehall Place London SW1A 2HH United Kingdom	penny.dunbabin@decc.gsi.gov.uk Tel: +44 (0) 300 068 5575	Jonathan Busby	**British Geological Survey,** Kingsley Dunham Centre, Keyworth, Nottingham NG12 5GG. e-mail jpbu@bgs.ac.uk Tel: +44 (0)115 936 3100
UNITED STATES OF AMERICA	**Jay Nathwani**	**Geothermal Technology Manager** **Geothermal Technologies Program, EE-2C** **Office of Energy Efficiency and Renewable Energy** **US Department of Energy** 1000 Independence Ave, SW Washington, DC 20585 UNITED STATES of AMERICA	Jay.Nathwani@ee.doe.gov Tel: +1-202-586-9410 Fax: +1-202-586-7114	To be appointed	-
STAFF	**Mike Mongillo** ***IEA-GIA Secretary***	**IEA-GIA Secretariat** **GNS Science** Wairakei Research Centre Private Bag 2000 Taupo 3352 NEW ZEALAND	mongillom@reap.org.nz (home office) Tel: +64-7-378-9774 (home office) Tel: +64-7-374-8211 Fax: +64-7-374-8199	-	-