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Contents

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

Cover Photograph: *The AMIS plant for the Hg and H_2S abatement installed at the 20 MW Nuova Gabbro power plant, Italy* (Photo courtesy of Guido Cappetti, ENEL)

Message from the Chair

In recent times, the IEA-Geothermal Implementing Agreement (GIA) has been swept along in a global tide of renewed enthusiasm for accelerated deployment of renewable energy resources. This urgency is motivated by the need to reduce greenhouse gas emissions and thereby mitigate the climate change effects of global warming. Several of our Executive Committee members have been actively involved as lead authors in preparing a chapter on the deployment potential of geothermal energy in a special renewable energy report for the Inter-Governmental Panel on Climate Change (IPCC). This has helped focus our efforts, and highlighted the importance of the regular summaries of factual information that are represented in these annual reports. The information here forms the basis for so many important deployment predictions and policy and investment decisions by governments, energy research funders, and commercial developers of geothermal energy resources.

It is with great satisfaction that we can report that membership of the IEA-GIA continues to grow. This has largely been due to the tireless efforts of our retiring Vice Chairman, Ladsi Rybach, and our Executive Committee Secretary, Mike Mongillo. In 2008, ORME Jeotermal (Turkey), the Canadian Geothermal Energy Association (CanGEA), and the Geothermal Group of the Spanish Renewable Energy Association (APPA) all joined as sponsors, and Spain joined the group as a Country Member. Mike attended the IEA Networks of Expertise in Energy Technology (NEET) Workshop in Moscow to encourage Russia to join up, and Ladsi successfully invited representatives from China, Indonesia and AltaRock Energy, to attend our meetings as invited guests and as prospective participants.

The enthusiasm displayed during ExCo meetings for better collaboration amongst members, sharing of past experiences and learning from past mistakes, has been very satisfying to observe. The work of the GIA is well presented on its website (www.iea-gia.org), through its publications and presentations by participants at key conferences and workshops, and by its contributions to the IEA, which publishes information on geothermal technology from its Implementing Agreements. In 2008, this included representation at an IEA-RETD workshop in Copenhagen, contributions to the IEA Energy Technology Perspectives Report and the Renewable Energy Heating and Cooling Report, and contribution of an article to the IEA OPEN Bulletin #48 on induced seismicity.

The IEA-GIA also participated actively in the international Renewable Energy 2008 conference (RE 2008) held in Busan, Korea, in October 2008. Another highlight of our 2008 year was the International Sustainability Workshop convened by Annex I participants in Taupo, New Zealand, to coincide with the 50th anniversary of Wairakei Power Station. I n 2010, The Geysers, California, USA, will be celebrating its 50 years of generation, and Larderello (Italy) recently celebrated 100 years of production. These are all milestones that we need to convey to international energy planners as strong messages of assurance that geothermal is here for the long-term.

In these times of financial uncertainty, and fluctuating energy supply costs, we must all work together even more closely to tackle the barriers that continue to stand in the way of accelerated geothermal development. Improving the awareness of geothermal technology, its environmental benefits and its economic advantages, remains high on my list of priorities.

In conclusion, I am pleased to recommend to you this comprehensive annual report on the GIA activities for 2008. It continues an established tradition of comprehensive reporting on the current world-wide status of geothermal energy development, and its promising future. The next few years should see geothermal taking an even more prominent part, as a "hot-rock" superstar, in the global "stage-show" that is promoting renewable energy deployment. By increasing awareness of geothermal resources, and breaking down some of the investment barriers, we expect to see a renaissance in geothermal exploration, development drilling, and power-plant construction.

Chris Bromley, Chairman
IEA-GIA Executive Committee

Craters of the Moon, or Karapiti, thermal area, Wairakei Geothermal Field, New Zealand. (Photo courtesy Mike Mongillo)

Introduction

2008 was a very active and successful year for the IEA Geothermal Implementing Agreement (GIA). Of particular note was the 25% growth in membership, with Spain becoming the 12th Country Member; and ORME Jeotermal (Turkey), the Geothermal Group of the Spanish Renewable Energy Association (GG-APPA) and the Canadian Geothermal Energy Association (CanGEA) joining as Sponsor Members, bringing Sponsor membership to 6, and **total GIA membership to 19**. This broad based membership, from Europe, Asia, the Americas and Oceania, is cooperating on a multitude of R&D projects, and sharing experience and information in order to overcome technical and other challenges to advance the sustainable development of geothermal energy worldwide and thereby contribute to the mitigation of climate change.

In 2008, the 12 GIA Member Countries had a combined installed capacity of 6,575 MW_e and generated 38,373 GWh/yr, contributing about 63% of the global geothermal installed capacity and 66% of the geothermal generation. The average national geothermal installed capacity and power generation for GIA Member Countries with non-negligible contributions were 5.8% and 7.1%, respectively; with a "contribution efficiency" of 5.8 GWh/MW_e, by far the highest of all renewables.

This Summary sets the global scene in which the IEA-GIA operates. A review of the current world energy situation is provided, the considerable worldwide geothermal energy potential is discussed and the contribution that geothermal made to the global energy supply in 2008 is described. An overview of the IEA-GIA and a review of the four Annexes' activities and summaries of their accomplishments are presented. Highlights of GIA Members' 2008 activities are provided and the major achievements of the GIA as an organization are described. Finally, the GIA's plans for 2009 and beyond are outlined.

Current World Energy Situation

The global demand for energy has grown nearly every year since 1981, with the 2007 worldwide total primary energy reaching 12,029 Mtoe, or about 504 EJ_{th} (139,900 TWh_{th}); a growth of about 2.5% over 2006 (IEA, 2009a). The electricity generation amounted to 19,771 TWh (*ibid.*). However, as a consequence of the 2008 global financial and economic crisis, the IEA predicts that energy use will actually fall in 2009 (IEA, 2009b). Subsequent recovery will, though, lead to the resumption of the continuing increase in energy demand. Assuming no change in government policies, the IEA's *Reference Scenario* indicates that by 2030, the energy demand will be 40% higher than in 2007, or about 16.8 billion [10^9] toe (Btoe) (706 EJ_{th}) (*ibid.*). About 90% of the increase will result from non-OECD countries, taking their portion of the total primary energy demand to 63%. Fossil fuels will remain the dominant energy supply source, making up 77% of the increase from 2007 to 2030; demand for oil will increase by about 24%, for gas 42% and for coal 53% during this period. Though it seems that the world's fossil fuel resources will be able to meet these needs to 2030, and beyond, this path would likely lead to serious energy security and economic development problems, and catastrophic consequences for climate change.

Urgent, tough action is needed to curb the greenhouse gas (GHG) emissions growth and resulting rise in global temperatures predicted in the *Reference Scenario:* GHG concentration of 1,000 ppm and temperature increase of 6 °C relative to pre-industrial levels, by the end of the century (IEA, 2009b). The IEA has developed two alternative climate-based scenarios to stabilize GHG concentrations at 550 ppm (*550 Policy Scenario*) and 450 ppm CO_2-eq (*450 Policy Scenario*), resulting in a 50% chance of restricting global temperature increases to about 3 °C and 2 °C, respectively (*ibid.*). The CO_2 and total GHG emissions in both of these scenarios are significantly less in 2030 than in the *Reference Scenario*, *vis*. energy-related CO_2 emissions: some 33 Gt for 550 Policy Scenario and 26 Gt for the 450 Policy Scenario; and total GHG emissions: 48 Gt for the 550 Policy Scenario and 39 Gt for the 450 Policy Scenario. However, both of these scenarios require major efficiency gains; CO_2 capture and storage (CCS) deployment; a major decrease in the contribution of fossil fuels, to be replaced by nuclear and renewables; as well as considerable public and private RD&D spending. Awareness of these possible future outcomes provides a strong incentive for expanding the use of clean, renewable energy resources. Providing affordable, reliable and clean energy to meet these needs 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 (~40%), and that generated by the gradual decay of radioactive isotopes in the earth's continental crust (~60%). Together, these result in an average terrestrial heat flow rate of 44 TW_{th} (1,400 EJ/yr), nearly three times the 2007 worldwide total primary energy supply, 504 EJ_{th} (139,900 TWh_{th}) (IEA, 2009a). Though the world's geothermal heat resources are enormous and ubiquitous, their generally *hidden nature* (underground) makes it difficult to accurately determine potentials on a global basis. This uncertainty is accentuated because the technologies used to develop geothermal resources are evolving, extending capabilities and reducing costs, and thereby increasing technical and economic potentials. Therefore, there are considerable uncertainties in estimating the global geothermal resource potentials, and revisions are likely as more information and new technologies become available.

In 2005, Stefansson (2005) estimated the *most likely* worldwide total technical potential for geothermal resources located along tectonic plate boundaries and near volcanic hot spots to be about 6.5 TW_{th} (205 EJ_{th}/yr), about 40% of the 2007 worldwide total annual supply. Of this total, hydrothermal resources capable of development for electricity generation using conventional methods (T > 130 °C) made up about 240 GW_e (6.5 EJ_e/yr, or 65 EJ_{th}/yr), assuming a 10% electrical conversion efficiency. The remaining 4.4 TWh_{th} (140 EJ_{th}/yr), comprise lower temperature resources (T ≤ 130 °C) considered useful mainly for direct heat applications. Incorporating approximations for as yet hidden/unidentified resources increases these estimates by factors of 5-10 (*ibid*.). In addition, with current conversion efficiencies increasing, and now ranging up to 20% (for high temperature [> 180-200 °C] fluids), power generation potentials are increasing.

In addition to the abovementioned hydrothermal resources, there are several other potentially significant geothermal sources capable of power generation and direct heat use, including: 1) the binary generation from the utilization 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 earth's crust using enhanced geothermal systems technology (EGS); 4) the energy resources in the form of super-critical fluids inferred to exist deep (3-5 km) beneath hydrothermal systems; 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.

Of the above non-hydrothermal resources, EGS is the first to have been identified as having an extremely large theoretical potential. Recent estimates indicate that the USA has over 200,000 EJ_{th} extractable heat via EGS techniques, with approximately 100 GW_e of cost-competitive generating capacity developable by 2050, given reasonable R&D investment (MIT, 2006). Estimates of EGS potential for the Rehai and Yangbajing geothermal fields of China (Wan *et al*., 2005) and for regions across India (Chandrasekhar and Chandrasekharam, 2007) also show capacities on the order of 100 GW_e, with further assessments of 35 GW_e for Germany, 12 GW_e for 23% of Switzerland and 13 GW_e for 3 project areas of South Australia (Goldstein, pers. comm., 2008), making a total of ≥ 360 GW_e. A first-order estimate of global EGS theoretical potential of ~ 2 TW_e was obtained by assuming the EGS capacity of 100 GW_e for the US continental area applied to worldwide continental land masses. Though this estimate appears low when compared with the ≥ 360 GW_e limited-area value obtained above, Fridleifsson *et al.* (2008) have indicated that 70 GW_e of EGS could be available by 2050; and considering the challenges facing large-scale EGS deployment (Rybach, pers. comm., 2009) tends to support the lower value. Recent discussions also highlight the continued uncertainties associated with estimating geothermal potentials (Mongillo, in prep.).

Geothermal development for electricity generation and direct use has been in a high-growth phase worldwide for the past few years (Figure ES1 and ES2), and though future prospects look very positive, it is unclear what effect the global financial crisis will have.

Geothermal is a major renewable global energy resource, with a multitude of 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 usually 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, albeit at lesser efficiency.

Clearly, there is the potential for geothermal resources to make a considerable contribution towards meeting the world's current and future energy needs well into the future, while contributing to reduced future emissions and to the mitigation of climate change. The global geothermal potential is enormous; however, more detailed studies are required to produce confident estimates of its possible contribution.

Status of Global Geothermal Energy in 2008

In 2008, at least 24 countries were producing electricity from geothermal resources, with a total geothermal installed capacity exceeding 10,400 MW_e, based on 2007 data (Bertani, 2007), revised with 2008 GIA Country Member data (Figure ES1, Table ES1). This result is in good agreement with the estimate of 10,587 MW_e expected to be online by 2008/09 based on new power plant that has been commissioned or ordered since 2000 (Bertani, 2008). As stated in the 2007 GIA Annual Report, the worldwide geothermal generation has not been updated since 2005; however, using 2008 GIA data in conjunction with the 2005 information, a minimum estimate of 57,957 GWh/yr is obtained for 2008. The worldwide geothermal installed capacity and power generation figures will be updated for reporting at the World Geothermal Congress 2010. In 2008, the 12 GIA Member Countries contributed about 63% of the global installed geothermal capacity, and 66% of the total geothermal power generated.

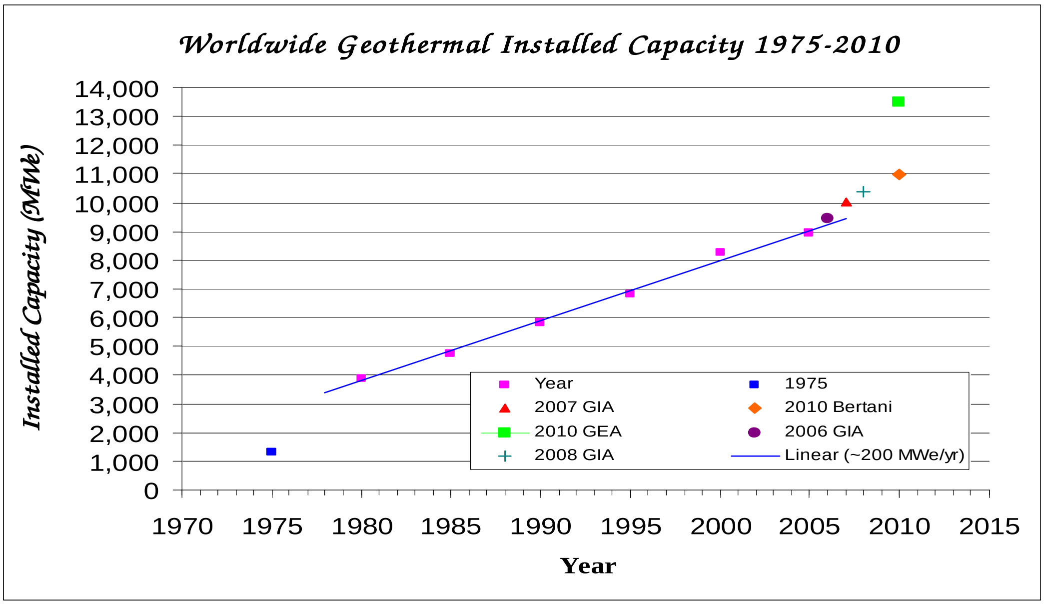

Figure ES1 Worldwide geothermal installed capacity for the period 1975-2010. The 2006 data [star] includes GIA data for 2006 and data for 16 other countries (Bertani, 2005). The 2007 [triangle] and 2008 [cross] data include 2007 and 2008 GIA data and data for 15 other countries (Bertani, 2007). The trendline was calculated using data for 1980-2005 and has a slope of 200 MW_e/yr; the 2010 estimates are from Bertani (2007) [diamond] and GEA (2007) [square].

During the period 1980-2005, the worldwide geothermal installed capacity increased by a factor of about 2.3, at a very uniform rate of ~ 200 MW_e/yr (Figure ES1). However, since 2005, an increase in geothermal development has become evident, with a linear trend of about 500 MW_e/yr to 2008, or an average increase of 16.5%/yr. The capacity increase in GIA Member Countries was: 2008 (6,575 MW_e) - 2005 (5,449 MW_e) ~ 1,126 MW_e, or about 20% (6.7%/yr); including data for new GIA Member France in the 2008 total. Table ES1 presents the 2008 data for GIA Member Countries, and 2007 capacity and 2005 generation data for many of the other 15 countries (Bertani, 2007; 2005). Table ES2 illustrates the growth in installed capacity (1995-2008) and generation (1995-2008), with 2006, 2007 and 2008 representing minimum estimates.

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 Lihir and San Miguel Islands), the geothermal installed capacity now exceeds 10% of their national capacity, and six obtain 15% or more of their electricity from geothermal. The average contribution to national

Table ES1 Geothermal power installed capacity and electricity generation for GIA Member Countries in 2008, plus 2007 installed capacity data for 15 other countries (Bertani, 2007) and 2005 generation data for the 15 non-GIA countries (Bertani, 2005).

Country	Installed Capacity (2008) [MW_e]	Annual Electricity Generated (GIA- 2008) (Others- 2005) [GWh/yr]	% of National Capacity	% of National Energy
Australia*	***0.12***	***2.0***	***Negligible***	***Negligible***
Austria	1.1	3.2	Negligible	Negligible
China (Tibet)	28	95.7	30	30
Costa Rica	163	1,145	8.4	15
El Salvador	204	967	14	24
Ethiopia	7	na	1	n/a
France* ***(Guadeloupe Island)*** ***(Soultz-sous-Forêts)***	***15*** ***2.2***	***90*** ***0***[#]	***~9 (for Island¶)***	***~9 (for Island¶)***
Germany*	***6.6***	***18.0***	***Negligible***	***Negligible***
Guatemala	53	212	1.7	3
Iceland*	***575***	***4,000***	***22.3***	***24.5***
Indonesia	992	6,085	2.2	6.7
Italy*	***810.5***	***5,181***	***1.0***	***1.8***
Japan*	***535.26***	***3,064***	***0.2***	***0.3***
Kenya	129	1,088	11.2	19.2
Mexico*	***958***	***7,056***	***1.9***	***~3***
New Zealand*	***632***	***3,962***	***6.0***	***~10.5***
Nicaragua	87	270.7	11.2	9.8
Papua New Guinea (Lihir Island)	56	17	10.9	n/a
Philippines	1,970	9,419	12.7	19.1
Portugal (San Miguel Island)	23	90	25	n/a
Russia	79	85	Negligible	Negligible
Thailand	0.3	1.8	Negligible	Negligible
Turkey	38	105	Negligible	Negligible
USA*	***3,040***	***15,000***	***~0.3***	***0.36***
Total	**10,405**	**57,957**	**9.4****	**11.6****
Total GIA Countries	***6,575***	***38,373***	***5.8*****	***7.1*****

* GIA Member Country (includes Guadeloupe Island); ¶ % from Bertani (2007)

[#] not commissioned in 2008; n/a = not available

** Average values exclude negligible contributions, but include Guadeloupe, Lihir and San Miguel Islands since this is the procedure for World Geothermal Congresses.

installed capacity for GIA Member Countries with *non-negligible* installation/generation was 5.8%, with the corresponding average contribution to national generation being about 7.1%. The corresponding worldwide values were 9.4% and 11.6%, respectively (Table ES1).

The total GIA geothermal generation of 38,373 GWh/yr is equivalent to a savings of about 9.7 Mtoe (using GIA conversion (Mongillo, 2005)) and avoided CO_2 emissions of 31.4 Mt. The equivalent savings for the worldwide total generation of 57,957 GWh/yr is about 14.7 Mtoe and avoided CO_2 emissions of some 47.4 Mt (*ibid.*).

Table ES2 Worldwide installed geothermal capacity (1975-2008) and electricity generation (1995-2008). The generation changes for 2006-2008 only include changes in GIA Member Countries.

Year	1975	1980	1985	1990	1995	2000	2005	2006*	2007	2008
Geothermal Installed Generating Capacity (MW_e)	1,300	3,887	4,764	5,832	6,798	7,974	8,930	9,452	10,026¶	10,405¶
Electricity Generation (GWh/yr)	-	-	-	-	37,744	49,261	53,649	55,209	56,782#	57,957#

* The 2006 values are indicative and consist of 2006 data for 8 GIA Members with corrected USA data, and 2005 data for the other 16 countries with geothermal power (Bertani, 2005)

¶ Includes 2007/2008 updated installed capacity data for 15 countries from Bertani (2007) plus GIA 2007/2008 data

\# The 2007/2008 generation data is from 2005 (Bertani, 2005) with updated 2007/2008 GIA Country data

Table ES3 Installed capacity, electricity generation and contribution efficiency for renewable resources in OECD Countries for 2006 (data from IEA (2008c)) and Wind and GIA Members for 2008.

Resource	Installed Capacity (MW_e)	Generation (GWh)	Contribution Efficiency (GWh/MW_e)
Geothermal			
GIA Members 2008	***6,575***	***38,373****	***5.8****
OECD (2006)	5,400	38,100	7.1
Solid Biomass (2006)	22,500	115,900	5.2
Hydro (2006)	344,600	1,286,300	3.7
Wind			
(2006)	63,700	116,200	1.8
(2008)	91,770	194,000	2.1
Tide, Wave, Ocean (2006)	300	550	1.8
Solar PV (2006)	4,100	2,626	0.6

* The new installed capacity for 2008 has not been operational for the whole of 2008; hence, the generation and contribution efficiency are low.

An excellent indicator for determining the contributions that renewable energy resources make is the ratio of the amount of power they provide to the given installed capacity, here called the *contribution efficiency*. This ratio takes into account the amount of time that the renewable generator actually produces power, i.e. the *availability factor*. For geothermal, this can be divided into resource availability (usually sustained by make-up drilling) and plant availability (affected by repairs, maintenance, transmission and load-following constraints). As shown in Table ES3, the contribution efficiencies for the various renewables in the 30 OECD countries in 2007 were: 7.1 GWh/MW_e for geothermal (5.8 for GIA Member Countries in 2008), 5.2 GWh/MW_e for solid biomass, 3.7 GWh/MW_e for hydro, 2.1 GWh/MW_e for wind (data from 2008 IEA Wind Annual Report), 1.8 GWh/MW_e for tide/wave/ocean, and 0.6 GWh/MW_e for solar PV (IEA 2008b). Geothermal's very high availability factor makes it valuable for baseload generation. It should be noted that the *contribution efficiency* for the GIA Countries in 2008 is less than for 2007 because the new installed capacity was not operating for the entire year.

Significant effort is made to collect and report worldwide geothermal direct use statistics every five years for the World Geothermal Congresses (as for electricity generation), and this will next be done in 2010. Therefore, the most current data available is based upon that reported by Lund, *et al.* (2005), and updated using the GIA country data reported in the 2008 Annual Report plus other information for Europe provided by Antics and Sanner (2007).

In 2005, 72 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*, 2005). The total installed capacity at the end of 2008 was estimated to be about 36,023 MW_{th}, by incorporating 2008 GIA updates to the 2007 total of 35,570 MW_{th} (Table ES4, Figure ES2). The total thermal energy usage for 2008 was similarly estimated to be about 329,880 TJ/yr (Table ES4). In 2008, the 12 GIA Member Countries had a total installed thermal power capacity of 21,000 MW_{th} and utilized 155,170 TJ/yr (Table ES6). In 2005, an estimated 1.3 million geothermal heat pumps (GHPs) installed in 33 countries contributed over 54% (15,384 MW_{th}) of direct use installed capacity, with a usage of 87,503 TJ. Estimates for 2007 show continued significant growth in the GHP market; about 1.6 million GHP units installed globally with > 19,000 MW_{th} of capacity and > 105,000 TJ utilization (Mongillo, 2008). Lack of data precludes reasonable heat pump estimates being made for 2008.

Table ES4 *Worldwide direct use categories and their development 1995-2005 (from Lund, et al., 2005), with 2007 total and GHP updates from GIA and Antics and Sanner (2007).*

Category	Capacity (MW_{th})					Utilization (TJ/yr)				
	1995	**2000**	**2005**	**2007**	**2008**	**1995**	**2000**	**2005**	**2007**	**2008**
Geothermal heat pumps	1,854	5,275	15,384	19,010	-	14,617	23,275	87,503	105,000	-
Space heating	2,579	3,263	4,366	-	-	38,230	42,926	55,256	-	-
Greenhouse heating	1,085	1,246	1,404	-	-	15,742	17,864	20,661	-	-
Aquaculture pond heating	1,097	605	616	-	-	13,493	11,733	10,976	-	-
Agricultural drying	67	74	157	-	-	1,124	1,038	2,013	-	-
Industrial uses	544	474	484	-	-	10,120	10,220	10,868	-	-
Bathing and swimming	1,085	3,957	5,401	-	-	15,742	79,546	83,018	-	-
Cooling/snow melting	115	114	371	-	-	1,124	1,063	2,032	-	-
Others	238	137	86	-	-	2,249	3,034	1,045	-	-
Total	**8,664**	**15,145**	**28,269**	**35,570**	**36,023**	**112,441**	**190,699**	**273,372**	**329,270**	**329,880**
Total GIA Countries	**-**	**-**	**-**	***20,547***	**21,000**	**-**	**-**	**-**	***154,560***	***155,170***

Worldwide direct use installed capacity has nearly doubled every 5 years since 1995 and this high growth trend continued through 2007 (Table ES4; Figure ES2). The estimated 2007 direct energy use increased by about 20% since 2005. However, as shown in Table ES4 and Figure ES2, both installed capacity and utilization appear relatively unchanged between 2007 and 2008. The primary cause of this "apparent" halt in growth is a major downward revision in the Japanese data, with the results of a more accurate 2008 survey of hot spring bath use in Japan replacing previous statistical estimates. This resulted in the 2007 estimates of 3,385 MW_{th} installed capacity and 41,518 TJ/yr being reduced by 1,285 MW_{th} and 15,818 TJ/yr, respectively. Iceland also reported a drop of 1,000 TJ/yr in utilization for 2008. The total use of about 329,880 TJ/yr is equivalent to an annual savings of about 11.6 Mtoe in fuel oil and 37.5 Mt in avoided CO_2 emissions (GIA conversions (Mongillo, 2005)).

The IEA-GIA: an Overview

The IEA-GIA was established in 1997, and was in the 2nd year of its 3rd 5-year term (2007-2012) of operation at the end of 2008. The GIA provides a flexible framework for wide-ranging international cooperation in geothermal R&D by bringing together national and industry programmes for exploration, development and utilization of geothermal resources, with a focus on enhancing effectiveness through establishing direct cooperative links among geothermal experts in

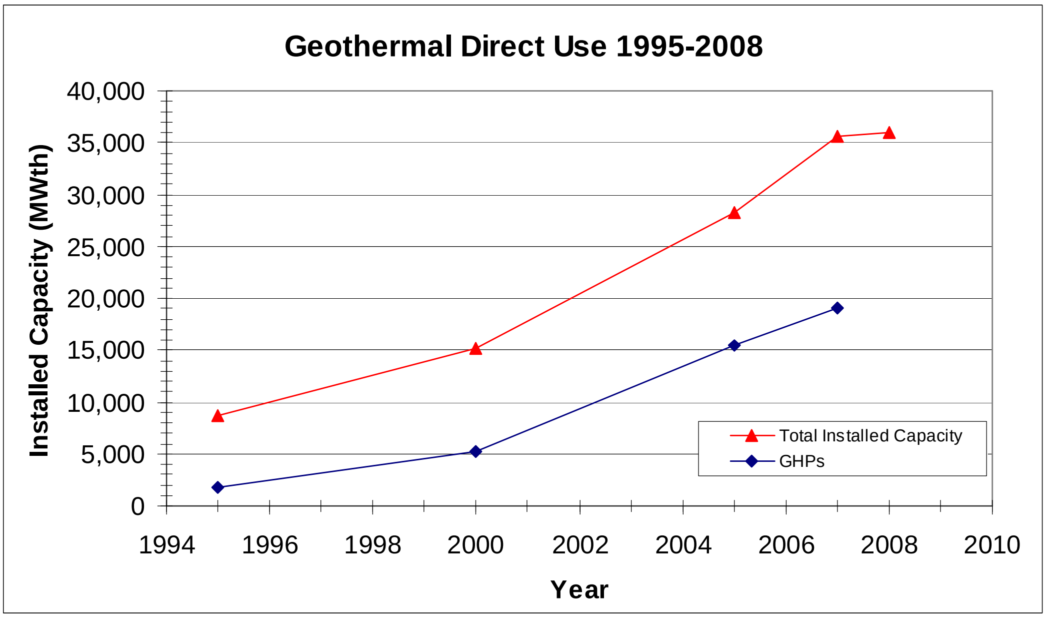

Figure ES2 Total worldwide geothermal direct use installed capacity for the period 1975-2008 (1995-2005 data from Lund, et al. (2005)), with estimates for 2007 and 2008 based on GIA data; and for GHPs for the period 1995-2007 (GIA 2007).

the participating countries and industries. The GIA's general scope of 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 can also participate in R&D projects and develop databases, models and handbooks. Policy and decision makers can 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 technologies 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.

To accomplish this Mission, six **Strategic Objectives** were set to target 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 presented in the 2008 GIA Annual Report (Table 1.2, Chapter 1). An Executive Committee (ExCo) supervises the GIA and its decisions are binding on all Members. The ExCo consists of one voting Member from each Member Country and Sponsor.

Since the GIA's commencement, 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 work performed under the auspices of the GIA has been estimated to be well over US$ 310,000/yr, plus several man-years (GIA, 2006a).

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 2008, membership of the IEA-GIA included: the European Commission; 12 countries: Australia, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, the Republic of Korea, Spain, Switzerland and the United States; 4 industry Sponsors: Geodynamics, GreenRock Energy, ORMAT Technologies and ORME Jeotermal; 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 2008, GIA participants worked on four broad research topics, 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

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 September 2006, Annexes I, III and VII were extended by the ExCo for a further 4 years, to 2009. Annex VIII, which officially started in 2003, completed its first term of operation in 2007, and was unanimously continued by the ExCo for another 4 years to 2011. 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 the 2008 GIA Annual Report (Table 1.2, Chapter 1).

A brief discussion of some of the GIA's activities and major highlights for the Annexes active in 2008 is presented below. Details are available in Chapter 1 and in the Annex Reports included in Chapters 2-5 of the 2008 GIA Annual Report.

IEA-GIA Annex Meetings 2008

The four GIA Annexes held technical meetings in association with the two 2008 ExCo Meetings in Paris, France (April 2008), and Busan, Korea (October 2008). Each Annex meeting is typically 2-3 hours long and provides the opportunity for detailed discussions of current and planned activities. Important issues that have arisen during the year, e.g. induced seismicity, are also examined.

IEA-GIA Annex I International Geothermal Sustainability Workshop

Task E- Sustainable Utilization Strategies of Annex I (Environmental Impacts of Geothermal Energy Development) co-sponsored, with GNS Science and Contact Energy, an international Sustainability Modelling Workshop dealing with reservoir modelling issues associated with long-term sustainability on 10 November 2008, in Taupo New Zealand. This workshop, which was held in association with the 50th Anniversary of the Wairakei Geothermal Power Station, attracted over 40 participants from 6 countries. The 20 presentations made at the workshop are available on the GIA website (Sustainability Workshop) and plans are proceeding to use these as the basis for a ***Geothermics*** Special Issue on Sustainable Geothermal Utilization to be published in 2010.

Renewable Energy 2008 International Conference, Busan

The GIA had a significant presence at the international Renewable Energy 2008 (RE 2008) conference held in Busan, Korea, on 13-17 October 2008. The GIA sponsored an exhibition booth promoting geothermal energy and the IEA-GIA's activities through the display of several posters (covering geothermal energy; and general GIA, Annex, Country and Sponsor activities) and continuously running PowerPoint presentations. Many GIA documents and CD-Roms were distributed (see photos below). GIA participants were also on hand to talk to visitors. In addition, several papers by GIA participants were presented at the conference, including a general one about the IEA-GIA, its activities and geothermal energy: *Geothermal Energy- IEA-GIA's Efforts Towards Accelerating Development of this Global, Under-Utilized Renewable Resource (*Bromley, et al., 2008).

(Photo courtesy Mike Mongillo)

(Photo courtesy Adrian Larking)

GIA Participation in IEA Activities

In 2008, the GIA continued its active participation in IEA workshops and meetings, and by providing information and comments on IEA reports.

An IEA-GIA paper reviewing induced seismicity associated with the development and operation of enhanced geothermal systems, entitled: *Geothermal Energy from Fractured Reservoirs- Dealing with Induced Seismicity* (Bromley and Mongillo, 2008) was published in the IEA Open Bulletin #48, February 2008. The GIA also provided information and comments on the geothermal section of the **IEA Energy Technology Perspectives 2008 Report** and participated in the **IEA-RETD Climate Change, Security of Supply and Soaring Energy Prices- the Role of Renewables in Global Energy Models Workshop- Copenhagen** (Denmark) with representation by Guðni Axelsson (Annex I Task E Leader). On 30 September-1 October 2008, the GIA Secretary, Mike Mongillo, participated in the **IEA Network of Expertise in Energy Technology (NEET) Workshop** held in Moscow, Russia, with a presentation: *The IEA Geothermal Implementing Agreement (GIA) Accelerating Sustainable Development of Geothermal Energy Through International Cooperation*.

Use of Geothermal Energy and the Environment

Energy utilization causes a variety of environmental impacts which can be of concern on the global scale. Though geothermal is a relatively benign renewable energy source, with important advantages over fossil fuels, e.g. significantly less carbon emissions, there are some environmental effects associated with its use that require attention. Annex I- Environmental Impacts of Geothermal Energy Development encourages the sustainable development of geothermal resources in an economic and environmentally responsible manner, while identifying and quantifying possible adverse and beneficial environmental impacts, and determining ways to avoid, remedy or minimize the adverse ones, while encouraging the beneficial.

Geothermal development may affect natural surface features like hot springs. Strategies to mitigate, recover or enhance such thermal features using targeted injection and strategic production were improved; and policies to aid regulators to monitor and manage effects on thermal features were refined. Results were presented at the RE 2008 Busan conference and at workshops in the USA and New Zealand.

The disposal of waste fluids and the small quantities of chemicals (e.g. arsenic) and gases (H_2S and CO_2) contained in them is an important issue; and optimum injection strategies for dealing with them were further investigated. Subsidence may arise from production in some geothermal areas; detailed investigations into its causes were conducted for two fields, with methods for improving predictive tools using coupled reservoir and subsidence models developed.

International collaboration continued to help advance understanding of induced seismicity mechanisms and a final version of the induced seismicity protocol was produced (Majer, et al., 2008). Reservoir modelling issues relating to long-term sustainable geothermal utilization were considered at a very successful international workshop on 10 November 2008, at Taupo, New Zealand. The Annex also contributed a poster for the GIA exhibition booth at RE 2008 Busan.

Accessing Geothermal Resources Using Enhancement Techniques

Huge heat resources consisting of high temperature, water-poor rock are available within current drilling depths (>3 km) almost anywhere on earth. To utilize the enormous amount of geothermal energy in this hot rock, Annex III- Enhanced Geothermal Systems (EGS) is investigating the development of new and improved technologies to artificially stimulate these resources (e.g. hydraulically fracture the rock) to enable commercial heat extraction for electricity production and, in some cases, co-generation of heat for direct use applications. These techniques 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.

Revision and restructuring continued in several of the Annex's activities, including those related to economic modelling; data acquisition and processing; and reservoir evaluation and field studies. Discussion continues on how conventional technologies like horizontal drilling, fracture detection and mapping and pumping can be modified for EGS applications; and the US DoE continues to fund such investigations, with several results presented at the 2008 GRC meeting and 2008 Stanford Geothermal Workshop.

The EGS plant at Soultz-sous-Forêts, France, was opened by a representative of the French Government in mid-2008; however, the plant will be "officially" commissioned when the feed-in tariff value is confirmed.

Reducing Geothermal Drilling Costs

One of the most expensive and essential parts of geothermal exploration, development and utilization is the drilling of wells; with subsequent logging and completion also expensive. Reducing well drilling, logging and completion costs can bring major benefits, since these can amount to up to about 50% of the capital cost of a geothermal power project. Annex VII- Advanced Geothermal Drilling Technology, is working to identify, develop and promote ways to reduce the costs of drilling, logging and completing geothermal wells.

Due to the significantly reduced US DoE geothermal budget in 2008, limited funding continued for the Annex Leader, and this severely restricted efforts in the Annex. However, there was still come activity, which mainly consisted of contributing to the 2008 GIA Annual Report, providing revised Annex descriptions for the developing GIA document, reporting to the ExCo and the holding an Annex meeting at the 19th ExCo Meeting (Paris, France). A poster was also provided for the GIA RE 2008 Busan exhibition booth.

Direct Use of Geothermal Heat

Geothermal heat and water have been used directly for bathing, cooking and therapeutic purposes for thousands of years. There are many applications for direct use today, including: building and district heating; industrial process heating; greenhouse heating; crop drying, temperature control for fish farming, bathing and swimming; and snow melting. In fact, the application of geothermal heat pumps allows heat from the earth's shallowest depths (< 100 m depth) to be used almost anywhere on earth for heating and cooling homes and buildings. Geothermal direct use has grown significantly, almost doubling every 5 years since 1995, and its scope for continued expansion remains great.

Though many direct use applications are now well developed and economically viable, implementation difficulties and unfavourable economics still provide major challenges. Annex VIII- Direct Use of Geothermal Resources, addresses all facets of direct use technology, with emphasis on improving implementation, reducing costs and expanding use.

Annex VIII held two meetings during 2008, in association with the two ExCo Meetings (Paris, France and Busan, Korea), at which reports were also made. The Annex contributed papers to the RE 2008 Busan and a poster for the GIA exhibition booth.

Results from the evaluation of temperature and chemical data from geothermal manifestations in Korea, Iceland, Japan and the US, showing that differences in rock types are related to geological environments was published at the RE 2008 Busan conference (Muraoka et al., 2008). The questionnaire for obtaining cost and performance information for direct use of geothermal energy was revised and more widely distributed than the first one. GIS-type methods to present and access direct use data are being investigated, with successful tests using Google Earth demonstrated and further development continuing.

National Activities

The geothermal programmes of the GIA Country Members provide the basis for the cooperative IEA 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 the 2008 GIa Annual Report (Chapters 6-18).

In 2008, Contracting Parties from 12 countries and the European Commission (EC) participated in the IEA-GIA. The Member Countries were: Australia, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, the Republic of Korea, Spain, Switzerland and the United States.

Contributions of GIA Members to Power Generation and Direct Use

In 2008, the 9 GIA Member Countries with geothermal generation had an installed capacity of about 6,575 MW_e, or about 63% of the total global geothermal capacity of 10,405 MW_e; and generated 38,373 GWh/yr, or about 66% of the total geothermal generation of 57,957 GWh/yr (Tables ES1 and ES5). The United States was by far the largest producer, generating about 15,000 GWh/yr, with Mexico second with 7,056 GWh/yr and Italy third with 5,181 GWh/yr. The percent of national installed capacity provided by geothermal in the 7 IEA-GIA Member Countries with non-negligible power development ranged from 0.2% for Japan to 22.3% for Iceland, with an average of about 5.8%. The contribution of geothermal to national generation in Member Countries ranged from 0.3% for Japan to 24.5% for Iceland, with an average of 7.1%.

Table ES5 *Total geothermal installed capacity, electricity generation and direct use in GIA Member Countries in 2008.*

Country	Electrical Installed Capacity (MW)	Annual Energy Generated (GWh/yr)	% of National Capacity	% of National Energy	Installed Thermal Power (MW_{th})	Annual Energy Used (TJ/yr)
GIA Member Countries	6,575	38,373	5.8*	7.1*	21,000	155,170
Worldwide Total**	10,405	57,957	9.4	11.6	36,023	329,880
GIA % of Worldwide Total	63	66	-	-	58	47

* Average % of 7 GIA Member Countries with non-negliglble generation, including Guadeloupe Island (France).

** For sources of worldwide total data see Tables ES 1 and ES4? above.

All 12 GIA Member Countries utilized geothermal in direct applications in 2008, with a total installed capacity of about 21,000 MW_{th} and total thermal energy used approximately 155,170 TJ/yr (Table ES6). In a few cases, the data presented are from 2005 (Lund, *et al*., 2005) or Antics and Sanner (2007), or has been estimated based on indicative rates of growth. Relative to 2007, there was significant growth in installed capacity for France, Iceland, Korea, Switzerland and the USA; and in the utilization for France, Germany, Korea, Switzerland and the USA. There was a significant decrease in Japan's installed capacity and utilization due to a "readjustment" that was made for the contribution from hot springs use. The three largest users of geothermal heat by far were the USA (46,831 TJ/yr), Japan (25,700 TJ/yr), and Iceland (25,000 TJ/yr). However, the non-high enthalpy geothermal countries, Germany (9,100 TJ/yr) and Switzerland (7,660 TJ/yr) also had very high utilization, mainly due to the large and growing geothermal heat pump usage.

In 2008, the GIA Member Countries were estimated to have saved the equivalent of approximately 16.1 Mtoe and avoided CO_2 emissions of about 45.8 Mt, assuming total fuel oil replacement (GIA conversions (Mongillo, 2005)) (Table ES6). The differences between the equivalent fuel oil savings reported by the GIA and the IEA values presented for geothermal electricity generation are mainly due to the use of the GIA relation (*ibid*.): 1 GWh = 253.4 toe, rather than that of the IEA: of 1 GWh = 860 toe. Some of the GIA Members have also taken into account the fuel source mix used in their countries.

Table ES6 Geothermal direct use in GIA Member Countries in 2008.

Country	Installed Thermal Power (MW_{th})	Annual Energy Used (TJ/yr)
Australia	130	3,672
France installed thermal capacity heat pumps	 307 1,300	 5,440 10,470
Germany near surface deep geothermal	 [952]	 8,500 600
Iceland	(1,844)	25,000
Italy	[650]	8,000
Japan	2,100	25,700
Mexico	156	(1,932)
New Zealand	(308)	10,000
Republic of Korea	149	1,365
Spain	6.0	na
Switzerland	1,057	7,660
USA	12,037	46,831
Total for GIA[1]	**21,000**	**155,170**

[1] Total excludes the EC; ( ) = from Lund, *et al.* (2005); na = not available
[ ] = from Antics and Sanner (2007)

Table ES6 Equivalent fuel oil savings and avoided CO_2 emissions in 2008.

Country	Equivalent Fuel Oil Savings (Mtoe)§			Avoided CO_2 Emissions (Mt)¥		
	Electricity Generation	Direct Use	Total	Electricity Generation	Direct Use	Total
Australia	negligible	0.09	0.09	negligible	0.44	0.44
France	0.03	0.13	0.16	0.07	0.40[1]	0.47[1]
Germany	negligible	0.32	0.32§	negligible	1.0	1.0
Iceland	1.01	0.88	1.89	3.44	1.20	4.64
Italy	1.31	0.28	1.59	4.23	0.91	5.14
Japan*	0.78	0.90	1.68	2.50	2.92	5.42
Mexico	1.79	0.07	1.86	5.76	0.22	5.98
New Zealand	1.00	0.35	1.35	3.19	1.10	4.29
Republic of Korea	0	0.07	0.07	0	0.16	0.16
Spain	0	na	na	0	na	na
Switzerland	0	0.18	0.18	0	0.58	0.58
USA	3.67	3.19	6.86	12.3	5.32	17.6
Total for GIA[2]	**9.59 [33.0]⁕**	**6.46 [7.42]⁕**	**16.1 [40.4]⁕**	**31.5**	**14.25**	**45.8**

* Year to March 2008; [1] Excluding geothermal heat pumps;
§ Where values are not provided, GIA conversions (Mongillo, 2005) are used: for electricity generation: 1 GWh = 253.4 toe, assuming oil thermal power plants; conversion for direct use assuming oil thermal power plants: 1 TJ = 35.2 toe
¥ Where values are not provided, GIA conversions used (*ibid.*): for electricity generation: 1 GWh = 817 tonnes CO_2; for direct use: 1 TJ = 113.6 tonnes CO_2; na = not available;
⁕ Totals using IEA conversion (1 GWh = 860 toe; 1 TJ ~ 47.8 toe)

Sponsor Activities

At the end of 2008, the GIA had 6 Sponsor Members, 4 from industry: Geodynamics Limited and Green Rock Energy Limited, from Australia; Ormat Technologies, Inc. from the USA and ORME Jeotermal from Turkey; and 2 organizations: the Canadian Geothermal Energy Association (CanGEA) and the Geothermal Group of the Spanish Renewable Energy Association (GG-APPA).

Industry Sponsors

Geodynamics Limited

Geodynamics is Australia's largest geothermal company and specifically focuses on the economic extraction of heat from hot rocks using enhanced geothermal systems (EGS) technology. In particular, its efforts are concentrating on drilling to depths of 3.6-4 km below surface into hot (T ~ 230 °C) fractured granite in the Cooper Basin area of northern South Australia.

Several flow tests involving wells Habanero 1 (Hb1) and Hb3 were performed in March and April 2008, with stimulation of Hb3 in mid-April. This was followed with the first closed-loop circulation between Hb3 and Hb1 achieved on 1 August, and a successful 6-week closed-loop circulation and tracer test that ended in February 2009. Stable flow rates of about 20 kg/s with surface temperatures of 212 °C have been achieved. Construction of a 1 MW power station began in mid-2008, and was virtually complete in March 2009. In late September, well Jolokia 1 was successfully completed to a depth of 4,911 m at a site 10 km west of the Habanero reservoir; with results demonstrating that the over-pressure that existed at Habanero extended to Jolokia. In mid-October, drilling commenced at the Savina site, 10 km west of Jolokia; where drilling of Savina 1 identified the over-pressured fracture at about 3,700 m depth- indicating that it extended 20 km from the Habanero site. An extensive microseismic monitoring network consisting of 18 permanent stations and covering an area of 160 km^2 has been installed and now extends over the Habanero-Jolokia-Sabina area. Geodynamics also plans to purchase another heavy-duty rig (US$ 38.3 M) with a capacity to drill to 6,000 m.

There has been further significant investment in Geodynamics in 2008, with the Sentient Group and Sunsuper Pty Ltd, and Tata Power agreeing to become cornerstone investors. In addition, in June, AUS$ 33.5 M was raised from a share purchase plan; in July, Origin committed a further AUS$ 9.6 M; and in November, Geodynamics received a NSW Government award of AUS$ 10 M for development of the Hunter Valley Geothermal Project.

Green Rock Energy Limited

Green Rock Energy Limited is a public company listed on the Australian Securities Exchange whose purpose is to evaluate and develop geothermal resources in Australia and abroad.

Over the next three years Green Rock is focussing on developing two commercial demonstration projects in sedimentary aquifers in each of Australia and Hungary, and one engineered geothermal system (EGS) project in thermally anomalous granite at Olympic Dam in South Australia. All three projects are located at markets, and can be commercialised quickly, given success with drilling and flow testing.

The chief challenges for both types of geothermal resources relate to: drilling to depths with sufficient temperatures for the end uses (2,000-5,000 m), finding or engineering sustainable permeability at reasonable cost, and proving the capacity of the geothermal reservoir to deliver enough energy at the surface to justify the investment.

Green Rock's Olympic Dam project, located at the site of a major market, the Olympic Dam mine, has demonstrated successful mini-hydro fracture stimulation, and is now seeking funding, via a "farm-in", before commencing deep drilling, stimulation and flow testing to prove commercial viability.

In August 2008, Green Rock, MOL (Hungary) and Enex (Iceland) formed Central European Geothermal Energy (CEGE) to pursue a demonstration project to produce electricity from geothermal water at depths of about 3,000 m. CEGE was acquired by MOL (50%) and Green Rock (50%) in January 2009. CEGE's aim is to use hot geothermal water produced from existing petroleum wells to generate electricity using ORC plants. CEGE is also considering investments in direct heat projects in Hungary.

Ormat Technologies, Inc.

Ormat Technologies, Inc., 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-based power plants. In addition, the company also designs, manufactures and sells power units and other power generating equipment for geothermal and recovered energy (RE) based electricity generation for third parties.

Ormat owns and operates 515 MW_e of geothermal and RE generation in 6 countries, including 350 MW_e of geothermal in the USA, and has deployed about 70% of all geothermal capacity in the US since 2000. In 2008 and early 2009, Ormat added about 187 MW_e of gross geothermal capacity worldwide, and signed US$ 230 M in contracts with third parties for power plants in Nevada, New Zealand Turkey and Costa Rica. The company has over 1,000 employees. It also has its own in-house drilling company, GeoDrill, with four rigs (capacity ~ 5,500 m) and over 90 staff.

In a joint project with the US DoE in 2008, Ormat validated the feasibility of using its proven ORC technology to commercially generate electricity using hot water produced during oil and gas field production, the first project of its type to provide on-site fuel-free power. Ormat is also involved in EGS projects at Desert Peak and Brady in the USA, and at Landau, Germany.

In 2008, Ormat's revenues were US$ 345 M, an increase of 16.5% over 2007, with 2009 revenues expected to increase by 9-15% over 2008.

ORME Jeotermal, Inc.

ORME Jeotermal, a geothermal engineering, industry and trade company based in Turkey, became an industry Sponsor Member in July 2008. ORME was founded in 1984 and became a joint-stock company in 1987.

ORME's scope of work includes: geothermal field studies; drilling, well testing, reservoir determination; feasibility, design and engineering; geothermal electricity production; district heating, greenhouse heating, and cooling systems; complete design of thermal tourist facilities; installation of geothermal district heating systems; and finance, investment and management of geothermal projects.

ORME's participation in GIA activities is currently being reviewed.

Organization Sponsors

Canadian Geothermal Energy Association (CanGEA)

The Canadian Geothermal Energy Association (CanGEA) became an organization Sponsor Member of the GIA in October 2008. CanGEA 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, working together with the British Columbia (BC) Provincial Government, produced a comprehensive white paper on best practices policy for Canadian geothermal energy development.

Reported activities in Canada include: a Geothermal Task Force was established by the BC Provincial Government to update current geothermal regulations in anticipation of a geothermal lease sale. Testing at Meager Creek hydrothermal project, located in BC and owned by Western GeoPower Corporation, verified Canada's first potentially commercial geothermal reservoir for electricity production.

Geothermal Group- Spanish Renewable Energy Association (GG-APPA)

The Geothermal Group of the Spanish Renewable Energy Association (GG-APPA) became a GIA Sponsor Member in October 2008. It represents its geothermal members' interests in politics, civil society and the media and participates in the development of Spanish energy and environmental policy. GG-APPA currently has a high enthalpy geothermal department and is proceeding to setup a low enthalpy one.

Though there are significant geothermal resources in Spain, they presently have low penetration in the energy balance. Studies show several favourable areas with potential for high temperature volcanic convective hydrothermal, conductive sedimentary and EGS systems for electricity generation. A significant number of medium/low temperature resources have also been identified across Spain and will be useful for direct heat applications, including district heating (Barcelona and Madrid); and geothermal heat pumps are applicable everywhere.

In 2008, more than 50 geothermal exploration and investigation licenses covering 7,500 km^2 were applied for in Spain and over 10 M€ was committed for exploration by companies over the next 3 years. The first district heating production is expected in 2011 and the first power generation in 2013 A feasibility study for a Madrid geothermal district heating scheme was conducted; and GG-APPA collaborated with the European Geothermal Energy Council (EGEC) to develop and prepare a research agenda for geothermal energy strategy for 2008-2030 and a geothermal regulation framework for Europe.

In addition, the high and low enthalpy departments of APPA manage the Secretariat of the recently initiated Spanish Geothermal Technology Platform (GEOPLAT), which aims to identify and develop sustainable strategies for the promotion and marketing of geothermal energy in Spain.

Plans for 2009 and Beyond

The end of 2008 sees the GIA nearly 2 years into its 3rd Term; having made significant progress towards meeting its Mission and Strategic Objectives. The GIA has participated at large international workshops/conferences in Korea, Russia and Denmark, co-sponsored an international workshop in New Zealand, contributed up-to-date geothermal information to several IEA reports, and membership has grown by 25%, with new Country Member Spain, and three new Sponsor Members: CanGEA, GG-APPA and ORME Jeothermal.

The GIA anticipates continued growth in its efforts and its membership in 2009, and onwards. The GIA already has plans to participate at the 2009 Geothermal Resources Council Meeting and at the very important World Geothermal Congress in 2010. There are commitments to hold a joint international GIA-IGA (International Geothermal Association) Workshop in Madrid, Spain, dealing with global geothermal development potential and its possible contribution to the mitigation of climate change; and arrangements have been made to produce a Special Issue of ***Geothermics*** on Sustainable Geothermal Utilization based upon the presentations made at the 2008 Workshop. The GIA will continue its strong support of the IEA by providing current geothermal data/information, contributing to their publications and by participating in IEA workshops. The ExCo is considering the possibility of using a part of the GIA Common Fund to support one-off Annex related activities to help advance joint Member projects and assist with the publication of Annex reports. In addition, the GIA will continue to pursue new membership in order to extend its base and expand its expertise.

Though there is some concern caused by the financial and economic crisis that appeared so suddenly during the later part of 2008, there is still optimism within the geothermal community, buoyed by a continuing growth in global geothermal development that became evident in 2007, and strengthened in November, with the election of US President (Elect) Obama, who strongly supports the development of renewable energy. It is clear that geothermal energy can make a substantial contribution towards meeting the future global energy needs, and the GIA sees the organization and its activities continuing and growing into the future in order to help ensure that geothermal provides its maximum sustainable contribution.

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Chapter 1

The Implementing Agreement

Champagne Pool, Waiotapu geothermal field, New Zealand (courtesy GNS Science, New Zealand).

1.0 The IEA Geothermal Research and Technology Programme

IEA involvement in geothermal energy began in 1978 with the commencement of two 3-year long studies which were completed in 1981. Then followed a 16-year lull, until the IEA Implementing Agreement for a Cooperative Programme on Geothermal Research and Technology, or Geothermal Implementing Agreement (GIA), was officially established on 7 March 1997, with an initial term of five years. Currently, the GIA is in its 3rd 5-year term of operation, taking its activities to 31 March 2012.

The GIA provides a flexible framework for wide-ranging international cooperation in geothermal research, development and deployment by bringing together national and industry programmes for exploration, development and utilization of geothermal resources. It focuses on enhancing effectiveness through establishing direct cooperative links among geothermal experts in the participating countries, industries and organizations.

The GIA's general scope of activities, defined in Article 1 of its Implementing Agreement document, provides guidance for the organization and consists of international scientific collaborative efforts to:

- ***Compile and exchange improved information*** on worldwide geothermal energy research and development concerning existing and potential technologies and practices
- ***Develop improved technologies*** for geothermal energy utilization
- ***Improve the understanding of the environmental benefits*** of geothermal energy and methods to avoid or minimize its environmental impacts.

The GIA's present efforts assist with the coordination of ongoing national programmes, with contributions from industry (Sponsor) members. Activities encompass 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 techniques, sustainable utilization strategies and presentation of data via the Web. New studies are also encouraged and implemented when the needs are established.

As of December 2008, the IEA-GIA had 19 Members: 12 Contracting Parties from 11 countries: Australia, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, the Republic of Korea, Spain, Switzerland, the United States, and the European Commission (EC); and six industry Sponsor Members: the Canadian Geothermal Association, Geodynamics, the Geothermal Group-Spanish Renewable Energy Association, Green Rock Energy Limited, ORMAT Technologies Inc. and ORME Jeotermal. See Table 1.1 for details.

1.1 Strategy and Objectives

The potential of geothermal energy is vast and its development can contribute significantly towards meeting the growing global renewable energy demand in both developed and developing countries. Geothermal development is currently in a rapid growth phase worldwide, and to maintain this accelerated development, it is essential to improve and develop new technologies, promote the benefits of sustainable geothermal utilization, and better educate the public, financial, and policy sectors.

The GIA began its 3rd 5-year term of operation in April 2007, with these goals strongly in mind, aiming to use its extensive international cooperation to focus particularly on disseminating information, improving environmental outcomes, enhancing EGS prospects, 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 (2007-2012) Mission (GIA, 2006b):***

To promote the sustainable utilization of geothermal energy throughout the world by improving existing technologies, by 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.

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 the more general *topic areas*, called *Annexes*. After approval by the ExCo, detailed descriptions of new Tasks, or of completely new Annexes including many new tasks, are appended to the IA by inclusion within existing Annexes, or as new Annexes, respectively (Chapters 2-5). 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 2008, participants worked on four broad research areas, specified in Annexes: I- Environmental Impacts of Geothermal Energy Development; III- Enhanced Geothermal Systems; VII- Advanced Geothermal Drilling Techniques; and Annex VIII- Direct Use of Geothermal Energy.

Annexes I and III, initiated in the original GIA, have continued their activities throughout 2008; as have Annexes VII (started in 2001) and VIII (begun in 2003). Annex V- Sustainability of Geothermal Energy Utilization has been placed on hold; however, a Sustainable Utilization Strategies task operates in Annex I. Annex VI- Geothermal Power Generation Cycles remains in its original draft form, and may be revised and initiated in the future.

A list of Annexes, Operating Agents, Annex Leaders, participants, and an indication of Annex status as of December 2008 are provided in Table 1.2. More complete details of objectives, results for 2008 and work planned for 2009 for the active Annexes are presented in the Annex Reports included in Chapters 2-5. 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. GIA Member involvement in the Annexes 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 2nd Term are estimated to be well over US$ 310,000 per year plus several man-years (GIA, 2006a).

Table 1.1 Contracting Parties, Sponsors, funding sources and periods of operation for the Annexes active to the end of December 2008.

Annex		I	III	VII	VIII
Country/Industry	**Contracting Party/Sponsor**	**Environmental Impacts of Geothermal Development**	**Enhanced Geothermal Systems**	**Advanced Geothermal Drilling Techniques**	**Direct Use of Geothermal Energy**
Australia	Primary Industries & Resources-South Australia (PIRSA)	G	G	G	
Canadian Geothermal Energy Association (CanGEA)	CanGEA, Canada		IO	IO	IO
EC	The Commission of the European Communities, Belgium	G	G	G	
France	Bureau de recherches géologiques et miniéres (BRGM)	G	G		G
Geothermal Group of Spanish Renewable Energy Association (GG-APPA)	GG-APPA, Spain		IO		IO
Germany	Forschungszentrum Jülich GmbH		G		
Geodynamics	Geodynamics Limited, Australia		OA, I		
Green Rock Energy	Green Rock Energy Limited, Australia		I		
Iceland	Orkustofnun	G, I		G	OA, G
Italy	ENEL Produzione	I	I		
Japan	National Institute of Advanced Industrial Science and Technology (AIST)	R	R		R
Mexico	Instituto de Investigaciones Electricas (IIE)	G		G	
New Zealand	GNS Science	OA, R, I		I	R
ORMAT Technologies	ORMAT Technologies, Inc, United States		I		
ORME Jeotermal	ORME Jeotermal, Turkey				I
Republic of Korea	Korea Institute of Geoscience & Mineral Resources (KIGAM)				R
Spain	Institute for Diversification and Saving Energy (IDAE)		G		G
Switzerland	Swiss Federal Office of Energy	G	G		G
USA	United States Department of Energy (US DOE)	N	N	OA, N	U
Annex Start Date		1997	1997	2001	2003
Date Current Term of Annex Continues To		2009	2009	2009	2011
End Date*		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 2008.

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, France, EC, Iceland, Italy, Japan, Mexico, New Zealand, Switzerland, USA	Active since 1997, Continuing through 2009
II	Shallow Geothermal Resources	Closed
III	Enhanced Geothermal Systems OA: Geodynamics Limited, Australia ALs: Roy Baria; MIL-TECH UK (for Geodynamics); roybaria@onetel.com and Doone Wyborn; Geodynamics, Australia; dwyborn@geodynamics.com.au Participants: Australia, CanGEA, EC, France, Geodynamics, Germany, GG-APPA, Green Rock Energy, Italy, Japan, ORMAT, Spain, Switzerland, USA	Active since 1997, Continuing through 2009
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, United States AL: Steven Bauer; Sandia National Laboratories, USA; sjbauer@sandia.gov Participants: Australia, CanGEA, EC, Iceland, Mexico, New Zealand, USA	Active since 2001, Continuing through 2009
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, Republic of Korea, Spain, Switzerland, USA	Active since 2003, Continuing through 2011
IX	Geothermal Market Acceleration	Closed

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", whereby 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 situation, activities and achievements made by 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 making-up Chapters 6-18 and 19-23, respectively.

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

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 one Contracting Party for each country, usually a government department or agency. The ExCo meets

Table 1.3 Annex number, name, description and status for draft and completed Annexes as of December 2008.

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

regularly twice each year to exchange information, discuss activities and progress in each of the Annexes and in each of the 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 document), 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 disseminated through participation at international conferences and workshops, and publication in scientific and technical journals and conference proceedings (details in Chapters 2-6). In addition, information is made widely available on the GIA's public website, through promotional material produced by the GIA Secretariat, and via IEA publications and the IEA website (www.iea.org).

In 2008, 12 countries, the EC, two international organizations and three industries formally participated in this programme (Table 1.1). One of the new industries, which became a Member in mid-2008, has been having problems initiating its participation, though it is hoped that the situation will be solved in the near future.

1.4 The Executive Committee

Officers

In 2008, Chris Bromley (New Zealand) was re-elected Chairman. Dr Ladislaus Rybach (Switzerland) and Dr Allan Jelacic (USA) were also re-elected to serve as Vice-Chairs for Policy and Administration, respectively.

Membership

There were several changes in the ExCo composition in 2008, with: Fabrice Boissier replacing Patrick Ledru as Member for France, Guido Cappetti becoming the Member for Italy, Lucien Bronicki replacing Dan Schochet for Ormat Technologies and Gunter Siddiqi replacing Ladsi Rybach as Member from Switzerland. Ladsi Rybach became Alternate Member for Switzerland, Paolo Romagnoli became Alternate Member for Italy, and Jay Nathwani was appointed Alternate Member for the USA. The joining of four new GIA Members in 2008 led to a corresponding large increase in the ExCo, with: Alison Thompson and Craig Dunn becoming Member and Alternate, respectively, for the Canadian Geothermal Energy Association (CanGEA); Margarita de Gregorio and Raúl Hidalgo Member and Alternate for the Geothermal Group of the Spanish Renewable Energy Association (GG-APPA), Orhan Mertoglu and Tevfik Kaya becoming Member and Alternate for ORME Jeotermal; and Ángel Chamero Ferrer and Carmen Mª Roa Tortosa Member and Alternate for Spain.

The list of ExCo Members and Alternates as at December 2008 is provided in Appendix B.

ExCo Meetings

The ExCo held two Meetings in 2008 to conduct business, which included discussing and reviewing ongoing tasks and the planning of future activities.

19th ExCo Meeting, 17-18 April 2008, Paris, France

The 19th ExCo Meeting was held on 17-18 April 2008, at the IEA Head Quarters in Paris, France, with the kind support of the IEA. There were 31 attendees, including 9 ExCo Members and 3 Alternate Members, 13 Observers, 5 invited Guests and the GIA Secretary. In addition to the IEA Secretariat representative, five IEA HQ staff attended from time to time as Observers throughout the meeting, mainly to provide information. Of the Observers and Invited Guests present, six represented prospective GIA Members.

All four GIA Annexes held meetings on Wednesday, 16 April 2008, at the IEA HQ. The four Annexes also reported on their activities at the ExCo meeting, as did 10 Country Members and the 3 Sponsor (industry) Members. Several Guest and Observer Reports were also presented by prospective GIA Members, including: China, Indonesia, Spain, AltaRock Energy (USA) and the Geothermal Group of the Spanish Renewable Energy Association.

The ExCo unanimously approved the re-election of Chris Bromley (New Zealand) as Chair, and Allan Jelacic (USA) and Ladislaus Rybach (Switzerland) as Vice-Chairs.

As a consequence of the GIA's growing Membership, and the organization's current excellent financial position, a proposal to use a portion of the GIA Common Funds to fund one-off special Annex Activities that might otherwise remain uncompleted, was discussed. There was support for this idea, and it is to be further developed for consideration at the next ExCo Meeting. Discussion continued on the issue of obtaining geothermal development-related costs so that the GIA would be better placed to provide such information when requested.

The Intergovernmental Panel on Climate Change (IPCC) geothermal paper produced for the IPCC Scoping Workshop held in January 2008 was discussed, and the lack of recognition of EGS's contribution was raised. The ExCo decided the paper should be posted on the GIA website with a call for comments in order to obtain input from the wider international geothermal community to help develop input for the final IPCC Special Report on Renewable Energy Contribution to Climate Change Mitigation (to be completed in 2010). The issue of CO_2 emissions from geothermal developments was discussed and, though very small, the importance of being able to provide accurate estimates was recognized, especially since this will be important information for the IPCC Special Report.

The Secretary provided a report on the operation (work accomplished and budgets) of the Secretariat for the 2007-year and the 2008-year to 31 March 2008, presented a work plan and revised budget for the remainder of 2008, and gave an update on the Common Fund. The GIA planned to participate in the October 2008 Renewable Energy Congress being held in Busan, Korea, and the Secretary would be contributing to a paper describing the GIA activities and geothermal energy, as well as managing a GIA exhibition booth for the week of the conference. Continued growth in GIA membership was discussed, with interest from Hungary and Spain reported.

The IEA Secretariat report was presented by Nobu Hara, who informed the meeting that he would be returning to his regular position at MITI, Japan, very soon. The excellent support for the GIA that Hara had provided during the past 4 years was recognized by the ExCo.

Because the GIA ExCo has a very open policy regarding attendance by Observers and Invited Guests at its meetings, it was decided to hold separate ExCo "business" meetings prior to the start of each regular ExCo Meeting.

The ExCo agreed to hold the 20th ExCo Meeting in Busan, Korea, on 9-10 October 2008, in association with the international Renewable Energy 2008 Congress. Annex Meetings could be held on Wednesday 8 October.

20th ExCo Meeting 9-10 October 2008, Busan, Korea

The 20th ExCo Meeting was hosted by the Korean Institute of Geoscience and Mineral Resources (KIGAM), and held at the Paradise Hotel in Busan, Korea, on 9-10 October 2008. The meeting was held in conjunction with the Renewable Energy 2008 Conference, Busan, Korea, thus allowing ExCo Meeting participants to take part (several papers were presented by GIA participants). Eighteen people attended, including: 9 ExCo Members, 3 Alternate Members, 3 Observers, two Invited Guests and the GIA Secretary. A fieldtrip to the Pohang geothermal site and a visit to Gyeongju Temple were also provided by KIGAM.

It was announced that the Swiss Federal Office of Energy's (Switzerland's Contracting Party) decision, to have a more active role in the GIA, led to Gunter Siddiqi replacing Ladsi Rybach as ExCo Member, with Ladsi Rybach taking up the position of Alternate Member and remaining the Vice-Chair Policy.

The ExCo discussed the GIA's progress vis-à-vis its Strategic Plan 2007-2012, and was happy with the current situation; efforts were on track and there were no reasons to modify objectives or goals.

It was reported that both ORME Jeotermal and Spain had become new GIA Members since the last ExCo Meeting, and that a few days prior to this ExCo Meeting, the IEA CERT had approved the new Membership of the Geothermal Group of the Spanish Renewable Energy Association (GG-APPA) and the Canadian Geothermal Energy Association (CanGEA). The ExCo recognized the importance of pursuing new Membership, especially targeting those major geothermal countries not yet Members- Indonesia and the Philippines; as well as China and Russia.

Annexes I and VIII held meetings on 8 October 2008. It was announced that as part of Annex I activities an International Sustainability Modelling Workshop is to be held in Taupo, New Zealand in November 2008. A new initiative by Annex VIII- Direct Use to develop a method to present direct use information/data/images on internet using Google Earth was making headway.

Reports from Annexes I, III, VII and VIII, and 8 Country, the EC, 3 Sponsor and 1 Invited Guest reports were presented and discussed. The Secretary reviewed activities since the 20th ExCo Meeting and submitted work plans and budgets for the remainder of 2008 and for 2009 along with the Common Fund report, and these were unanimously accepted by the ExCo. He also reviewed his participation at the IEA NEET Workshop in Moscow, Russia, on his journey to this ExCo Meeting.

The plans for a joint GIA-IGA (International Geothermal Association) Workshop on geothermal energy and its potential for mitigation of climate change, to be held in association with the 21st ExCo Meeting in Madrid, Spain, were discussed. The outcome is to provide input for the IPCC Special Report on Renewable Energy Contribution to the Mitigation of Climate Change.

Iceland introduced the idea for development of a Geothermal Sustainability Assessment Protocol; this was discussed and gained some support from the ExCo. The possibility of pursuing this work in a new Annex could be considered after Iceland reports at the next ExCo Meeting. The issue of promotion of geothermal energy use and communicating its benefits were considered and a decision to investigate an action plan made.

As part of the GIA's efforts to disseminate information about geothermal energy and promote the IEA-GIA, the GIA would be participating in the RE 2008 Busan international conference (13-17 October 2008) by presenting several papers and sponsoring an exhibition booth Conference at which several Annex and Member posters would be shown.

The ExCo agreed to hold the 21st ExCo Meeting in Madrid, Spain, at the invitation of IDEA, on 7-8 May 2009. There would also be an associated two-day joint GIA-IGA Workshop on 5-6 May 2009, also hosted by IDEA.

1.5 GIA Participation in IEA Activities in 2008

The GIA continued its active participation with the IEA in 2008. The GIA provided a comprehensive article (*Geothermal Energy from Fractured Reservoirs- Dealing with Induced Seismicity*) for the **IEA OPEN Bulletin Issue #48**; commented on and provided information for the geothermal section of the **IEA Energy Technology Perspectives 2008 Report**; provided information on geothermal development material needs, participated in the **IEA-RETD Climate Change, Security of Supply and Soaring Energy Prices- the Role of Renewables in Global Energy Models Workshop- Copenhagen** (Denmark) with representation by Guðni Axelsson;

and participated in the **IEA Networks of Expertise in Energy Technology (NEET) Workshop in Moscow**, Russia.

1.6 Other GIA Activities

The GIA participated in the International Renewable Energy 2008 Conference, Busan, Korea, with presentations of several geothermal papers, including one about the IEA-GIA's activities by Bromley, Mongillo, Rybach, Jelacic and Song: *Geothermal Energy- IEA-GIA's Efforts Towards Accelerating Development of this Global, Under-Utilized Renewable Resource* and through the sponsorship of an exhibition booth at which several Annex and Member Posters were exhibited, many GIA documents and CD-Roms with Annual Reports and other information were distributed, PowerPoint presentations about the GIA's activities were projected and representatives of the GIA were present and discussed geothermal energy and the IEA-GIA's activities with many visitors

Exhibition booth at RE2008 Busan, Korea. (Photos courtesy Mike Mongillo).

An International Sustainability Modelling Workshop, sponsored by GIA Annex I, GNS Science and Contact Energy, was held in Taupo, New Zealand, on 10 November 2008, in association with the 50th Anniversary of the Wairakei Geothermal Power Station; there were over 20 presentations, with about 40 participants from 6 countries.

The GIA also submitted comprehensive comments on the European Geothermal Energy Council (EGEC) REsearch Agenda for Geothermal Energy- Strategy 2008-2030.

The GIA's public website (www.iea-gia.org), continued to grow as a source for information dissemination and discussion.

1.7 Costs of the Agreement

The IEA-GIA has a dedicated Secretariat, currently located in New Zealand. It is supported by a part-time Secretary, who deals with the administration, assists with the management of the organization and provides a significant part of the information dissemination, including the preparation of GIA documents and publications, the GIA annual reports and development and maintenance of the GIA website.

The expenses for operating the GIA Secretariat, including the Secretary's salary and travel, website hosting, and other common costs of the ExCo, are met from a GIA Common Fund. In 2008, these costs amounted to a total of US$ 98,000. The Common Fund is administered by a Custodian, currently the National Renewable Energy Laboratory (NREL), based in Golden, Colorado, USA, who also conducts an annual review of its financial operations.

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 ExCo acting in unanimity. The apportionment for the current GIA Membership is shown in Table 1.4.

The cost per Common Fund share, set by unanimous ExCo decision, was US$ 3,500/yr in 2008. Contributions are made annually on a calendar year basis.

Table 1.4 Common fund share apportionment among the GIA Members as of December 2008.

Australia	2	Spain	2
European Commission	4	Switzerland	2
France	4	United States	4
Germany	4	CanGEA	1
Iceland	1	Geodynamics	1
Italy	2	GG-APPA	1
Japan	4	Green Rock Energy	1
Mexico	1	ORMAT	2
New Zealand	1	ORME Jeotermal	1
Republic of Korea	2	-	-
Total = 40 shares			

1.8 References

Bromley, C.J., Mongillo, M.A., Rybach, L., Jelacic, A. and Song, Y. (2008) Geothermal Energy- IEA-GIA's Efforts Towards Accelerating Development of this Global, Under-Utilized Renewable Resource. *RE 2008, Busan Korea, 13-17 October 2008, 4p.*

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

Chapter 2

Annex I- Environmental Impacts of Geothermal Energy Development

Figure 2.1 *Steaming ground and thermal vegetation at "Craters-of-the-Moon", Wairakei, New Zealand (an example of indirect beneficial effects of liquid pressure drawdown). (Photo courtesy C. Bromley)*

2.0 Introduction

The goals of Annex 1 (Environmental Effects) 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 adverse effects.

Geothermal is generally considered to be an environmentally benign, renewable energy source. It has significant benefits relative to fossil fuels with respect to global carbon-dioxide emissions, and consequential potential for reducing global warming. There remain, however, some local environmental problems associated with its utilization. To further the use of geothermal energy, possible adverse and beneficial environmental effects are identified, and measures devised and adopted to avoid or minimize adverse impacts, while encouraging the benefits.

Participants in Annex 1 include: Australia, European Commission, Iceland, Italy, Japan, Mexico, 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

Annex I has five Tasks, described below.

2.1.1 Task A- Impacts on Natural Features

(Task Leader: Chris Bromley, GNS Science, New Zealand)

Impacts of geothermal developments on natural geothermal features such as geysers, hot springs and fumaroles are documented. Methods are devised to accurately monitor changes and to avoid or mitigate the adverse impacts of development on these geothermal features, which often have significant economic value for tourism and cultural value for indigenous peoples.

2.1.2 Task B- Discharge and Reinjection Problems

(Task Leader: Trevor Hunt, New Zealand)

Better methods of overcoming any adverse impacts of geothermal developments on other aspects of the environment are also developed. These include the effects of gas emissions from geothermal power plants on air quality; 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 and the effects of CO_2, Hg and H_2S gas emissions, along with mechanisms and mitigation options, using injection, for ground subsidence.

Figure 2.2 Yellowstone National Park "Morning Glory" hot spring (USA);an example of a natural feature occasionally affected by tourism: thrown objects block the vent. (Photo courtesy C. Bromley)

2.1.3 Task C- Methods of Impact Mitigation and Environmental Procedures

(Task Leader: Chris Bromley, GNS Science, New Zealand)

By developing an effective, standard, environmental analysis process, the objective of this task is to reduce the risks of adverse effects, reduce the costs of environmental compliance, and stream-line the process for project consenting, thereby contributing to the responsible and timely deployment of future geothermal energy projects. Field management strategies that result in improved environmental outcomes are identified and publicized. Successful mitigation schemes that provide developers and regulators with options for compensating unavoidable effects are also identified, documented and publicized.

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

(Task Leaders: Ernie Majer, Lawrence Berkeley National Laboratories, USA; and Roy Baria, United Kingdom)

The purpose of this task is to investigate the occurrences of felt induced seismic events, particularly in connection with high pressure fracture stimulation, and their effects on the local population. The objective is to obtain a better understanding of why these events occur so that they can either be avoided or mitigated. Additional objectives are to assess and generate appropriate source parameter models, and test the models in relation to the hydraulic injection history, temperature gradients, stress field and the tectonic/geological background, using stress modelling and rock mechanics. Once various mechanisms of the events are understood, the injection process to fracture stimulate a geothermal reservoir may be modified to reduce or eliminate the occurrence of large events. This task is complementary to a similar research objective under Annex III (for EGS).

2.1.5 Task E- Sustainable Utilization Strategies

(Task Leader: Guðni Axelsson, Iceland Geological Survey (ISOR), Iceland)

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.

Figure 2.3 Svartsengi "resource park" – sustainably-managed, integrated power station, hot water supply and thermal spa (Blue Lagoon, Iceland). (Photo courtesy C. Bromley)

2.2 Work Performed in 2008

2.2.1 Task A- Impacts on Natural Features

Changes observed in thermal features caused by geothermal developments were further studied. Strategies to mitigate, recover or enhance thermal features using targeted injection and strategic production were improved. Policies were further refined to help regulators to monitor and manage effects on thermal features in a practical manner. Results were presented at renewable energy workshops in Korea (RE2008) and geothermal workshops in New Zealand and the USA.

2.2.2 Task B- Discharge and Reinjection Problems

Optimum injection strategies, including scaling treatment and avoidance, methods of reduction of CO_2 emissions by injection, and arsenic reduction through silica precipitation were further investigated.

Causes of subsidence in two geothermal fields were investigated in detail and methods to improve predictive tools using coupled reservoir and subsidence models were developed.

2.2.3 Task C- Methods of Impact Mitigation and Environmental Procedures

International geothermal policy and planning guidelines were compared and tables of effects and avoidance strategies were further developed. Examples of successful mitigation strategies were collated and discussed at two Annex I meetings.

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

Collaboration between participants involved in EGS projects and geothermal researchers with experience of induced seismicity continued in order to advance understanding of induced seismicity mechanisms. Methods to address the issue of large induced earthquakes from injection/production activities were discussed from the perspective of vibration amplitude and frequency. Modifications were made to the induced seismicity protocol (available on IEA-GIA website). Improved seismic monitoring and processing methods were also discussed.

2.2.5 Task E- Sustainable Utilization Strategies

An international workshop (10 November 2008) to address reservoir modelling issues concerning long term sustainability was convened in conjunction with the Wairakei 50th anniversary held at Taupo, New Zealand. Preparations were also made for a special issue of the ***Geothermics*** journal on this topic, using the workshop presentations as a starting point.

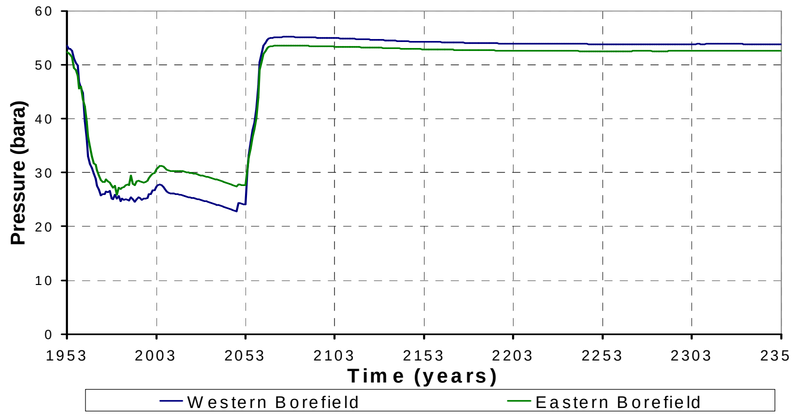
Issues of long-term reservoir performance and potential constraints were discussed during Annex 1 meetings. The results showed that resources that are depleted in pressure and temperature are generally recoverable (i.e. renewable) over time frames comparable in duration to the initial period of draw-down (Figure 2.4).

2.3 Highlights of Annex I Programme Work for 2008

The highlights for the 2008-year were:

- Interest in sustainability issues led to a successful workshop on this topic, held in Taupo, New Zealand
- Papers were presented by participants and work colleagues on improved environmental sustainability strategies and monitoring methods at the 2008 New Zealand Geothermal Workshop, the 2008 Stanford Geothermal Reservoir Workshop, the 2008 Geothermal Resources Council conference, and RE2008 in Busan, Korea

- An IEA Open Energy Technology Bulletin article on induced seismicity was published (Bromley and Mongillo, February 2008, Vol 48)
- Discussions on longer-term research and development needs were held with industry representatives at international conferences, including research into: induced seismicity, monitoring natural CO_2 and convective heat flux, using injection to reduce CO_2 and H_2S emissions, classifying thermal feature vulnerability, testing mitigation and remedial methods and developing bio-remediation methods to remove toxic elements from geothermal water discharges
- Improved methods to monitor, avoid or mitigate environmental effects such as subsidence, gas and heat emissions and induced seismicity were developed
- Geothermal environmental mitigation costs, best-practice government policy options and strategies to protect geysers from development effects were further developed to assist countries that are new to geothermal development
- Annex participants took part in discussions at meetings in conjunction with the IEA-GIA Executive Committee meetings in Paris (April) and in Korea (September) to discuss progress on the existing Tasks and planning for new Tasks



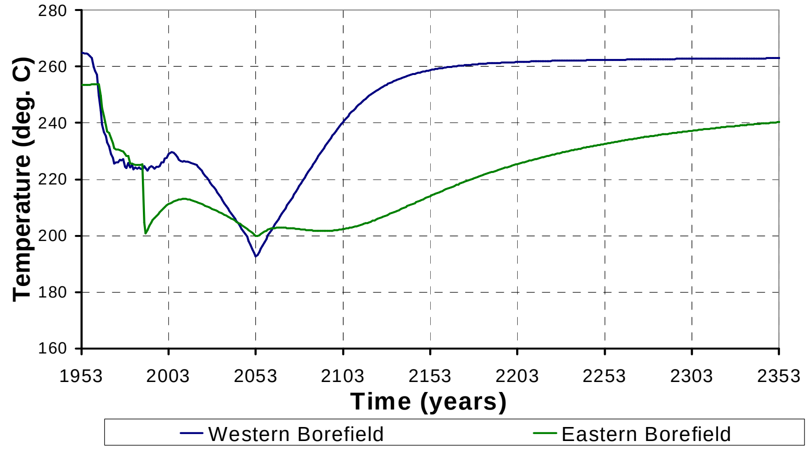


Figure 2.4 Example of reservoir simulation of Wairakei: 200 years of pressure and temperature recovery, after 100 years of production (O'Sullivan, 2008).

2.4 Work Planned for 2009 and Beyond

2.4.1 Task A

- Distinguishing natural and induced variations in thermal discharges
- Modelling causes of groundwater effects from deep pressure change
- Methods of ranking thermal features and ecosystems for protection
- Classifying vulnerability of thermal features to reservoir pressure changes

2.4.2 Task B

- Geothermal CO_2 capture for horticulture and bottling
- CO_2 sequestration by injection or 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

2.4.3 Task C

- Test the use of targeted injection to rejuvenate failed geysers
- Test the use of targeted injection to stop subsidence
- Review international geothermal environmental policies and procedures
- Review costs of mitigation options for environmental effects

2.4.4 Task D

- Review Induced Seismicity protocol to emphasize vibration monitoring approach
- Discriminate between EGS-related and natural seismic events- identify and characterize attributes typical of induced events (duration, frequency content, dominant frequency)
- Investigate possible seismic effects during long-term EGS operation (production phase). There is little experience regarding long-term thermo-elastic effects (cooling cracks). Will the level of seismicity due to hot fluid production be lower than that during stimulation?
- Define how far relevant stress field perturbations can extend from EGS operations. What are the implications of this in terms of safe proximity of stimulated EGS reservoirs to major active faults?
- Undertake further studies on post shut-in seismicity. Why do micro-seismic events continue to occur after suspension of injection?
- Design downhole EGS operations to minimize ground shaking. The management scheme may involve adjusting volume, rate or temperature of fluid injection. Research should investigate the nature and degree of dependency of these factors on the local conditions at depth
- Predict likelihood of damaging induced earthquakes and devise avoidance or mitigation schemes

2.4.5 Task E

- Compile papers for a ***Geothermics*** special issue on sustainability of geothermal resource utilisation
- Compare simulations of >100 year continuous and periodic (30-50 yr interval) production/injection scenarios. What are the optimum strategies?
- How rapidly and effectively do geothermal systems recover during breaks after periods of excessive production?
- What factors are most significant in controlling long-term behaviour/capacity; boundary conditions, inflow/recharge, reinjection, etc.?

- How significant and far-reaching are long-term production pressure drawdown and injection cooling effects, i.e. how significant is interference between adjacent geothermal areas?
- Using case histories, what is the reliability of long term predictions of reservoir behaviour using various methods (stored heat, simple analytical models, complex 3D models, etc.)?
- What information should be collected at pre-exploitation and early development stages to significantly reduce uncertainties in long-term resource sustainability assessments?

Each task is dependant on time and resources being made available by participants and the cooperation of geothermal development companies.

All environmental tasks would benefit from supportive funding. Specific examples are:

- Preparation of an international geothermal environmental protocol document (improve on existing documents)
- Induced seismicity and sustainability workshops and publishing costs
- Field trials using targeted shallow reinjection of hot fluids to recover/enhance thermal features
- Field trials of injection as a means of suppressing subsidence
- Field trials of gas injection in geothermal wells
- Field trials of injection/production methods to influence the rate of induced seismicity
- Field trials of water treatment to remove toxic elements

2.5 Outputs for 2008

Reports and papers posted on the IEA-GIA website (www.iea-gia.org):

1. Majer, E., Baria, R., Stark, M., Bromley, C.J., Cumming, W., Jelacic, A. and Rybach, L. (2008) Protocol for induced seismicity associated with enhanced geothermal systems. IEA-GIA, 8 p.

2. Geothermal sustainability – a reference list.

3. List of authors and presentations made at the Sustainability Modelling Workshop convened by Chris Bromley and Gudni Axelsson on 10 November 2008 at Taupo, New Zealand (presentations in pdf format available from IEA-GIA website):

Axelsson- Sustainability Modelling Overview 1 (638 kB)
Bjornsson- Hengill Sustainability & Renewability (2.4 MB)
Bromley- Sustainability Modelling Overview 2 (2.2 MB)
Clotworthy- Development End Point (275 kB)
Cumming- Decisions & Risk (210 kB)
Ehara- Hatchobaru Sustainability & Gravity (784 kB)
Kamojang- History & Future (1.6 MB)
Kaya & O'Sullivan- Modelling Injection (1.4 MB)
Kissling- Modeller's Perspective (2.7 MB)
Leary- Fracture models (981 kB)
Mongillo- IEA-GIA Sustainability Efforts (532 kB)
Montalvo- Ahuacapan Improving Capacity (3.1 MB)
Monterrosa Ahuachapan Guide for Assessing Sustainability (261 kB)
Onacha- Geophysical Data & Modelling (2.3 MB)
O'Sullivan- Wairakei (2.9 MB)

Siddiqi- Riehen 15 Years of District Heating (1.9 MB)
White- Water Production & Sustainability (527 kB)
Zarrouk & O'Sullivan- Modelling Ohaaki (1.4 MB)
Lopez- Dogger Aquifer Management, Paris Basin (480 kB)
Szanyi & Kovács- Reinjection Experience in SE Hungary (1.5 MB)

Environmental publications:

Allis, R., Bromley, C.J. and Currie, S. (2008) Update on subsidence at the Wairakei-Tauhara geothermal system. In: *Handbook & proceedings of the 30th New Zealand Geothermal Workshop 2008*, Auckland, NZ, p. 37.

Bannister, S.; Sherburn, S.; Powell, T.; Bowyer, D. (2008) Microearthquakes at the Rotokawa Geothermal Field, New Zealand. *Trans. GRC 2008 Vol 32*, 259-264.

Boothroyd, I. (2008) Ecological characteristics of geothermal systems of the Taupo Volcanic Zone, New Zealand. *Proc. 30th NZ geothermal Workshop.*

Bromley, C.J. and Mongillo, M.A. (2008) Geothermal energy from fractured reservoirs: dealing with induced seismicity. *OPEN energy technology bulletin, 48, 7* p.

Bromley, C.J. (2008) Groundwater changes in the Wairakei-Tauhara geothermal system. In: *Handbook & proceedings of the 30th New Zealand Geothermal Workshop 2008,* p. 72.

Bromley, C.J.; Currie, S.; Manville, V.R. and Rosenberg, M.D. (2008) Recent ground subsidence at Crown Road, Tauhara and its probable causes. In: *Handbook & proceedings of the 30th New Zealand Geothermal Workshop 2008,* p. 75.

Bromley, C.J.; Jolly, S.; Allis, R.; Samsonov, S.; Ryan, G. (2008) Update on subsidence at Ohaaki geothermal field. In: *Handbook & proceedings of the 30th New Zealand Geothermal Workshop 2008,* p. 38.

Bromley, C.J.; Mongillo, M.A.; Rybach, L.; Song, Y. (2008) Geothermal energy : IEA-GIA's efforts towards accelerating development of this global, under-utilized renewable resource. Paper IN-GT-002 In: *Renewable energy 2008: international conference and exhibition, October 13-17, 2008, Busan, Korea.*

Ehara, S. and Nishsjima, J. (2008) Sustainable development of geothermal energy. Paper O-GT-008 In: *Renewable energy 2008: international conference and exhibition, October 13-17, 2008* RE2008, Busan, Korea.

Foulger, G., Julian, B.R. and Monastero, F.C. (2008) Seismic monitoring of EGS tests at the Coso Geothermal Area, California, using accurate MEQ locations and full moment yensors, *Proc 2008 Stanford Geothermal Workshop.*

Hochstein, M.P.; Bromley, C.J. (2008) Heat flux measurement of hot ground. In: *Spontaneous coal seam fires: mitigating a global disaster.* Beijing: Unesco. Ecological book series 4, 259-276.

Kneafsey, T.J., Pruess, K., and Spycher, N. (2008) Preliminary experimental investigation of water injection to reduce non-condensible and corrosive gases in steam produced from vapor-dominated reservoirs. *Proc. 2008 Stanford Geothermal workshop.*

Mukuhira, Y.; Asanuma, H.; Niitsuma, H.; Schanz, U. and Haring, M. (2008) Characterization of microseismic events with larger magnitude collected at Basel, Switzerland, in 2006. *Transactions GRC 2008, vol32,* 87-94.

Nishi, K., Fujii, H., Ishikami,T., Fujiwara, K., and Kawakita, M.(2008) Study on environmental impacts of ground heat disposal. Paper P-GT001, In: *Renewable energy 2008 : international conference and exhibition, October 13-17, 2008* RE2008, Busan, Korea.

Sorey, M.L. and Spielman, P. (2008) Thermal-water discharge from Steamboat Hills Geothermal System. *Trans. GRC 2008 Vol 32*, 479-482.

Yousefi, H., Ehara, S. and Noorollahi Y. (2008) Air quality impact assessment of Sabalan Geothermal Power Plant Project, NW Iran. *Proc. 2008 Stanford Geothermal Workshop*.

Yousefi, H. and Ehara, S. (2008) Noise impacts assessment of Sabalan geothermal power Project, NW Iran. *Paper O-GT-010* In: *Renewable energy 2008 : international conference and exhibition, October 13-17, 2008* RE2008, Busan, Korea.

2.6 Websites Related to Annex I Work

- IEA Geothermal Implementing Agreement hosting seismicity protocol, sustainability reference list, etc.: http://www.iea-gia.org
- Website hosting the results of three IEA-GIA convened induced seismicity workshops, containing presentations and links to sources of information and data: http://esd.lbl.gov/EGS/

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Figure 2.5 Geometricas Hot Springs, Villarica, Southern Chile.

IEA Geothermal R & D Programme

Chapter 3

Annex III- Enhanced Geothermal Systems (EGS)

Habanero site in Cooper Basin, South Australia. (Photo courtesy Geodynamics Limited).

3.0 Introduction

Engineered (previously known as Enhanced) Geothermal Systems (EGS) technologies have been developed to extract the natural heat contained in high temperature rocks which are not associated with hydrothermal systems and not dependent on special geological conditions. There is significantly more energy available in the form of heat from the Earth which is not associated with hydrothermal energy and it is anticipated that EGS technology will allow the underground to be manipulated to extract the energy at commercially viable rates. Normally, EGS is associated with extraction of energy from water-poor rocks, in formations that are either too dry or too impermeable to allow extraction of available heat, but EGS knowledge of flow and stress can also be used to target permeable faults with abundant natural fluid flow to transport heat energy to the surface as at commercially viable rates. Once the heat energy has been extracted the fluid is re-injected into the formation to support the sustainability of fluid in the formation. The dominant technology involves high-pressure injection of a fluid, known as hydraulic stimulation which results in enhanced permeability of the existing fracture network. If necessary, pre-existing fractures can be jacked open to add to the reservoir permeability.

The objective of this EGS Annex is to address new and improved technologies, which can be used to access the huge heat resources present in the majority of the continental land masses by engineering heat exchangers at depth in order to allow the extraction of geothermal energy at commercially viable rates. This technology will bring in to play a significant worldwide geothermal resource to generate base load power and reduce environmental pollution. It will also help sustain hydrothermal systems through the use of re-injection, which is an EGS technology.

The countries and organizations that participated in Annex III in 2008 were: Australia, CanGEA, the EC, France, Geodynamics Limited, Germany, GG-APPA, Green Rock Energy, Italy, Japan, ORMAT Technologies, Spain, Switzerland and the USA.

The operating agent for the coordination for this Annex is Geodynamics Limited, Australia. The two Leaders of this Annex are Roy Baria (MIL-TECH, UK) and Doone Wyborn, of Geodynamics Limited, Australia.

3.1 Tasks of Annex III

Annex III has five Tasks, described below. Many of these Tasks were revised during 2007.

3.1.1 Task A- Economic Modelling

(Task Leader: Adrian Williams; Geodynamics)

Task A, which originally involved the evaluation of the economics of EGS systems, was successfully completed in 2001 and numerical models were generated by the US and other countries. However, it 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 application. New EGS projects are likely to take 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 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 the 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 market.

There is concern that financiers may be disenchanted with some of the optimistic claims made, 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. It is believed that this will 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 is the resource assessment, so that the market can compare like with like quantification of resource. A draft report has been prepared by the Australian Geothermal Association to address this aspect and is being reviewed. It is anticipated that this task will continuously evolve depending on the regional requirement, the strategic importance of the resource and economic viability.

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

3.1.2 *Task B- Application of Conventional Geothermal Technology to EGS*

(Task Leader: Joel Renner, Idaho National laboratory, USA)

This Task is aimed to modify conventional hydrothermal development technology, such as horizontal drilling, fracture detecting and mapping, and pumping, for application to EGS energy development. A coordinated list of actions was prepared to see how this can help the development of EGS. The list was circulated and discussions are continuing to see what can be feasible within the existing budget.

3.1.3 *Task C- Data Acquisition and Processing*

(Task Leader: Thomas Mégel, Geowatt, Switzerland)

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.

Access to past data and reports from various projects has always been a difficult task. The US DOE developed the "Legacy project", which allows access to some of the reports from previous EGS projects. This needs reinforcing with additional missing reports and a better search engine, with the latter needing refining or replacing. The implementation of a search engine previously developed by Geowatt under this task was considered at first but it had to be dropped due to lack of support. Alterative means are being considered to address this particular problem, such as by the common funded program, or the full program being funded by an organisation, joint consortium of partners, etc.

Access to all the data is still a major problem as some of it will have been lost or may be regarded as confidential. The data, which is available, ought 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 the wells
- Microseismic data: both located events and raw data
- Reports and papers

3.1.4 *Task D- Reservoir Evaluation*

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

The overall object 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. The plan is to define agreed procedures to test and evaluate the reservoir parameters so that they can be compared. Some of the procedures that could be standardized are:

- Well testing models
    - Before stimulation
    - For stimulation
    - For circulation
- Borehole measurements
    - Wellbore images
    - Temperature

- Flow
- Pressure

➢ Water management
- Open system
- Closed system
- Over pressured system

➢ Review of numerical methods
- Flac 3D
- uDec
- Geocrak
- FRIP
- Others

➢ Microseismic measurements
- Design of network and errors
- Automatic location of data
- Interpretation of data
- Quantification of stimulated area and hear transfer volume

➢ Tracer studies
- Selection of tracers
- Sampling, breakthrough time and modal volume
- Heat transfer area
- Identification of preferential paths
- Life of a reservoir

Work has started and some of the parameters have been defined for discussion. The work has progressed more slowly than anticipated on this task due to the demand of the task leader on the existing commercial EGS projects, but additional support is being considered and investigated.

3.1.5 Task E- Field Studies of EGS

(Task Leaders: Peter Rose, EGI University of Utah, USA and Albert Genter, EEIG and EC)

The objective of Task E is to conduct Enhanced Geothermal Systems (EGS) research and development 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, fluid flow modelling of hydraulic and chemical stimulation processes, tracer technologies and geophysical methods. This was a collaborative task between the EGS projects at Soultz-sous-Forêts (France) and Coso, California (USA).

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 things like 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 this requires updating and integration with the limited experience at the Soultz site.

The program at Soultz is preparing for a circulation test and power generation plant before some of these parameters can be tested and quantified. This is expected to be completed by the end of 2008. Discussion and cooperation on the defining of these tests are continuing.

3.2 Work Performed in 2008

Many of the Task activities were revised during 2007. As a consequence of reduced funding from various participating organizations, efforts on Task projects were much reduced. It is expected that this will pick up in 2009 as more funding is released.

3.2.1 Task A- Economic Modelling

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 has started and is continuing.

3.2.2 Task B- Application of Conventional Geothermal Technology to EGS

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 Geothermal Resources Council (2008) and the Stanford Geothermal Engineering Reservoir Workshop (2008). Further discussion and plans are being prepared to see how recent experiences from hydrothermal can be adapted to help EGS.

3.2.3 Task C- Data Acquisition and Processing

During the year 2008, 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 (see IEA-GIA website under http://www.iea-gia.org/geothermal_information.asp) is still being distributed at a cost 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.

3.2.4 Task D- Reservoir Evaluation

A final report of Task D activities was compiled, made available on CD-Rom and distributed to many IEA-GIA Members in 2006. The final report consists of two sections: "Circulation and Heat Extraction" and "Monitoring". Both sections include the essence of experience and knowledge which has been obtained at the Japanese Hijiori and Ogachi HDR fields.

This task is being restructured to define and find a way to quantify these parameters to suit economic evaluation and site comparison. The process has started and information is being put together. See the details list in the previous section.

3.2.5 Task E- Field Studies of EGS Reservoir Performance

As stated above, this Task was being re-designed during 2007; consequently, no other activity was pursued in 2008. The activities have been defined and are under discussion. The Soultz site is preparing for the installation of a power plant and circulation. It is anticipated that new data from Soultz will take a major part of 2009.

3.3 Work Planned for 2009

The changeover of the work program with the Operating Agent from NEDO, Japan (2007) to Geodynamics Limited, Australia, took longer than anticipated for various reasons including the restraint in the funding of EGS research and organisations. The new coordinating team is getting together the momentum required to get the program back on target.

Following these changes, there was an assessment of Annex activities; with the remainder of the year taken-up with the re-development of most of the activities.

3.4 Websites Related to Annex III Work

- Habanero project, Australia: http://www.geodynamics.com.au/IRM/content/default.htm
- Germany's Resources: http://www.tab.fzk.de/
- GeneSys-Project, Germany: http://www.bgr.de/
- Hijiori project, Japan: http://www.nedo.go.jp/chinetsu/hdr/hijiorinow/html
- Deep Heat Mining, Switzerland: http://www.dhm.ch
- EGS-PMDA promotion on: http://www.iea-gia.ch
- DOE technical projects: http://www.eere.energy.gov/geothermal
- EGS Program Review: http://www1.eere.energy.gov/geothermal/egs_prog_review.html
- Coso stimulation Project, USA: http://www.egs.egi.utah.edu
- Soultz European HDR Project: http://www.soultz.net/

3.5 References

GRC (2007) EGS Session. In: *Transactions Geothermal Resources Council 2007*, vol. 31, 265-327.

SGERW (2007) *32nd Workshop- Geothermal Reservoir Engineering*, Stanford University, USA.

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Annex VII- Advanced Geothermal Drilling Technology

Sandia high temperature seismic tool (courtesy Sandia National Laboratories).
(contact Joe Henfling for further information: jahenfl@sandia.gov)

4.0 Introduction

The objective of advanced drilling technology 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 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 cost 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 Technology Annex 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 technology

The objectives of the Advanced Geothermal Drilling Task 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 technology

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

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

Sandia National Laboratories (USA) is the Operating Agent for Annex VII. Stephen Bauer, from Sandia National Laboratories, is Annex Leader (sjbauer@sandia.gov).

Sandia-developed telemetry package being assembled into one of Novetek's wired pipe subs. (Courtesy Sandia National Laboratories)

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: Steven 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 costs, 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: Steven Bauer, Sandia National Laboratories (SNL), USA)

The participants plan to identify and catalogue the technologies that have been most successful for drilling, logging and completing geothermal wells. A complete Handbook will contain drilling practices for both direct use (low temperature) and electrical generation (high temperature) wells. The complete Handbook will eventually include, but not be limited to: 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: Steven 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.

Sandia-developed precision pressure/temperature well monitoring tool that was fielded downhole at the Coso geothermal site for about 1 year. (Courtesy Sandia National Laboratories)

4.2 Work Performed in 2008

4.2.1 General

The US DOE Geothermal budget was diminished significantly for 2008; therefore, activities by the Annex Leader were limited primarily to reporting.

- Reported to the 19th ExCo meeting
- Completed written Annex VII reports for the 19th and 20th ExCo Meetings
- Contributed to the 2008 GIA Annual Report
- Provided Annex VII revised descriptions for the Revised GIA Document

4.2.2 Review of Annex VII Meeting (Paris, France)

Annex VII met in Paris, France, on 16 April 2008. The following is an update of Annex VII activities presented and discussed at that meeting, and that which took place in the past 6 months.

Key Points from Meeting:

- All five active participants in the Annex were represented: Iceland, Mexico, New Zealand, European Commission, and the United States
- Australia joined the Annex during the meeting and agreed to actively participate in Tasks 1 and 2
- Each Task was discussed, with a view towards maintaining a substantive path forward

Task A- At the meeting, it was reported that cost data from Mighty River Power (6 wells (2006); CFE (13 wells) and Ormat (8 wells) in 2007 had been added to the accumulated dataset; no new well data had been added since, and work was suspended.

Task B- Work on the Drilling Handbook was suspended. The need to combine and merge input to the handbook was discussed. The potential input from the ENGINE effort was transmitted to the task leader by the EU.

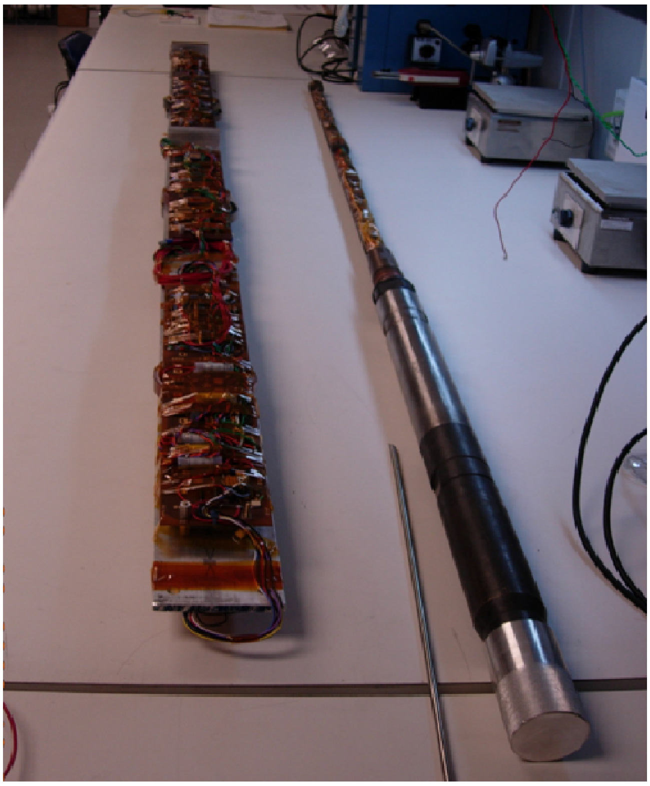
Task C- Requests for collaboration have been received, discussed, and information exchanged between principal investigators. Potential for technology sharing continues; collaborations with Australia were pursued, but were ultimately cancelled due to unsuitable downhole conditions.

The Annex VII meeting was extremely well attended, and participants included:

Barry Goldstein (Australia), Tony Hill (Australia), Adrian Larking (Australia), Andreas Piontek (EC), Zhonghe Pang (China), Roy Baria (England), Jonas Ketilsson (Iceland), Einar Gunnlaugsson (Iceland), Guðni Axelsson (Iceland), Lucien Bronicki (Ormat USA), Taufan Surana (Indonesia), Susan Petty (USA), Tubagus Nugraha (Indonesia), Yoonho Song (Republic of Korea), Mike Mongillo (New Zealand), Margarita de Gregorio (Spain), Amaya Lizaur (Spain), Carmen Roa Tortosa (Spain), Allan Jelacic (USA) and Jay Nathwani (USA).

4.3 Highlights of Annex Programme Work for 2008

Great interest in Annex VII activities has developed as judged by attendance at Annex VII meetings, and increased participation is anticipated.



Left- Preassembly of diagnostics-while-drilling (DWD) electronics; Right- Dewarless pressure/temperature tool. (Courtesy Sandia National Laboratories)

4.4 Work Planned for 2009

Increased participation in the Annex is being solicited and is anticipated.

Task A- The US will continue to solicit drilling performance/cost data from operators. The Annex VII participants will begin to discuss, assimilate and analyze information. Report will be made to the Executive Committee.

Output: A more comprehensive compilation of cost data received.

Task B- Develop full draft of the Handbook for review and comment to a limited set of reviewers.

Output: Report to Executive Committee.

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 2008

Publications for 2008 included:

Mansure, A. J. and D. A. Blankenship (2008) Drilling and completion technology for geothermal well cost analyses 2008, Sandia National Laboratories. *Geothermal Resources Council Transactions, Vol. 32.*

Raymond, David W., Y. Polsky, S. S. Kuszmaul, and M. A. Elsayed (2008) Laboratory simulation of drill bit dynamics using a model-based servo-hydraulic controller. *Journal of Engineering Resources Technology, ASME.*

Yarom Polsky, Louis Capuano Jr., John Finger, Michael Huh, Steve Knudsen, A.J. Mansure, David Raymond and Robert Swanson (2008) Enhanced Geothermal Systems (EGS) Well Construction Technology Evaluation Report. SAND2008-7866, Dec. 2008.

4.6 Websites Related to Annex Work

- Sandia geothermal programme: http://www.sandia.gov/geothermal
- National Renewable Energy Laboratory: http://www.nrel.gov/geothermal/
- ENGINE: http://engine.brgm.fr

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Chapter 5

Annex VIII- Direct Use of Geothermal Energy

Picture from Hveravellir nature pool in central Iceland. (Photo courtesy Einar Gunnlaugsson)

5.0 Introduction

Geothermal water has been used for various applications for thousands of years. The Romans, Chinese, and Native Americans used hot mineral springs for bathing, cooking and for therapeutic purposes. In earlier times the water was only used where geothermal water was in surface springs. During last decades, direct use of geothermal water has increased; and today, direct use of geothermal energy can be everywhere as the use of geothermal heat pumps have proved. Today, geothermal water is used for many applications that require heat, such as heating buildings, either individually or for whole towns; raising plants in greenhouses, drying crops, heating water at fish farms, snow melting and several industrial processes. To promote further direct use of geothermal water and to learn from each other, it was 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

The Contracting Parties who officially agreed to participate in this Annex as of the end of 2004 were: Iceland and Switzerland. In 2005, Japan, New Zealand, the USA and Korea confirmed their participation in the Annex, increasing the total participation to six countries. In 2007 France decided to participate in the Annex, but contact person was not appointed at that time. In 2008, Spain joined IEA-GIA and became a participant in Annex VIII. CanGEA and GG-APPA are also new participants, but because their GIA Membership was confirmed late in 2008, details of their involvement in the Annex have not yet been worked out. Non-GIA Members have shown interest in participating; however, the GIA is initially pursuing avenues for them to join the GIA before allowing participation.

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 Reykjavíkur.

5.1 Tasks of Annex VIII

Initially, five tasks were defined for this Annex, and work has started for four of these tasks. In 2007, it was decided to add a new task, Task F, dealing with publication and availability of data to be presented geographically on the web.

5.1.1 Task A- Resource Characterization

(Task Leader: Hirofumi Muraoka, National Institute of Advanced Industrial Science and Technology (AIST), 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).

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)

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 in parallel with Task B.

5.1.4 Task D- Equipment Performance Validation

(Task Leader: To be appointed)

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. Work in this task has not yet begun and no task leader has been appointed.

5.1.5 Task E- Design Configuration and Engineering Standards

(Task Leader: Ladsi Rybach, Geowatt, 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.

Mývatn Nature Baths. (Photo courtesy Einar Gunnlaugsson)

A new geothermal swimming pool in Tianjin, China.
(Photo courtesy Einar Gunnlaugsson)

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 between 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 2008

Two Annex VIII meetings were held in 2008, in connection with the ExCo meetings in Paris, France, and in Busan, Korea. The Busan meeting was held in connection with the Renewable Energy 2008 conference where members of the Annex VIII actively participated.

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. A paper was presented at the Renewable Energy 2008 conference in Busan:

Muraoka, H., Gunnlaugsson, E., Song, Y., Lund, J.W., Bromley, C.J. and Rybach, L.: Host rock controls to thermal water chemistry induced from the global comparison.

The Muraoka et al. paper will also be submitted to Current Applied Physics.

5.2.2 Tasks B and C- Barriers and Opportunities (Costa and Performance)

The *Questionnaire for Direct Use of Geothermal Energy* which was first developed in 2006, was revised and sent to more countries than the first one. The revision was focused on barrier and opportunity identification.

5.2.3 Task E- Design Configuration (Engineering Standards)

The collection of available information has begun and a list of references regarding published material is available.

5.2.4 Task F- Publication and Geographical Presentation on the Web

The aim of this task is to define 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. This method looks promising and future work will be to develop this method further. Minimum data which have to be collected to be able to show data in graphical information systems was listed for various applications.

5.3 Work Planned for 2009

5.3.1 Task A- Resource Characterization (Temperature and Chemistry)

Proposed next steps:

- Include data from other countries. The data will be evaluated similarly as other data
- Submit paper to Current Applied Physics based on the Busan paper
- Prepare paper to be submitted to WGC2010 in Bali
- Define how resource characteristics are affecting direct use of the recourses
- As an output for Task A until the end of the third term is to publish ***An Atlas of World Hydrothermal Systems*** that contains a variety of diagrams and maps

5.3.2 Tasks B and C- Barriers and Opportunities (Costa and Performance)

The questionnaire has been revised and further evaluation of the data collected will be performed. New participants to Annex VIII will be asked to complete the questionnaire, and information from other countries will be collected similarly. The new data will be compiled.

5.3.3 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 list available at the Web

5.3.4 Task F- Publication and Geographical Presentation on the Web

Proposed next steps:

- Guidelines regarding files for Google Earth and other geographical information systems
- Find best option to open web-page for the work regarding Annex VIII
- Try to get web-page on material selection related to the chemistry of water translated to English (Website: http://www.lagnaval.is)

5.3.5 Expected Outputs for 2009

- A simple standardized database will be identified that can be used to show the direct use applications by each of the participating countries
- Preparation of papers to be presented at the World Geothermal Congress 2010

5.4 Publications in 2008

Gunnlaugsson, E. (2008) Geothermal district heating in Reykjavík, Iceland. *Renewable Energy 2008, October 13-17,2008, Busan Korea.*

Gunnlaugsson, E. (2008) CO_2 saving by using geothermal energy for house heating in Iceland. Presented at the *Workshop for Decision Makers on Direct Heating Use of Geothermal Resources in Asia*, organized by UNU-GTP, TBLRREM and TBGMED, in Tianjin, China, 11-18 May, 2008.

Gunnlaugsson, E. (2008) Importance of chemistry in geothermal exploration and utilization. Presented at the *Workshop for Decision Makers on Direct Heating Use of Geothermal Resources in Asia,* organized by UNU-GTP, TBLRREM and TBGMED, in Tianjin, China, 11-18 May, 2008.

Gunnlaugsson, E. (2008) Permit process for geothermal development in Iceland. Presented at the *Workshop for Decision Makers on Direct Heating Use of Geothermal Resources in Asia,* organized by UNU-GTP, TBLRREM and TBGMED, in Tianjin, China, 11-18 May, 2008.

Lund, J.W. (2008) Direct heat utilization of geothermal resources. *Renewable Energy 2008, October 13-17, 2008, Busan Korea.*

Lund, J.W. (2008) Characteristics, development and utilization of geothermal resources. *Distinguished lecture course on geothermal development and utilization,* held in connection with *Renewable Energy 2008, October 13-17,2008, Busan Korea.*

Lund, J.W. (2008) Industrial applications. *Distinguished lecture course on geothermal development and utilization,* held in connection with *Renewable Energy 2008, October 13-17, 2008, Busan Korea.*

Lund, J.W. (2008) Examples of combined heat and power plants using geothermal energy. *Distinguished lecture course on geothermal development and utilization,* held in connection with *Renewable Energy 2008, October 13-17,2008, Busan Korea.*

Muraoka, H., Gunnlaugsson, E., Song, Y., Lund, J.W., Bromley, C.J. and Rybach, L. (2008) Host rock controls to thermal water chemistry induced from the global comparison. *Renewable Energy 2008, October 13-17,2008, Busan Korea.*

Rybach, L. (2008) The international status, development and future prospects of geothermal energy. *Renewable Energy 2008, October 13-17, 2008, Busan Korea.*

Rybach, L. (2008) Standard and innovative technologies for geothermal heat pumps- from small to large systems. *Distinguished lecture course on geothermal development and utilization,* held in connection with *Renewable Energy 2008, October 13-17, 2008, Busan Korea.*

Rybach, L. (2008) Importance of subsurface parameters in geothermal heat pump applications. *Distinguished lecture course on geothermal development and utilization,* held in connection with *Renewable Energy 2008, October 13-17, 2008, Busan Korea.*

Rybach, L. (2008) Success factors and environmental benefits of geothermal heat pumps- especially CO_2 emission saving. *Distinguished lecture course on geothermal development and utilization,* held in connection with *Renewable Energy 2008, October 13-17, 2008, Busan Korea.*

Rybach, L. (2008) CO_2 emission savings by using heat pumps in Europe. Presented at the *Workshop for Decision Makers on Direct Heating Use of Geothermal Resources in Asia,* organized by UNU-GTP, TBLRREM and TBGMED, in Tianjin, China, 11-18 May, 2008.

Rybach, L. (2008) How to advance geothermal heat pumps? The examples of Switzerland and the HYY single well system in China. Presented at the *Workshop for Decision Makers on Direct Heating Use of Geothermal Resources in Asia,* organized by UNU-GTP, TBLRREM and TBGMED, in Tianjin, China, 11-18 May, 2008.

Song, Y., Lee, Y., Kim, H. and Lee, T. J. (2008) Characteristics and development activities of geothermal resources in Korea. *Renewable Energy 2008, October 13-17, 2008, Busan Korea.*

Song, Y. (2008) Geothermal resources and development in the Republic of Korea. Presented at the *Workshop for Decision Makers on Direct Heating Use of Geothermal Resources in Asia,* organized by UNU-GTP, TBLRREM and TBGMED, in Tianjin, China, 11-18 May, 2008.

Yasukawa, K., Noda, T., Muraoka, H., Adachi, M., Matsunaga, I. and Ehara, S. (2008) A long-term prospect of geothermal energy use in Japan. *Renewable Energy 2008, October 13-17, 2008, Busan Korea.*

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National Activities

Chapter 6

Australia

Innamincka 1 MW Pilot Plant and Visitor Centre, Habanero, Cooper Basin, South Australia. (Photo courtesy of Geodynamics)

6.0 Introduction

Concern about climate change, rising costs of fossil fuels, and evidence of enormous hot rock resources are key factors stimulating growth in geothermal energy research (exploration), proof-of-concept (appraisal) and demonstration (pilot development) projects in Australia.

Since the grant of the first Geothermal Exploration Licence (GEL) in Australia in 2001 through year-end 2008, 48 companies have joined the hunt for renewable and emissions-free geothermal energy resources in 385 licence application areas covering ~360,000 km^2 in Australia (Figure 6a). This represents a 39% increase in applications in the last year, but leaves vast prospective areas still to be licensed (Figure 6b). The associated work programs correspond to an estimated investment of AUS$ 1,523 million (US$ 1,066 million; assumed exchange rate for this report is 0.7017) over the period 2002-2013 (a 79% increase since year-end 2007); and this excludes deployment projects assumed in the Energy Supply Association of Australia's scenario for 6.8% (~5.5 GWe) of Australia's baseload power sourced from geothermal resources by 2030. This progress follows encouraging geothermal drilling, temperature logging and flow testing programs in South Australia in the term 2004-2008, the dissemination of information that publicises the vast potential for Australia's geothermal resources, and the implementation of legislation to clarify investment frameworks to explore for and sell geothermal energy in a number of Australian jurisdictions.

Australia's geothermal resources that have considerable potential to fuel power generation fall into two categories: (1) Hot Sedimentary Aquifer (HSA) plays (e.g. hydrothermal groundwater resources) and (2) Hot Rock (HR) plays, including Hot Dry Rocks (HDR) and Hot Fractured Rocks (HFR) which are likely to be fluid saturated. Where geothermal reservoirs are enhanced with fracture and/or chemical stimulation, HR resources constitute EGS. Currently, the only geothermal energy being used in Australia emanates from a 120 kW geothermal energy plant located in Birdsville, Queensland that sources hot hydrothermal waters at relatively shallow depths from the Great Artesian (Eromanga) Basin.

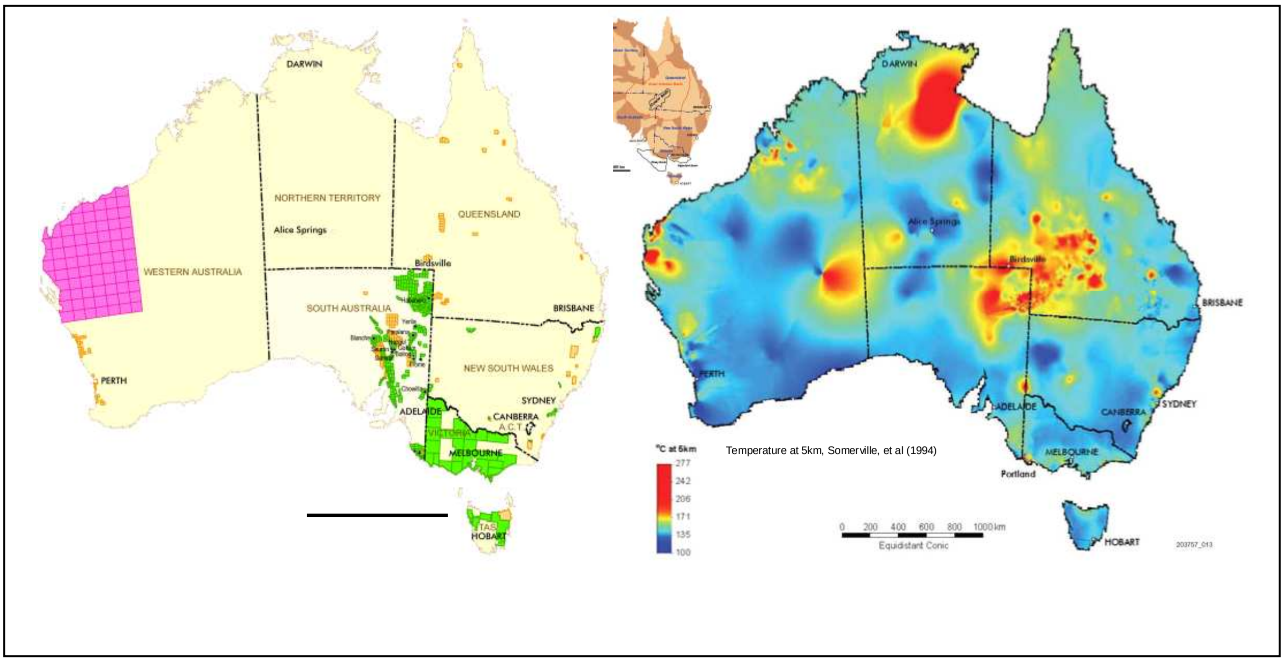


***Figure 6.1a** (left) Geothermal licences, applications and gazettal areas as at 31 December 2008 (see Appendix B for details).*
***Figure 6.1b** (right) Extrapolated temperature at 5km. This map is based on available, in places sparse, data. See Section 6.2 for details.*

Current investment to explore for, and demonstrate the potential of geothermal energy for power generation in Australia is focused on:

- HR EGS plays in the South Australian Heat Flow Anomaly (SAHFA) and the eastern half of Tasmania
- HSA plays in the Otway and Gippsland basins in the states of South Australia and Victoria.

Licences applied-for (and yet to be granted), and further applications are expected to expand investment in HR EGS and HSA plays across Australia in 2009.

A few companies are also focused on the deployment of direct use applications, including ground-sourced heat pumps.

In 2008, government grants from the Australian Federal, South Australian State and Queensland State Governments for geothermal energy projects totalled AUS$ 64.6 million (US$ 45.3 million). In the term 1 January 2000 - 31 December 2008, the Australian Federal Government has committed AUS$ 92.2 million (US$ 64.5 million) to foster progress towards commercialising geothermal energy resources and cognate technologies. Details of these awards are provided in Section 2d. This includes the AUS$ 50 million Geothermal Drilling Program (GDP) for meritorious proof-of-concept deep geothermal drilling and flow test projects. This excludes the AUS$ 300 million of Renewable

Energy Demonstration Program (REDP) (see: http://www.aph.gov.au/Library/pubs/RP/BudgetReview2009-10/Climate_Energy.htm) funding, designed to accelerate commercialisation and deployment of new renewable energy technologies for power generation in Australia. Additionally, the Australian Federal Government's five year funding (AUS$ 58.9 million) for an *Onshore Energy Security Program* (for details see: http://www.ga.gov.au/minerals/research/national/geothermal/index.jsp, or Budd et al., 2008) will enable the national geoscience and geospatial information agency (Geoscience Australia) to acquire precompetitive data and conduct research in support of geothermal energy exploitation. Geoscience Australia has consulted with industry, State and Territory governments and academic experts in developing its geothermal energy project plan.

Ten Australian geothermal projects have reached a drilling phase in the term 2002 to 31 December 2008. One additional project concluded magneto-telluric (MT) surveys in 2008 to define potential geothermal reservoirs partly intersected in pre-existing petroleum wells. These 11 projects are located in Figure 6.2. Appendix A provides a summary of the operations of 14 companies with joint venture equity in Australian geothermal drilling and/or geophysical survey and/or power production operations in the term 2002-2008.

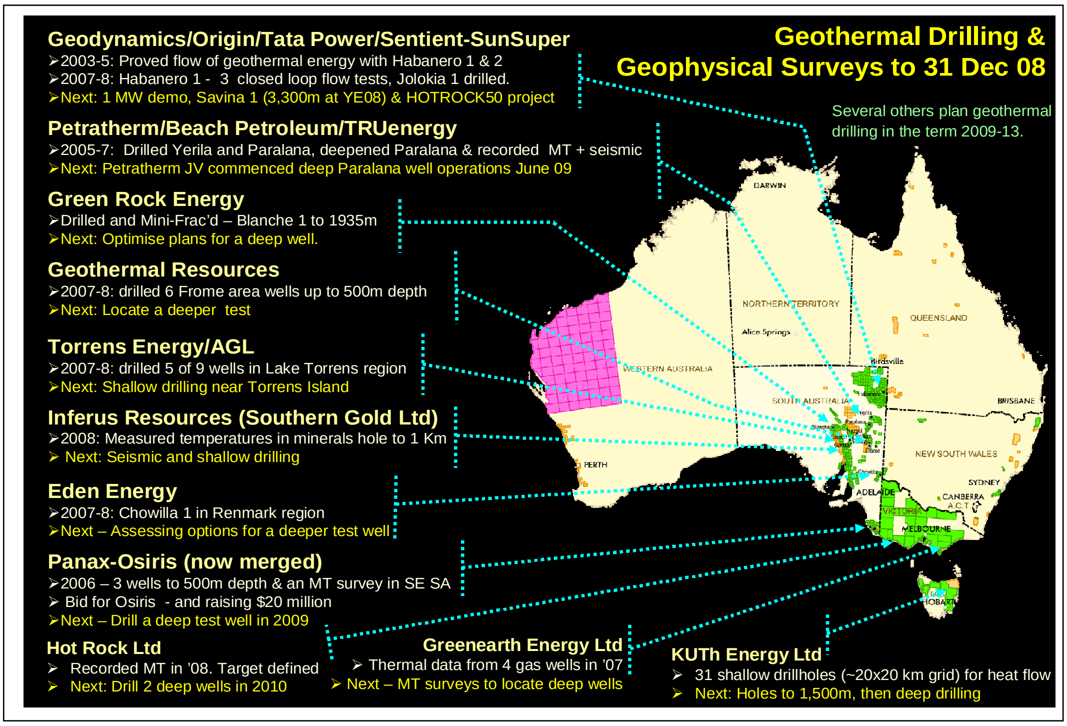


Figure 6.2 Geothermal drilling and downhole measurements to year-end 2008.

6.1 Highlights and Achievements

Highlights and achievements to the end of 2008 are summarised as follows:

- At year-end 2008, 48 companies have joined the hunt for renewable and emissions-free geothermal energy resources in 385 geothermal licence areas covering ~ 358,906 km² in Australia. This represents a 39% increase in geothermal licences in the last year. Most (272 or 71%) of the areas applied for are GELs covering 126,866 km² in the state of South Australia. The balance include: 27 Geothermal Exploration Permits (GEPs) applied-for in the state of Queensland, 23 Geothermal Exploration Permits (GEPs) awarded in the state of Victoria covering a total area of 162,000 km², 21 Exploration Licences (ELs) for geothermal exploration have been applied for in the state New South Wales; 36

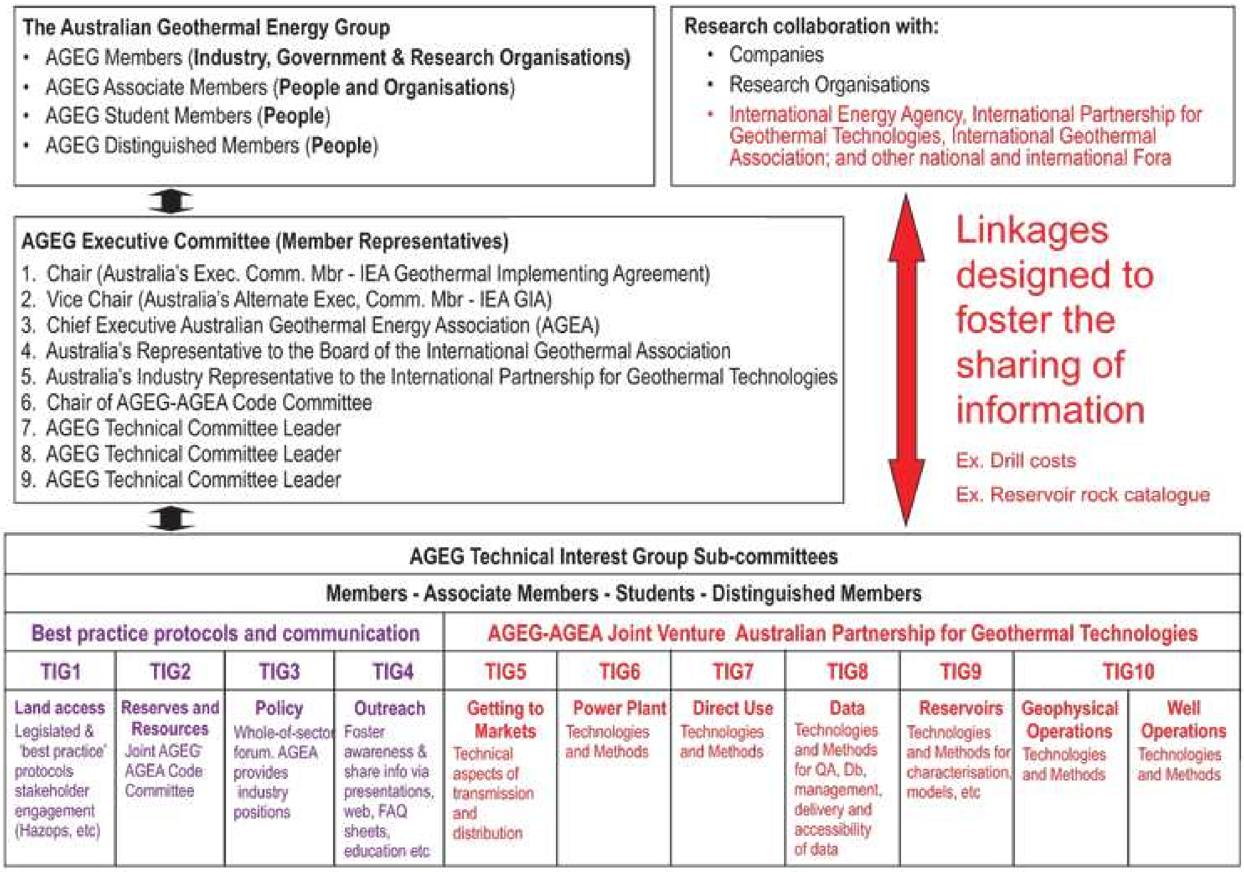
Geothermal Licences applied-for in Western Australia and 6 Special Exploration Licence (SEL) have been granted or applied for in the state of Tasmania.

- As at 31 December 2008, AUS$ 1,523 million (US$ 1,066 million) in work program investment is forecast for the period 2002-2013. Approximately AUS$ 325 million (US$ 227 million) of this forecast was invested in the term 2002-2008; 97% of which was spent in South Australia. This current forecast (for the term 2002-2013) represents an increase of AUS$ 671 million (US$ 470 million) over the forecast for the same period stated in the 2007 annual report. These forecasts exclude capital expenditure associated with demonstration power plants.
- Highlights in legislation and acreage release activity in Australia are summarised in Section 6.7.2.
- Drilling to test HR play concepts by geothermal licence holders was undertaken in 2008 by Geodynamics Limited, KUTh Energy Limited, Geothermal Resources Limited, Eden Energy Limited and Torrens Energy Limited.
- The Australian Federal Government's five year AUS$ 58.9 million Onshore Energy Security Program conducted by the national geoscience and geospatial information agency (Geoscience Australia) continued to acquire precompetitive data and conduct research in support of geothermal energy exploitation. Geoscience Australia has consulted with industry, State and Territory governments and academic experts in developing its geothermal energy project plan. A nation-wide resource inventory was calculated from the Austherm temperature at 5 km dataset of Chopra and Holgate (2005). This work suggests a total thermal energy in place between a lower base of 5 km depth and an upper limit of the depth at which 150°C occurs of 1.9 x 10^{25} PJ. A map was produced that categorises outcropping granites by their radiogenic heat production and includes thickness of sedimentary basins. This map works as a first-pass geothermal play map.
- In the term 2000-2008, Australian Federal and State grants totalling ~AUS$ 111 million (US$ 77.7 million) for geothermal research and exploration projects (detailed in Section 6.2.4). Highlights in 2008 are:
    - The Australian Federal Government committed AUS$ 50 million (US$ 35 million) for its GDP. The GDP will provide up to AUS$ 7 million (US$ 4.9 million) for proof-of-concept deep drilling projects on a $:$ basis to establish flow rates at a sufficient temperature to support either power generation or an industrial process. Additionally, the Australian Federal Government has committed AUS$ 300 million (US$ 210 million) from its REDP for meritorious, commercial-in-scale renewable energy demonstration projects. Separate budgets have been committed to support the demonstration of solar and carbon capture and storage technologies.
    - The NSW State Government has offered $10 million in matching funds for proof-of-concept drilling of a HR play in the Hunter Valley, NSW.
    - The West Australian State Government committed AUS$ 2.3 million (US$ 1.6 million) to establish a West Australian Geothermal Centre of Excellence as a joint venture with the University of WA, Curtin University and the CSIRO.
    - A Federal Government Renewable Energy Demonstration Initiative (REDI) AUS$ 2.3 million (US$ 1.6 million) grant was provided to KUTh Energy for its Tasmanian Tamar Conductivity Zone project.
    - The South Australian Government's continued support for the geothermal sector as contracting party to the IEA's GIA, secretariat for the AGEG, and providing AUS$ 550,000 (US$ 385,000) in grants for geothermal research projects.
- The Australian Geothermal Energy Group (AGEG) is the peak Australian whole-of-sector representative body for industry, research and government organisations interested in the use of geothermal energy. The AGEG provides financial and

intellectual support for Australia's membership in the IEA's GIA. The AGEG's vision is for geothermal resources to provide the lowest cost emissions-free renewable base load and direct-use energy for centuries to come. In the year to 31 December 2008, the AGEG increased from 65 to 92 member organisations including: an increase from 48 to 70 companies (including Australian licence holders and licence applicants and service companies); an increase from 8 to 11 Universities with geothermal research programs; and all Federal, State and Territory government agencies responsible for geoscience information provision, investment attraction and licence regulation for the geothermal sector. The organisational links of the AGEG and its Technical Interest Groups (TIGs) are illustrated in Table 6.1. The structure is devised to foster national and international sharing of information. The AGEG's membership is provided in Appendix D; for further information , see http:///www.pir.sa.gov.au/geothermal/ageg.

The AGEG's TIGs have active links to the International Energy Agency's (IEA's) research annexes, and will attain strong linkages to all other reputable international geothermal research clusters, to ensure that Australia's HR geothermal projects can leveraged on coordinated national and international expertise and geothermal research into improved technologies and techniques.

Table 6.1 *The organisational structure for the Australian Geothermal Energy Group (AGEG) and its Technical Interest Groups are designed to foster national and international sharing of information.*



➢ Since forming in November 2007 from the AGEG's Technical Interest Group for Policy, Australia's peak geothermal industry association – the Australian Geothermal Energy Association (the AGEA) has grown to have 23 company members. The aim of the AGEA is to realise the potential for geothermal energy to provide both:

- A low-cost, emissions-free baseload of reliable and secure energy for the Australian national market over the next decade; and
- A reliable, low-cost source of heat to drive energy efficiency and industrial applications.

AGEA and its members work with all Australian Governments, the academic community, relevant scientific organisations and the media to promote information about the progress of the industry and its capabilities. All members of the AGEA are also members of the AGEG.

- The AGEA and the AGEG have agreed to:
  - Coordinate research through the AGEG's 10 Technical Interest Groups (TIGs)
  - Designate TIG 2 as the AGEG-AGEA Reserves and Resource Code Committee. The purpose of this joint committee is develop and sustain an evergreen code for the reporting of geothermal exploration results, geothermal resource estimates and geothermal reserve estimates
  - Designate AGEG as the Australian affiliate for the International Geothermal Association
  - Designate the Chief Executive of AGEA as the Chair of the AGEG's TIG for Policy, to assure industry's leadership in providing advice to government in relation to legislation, policies and programs
- The Australian Federal Government's Geothermal Industry Development Framework was instigated in March 2007, and was published in December 2008 (GIDF; for more information see: http://www.ret.gov.au/energy/clean_energy_technologies/energy_technology_framework_and_roadmaps/geothermal_industry_development_framework_and_technology_roadmap/Pages/GeothermalIndustryDevelopmentandTechnologyRoadmap.aspx). The GIDF sets out to identify the challenges for the Australian geothermal sector and to recommend actions, including high level national and international alliances, to encourage the development of a viable geothermal energy industry. The GIDF has been developed in parallel to a Council of Australian Government (CoAG) Technology Roadmap for the development of Australia's geothermal energy resources and technologies which was also released in December 2008. The Technology Roadmap has identified technology and research needs for the pre-competitive demonstration and subsequent development of geothermal energy resources. These initiatives follow the Australian Government's 2004 White Paper, Securing Australia's Energy Future, which classified hot dry rocks as a technology in which Australia had comparative advantages. Government support for geothermal exploration (research), appraisal (proof-of-concept) and demonstration projects manifest the view that geothermal energy has potential to contribute significantly to Australia's baseload electricity supplies, without generating greenhouse gas emissions. Initial drilling results indicate that Australia's HR resources are amongst the best in the world for the development of EGS.
- Significant opportunities for the direct use of geothermal energy are gaining recognition, in parallel to growth internationally in the deployment of direct use applications. In particular, ground-sourced geothermal heat pumps, circulating hot water for heating and drying applications, and the use of geothermal steam for osmotic desalination are forms of direct use that hold material potential for deployment in Australia.

6.2 National Policy

6.2.1 Strategy

When invited to provide advice to the Australian Federal Government in March 2007, the Australian geothermal sector articulated the following vision and milestones, and since that time, strong bi-partisan support has been provided to support the attainment of the milestones at both Federal and State government levels:

Vision: Geothermal power as safe, secure, reliable, competitively priced, emissions-free and renewable base load power for centuries.

Milestones for the Vision – Geothermal Energy Roadmap:

- Several successful research (exploration) and proof-of-concept (heat energy is flowed) geothermal projects. At least 10 by 2010.

  Status at 31 December 2008: Three locations (Habanero, Jolokia and Savina) have been drilled in the Cooper Basin, and Australian Federal Government GDP grants to be determined in 2009 will provide funding to support proof-of-concept projects at an additional seven locations.

- Several geothermal power generation demonstration projects in distinctively different geologic settings. At least 3 by 2012.

  Status at 31 December 2008: Proof-of-concept was essentially attained at Habanero. At least 3 companies are expected to apply for support from the Australian Federal Government's REDP program to demonstrate geothermal energy production at commercially significant scales

- Compelling success with geothermal power generation demonstration so the investment community is convinced geothermal energy is real. By 2012.

  Status at 31 December 2008: The proponents of the most advanced geothermal projects in Australia have plans to progress to commercial scale deployment by circa 2015+, based on compelling evidence from earlier demonstration scale projects

- Safe, secure, reliable, competitively priced, renewable and emissions-free base load power from geothermal energy for centuries to come. At least 7% of base-load demand from hot rock power by 2030.

  Status at 31 December 2008: The proponents of the most advanced geothermal projects in Australia have plans to progress to commercial scale deployment by circa 2015+, based on compelling evidence from earlier demonstration scale projects

A continuing strategy for both the AGEG and AGEA is to foster awareness of the realistic potential benefits that will flow from the widespread use of geothermal energy. In this regard, the AGEA and the AGEG continue to provide advice as participants in the Reference Group for the implementation of the Australian Federal Government's GIDF which incorporates the CoAG Roadmap for Geothermal Technologies. Also, in 2008 the AGEG made a submission to the Garnaut Climate Change Review (download from: http://www.pir.sa.gov.au/__data/assets/pdf_file/0010/71389/AGEG_Submission_Garnaut_4April08.pdf)

The AGEA made submissions as follows:

Subject of Submission	Web Reference to Download Submission
Garnaut Climate Change Review	http://www.agea.org.au/media/docs/agea_submission_garnautreview.pdf
National Renewable Energy Target Scheme	http://www.agea.org.au/media/docs/national_ret_submission.pdf
Review of Energy Market Frameworks in light of Climate Change Policies	http://www.agea.org.au/media/docs/aemc_scoping_paper.pdf http://www.agea.org.au/media/docs/aemc_scoping_paper.pdf

The AGEA also commissioned a report "Installed capacity and generation from geothermal sources by 2020" (AGEA, 2008), to estimate the future electricity generation capacity of geothermal energy in 2020 and the price. The report highlights the potential of the Australian Geothermal Industry to make a significant contribution to Australia's future energy needs, with a forecast of 2200 MW baseload capacity by 2020 under current policy settings.

6.2.2 Legislation and Regulation

To end 2008, six states (New South Wales, Queensland, South Australia, Tasmania, Victoria and Western Australia) have legislation in place to regulate geothermal exploration and development. The Northern Territory expects to have legislation in place by mid-2009. Relevant legislation is summarised below.

6.2.2.1 South Australia

The *Petroleum Act 2000* covers licensing and activity approvals for upstream petroleum, geothermal, gas storage and petroleum pipeline projects. The Petroleum Act has recently undergone a review and amendment process and will be renamed the Petroleum and Geothermal Energy Act 2000. A paper outlining proposed amendments to the *Petroleum Act 2000* closed for public comment on 29 June 2007. The Petroleum (Miscellaneous) Amendment Bill 2008 was released in April 2008 for public consultation. The intended changes will increase the maximum size of geothermal licences to 3,000 km² and lower licence fees. It is expected that the *Petroleum and Geothermal Energy Act, 2000* will be enacted in 2009 (see: http://www.austlii.edu.au/au/legis/sa/consol_act/pa2000137/).

The number (136 to 273) and extent (62,182 km² to 126,866 km²) of Geothermal Exploration Licenses in South Australia increased by more than 100% in 2008.

6.2.2.2 Victoria

The *Geothermal Energy Resources Act* (GER Act) was passed in April 2005 and the *Regulatory Impact Statement and Geothermal Energy Resources Regulations 2006* came into effect during 2006. See: http://www.austlii.edu.au/au/legis/vic/consol_act/gera2005297/

The GER Act aims to encourage large-scale commercial and sustainable exploration and extraction of Victoria's geothermal energy resources. It does not apply to small-scale extraction operations or to exploration or extraction where the target in situ resource is less than 70 °C temperature or less than 1 kilometre below the surface.
To facilitate the development of these potential resources, the Victorian Department of Primary Industries conducted a public tender process for Geothermal Exploration Permits (GEP). A total of 5 companies accepted offers over 12 separate GEPs in 2007. These permits cover 73,000 km² in southern Victoria, with the companies committing over $64 million in expenditure over the five year term of the permits.

The number (12 to 23) and extent (74,000 km² to 162,408 km²) of GEPs in Victoria increased by 92% and 120% respectively in 2008. This followed bidding in April 2008 on 19 permits, covering 154,000 km². In December 2008, 11 GEPs were awarded over an area of almost 90,000 km² to three companies. A further eight geothermal acreage areas remain unallocated in Victoria. These areas are likely to be offered for tender again at a later date as the geothermal industry in Victoria gains momentum.

6.2.2.3 New South Wales

The *Mining Act, 1992*, governing geothermal exploration in New South Wales is on its final review stage for a bill amendment. Currently geothermal exploration is considered Group 8 -Geothermal Substances. Application for a Group 8 geothermal exploration licence requires the Minister's consent especially if it is under mineral allocation areas, usually within coal basins. In other areas of the state over the counter applications are still accepted. If successful, a maximum 5-year term is granted based on work program commitments. See: http://www.austlii.edu.au/au/legis/nsw/consol_act/ma199281/

In the last year, six Group 8 ELAs were received and all were granted titles. Two ELs have been renewed and ten Group 8 EL applications are currently under review.

NSW Department of Primary Industries is continuing its state wide geothermal resource assessment and data compilation. The Sydney Basin Geothermal data package has been completed and the Gunnedah Basin Geothermal package will be released shortly. New South Wales will be introducing a tender process for geothermal exploration licences for Sydney Basin.

Geodynamics received a $10 million grant under the NSW Climate Change Fund Renewable Energy Development Program to accelerate the exploration and development of its resource in the Hunter Valley.

6.2.2.4 Queensland

The *Geothermal Exploration Act 2004 and Geothermal Exploration Regulation 2005* provides a competitive permit system to encourage and facilitate efficient and responsible exploration for the State's geothermal resources. See:
http://www.legislation.qld.gov.au/LEGISLTN/CURRENT/G/GeoExpA04.pdf

In 2008, the Queensland Government continued work aimed at expanding the scope of the current regime. The development of a proposed Geothermal Energy Bill to facilitate and promote the responsible management of both geothermal exploration and production activities is currently well advanced.

27 Geothermal Exploration Permits (GEP) covering over 15,461 km^2 have been offered to applicants following two highly successful acreage releases in late 2007 and mid 2008. GEP-17 was granted to Granite Power Limited on 1 June 2008 for a period of four years. Remaining high-bid applications are progressing through necessary approval processes.

There were no calls for tender in 2008 with planning for a call for tenders in 2009 being well advanced.

6.2.2.5 Tasmania

Geothermal exploration and development has been covered for over a decade by the *Mineral Resources Development Act* (1995) (MRD Act) and using this tried legislation, exploration has been able to be conducted with little regulatory impediment or uncertainty. See:
http://www.austlii.edu.au/au/legis/tas/consol_act/mrda1995320/ .

The MRD Act operates an "over the counter" system, where explorers can apply for those areas wanted to be explored, and these co-exist with existing or future minerals and petroleum exploration titles. Geothermal tenements are granted as "Special Exploration Licences" (SEL) which have cheap annual rentals and cover large areas. Initial grant is for 5 years, with annual reviews determining work programmes and mandated expenditures. An SEL can be renewed for an additional 5 years at the discretion of the Minister.
The MRD Act in its present form would allow a geothermal play to come into production via a Mining Lease but this is viewed as being impractical, due to the likely large size and exclusion of other resources exploration, and geothermal production aspects of the Act are currently under review.

To the end of 2008, 5 SELs for geothermal substances had been granted, totalling 22,663 km^2. See http://www.mrt.tas.gov.au .

6.2.2.6 Western Australia

The West Australian (WA) *Petroleum and Geothermal Energy Resources Act 1967* (PGERA67) was proclaimed on 15 January 2008, providing legislative coverage for both conventional (hydrothermal) geothermal energy and hot dry rock geothermal energy. The legislation provides a clear legal framework for companies to pursue large-scale geothermal energy projects in the State.

The PGERA67 is under the portfolio of the Minister for Resources and will be administered by the Petroleum and Royalties Division of the Department of Industry and Resources (DoIR).

Western Australia had two open gazettal releases for geothermal exploration acreage during 2008 leading to bids for 46 areas covering some 75,500 km^2. Permits will be offered to 12 different companies during the first half of 2009. Three acreage releases are planned for 2009, including the re-release of the Perth area, the southern/eastern region and late in 2009 the interior/northern region.

6.2.2.7 Northern Territory

The Northern Territory of Australia Geothermal Energy Act 2009 has been passed and assented to and is expected to come into operation in mid-August 2009. The NT Government is in the process of developing the Regulations, Forms and Guidelines prior to triggering the Act. The intent is to reserve a relatively small region around the Katherine area, for later tendered release, while providing for "over-the-counter" application for geothermal authorities over the remainder of the Territory. To view the legislation, visit: http://notes.nt.gov.au/dcm/legislat/Acts.nsf/830a91a0fb6c1fed6925649e0009c237/3049cc0938e9139a6925750e000a0a4c/$FILE/Actg013.pdf

6.2.3 Progress Towards National Targets for Renewable Energy and Emissions

In 2008, the Australian Government initiated development of a comprehensive set of policies and programs to support the development of renewable energy technologies in Australia which the geothermal sector will also benefit from. In addition, several initiatives were put in place specifically to support the geothermal industry.

Through the expanded Renewable Energy Target (RET), the Australian Government's goal is to have at least 20 per cent of Australia's electricity supply coming from renewable energy sources by 2020. This will provide a cross-subsidy to the renewable energy sector worth many billions of dollars. The Australian Government's modelling shows that by 2020, geothermal projects could take up one fifth of the target, or around 10,000 GWh.

The Government is also moving to meet its long-term national emissions reduction target of 60 per cent below 2000 levels by 2050, through the introduction of the national Carbon Pollution Reduction Scheme (CPRS). Together with the RET, the CPRS will provide a very strong incentive for investment in renewable energy.

These policy initiatives are supported by two new funds: the $500 million Renewable Energy Fund and the $150 million Energy Innovation Fund. These funds should stimulate over $1.5 billion investment in renewable energy generation and are discussed in Sections 6.2.4 and 6.4.1.

6.2.4 Government Expenditure on Geothermal Research and Development

A total of AUS$ 111 million (US$ 77.7 million) in Australian Federal and State grants have been committed to support Australian geothermal research, exploration and proof-of-concept projects for the period 2000 to end December 2008 (Appendix C). This tally excludes the AUS$ 300 million (US$ 210 million) committed to support up to one-third of the costs of meritorious, non-solar demonstration projects under the Federal Government's REDP; the AUS$ 72 million (US$ 50.4 million) State of Victoria's Energy Technology Innovation Strategy (DPI, 2008); as well as support from Australian Renewable Energy Certificates (ORER, 2008); and Australia's emissions cap and trade scheme (DoCC, 2008), all of which will be described in more detail in the following sections.

6.2.4.1 Federal Government

The Australian Federal government has committed AUS$ 51.8 million (US$ 36.3 million) in grants for industry-backed, geothermal exploration and proof-of-concept projects in 2008. The majority (AUS$ 50 million or US$ 35 million) of that commitment takes the form of the GDP that will be dispersed in 2009. A total AUS$ 82.1 million (US$ 57.5 million) in Federal Government grants has been committed to underpin meritorious, industry-backed geothermal projects in the term 2000-2008. Descriptions of these grant programs are outlined in Section 6.4 (under Support Initiatives and Market Stimulation Incentives) and in Appendix C.

Renewable Energy Fund (REF): Details of the REF are provided in Section 6.4.1.

Energy Innovation Fund (EIF): The $150 million EIF was announced in 2008 to provide $100 million through the Australian Solar Institute to support research and development in solar energy technologies. The Australian Solar Institute will be launched in January 2009 and the interim management is developing guidelines for grant programs. The EIF will also provide $50 million for the Clean Energy Program (CEP) to support other clean energy research and development, including energy efficiency, energy storage and hydrogen. The Department of Resources, Energy and Tourism is currently developing guidelines for the CEP.

Geothermal Industry Development Framework and Geothermal Technology Roadmap: On 1 December 2008, the Minister for Resources, Energy and Tourism, Martin Ferguson, released the Geothermal Industry Development Framework (GIDF) and the Geothermal Technology Roadmap, joint efforts between industry, researchers and governments to identify the key challenges facing the geothermal industry in Australia, and actions to overcome these challenges.

The GIDF has been developed jointly by the Australian Department of Resources, Energy and Tourism and the AGEA. The Framework maps out a development path for Australia's geothermal industry and is designed to accelerate the development of geothermal energy in Australia. It contains 10 recommendations, each accompanied by several suggested strategies.

The GIDF recommendations include the following.

- Attracting investment
- Gathering geoscientific data
- Developing networks and international linkages
- Progressing research and development
- Building human capacity in the field of geothermal

The Geothermal Technology Roadmap, which was requested by the Council of Australian Governments, is part of the GIDF and identifies technology requirements for the geothermal sector throughout the geothermal project development process, from surface exploration to drilling to power plant construction and dealing with environmental issues.

The Roadmap makes recommendations for high priority technology needs, suggesting that key issues are for industry to demonstrate proof of concept by establishing circulation of geothermal fluids between wells in different geological settings, and to establish proof of concept power plants. The GDP (see above) already addresses this issue. Other priority technical needs include improving well technologies including fracture stimulation, geoscience to better understand Australian conditions, and power plant technologies including cooling in hot, arid climates.

The Roadmap proposes a collaborative approach to addressing these technology needs, drawing on expertise existing in the Australian geothermal industry, in other industries, particularly the electricity and oil and gas sectors, internationally, and in research institutions. Government leadership is suggested where agencies have required expertise, particularly pre-competitive geoscience data.

The GIDF and the Geothermal Technology Roadmap can be accessed at the homepage of the Department of Resources, Energy and Tourism, at www.ret.gov.au.

Australia's Onshore Energy Security Program: A part of the Federal Government's AUS$ 58.9 million (US$ 41.2 million) funding over five years for Australia's Onshore Energy Security Program (OESP) will be directed towards the advancement of geothermal energy projects. This program is discussed in greater detail in Section 6.7.2. Approximately AUS$ 1,000,000 from this program has been spent directly on geothermal projects (including salaries) up until December 2008 and it is expected that a further AUS$ 300,000 will be spent in 2009.

6.2.4.2 States and Northern Territory Governments

South Australia: A total of AUS$ 1.6 million (US$ 1.1 million) in South Australian Plan to Accelerate Exploration (PACE) drilling and other research grants has been provided to underpin the advancement of geothermal energy projects since July 2004 (Appendix C). Two grants of AUS$ 100,000 each were awarded to Petratherm Ltd and Torrens Energy Ltd in February 2008. PACE grants assist in addressing critical uncertainties in frontier geothermal exploration regions and include partial funding of shallow drilling, temperature logging and thermal conductivity analyses. The South Australian Government also continues to provide the secretariat for the AGEG and is the Contracting Party to the IEA's GIA for Australia. Research projects supported by the South Australian government are summarised in Section 6.7 herein.

Western Australia: Leveraging on studies concluded in 2007, the Department of Industry and Resources, Geological Survey has enabled easy access to onshore petroleum well log data and headers, including bottom hole temperatures and data necessary to estimate equilibrium geothermal gradients in the Perth, Canning and Carnarvon Basins. Further temperature data was gathered from water bores in the Perth Basin and more water bore data will be collected for the other sedimentary basins in 2008. These data will provide the basis for further studies.

The Geological Survey has also collected seismic, magnetic and gravity data for the Perth Basin and produced a combined well and geophysical survey data package to assist companies in assessments of the areas offered for work program bids in 2008.

In March 2008, the Western Australian Government committed $2.3 million for a grant to establish the Western Australia Geothermal Centre of Excellence (WAGCOE), a partnership between the University of WA, Curtin University and the CSIRO, to foster geothermal research into low-grade (up to 130°C) heat in permeable sedimentary settings such as the Perth Basin.

New South Wales: In 2007, as part of its New Frontiers initiative programme, the NSW Department of Primary Industries, Petroleum Geoscience Group initiated a project focused on mapping and identification of prospective geothermal energy systems. A suite of scientific data such as: granite geochemistry, potential field data, heat flow units, bottom-hole temperatures from petroleum wells have been compiled and presented as an ArcGIS project and forms the main portion of a comprehensive geological and geophysical database called "The Sydney Basin Geothermal Data Package". This is a first geothermal data package prepared by the New South Wales Department of Primary Industries and was released in 2008. A Gunnedah Basin geothermal data package is the next planned similar work to be concluded.

Tasmania: In 2006, Mineral Resources Tasmania launched its four year TasExplore initiative, which incorporates the acquisition of gravity and airborne magnetics and radiometrics, upgrading of the geology on north and northeast Tasmania and upgrading the 3D Geological Model of Tasmania. In focussing on the east and north-east granite terrain of Tasmania, this work will advance the understanding of the state's geothermal province.

Queensland: Under its Renewable Energy Plan (see: http://www.cleanenergy.qld.gov.au/zone_files/Renewable_Energy/oce_rep_11_web_final.pdf) the Queensland Government has taken a number of steps that support the wider use of geothermal energy; included are:

- $4.3 million committed to Ergon Energy for the new Birdsville Geothermal Power Station. The project will replace existing plant that is reaching the end of its design life with more efficient equipment that will use the existing wet geothermal resources more efficiently, producing more energy from these hydrothermal resources.

- The Coastal Geothermal Energy Initiative (CGEI) is a $5 million drilling program that will build on existing geological data in Queensland. Its aim is to identify HR resources close to existing electricity transmission lines and population centres.
- The release of legislation covering geothermal energy production in 2009.
- An investigation of steps needed to commence a pilot geothermal project in Queensland by 2014.
- Starting to map geothermal resources in Queensland in 2009.
- The provision of $15 million to establish the Queensland Geothermal Energy Centre of Excellence (QGECE) at the University of Queensland. The QGECE will establish a critical mass of scientific and engineering expertise providing the potential for development of large scale, zero emission geothermal power generation. The QGECE which will officially launch in 2009.

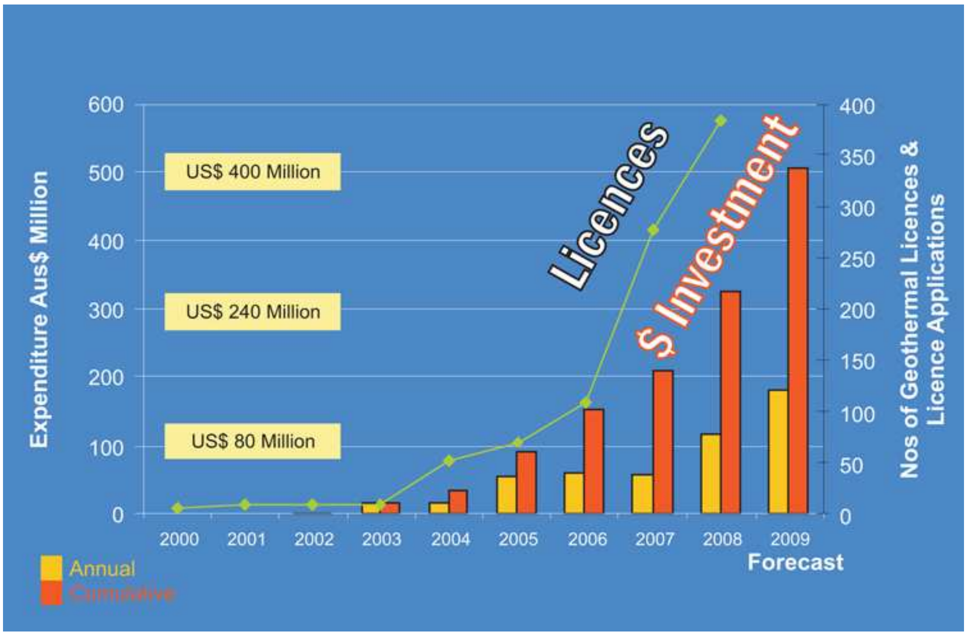


Figure 6.3 Growth in Australian Hot Rock and Hot Sedimentary Aquifer projects since 2000. Geothermal licence applications and exploration expenditure, 2000 to 2008 actuals and the forecast for 2009. (Source: PIRSA)

6.2.5 Industry Expenditure on Geothermal R&D

Australian geothermal industry field expenditure is classed as research and totalled AUS$ 116 million (US$ 81.2 million) for the year 2008. This represents a 103% increase of AUS$ 59 million (US$ 41.3 million) from the previous year. A 156% increase to AUS$ 182 million ($US127.4 million) is forecast to be expended in 2009. Historical, current and projected expenditure for 2009 are highlighted in Figure 6.3.

6.3 Status of Geothermal Energy Use in 2008

6.3.1 Electricity Generation

Geothermal energy is currently produced at one small binary power station at Birdsville in western 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) that overlies the Cooper Basin. The water is run through a gas filled Organic Rankine cycle heat exchanger which heats and pressurises the gas which drives a turbine and alternator to produce electricity. The partly cooled water is channelled into a pond for further cooling and reticulation into the town's water supply and the lagoon. The gross capacity of the plant is 120 kW and the plant power consumption is 40 kW, which equates to a net output of 80 kW.

Total power generation in 2008 was 2,001,757 kWh of which 768,542 kWh was provided by the geothermal power plant. This equates to 38% of total power output.

In late 2007 Ergon Energy completed a feasibility study into whether it could provide Birdsville's entire power requirements and relegate the existing LPG and diesel-fuelled generators to be used only as a back-up at peak times such as the annual Birdsville races which attract large crowds for several days. In response to Ergon Energy's 2008 application for funding to replace the aging plant, the Queensland Government has committed $4.3 million for this purpose. For more information, visit: http://www.ergon.com.au/network_info/isolated_and_remote_power_stations.

6.3.2 Direct Use

6.3.2.1 Installed Thermal Power

Australia's total installed capacity in direct geothermal applications is estimated to be 130 MW_{th}. This is up from the 2005 estimate of 109.5 MW_{th} (Lund et al., 2005).

6.3.2.2 Thermal Energy Used

Following Lund et al. (2005) with a capacity factor of 0.9, the thermal energy used is estimated to be 3,672 TJ/year, up from the 2005 estimate of 2,968 TJ/year.

6.3.2.3 Category Use

District heating (space heating) constitutes the majority with an estimated 98 MW_{th}. Bathing and swimming installations total 8 MW_{th}. Ground Source Heat Pumps (GSHPs) constitute the remaining 24 MW_{th}. The GSHP installations include over 300 residence and several commercial sites. See Chopra (2005) and Appendix E for an abridged list of significant sites.

6.3.2.4 New Developments During 2008

Red highlight = same as 2007, so no new developments in 2008, so delete this section or indicate nothing new.

The AGEA was founded late in 2007 to represent Australian Geothermal power generation and direct use industries. For direct use geothermal applications including GSHPs, AGEA is calling for government incentives and rebates. Any progress here will substantially increase uptake of GSHPs. Regional Development Victoria launched the Four Seasons Pilot Program which funds up to 50% of commercial and 100% of public GSHP installations in regional areas without a natural gas supply. Further, Sustainability Victoria is funding 20% of some commercial, innovative Direct Use installations through the Renewable Energy Support Fund (RESF).

New direct use installations include a resort in Warrnambool which uses 45°C water drawn from a bore approximately 770 m deep with a flow rate of up to 50 l/s to provide domestic hot water, space heating, and pool and spa heating to a 122 room tourist facility. The estimated thermal capacity is 0.2 MW_{th} or 5.6 TJ/year. This project can abate up to 412 tonne CO_2-eqivalent/year.

GSHPs can be broken into subcategories: water-loop and refrigerant-loop or Direct Exchange (DX). Over the last two decades, only water-loop district heating and GSHPs have been installed in Australia. Over the last couple of years, DX GSHPs have been introduced to Australia. DX GSHPs are generally more viable for the residential and small-commercial markets: instead of 15-cm wide, 100-metre deep bore holes (as required for water-loop systems), only 5-7 cm wide, 15 - 30-metre deep bore holes are required, substantially reducing the drilling cost. There are now ten DX GSHP installations in Victoria with a total capacity of roughly 0.3 MWth. These include seven residences, a factory, council offices, and a ski chalet.

6.3.2.5 Rates and Trends in Development

In the face of increasing public and political will to act on climate change, rising energy prices, and an emerging GSHP industry, it is expected that the installation of GSHPs will accelerate.

6.3.2.6 Number of Wells Drilled

No new wells were drilled in 2008.

6.3.3 Energy Savings (Direct Use)

6.3.3.1 Fossil Fuel Savings/Replacement

The estimated fossil fuel savings is 87,440 tonne of oil equivalent (toe), with 1 toe = 42 GJ).

6.3.3.2 Reduced/Avoided CO_2 Emissions

Using the DTI/Carbon Trust/DEFRA/Ofgem recommended figure of 0.43kg CO_2 per kWh saved yields avoided emissions of CO_2 of 439 kilotonne/year.

6.4 Market Development and Stimulation

6.4.1 Support Initiatives and Market Stimulation Incentives

There are a number of Federal and State government support initiatives designed to support and accelerate commercialisation of renewable energy technologies and R&D in general including geothermal energy. For information of earlier programs that are no longer active or have been superseded including the START program, the Greenhouse Gas Abatement Program (GGAP), the Renewable Energy Commercialisation Program (RECP), Low Emissions Technology Demonstration Fund (LETDF), the Low Emissions Technology and Abatement initiative (LETA; see: http://www.environment.gov.au/settlements/programs/leta/index.html) and the Renewable Energy Equity Fund (REEF), please see Chapter 7 in the IEA-GIA Annual Report 2007 (IEA-GIA, 2007). The following are current Federal and State government support initiatives.

6.4.1.1 Renewable Energy Certificates (RECs)

The MRET Scheme operates through a system of tradable RECs that are created by renewable energy generators at the rate of one REC for each MWh of electricity generated from an eligible renewable source.

6.4.1.2 Renewable Energy Development Initiative (REDI) Program

This Federal government initiative is a competitive, merit based grants program supporting renewable energy innovation and its early stage commercialisation. The AUS$ 100 million program commenced in 2003 and will provide individual grants from AUS$ 50 000 to AUS$ 5 million over seven years. The REDI finished on 28 April 2008, and was supplanted with a number of new Government programs to support renewable and clean energy development in Australia. In 2008, KUTh Energy Ltd received AUS$ 1.8 million for drilling its Tamar Conductivity Zone project area in northeast Tasmania. See Chapter 7 in IEA-GIA 2007 for a list of previous REDI grant recipients.

- In 2005, Geodynamics received AUS$ 5 million for the construction and operation of a high efficiency Kalina cycle generation plant based on existing geothermal wells near Innamincka, South Australia
- In 2005, Scopenergy Limited received AUS$ 3.98 million for a proof-of-concept geothermal energy project on the Limestone Coast
- In 2006, Geothermal Resources Ltd received AUS$ 2.4 million to identify (with geophysical methods and drilling) and map the composition of granites in the Curnamona Craton region of South Australia
- In 2006, Proactive Energy Developments Limited received AUS$ 1.22 million under REDI for the development of a novel regenerator for adapting supercritical cycles to geothermal power applications
- In February 2007, Petratherm Ltd received AUS$ 5 million under REDI for its Paralana project to supply electricity to the Beverley mine in South Australia
- In August 2007, Torrens Energy Ltd received AUS$ 3,000,000 under REDI to undertake 3D modelling of HR resources in South Australia
- In April 2008, KUTh Energy Ltd received AUS$ 1,800,000 for drilling in its Tamar Conductivity Zone project area in northeast Tasmania

6.4.1.3 Renewable Energy Fund (REF)

The REF objectives include:

- Leveraging around $1.5 billion worth of investment in renewable energy technologies through encouraging private investment with government funding;
- Supporting a range of technologies across a range of geographic areas in Australia; and
- Taking technology from the laboratory to the field to help prove a project's viability on a technical and economic basis.

The REF has three components (for details see: http://www.ret.gov.au/energy/energy%20programs/RenewableEnergyFund/Pages/RenewableEnergyFund.aspx):

- *Geothermal Drilling Program (GDP)-* AUS$ 50 million (US$ 35 million) of the REF has been allocated for the GDP. The GDP (launched on 20 August 2008) provides up to one-half (on a $:$ basis, capped at AUS$ 7 million or US$ 4.9 million) of the cost of proof-of-concept projects including drilling, stimulating and flow testing geothermal wells. The GDP is a competitive merit-based grants program. Applications to the first round of the GDP closed on 5 January 2009.
- *Renewable Energy Demonstration Program (REDP)-* The objective of the REDP is to accelerate the commercialisation and deployment of new renewable energy technologies for power generation in Australia by assisting the demonstration of these technologies on a commercial scale. The REDP provides grants for eligible renewable energy power generation demonstration projects, of up to one third of the eligible expenditure of the project. The size of grants to successful projects is expected to be in the range of $50 million to $100 million. Renewable energy technologies eligible for the REDP are: solar, geothermal, wind, biomass, hydro systems, ocean energy, combinations of these technologies, and energy storage where it is part of one of those technologies. This is designed to fill the gap between post-research and commercial uptake for renewable energy technologies. A large part of the REDP (AUS$ 300 million equivalent to US$ 210 million) is set aside for the commercial scale demonstration of non-solar technologies (e.g. geothermal, ocean and bio-fuel demonstration projects).

- *Second Generation (Gen2) Biofuels Research and Development Program-* This portion of the REF provides AUS$ 15 million (US$ 10.5 million) for certain forms of bio-fuel research and development projects.

6.4.1.4 Energy Innovation Fund (EIF)

The EIF has been established by the Australian Government to provide $150 million over five years to support the development of clean energy technologies. The aspect of the EIF that may become relevant to geothermal technologies includes $50 million for competitive grants for research and development in clean energy technologies. Relevant objectives of the Energy Innovation Fund include:

- Accelerate the development of new and innovative clean energy technologies that will lead to medium to long term reductions in emissions from energy production and use
- Increase the level of collaboration within Australia and internationally on clean energy research and development
- Create clean energy technology development, growth and export opportunities for Australian businesses

6.4.1.5 PACE

The **P**lan for **AC**celerating **E**xploration was launched in April 2004 by the South Australian government and includes funding for collaborative exploration programs that will address critical uncertainties in mineral, petroleum and geothermal exploration. The AUS$ 22.5 million program (of which AUS$ 10 million has been designated for direct drilling initiatives) will be operative until at least 2009. A total of AUS$ 959,000 in South Australian PACE drilling grants has been provided to 7 geothermal explorers as listed in Appendix C. This includes PACE grants in February 2008 to Torrens Energy (AUS$ 100,000) and Petratherm (AUS$ 100,000). For details, see: http://www.pir.sa.gov.au/minerals/pace/theme_2/current_round_of_pace_projects.

6.4.1.6 Renewable Energy Support Fund

Sustainability Victoria offers a Renewable Energy Support Fund that helps to pay 50% of the capital cost for new operations (such as fish farms, horticulture and swimming pool heating). For details see: http://www.sustainability.vic.gov.au

6.4.1.7 NSW Climate Change Fund

The NSW Climate Change Fund was established in July 2007. It includes $40 million Renewable Energy Development Grant (RED). The Climate Change Fund was established under the Energy and Utilities Administration Act 1987. It provides $40 million over five years to support projects which are expected to lead to large scale greenhouse gas emission savings in NSW by demonstrating renewable energy technologies in NSW and supporting the early commercialisation of renewable energy technologies in NSW. The Renewable Energy Development Program was open for Expressions of Interest for any renewable energy project, which will generate electricity or displace grid electricity use in NSW for stationary energy purposes.

6.4.2 Development Cost Trends

Drilling costs for high temperature non-sedimentary targets remain a challenge to be managed, especially while there is significant competition for a limited fleet of fit-for-purpose rigs. With each deep geothermal well drilled in Australia, "learnings" will be applied to foster more efficient operations in hostile, deep and hot hole conditions, including the development of increasingly resilient drilling assemblies. With increasing numbers of companies planning to drill deep wells, the opportunity will arise for one or more companies to commit to long-term arrangements for drilling rigs that can be expeditiously mobilised, commissioned, decommissioned and transported in a relatively low number of truck loads. Substantial increases in the cost of consumables and steel casing are also a challenge to efficiency.

6.5 Development Constraints

Whilst geothermal energy resources in Australia have vast potential, geothermal power generation is not yet price-competitive, and remains to be demonstrated to be economic at price levels that may be realised with the addition of costs to constrain greenhouse gas emissions in the cost of electricity from emissive fuels such as coal and natural gas.

6.6 Economics

6.6.1 Trends in Geothermal Investment

Assuming success in demonstration and proof of concept projects, the Electricity Supply Association of Australia concluded that 6.8% of all Australia's power could come from geothermal by 2030 under a scenario that emissions are reduced to 70% of 2000 levels by 2030. The forecast 6.8% represents 5.5 GW in generating capacity from EGS. At roughly 2% growth, Australia's power demand will grow from approximately 50 GW current generation capacity to approximately 80 GW in 2030.

Figure 6.4 illustrates the current costs of power generation from alternative fuels, including geothermal, coal, wind, gas and nuclear energy. At this point in time, coal and gas are the most competitively priced fuels for electricity generation.

In a global market with carbon pricing, geothermal energy is likely to be a significant growth industry. The anticipated cost of EGS electricity generation in Australia has been estimated at $68-$128/MWh (ESIPC, 2008). Without carbon pricing, many forms of conventional energy generation such as coal and natural gas are more cost effective.
Investors have continued to support capital requirements for geothermal projects, and funding has continued to increase in 2007, with ten companies now listed on the Australian Stock Exchange. By the end of October 2008, the market capitalisation of these ten companies amounted to more than AUS$ 315 million.

6.6.2 Trends in Cost of Energy

Estimated costs to generate electricity from various fuels and plant-types are indicated on Figure 6.4. Australia's vast coal and gas reserves and resources are an important factor behind our very competitively priced domestic power supplies. Public opinion polls suggest that a majority of Australians would be willing to pay some price to help reduce greenhouse gas emissions. Certainly, the cost of energy is likely to rise in excess of the underlying rate of inflation if the cost of reducing emissions is factored into the price of power supplies. The precise timing and level of price increase is, however, uncertain.

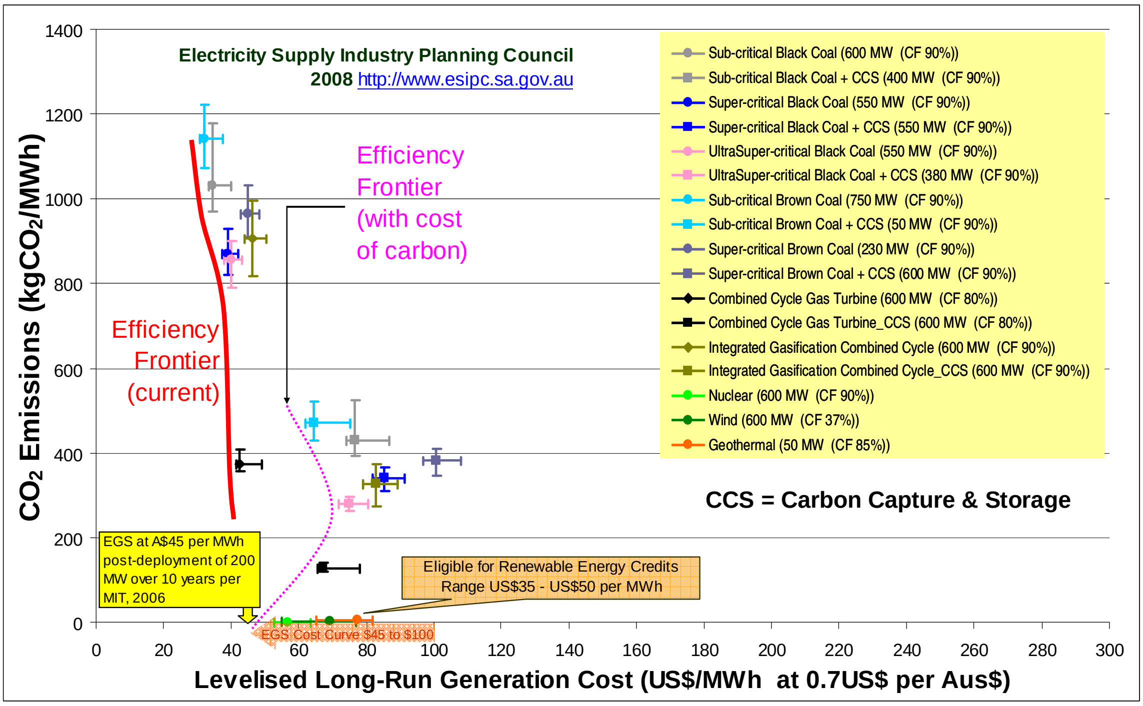


Figure 6.4 CO_2 emissions (k/MWh) on the vertical axis versus A$ costs to generate electricity power in Australia on the horizontal axis to indicate relative costs and CO_2 emissions from various fuels, with and without carbon capture and storage (geosequestration).
(Source: Electricity Supply Industry Planning Council 2008 Annual Planning Report, http://www.esipc.sa.gov.au/webdata/resources/files/APR_Final_for_Website.pdf)

6.7 Research Activities

Three states (Queensland, Western Australia and South Australia) have thus far set plans to support Centres of Excellence (CoE) in Geothermal Energy Research in local Universities.
The organisational structure of the AGEG and its TIGs (as illustrated in Table 6.3) are designed to foster national and international cooperation in planning for complementary, high priority research into advanced geothermal technologies and techniques.

6.7.1 Focus Topics

The principal focus topics of Australian research relate to challenges faced by proponents of drilling deep hot geothermal wells for the development of EGS and challenges shared in the development of EGS and HSA resources, including but limited to: environmental impacts (such as potential induced seismicity and efficient water use), predictive production modelling, and pre-drill prognostication of geothermal reservoir potential.

Considerable alignment exists between the research priorities for EGS as determined in Australia (DRET, 2008), the USA (DoE, 2008), the EU (ENGINE, 2008) and most recently by the International Partnership for Geothermal Technologies (IPGT, 2008), as summarised in Table 6.2. The list includes high priority techniques along with research priorities. Many of the technology targets will also assist the petroleum industry, and successful deployment of the associated services and equipment will also be relevant to HSA projects. These research directions are also aligned with GIA Research Annexes.

Table 6.2 International priorities for geothermal research –with a strong focus on unlocking the potential of magmatic resources. Several of these priorities are also targeted by the petroleum industry. HTHP: high temperature and high pressure (Adapted from Goldstein (2009).

Share knowledge & drive complementary research	
Standard geothermal resource & reserve definitions	Improved / revolutionary HTHP hard rock drill equipment
Predictive production modeling	Improved HTHP zonal isolation, e.g. materials, methods and equipment to enable the temporary of permanent isolation of multiple zones in a single well
Predictive reservoir and stress field characterisation	Reliable HTHP submersible pumps for modest hole diameter
Mitigate induced seismicity / other HAZOPS	Enable well longevity (20-30 years), e.g. tubulars that are resilient to HTHP and potentially corrosive conditions.
Condensers for high ambient-surface temperatures	Optimum HTHP fracture stimulation methods
Use of CO_2 as a working fluid for heat exchange	HTHP temperature logging tools and monitoring sensors
Improve power systems	HTHP flow survey tools
Education / training	HTHP fluid flow tracers
Technologies & methods to minimise water use	Mitigation of formation damage, scale and corrosion
Exploration technologies to predict heat flow and reservoirs ahead of the drill bit	Research priorities shared with the petroleum industry

6.7.2 Government Funded Research

6.7.2.1 Geoscience Australia

Key activities of Geoscience Australia's geothermal energy project under the auspices of the Federal Government's five year (2006-2011) Onshore Energy Security Program during 2008 included continuing a series of factsheets by producing one on risks posed by induced seismicity, preliminary design work on a heat flow database, refining the geological datasets used in the Austherm05 dataset of Chopra and Holgate (2005) and installing a heat flow measurement capability comprising downhole temperature logging and thermal conductivity measurement equipment. Acquisition of seismic, MT, gravity, magnetics and geochemistry data continued in areas with energy potential. Technical advice was provided on numerous geothermal matters to the relevant Australian Government Minister and Department. A 3D model of the Cooper Basin was made and a new thermal modelling capability was trialled using the model.

6.7.2.2 South Australia

As detailed in Appendix C, in the term April 2005 through 2008, the South Australian Government has provided AUS$ 1.6 million (US$ 1.12 million) in grants for Australian geothermal projects and research, and additional support is expected.
In 2008, Primary Industries and Resources South Australia (PIRSA) made three tied grants to the University of Adelaide to foster competence and capacity in geothermal research in Australia; and these include:

- As follow-up to Hunt et al. (2006; which can be found at: http://www.iea-gia.org/publications.asp). PIRSA provided AUS$ 50,000 for research by the Australian School of Petroleum at University of Adelaide to extend the findings from a study area in the Cooper Basin to the Adelaide Geosyncline, and to establish generic protocols for managing potential risks posed by induced seismicity associated with the fracture stimulation of EGS wells. Operators of geothermal energy projects in Australia will then have a credible foundation to develop or their own hazard management strategies to avoid negative impacts from induced seismicity. PIRSA's regulatory aim is two-fold: (1) foster robust risk-management frameworks and (2) sustain widespread, multiple-use land access for geothermal energy projects by attaining stakeholders' confidence that regulated activities undertaken by companies will deliver safe and sustainable operations. The results of this follow-up research into induced seismicity (Morelli and Malavazos, 2008) was presented at the AGEG-AGEA Geothermal Energy Conference in 2008 with the final report to be released in 2009.
- To stimulate national cooperation in high priority geothermal research, PIRSA provided an AUS$ 250,000 tied-grant in June 2007 to initiate HR geothermal research in the South Australian context, but open to project proponents from anywhere in Australia. The terms of the tied grant required projects to be endorsed by the geothermal sector through the AGEG. The framework specified in the relevant Deed between the University of Adelaide and South Australia's Minister for Mineral Resources Development is designed to:
    - Enable and stimulate national and international collaboration in geothermal energy research with up to 80% of the funds for any single project (and up to 80% of the $250,000 tied grant) available to bring to bear expertise from outside the University of Adelaide.
    - Attract in-kind and financial inputs from non-SA Government sources that are a multiple of the SA Government inputs. The Australian geothermal industry, the Federal Government (through Geoscience Australia and the CSIRO) and capable universities both in and outside South Australia (in addition to the University of Adelaide) were invited to participate in this initiative, and/or complement the initiatives with.
    - Ensure that funded projects focused on what industry considered to be high priority research; findings underwent high quality peer review; and final reports of findings are prepared and made freely and openly available.

All of the associated research remained in progress in 2008. Table 6.1 summarises the nature of the AGEG endorsed research projects underway under the PIRSA grant to the University of Adelaide. The aggregate budget for these AGEG endorsed research projects is AUS$ 737,538 (including the AUS$ 250,000 from PIRSA). The quality and impact of reports on findings and scope of inputs from non-SA Government sources are key performance indicators for this initiative. The findings of these research projects will be made freely available, and the experience gained will inevitably be leveraged into further valuable research and the development of a service sector for the geothermal industry. This initiative will be complementary to any/all other proposals from the Federal Government and other jurisdictions to support geothermal research. A further tied grant of AUS$ 250,000 for additional geothermal research was provided to the University of Adelaide in June 2008 on the same terms described above; and AUS$800,000/year for two years has been granted by the SA Government to establish the Centre for Geothermal Energy Research at the University of Adelaide.

6.7.2.3 Queensland

The Queensland State Government provision of AUS$ 15 million (US$ 10.5 million) to the Queensland Geothermal Energy Centre of Excellence (QGECE) at the University of Queensland will enable research relevant to the development of deep geothermal resources in South Australia and Queensland. Research priorities for the QGECE were established in 2008, and the key foci for research will include:

- New turbines for supercritical CO_2 cycles
- Natural draft dry cooling towers and efficient heat exchangers
- Electricity transmission and power network modeling
- Geothermal reservoir exploration , characterization and management

The QGECE will work with other national and international research groups to address all challenges that need to be overcome before deep geothermal energy becomes a proven commercial reality. The QGECE will also work with other Australian universities to introduce undergraduate and post-graduate programs to develop a skill base, and train postgraduate students. For further details of planned QGECE research priorities, see: http://www.uq.edu.au/geothermal/docs/2009-QGECE-Research-Mar.pdf.

In 2008, the QGCECE made a submission to the Garnaut Review to elaborate the prospectivity of circulating stored supercritical CO_2 in a closed loop through a hot dry rock reservoir both to yield geothermal power and sequester CO_2 as a by-product. For details, see: http://www.uq.edu.au/geothermal/centre-makes-submission-to-garnaut-review-on-climate-change.

6.7.2.4 Western Australia

On the 29th of February 2008, the Western Australian State Government announced AUS$ 2.3 million in funding for the WA Geothermal Centre of Excellence (WAGCOE). The Centre comprises three participants: CSIRO, The University of Western Australia and Curtin University of Technology. Because of Perth's geological setting, the Centre is initially focussing on direct heat use technologies (e.g. geothermally powered air conditioning and desalination) for use in population centres where there is shallow groundwater of moderate temperature. Geothermal groundwater convection in settings such as the Perth basin provides a natural underground heat exchanger. Owing to the high natural permeability there is no need for artificial hydraulic fracturing. For 3-D modelling of these geothermal systems the Centre will harness the supercomputers now being set up in Perth, and will make it possible to drive geothermal research into computationally intensive directions that had previously been out of reach in Australia. The Centre will also offer geothermal training to students and industry. The research is organised in three interlinked Programs: 1) Assessment of Perth Basin Geothermal Opportunities using presently available data; 2) Optimal use of geothermal resources; 3) Identification of Future Potential by going deeper. For details, see: http://www.geothermal.org.au/.

6.7.2.5 Northern Territory

The Northern Territory government has undertaken pre-competitive geologic studies to determine that the existing physiography and HR potential of an area in the vicinity of Katherine and within the zone covered by the existing major Northern Territory power transmission grid looks promising for geothermal exploration and proof-of-concept projects. Hot Springs in the Daly region 100 km north west Katherine and at Mataranka 120 km SE of Katherine coincide with an interpreted presence of a major crustal heat source in the region. Good regional magnetic, gravity and particularly radiometric coverage exists to be utilised by explorers to focus their research. The Northern Territory has commissioned an expert review of the geothermal potential of the Territory. The results of this study were presented at Annual Geoscience Exploration Seminar (AGES) at Alice Springs in March 2007, and they have been released on a CD containing a summary report and GIS. The GIS is intended to be a toolkit for use by geothermal explorers, containing multiple layers of information relevant to the assessment of geothermal potential.

6.7.2.6 Victoria

Geological Survey Victoria (GSV) initiated geothermal exploration activities in Victoria by integrating and adding value to assorted petroleum, mineral and water datasets and by commissioning new temperature sampling in boreholes. In addition, GSV is supporting heat flow research work at Melbourne University and is collaborating with Geoscience Australia to acquire thermal conductivity and downhole temperature data.

Additionally, GSV has commenced a series of major studies that will better characterise the potential of Victoria's sedimentary basins and bedrock for geothermal potential. The core of these studies will be the construction, as part of GSV's four-year (to 2012) Rediscover Victoria in 3-D initiative, of a fully attributed 3-D geological model of Victoria's sedimentary basins and basement terrains. The model will include the key sedimentary horizons and surfaces in basins across the entire state. Basin and crustal architecture, as well as basin thermal structure and subsurface fluid flow, are key science themes of the initiative. The major sedimentary basins, the Gippsland, Otway and Murray basins will be evaluated sequentially. Detailed investigations will be undertaken into factors such as top seal integrity, reservoir and source rock quality and distribution and fault geometries. Integration of these data will allow the development of high-resolution, 3-D fluid flow models.

6.8 Geothermal Education and Conferences

Geoscience Australia produced new factsheets to supplement two previous factsheets, Induced Seismicity and Geothermal Power Development in Australia available at: http://www.ga.gov.au/minerals/research/national/geothermal/index.jsp

PIRSA, as Contracting Party to the IEA-GIA and the secretariat for the AGEG, has developed a geothermal web page that currently serves as a public portal to salient information pertaining to geothermal energy in Australia, including Australia's GIA membership. Members are detailed at the following webpage: http://www.pir.sa.gov.au/geothermal/ageg/membership

The Northern Territory proposes to develop web pages (as part of the Departmental web site) for geothermal education and information and will be seeking assistance from other State Governments and companies as the site develops.

There is a growing awareness of geothermal energy in Australia and this is reflected in the inclusion of geothermal energy within mainstream energy, petroleum and mineral conferences. On 19-22 August 2008, the inaugural Australian Geothermal Energy Conference was held in Melbourne, Victoria. This was attended by over 300 professionals from the geothermal sector, business and government. Forty-eight papers were presented over the 3 day conference. The conference was supported by a grant from the Sir Mark Oliphant International Frontiers of Science and Technology scheme administered by the Australian Academy of Sciences and the Australian Academy of Technological Sciences and Engineering. The Western Pacific Regional Branch of the International Geothermal Agency and the AGEG presented a pre-conference one day seminar on Geothermal Reservoir Management by Cedric Malate, Philippines National Oil Company.

6.9 International Cooperative Activities

Australia is a member of the IEA Geothermal Implementing Agreement. Geodynamics, Green Rock Energy and Petratherm are Sponsor members of the IEA Geothermal Implementing Agreement.

Petratherm has entered into an exclusive cooperative agreement with four Chinese government institutions to identify high prospect geothermal energy projects in China. The Asia Pacific Partnership (APP) which is supported by the Chinese and Australian governments will identify the potential for conventional geothermal, EGS, hot water and electricity plays in a number of provinces in China.

Table 6.3 AGEG endorsed research projects supported with joint PIRSA and geothermal sector support.

Theme	Project Name	Summary of key project objectives	Research Partners	
AGEG TIG 4 Engineering EGS	Geochemistry, Corrosion and Scaling in HDR Energy Extraction Systems	Determine the effect of variations in geochemical composition of circulating water on clogging of fracture networks in reservoir rock. **Budget:** $110,000 (50% from sector participants)	◆ U Adel (Ngothai & O'Neil) ◆ S.A Museum (Brugger) ◆ Ian Warke Inst. U of SA (Pring) ◆ Geodynamics (Wyborn)	◆ Petratherm (Reid) ◆ Eden Energy (Jeffress) ◆ Greenrock (Larking) ◆ PIRSA (Malavazos)
AGEG TIG 4 Engineering EGS	Full life-cycle water requirements for deep geothermal energy developments in South Australia	Water requirements for each step of geothermal through production will be quantified. An atlas of available water resources; processes for accessing these resources; and (possibly) software for calculating water requirements for specific projects will be developed. The aims are to allow individual project managers to manage water availability, and the industry to counter potential community concerns over water use for geothermal projects. **Budget**: $33,000 ($12,375 from PIRSA Tied Grant; balance from sponsor participants). Final report completed in 2008 (Cordon and Driscoll, 2008).	◆ Hot Dry Rocks Pty Ltd (HDRPL: Beardsmore, Baria, Cordon, Walsh, Waining & Cooper)	◆ PIRSA (Hill) ◆ Panax (de Graaf)
AGEG TIG 6 Engineering Power Generation	Preliminary assessment of the impact of geo-fluid properties on power cycle design	Study the relationship between the effect of non-condensable gas, fouling and corrosion caused by geofluid properties on surface heat exchangers and the heat transfer efficiency of the exchangers. **Budget:** $85,729 ($6,784 from PIRSA Tied Grant; balance from sponsor participants). Final report expected in 2009.	◆ U Adel. (Ashman, Gamboa & Nathan) ◆ Petratherm (Reid) ◆ Pac Hydro (Teoh)	◆ Eden Energy (Jefress) ◆ Greenrock (Larking) ◆ PIRSA (Malavazos)
AGEG TIG 6 Engineering Power Generation	Preliminary assessment of the potential for underground cooling on power cycle design	Test the cost-saving potential of using the thermally cool and stable soil layer to cool surface geothermal exchangers, pipework and plant. Compare different underground cooling systems with air cooling systems in Australian conditions. **Budget:** $44,550 ($22,275 375 from PIRSA Tied Grant; balance from sponsor participants). Final report expected in 2009 (Dally et al., 2009)	◆ U Adel. (Dally, Nathan & Ashman) ◆ Pac Hydro (Teoh) ◆ Petratherm (Reid)	◆ Eden Energy (Jeffress) ◆ Greenrock (Larking) ◆ PIRSA (Malavazos)
AGEG TIG 6 Engineering Power Generation	State of the Art in Power Cycles for geothermal applications and bottoming cycles	Make a detailed comparison of the performance and operating conditions of selected existing geothermal power plants with the range of conditions expected to apply in South Australia. Develop a detailed model of the Kalina cycle using HYSYS and compare with existing models - ORC and SC. **Budget**: $83,710 ($41,855 from PIRSA Tied Grant; balance from sponsor participants) Final report expected in 2009 (Doroodchi and Moghtaderi, 2009).	◆ U of Newcastle (Doroodchi) ◆ U Adel (Nathan & Ashman) ◆ Pac Hydro (Teoh) ◆ Petratherm (Reid)	◆ Eden Energy (Jeffress) ◆ Greenrock (Larking) ◆ PIRSA (Malavazos)
AGEG TIG 6 Engineering Power Generation	Development of a geothermal power plant cost estimator - Stage 1: basic estimates	Develop a model to estimate costs of geothermal power generation (South Australian conditions). The model will provide input options for key variables such as well depth, ambient conditions, geofluid temperature etc. **Budget:** $40,979 ($8,610 from PIRSA Tied Grant; balance from sponsor participants)	◆ U Adel.(Nathan) ◆ Petratherm (Reid) ◆ Eden Energy (Jeffress)	◆ Greenrock (Larking) ◆ PIRSA (Malavazos)
AGEG TIG 4 Geology EGS	Adelaidean reservoir characterisation	Characterise Adelaidean rocks for their potential to serve as heat exchange reservoirs within geothermal insulators and potential for geosequestration reservoirs in the vicinity of coal-fired electricity plants in the Port Augusta region **Budget:** $55,000 ($27,500 from PIRSA Tied Grant; balance from sponsor participants)	◆ U Adel. (Ainsworth) ◆ Petratherm (Reid) ◆ Eden Energy(Jeffress)	◆ Torrens (Matthews) ◆ PIRSA (Hill)
AGEG TIG 9 Geology Data Management	Forward prediction of spatial temperature variation from 3D geology models	Develop model for rapid calculation of spatial variations of temperature from 3D geology. Compare model-derived temperatures with observed to refine model. Demonstrate methodology via a case study of Petratherm's Paralana Project. **Budget:** $110,000 ($27,500 from PIRSA Tied Grant; balance from sponsor participants). A paper on this project was presented at the 2008 Australian Geothermal Energy Conference (Gibson et al., 2008).	◆ Intrepid (Gibson) ◆ Calcagno (BRGM), ◆ GA (Budd)	◆ Petratherm (Reid)Eden Energy (Jeffress) ◆ PIRSA (Hill)
AGEG TIG 4 Geology EGS	3D reconstruction of the Adelaide Geosyncline	Produce a geologically and geophysically sound 3D model of the Adelaide Geosyncline from studies of outcrop geology (existing geological maps, satellite images analysis, field work) and potential field data (gravity and magnetic data) interpretation and forward modelling. **Budget**: $248,324 ($27,858 via PIRSA Tied Grant; balance from sponsor participants). Final report by Backé and Giles (2008).	◆ U Adel. (Backe & Giles) ◆ U of Pau (France); ◆ U of Toulouse (France)	◆ HDRPL (Beardsmore) ◆ Torrens (Matthews)
AGEG TIG 2 Geol. / Engin../ Finance Reserve Definitions	Geothermal Reserve and Resource Estimates and Definitions	Establish a trustworthy code and guidelines for estimates of the in-place and extractable geothermal heat energy in hot rock resources. Sustain the draft to international peer review, including comments from the ASX, the JORC Committee, the IEA's GIA, AGEG members, and others. Budget: $27,500 (50% from sector participants) To view the *Code* (AGCC, 2008) please see the website link in the References.	◆ SKM (Lawless) ◆ Geodynamics (Williams); ◆ GA (Holgate); ◆ Petratherm (Reid) ◆ Torrens (Matthews)	◆ Greenrock (Larking); ◆ HDRPL (Beardsmore) ◆ Eden (Graham Jeffress) ◆ Intrepid (Gibson) ◆ PIRSA (Goldstein)

Geodynamics Limited and the Australian National University have formal agreements with Japanese researchers in geothermal energy.

PIRSA and Geoscience Australia have co-authored papers for presentation on the behalf of the AGEG at the annual Stanford Geothermal Workshops, annual Geothermal Resource Council Conferences, as well as international conferences of the American Association of Petroleum Geologists, the Society of Petroleum Engineers, and the Society of Exploration Geophysicists.

AGEG representatives held discussions on research directions with the venture capitalists and banks in North America and Europe; USA's Department of Energy (Renewable Energy Group), Lawrence Berkeley National Labs and deep well tubular manufacturers in Japan.

Australia is providing a Coordinating Lead Author for geothermal energy in Working Group III that is developing the Special Report on Renewable Energy scheduled to be published by the Intergovernmental Panel for Climate Change in 2010.

The French Bureau de Recherches Geologiques et Minieres (BRGM) has linkages with Intrepid Geophysics and Petratherm. BRGM have expertise in the integration of state of the art rapid 3-D geological modelling with geothermal temperature and thermal capacity latent in radiogenic granites.

In August 2008, Australia became a founding member of the International Partnership for Geothermal Technology (IPGT) with Iceland and the United States. These countries are pursuing a range of activities in EGS, which is the key technology of interest to Australia. The IPGT provides a forum for government and industry leaders to coordinate their efforts, and collaborate on projects, and the Steering Committee includes both government and industry participants from each country. The IPGT has the advantage that it involves a small group of participants working on a specific subject; it is very focussed, relatively informal and flexible in responding to the needs of members. Its approach to technology issues is first to identify the high priority technology needs of the industry (e.g. pumps, drilling, high temperature tools), then to seek to develop projects in each area with government and industry participants.

Further information can be found at the IPGT homepage: http://www.internationalgeothermal.org.

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Appendix A

Summaries follow of the activities of the 14 Australian geothermal licence holders who undertook well and/or geophysical survey operations in the term 2002-2008. Drilling has been undertaken by: the Geodynamics-Origin Joint Venture (5 deep holes, maximum depth of 4,911 m); Green Rock Energy (1 hole to 1935 m); Petratherm (3 holes, maximum depth 1,807 m); Geothermal Resources (8 holes, maximum 1,761 m); Inferus Resources (2 holes, maximum depth 1,034 m); Torrens Energy (7 holes, maximum depth 760 m); Panax (Scopenergy) (5 holes; maximum depth 531 m); Eden Energy (1 hole, maximum depth 512 m) and KUTh Energy (37 holes, maximum depth 300 m). Greenearth Energy and Pacific Hydro gained access to boreholes to measure geothermal parameters and Hot Rock Ltd completed an MT survey near pre-existing petroleum wells. Ergon continued to operate the Birdsville geothermal power plant in 2008.

Eden Energy Ltd (ASX Code: EDE) has transferred its geothermal projects into a subsidiary company (Terratherma) that holds 23 geothermal licences covering just under 12,000 km^2. These include 22 GELs in South Australia and 1 Exploration Licence (EL) in New South Wales. EDE's South Australian licences are located in four distinct geothermal areas: (1) targets associated with buried radiogenic iron oxide and granites in the northern Torrens Hinge Zone, including the Witchellina project area northwest of Leigh Creek (GELs 166-168) and Coorichina in the Mulgaria basin NW of Lake Torrens (GEL 329-30); (2) an area where anomalously high heat flow has been mapped in the Renmark Project area north of the Murray River (GELs 175-176); (3) deep hot fractured granite targets in the Cooper Basin north of Moomba (GEL 185) and at Bollards Lagoon (GEL 169) and at Mungeranie, on the Birdsville Track (GEL 177); and (4) the Pirie area between Adelaide and Port Augusta (GELs 411-422).

Given success in its proof-of-concept drilling, Eden plans to target electricity markets, direct use applications and hydrogen production opportunities. Eden's first shallow heat exploration well, Chowilla-1, was drilled near Renmark to a depth of 512m in the first half of 2008, with the assistance of $100,000 from the PACE 4 initiative. For more information, visit http://www.edenenergy.com.au

Ergon Energy currently has the only operating utility owned geothermal power station in Australia. The power station uses low temperature bore water at ~ 98°C at a flow rate of 27 l/s and produces ~120kW gross and ~80kW net of energy. Ergon Energy is in the process of reviewing the remaining life of the power station and investigating options and plans to replace the aging equipment with new and more efficient geothermal generation equipment. For more information, visit: http://www.ergon.com.au

Geodynamics Limited (ASX Code: GDY) has the most advanced hot rock geothermal project in Australia. Geodynamics has first mover advantage in Australia with its Habanero-Jolokia-Savina project in granites beneath the Cooper Basin in northeast South Australia and is the only proponent with a proven EGS in its tenements. Geodynamics has drilled four deep wells and is drilling a fifth in this project area, including: Habanero 1 (Total Depth: 4,421 m), Habanero 2 (total depth: 4,357 m; 500m SE of Habanero 1), Habanero 3 (Total depth: 4,221 m; 550m NE of Habanero 1) Jolokia 1 (Total Depth: 4,911 m; 9.5 km WNW from Habanero 3) and Savina (Drilling ahead at 3,244 m on 19 December 2008 with a planned total depth of 4,250 m; 10km WSW of Jolokia 1 and 19km W of Habanero 3). The granites at both Jolokia and Savina will be hotter at shallower depths than encountered in the Habanero wells. These wells will enable Geodynamics to firm up its reserves estimates and provide a choice for locating its planned 50 MW demonstration project.
The Habanero Project was the first and remains the most advanced Hot Rock 'proof of concept' project in Australia. Flow of geothermally heated formation waters (with 20,000 ppm Total Dissolved Solids) from Habanero 2 was achieved in 2005 at a maximum rate of 25 litres/second to surface at (up to) 210ºC. The geothermal reservoir in the Habanero wells is a water-saturated, naturally fractured basement granite (250ºC at 4,300 m as reported by Geodynamics) with permeability that was effectively enhanced by fracture stimulation. The connected EGS created at Habanero is laterally more extensive than achieved anywhere else in the world. Two fractured reservoir zones are present in the Habanero wells: a shallower, less permeable zone at 4,200 m; and

a deeper, more permeable zone below 4,300 m. An obstruction in Habanero 2 (the intended production well) interfered with a planned flow test of the main fractured reservoir below 4,300 m while the less-productive upper fractured reservoir zone at 4,200 m remained accessible. To conclude a circulation test of the main fracture zone, Geodynamics drilled a sidetrack borehole around the blockage in Habanero 2. The sidetrack progressed to a depth 100 m above the target reservoir when the drill bit became stuck. Attempts to conclude drilling operations in the Habanero 2 sidetrack were abandoned in June 2006. Geodynamics subsequently drilled Habanero 3 with an 8 ½ inch hole through its Hot Fractured Rock (HFR) reservoirs (compared to 6 inch through reservoirs in Habanero 1 and 2). During testing, Habanero 3 was sustaining production of 208 °C formation water at a rate of 18 kg/second and at a flowing pressure of 27.5 MPa (3,990 psi) through a 12.5 mm fixed choke. The flow is directed to a steam separator designed for up to 25 kg/second input, the rate achieved with an output temperature of 210ºC from Habanero 2 in 2005. Produced fluids from Habanero 3 flow through a variable choke capable of increasing production. In one short experiment lasting 3 minutes the variable choke was opened to 100% and production of 40 kg/second was sustained over that period. Productivity is 400% higher than that obtained from Habanero 2 in 2005, where lost down-hole equipment impeded flow and eventually caused blockage from the main fracture zone. During production and shut-in of Habanero 3, the monitored well head pressure at Habanero 1 responded as expected, indicating good communication between the wells at 4,250 m depth. The high rates of injectivity into the heat exchanger from Habanero 1 and 2 and pressures measured at Habanero 1 and Habanero 3 during flow testing in March 2008 indicate the presence of a large volume of low impedance, water saturated reservoir where the rock temperature is 250ºC (at 4.3 km). The flow tests of Habanero 1 and 3 are continuing in late 2008 through early 2009. Chemical tracer injection between Habanero 1 (the injection well) and Habanero 3 (the production well) commenced in mid December 2008 and will continue in 2009 as a further step in demonstrating commercial viability. The horizontal extension of stimulated reservoirs at the Cooper Basin site lends itself to multi-well developments. A small (1 MWe) power generation plant is expected to be commissioned in early 2009, and will supply electricity to the local town, Innamincka. That will be the final phase of work to precede Geodynamics' HOTROCK 50 project. That next step entails a proposed 9-well, 50 MW power station. The 9 wells will be drilled 1 km apart at 4 km depth. This will entail 4 injection wells and 5 production wells forecast to yield 10 MW net per well from flows of 120 kg/second/well. This will be an important milestone for the demonstration of EGS from HFR in Australia and a stepping stone towards commercialising vast renewable and emissions-free geothermal energy supplies to meet Australia's future baseload energy requirements. Geodynamics believes that a successful flow test between Habanero 1 and 3 will lead to large-scale development of an extensive area of more than 1,000 km² where rock temperatures, stress conditions and rock properties are extensive and favourable for geothermal energy production. Geodynamics has three key cornerstone investors, Origin Energy, Sentient/Sunsuper and Tata Power. Origin Energy has extensive upstream petroleum interest and Tata Power has extensive power station development interests. For more information visit http://www.geodynamics.com.au

Geothermal Resources Ltd (ASX Code; GTH) has three hot rock geothermal exploration projects: Frome, Crower and the Otway Basin, all in South Australia. The Frome project lies within the Arrowie Basin, which is underlain by some of the most radiogenic Mesoproterozoic granites in Australia, associated with numerous historic uranium occurrences in the Curnamona Province. In the Frome project area a large body of granite reached in Frome 12 is also evidenced by a regional gravity low and non-reflective seismic responses, is interpreted to lie beneath 2-4 kilometres thickness of younger sedimentary cover rocks. With the assistance of a Commonwealth government REDI grant of $2.4 million and a $100,000 PACE 3 grant by the South Australian government, the company completed 4 holes to approximately 500 metres depth on its Frome Project during 2007. Temperature logging indicated abnormally high temperatures within the sediments above the interpreted buried granite body, with geothermal gradients comparable to the Cooper Basin, thus vindicating the buried granite heat source model. Geothermal Resources drilled 3 wells in 2008 (Frome 5A, 10 and 11), providing encouragement to locate Frome 12 to reach up to 1,800 m (drilling at 1761 m in late December 2008. Samples of the granite in Frome 12 are reported as having 'well developed sub-horizontal fracturing'. Geothermal Resources will log Frome 12 and then plan to drill at least two additional holes to roughly 1,800m in the Frome area during the first half of 2009. These wells will be tied to existing seismic data to select a deep well location. The Frome project is located some 120 kms away from the extension of the NEM to the township of Broken Hill. A number of active minerals exploration projects that lie between the Frome Project and Broken Hill are additional, potential future power markets.

Owing to current market conditions, Geothermal Resources will defer in the Crower project in favour of more drilling on the Frome project. Crower lies along the northern margin of the onshore Otway Basin where early Palaeozoic granites of the Padthaway Ridge dip beneath onlapping Jurassic to Cretaceous sediments.

Geothermal Resources was also granted 2 GELs in the South Australian Otway Basin in 2008, where pre-existing petroleum wells define a prospective HSA play.

For more information visit: http://www.geothermal-resources.com.au

Greenearth Energy Ltd **(ASX Code: GRE)** has 3 Geothermal Exploration Permits (GEP 10, 12 and 13) in Victoria covering 18,795 km² over prospective HSA and EGS plays in the onshore Gippsland Basin, in the Latrobe Valley and the Geelong areas. Two announcements of inferred geothermal resource estimates have been made by Greenearth, for GEP 10 in December 2008 and GEP 13 in January 2009. The inferred geothermal resource in the GEP 10 area was estimated at 260,000 PJ, covering an area of 462 km² and including both EGS and HSA prospects. The inferred resource estimate for the GEP 13 area was 3,600 PJ, over an area of only 27.5 km². This inferred resource estimate was confined within the area of a 2008 seismic survey which itself covered an area of 29km² , which is only 0.54% of the total GEP 13 area. With reference to this inferred resource estimate, Greenearth estimate that 10MWe could be generated over 30 years by recovering only 2.8% of the stored heat.

The seed capital for Greenearth came from companies that drilled a gas exploration well (within what is now one of Greenearth's GEPs) that flowed 90° C water from 2,200 metres in 2004. In addition to deriving valuable information from three petroleum wells in petroleum permits coincident with its geothermal licences: Hazelwood-1 (PEP 166 - total depth: 2,081m) and Boola Boola-2 (PEP 166 - suspended with a log total depth of 1,715m); Alberton-1 (PEP 158 – total depth: 998m).

In November 2008, Greenearth concluded a magneto-telluric ground resistivity (MT) survey in the Geelong/Bellarine Peninsula area (In GEP 10) to delineate permeable aquifers below 3 km in its licences. A pilot, 18 month trial of micro earthquake monitoring as an exploration tool will be implemented in 2009 in GEP 13 with a sonde to be placed at 1,430m in Loy Yang -2. This aims to help delineate major fracture zones. Shear wave splitting may also define potential permeable zones. For more information visit: http://www.greenearthenergy.com.au/

Green Rock Energy Ltd **(ASX Code; GRK)** has 16 GELs in South Australia (7 GELs covering 2,899 km² in proximity to Olympic Dam, 3 GELs covering 3,834 km² in the Cooper Basin and 6 GELs covering 1,938 km²); 5 geothermal licence applications covering 3,950 km² in the West Australian Perth Basin and projects in Hungary.

Green Rock plans to commence drilling the first of two deep evaluation wells in proximity to the Olympic Dam mine in the second half of 2009. This will enable water circulation testing and follows hydraulic testing in the Blanche-1 well in 2008. The two new wells will be drilled a few kilometres to the west of Blanche-1, and approximately 15 km from BHP Billiton's mining operation. An in-place resource estimate compliant with the AGEG-AGEA Geothermal Reporting Code defines 120,000 PJ of heat in place in a 460 km² area of Greenrock's Olympic Dam area GELs. Greenrock have estimated that the production of 3% of that 460 km² target area is enough heat energy to deliver 400 MWe for 30 years.

In 2005 Green Rock drilled Blanche-1, its first exploratory diamond geothermal well, to 1,935 m (718 m of sedimentary rocks and 1,216 m of homogenous hot granite) 8 km from the giant Olympic

Dam mine and 5 km from a high voltage power transmission line connected to the national power grid. The target granite is interpreted to persist to depths of 6,000 m over an area of about 400 km^2 and represents a potential geothermal resource in excess of 1,000 MW_e. Cores and wireline logs from Blanche-1 suggested natural fractures exist. In 2008, Green Rock undertook a mini-fracture stimulation program in Blanche-1 to inform the design of a deep well stimulation. Thirteen zones were tested and the well bore was imaged with a slim-hole acoustic televiewer to enable the analysis of fractures, post fracture stimulation. Green Rock was awarded a $68,000 South Australian PACE Grant to advance its Blanche project. Greenrock's project in Hungary targets the production of geothermal water for electricity generation and direct heat for industrial and agricultural uses. For more information, visit http://www.greenrock.com.au

Hot Rock Limited (ASX Code: HRL) holds five Geothermal Exploration Permits (GEPs 6, 7, 8, 9 and 23) in Victoria covering over 27,000 km^2 in the search for commercial hot wet rock targets. The permits are located proximal to transmission infrastructure and power markets. Prospective water temperatures have been measured in petroleum wells in HRL's Otway Basin GEPs, including: 143°C in Windermere 2 at 3,595 m in GEP 7; and 142°C in Ross Creek 1 at 3,659 m in GEP 8. HRL is planning to develop these hot wet rock resources. Future plans for HRL are to drill its first and second deep wells. The well locations are selected on the basis of information from existing well and reflection seismic data, and a magneto-telluric survey completed by HRL in mid 2008. Pending encouragement from its deep tests, HRL plans to commission a small binary power plant. The intended pilot plant will use standard, proven technology. HRL has estimated its GEP-8 Koroit project has power generation potential of some 200 MWe. Hot Rock Limited also holds an Exploration Permit (EPG 19) in Queensland, covering an area of 657 km^2. Hot Rock Limited is also investigating direct use markets for its geothermal energy. For more information visit: http://www.hotrockltd.com

Inferus Resources Pty Ltd is a wholly owned subsidiary of Southern Gold Limited (ASX: SAU). Inferus Resources has four GELs covering 1,990 km^2 in the eastern Gawler Craton (north of Port Augusta and south of Olympic Dam), within the South Australian Heat Flow Anomaly (SAHFA). Southern Gold took up these GELs after drilling two mineral exploration drill holes to depths of 996 m and 1,034 m in which heat flows at up to 94.1 mW/m^2. Sedimentary rocks of the Adelaide Geosyncline provide insulation for trapping heat from the older basement rocks and granite in this play-trend. For more information visit: www.southerngold.com.au

KUTh Energy Limited (ASX Code: KEN) has geothermal licenses covering 14,171 km^2 in eastern Tasmania and has been named as the preferred tenderer for 2 geothermal tenements in Queensland. In its eastern Tasmania licenses, high heat producing granites are a recognized source of heat flows up to 159mW/m^2 (measured in shallow boreholes). KUTh completed an in-fill gravity survey in 2007 to delineate those prospective high heat producing granites, and that data indicates the target Hot Rocks below 3-5 km of a sedimentary sequence (including some coal measures). KUTh has since drilled (in 2008) 37 drill holes to depths of 250-300 m in a 20 km x 20 km grid across its eastern Tasmanian tenements. Measurements from these drillholes (to late November 2008) define a 5,000 km^2 area with heat flows of 92 to 118 mW/m^2. From this, KUTh plans to undertake deep drilling and, ultimately, production drilling. The Tasmanian licenses were also applied for to capture "direct heat" opportunities (industrial heating and drying) in urban and industrial areas. KUTh Energy's strategy is to establish a generation capacity within five years, and to have a commercial Direct Use project within three years. KUTh efforts in Tasmania have been assisted with a $1.8 million REDI Grant. KUTh's subsidiary companies have applied for geothermal exploration licenses in the Pacific Region. For more information visit: www.kuthenergy.com

Origin Energy Ltd (ASX Code: ORG) is a cornerstone investor in Geodynamics. In 2007, Origin purchased a 30% equity position in Geodynamics' South Australian geothermal tenements together with 30% of the Lightning drilling rig. In addition to its 30% share of on-going project expenditure, Origin Energy's forecast expenditure in Geodynamics' Cooper Basin project is expected to be about $150 million. Origin is a diversified energy company with more than 2,400 PJ_e of proven plus probable petroleum reserves, of which 90% is gas. Origin is significant producer of coal seam gas in Queensland. Origin owns and operates gas and wind fuelled power stations in Australia, and owns 51.4% of Contact Energy, a major electricity generator from geothermal and wind, and a wholesaler and retailer of natural gas and LPG in NZ. For more information see: http://www.originenergy.com.au

Pacific Hydro Ltd is owned by IFM Renewable Energy under the control of Industry Funds Services Pty Ltd. Pacific Hydro holds 18 Geothermal Exploration Licenses covering 9,000 km^2 in the South Australian extent of the Mesozoic Eromanga Basin (also called the Great Artesian Basin). In the second quarter of 2006, Pacific Hydro conducted downhole temperature measurements on three water bores to a depth of 1,500 m to confirm 56.1°C/km, which suggests temperatures of 133 °C at 2,000 m in the Jurassic-aged (Hutton and Poolowanna Formations) hot wet sedimentary rock targets. Laboratory permeability tests of Hutton core samples and thin section analyses provide further verification of high permeability at target reservoir depths. One slim hole is planned to be drilled in 2009, in the gravity low (deepest, so hottest Jurassic targets) in the eastern section of Pacific Hydro's GEL. That drilling program will establish potential upside above the 133 °C temperature projected from measurements taken at 1,500 m. Theses wells will drill in a geological setting with benign fluid chemistry, high permeability and lateral continuity. This drilling aims to establish a very large scale hydrothermal resource that could be developed with existing technologies. For more information, visit: http://www.pacifichydro.com.au/

Panax Geothermal Ltd (ASX Code: PAX) acquired **Scopenergy** in October 2007 and merged with **Osiris Energy Ltd** in December 2008. The combined assets now held by Panax include projects in both the South Australian Otway and Cooper Basins. Panax's Limestone Coast Geothermal Project in the South Australian Otway Basin covers 3,127 km^2 in GELs 170-173, 184, 212 and 223. The Otway Basin in the southeast of South Australia represents an area of anomalously high heat flows proximal to the National Electricity Market transmission grid and with an extensive database of petroleum well and seismic data that define hot wet sedimentary rock targets.

These three sub-basins within the boundaries of Panax's GELs have an estimated generating potential in excess of 1,500 MW_e. Scopenergy drilled three slim-hole wells (Heatflow 1A, 3A and 4) in the Limestone Coast Project near Millicent and Beachport in southeast South Australia in 2006. Surveys of those three slimholes added to measurements in 19 petroleum exploration wells and 26 water wells in the vicinity of Panax's tenements. This well data supports interpretations of temperatures of 170°C or higher at depths between 3,300 m and 3,700 m and 186°C to 200 °C at 4,000 m in Lower Cretaceous-Jurassic aged sandstones, and this prospectivity was recognised by the Federal Government through the issue of a $4 million REDI grant (not consummated). Panax is planning to drill a well in GEL 223 in mid 2009. Scopenergy was awarded a $130,000 South Australian PACE grant to advance understanding of the Limestone Coast Geothermal Project area.

Osiris has established an agreement with Protavia Pty Ltd to delineate potential to economically supply approximately 2 PJs of geothermal heat per annum for drying the final pulp in Protavia's (to be commissioned) paper pulp plant.
Panax plans to drill a deep test (Salamander 1) in its Otway Basin HSA play in 2009 with Weatherford Drilling International providing a newly constructed WDI Rig # 828, Le Tourneau "Lightning" Rig. For more information visit www.panaxgeothermal.com.au

Petratherm Ltd (ASX Code: PTR) is actively involved in projects in Australia, Spain and China, and is a leader in developing conventional, EGS and direct heat energy projects in Spain. Benefiting from a grant associated with the Asia Pacific Partnership on Clean Development and Technology Petratherm entered into an exclusive agreement with four key Chinese geological/geothermal institutions to undertake a co-operative assessment to identify prospective geothermal projects in China.

Petratherm has four geothermal projects in South Australia, which are the Paralana and Callabonna projects in the northern Flinders Range; and the Ferguson Hill and Stuart Shelf projects near Olympic Dam. Petratherm's most advanced Australian project is the Paralana Geothermal Energy JV Project.

Petratherm drilled two wells to establish thermal gradients down to about 600 m above exceptionally high heat producing granites in South Australia. Results from both wells were encouraging, with the Callabonna and Paralana sites respectively exhibiting 68 and 81°C/km thermal gradients. In June 2006, the phase-2 drilling program at Paralana was successfully completed with the geothermal test well being extended to 1,807 m. Geologic modelling indicates temperatures of 200°C can be expected at a depth of 3600m within insulating sedimentary overlying high heat producing granites at Paralana. Both the granite and the overlying sedimentary strata are expected to be susceptible to fracture stimulation. This concept of targeting geothermal reservoirs within sedimentary cover over high heat producing granites is referred to (by Petratherm) as its Heat Exchanger Within Insulator (HEWI) model. Petratherm has been successful in obtaining a $ 5M Renewable Energy Development Initiative (REDI) Grant from the Federal Government to assist in testing the HEWI concept. In addition, the Company has also received two grants worth $ 240,000 from the South Australian Government funded PACE scheme to underpin developmental components of the project. This funding is complemented by two significant Joint Ventures for the Paralana Project. In early 2007, Beach Petroleum Ltd entered an agreement with Petratherm to contribute up to $ 30 M for a 36% interest in the Paralana project. In August 2008, TRUenergy (a wholly owned subsidiary of China Power and Light) has agreed to pay up to $ 57 M to earn 30% equity in the Paralana Project.

Reflection seismic, magneto-telluric and passive seismic have been integrated to optimise the location of the Paralana 2 deep well. This has provided Petratherm with sufficient confidence to contract with Weatherford Drilling International to import a new 2,000 HP LeTourneau "Lightning" Drilling Rig. Petratherm expects to spud the Paralana 2 well in May 2009 and drill up to 4 km deep. Given success in its first deep well, Petratherm plans to spud Paralana 3 well in early 2010. The next phase will be to use one well as an injector and a second well as a producer as a sub-surface heat exchange system. Under the terms of the Paralana Joint Venture agreement, Beach Petroleum will take the lead role in the drilling operations required to create the underground heat exchanger. It is anticipated that the technical challenges to achieve long term heat extraction are lower within the sedimentary layer thereby potentially reducing project risks. The drilling and circulation work will be a precursor to constructing an electricity generation plant (of around 7.5 MW) to meet the local power needs at Heathgate Resource's Beverley Uranium Mine, 10 km away. This plan is the subject of a Memorandum of Understanding between Petratherm and Heathgate Resources who own the mine. The Company's longer term development goal is to supply 520 MW_e into the national electricity grid.

In late November 2008, Petratherm gained title to a prospective HSA play in a 9,000 km^2 Geothermal Exploration Permit (GEP - 24) in Victoria's East Gippsland Basin.

In February 2007, Petratherm began the process of securing geothermal energy sites in Spain. The strategic entry into Spain has provided a first mover advantage for Petratherm which, to date, has eight projects on the mainland and in the Canary Islands spanning conventional geothermal, EGS and direct heating targets. Most advanced of the Spanish projects is the Geo-Madrid 8 MW District Heating project. Construction of the Geo-Madrid DH project could commence by November 2009 with geothermal heat production, and production to markets by July 2010. On the volcanic island of Tenerife, Petratherm is exploring for high temperature, conventional geothermal resources with the view of supplying 50MW_e.

Petratherm's agreement with Chinese Government institutions is focused on securing tenure over high value geothermal projects in China. To date, work has focused on analyzing the various datasets provided by the Chinese institutions to identify projects develop project joint ventures. For more information, visit http://www.petratherm.com.au/

Teck Cominco Australia Pty Ltd is a subsidiary of **Teck Cominco (**NYSE Code: TCK and TSX Code: TCK.A and TCK.B) and has been offered South Australian GELs 294 and 295 covering 994 km^2 in the eastern Gawler Craton in proximity to Teck Cominco's Carrapateena Cu-Au discovery. Teck Cominco's exploration for geothermal resources has been implemented in parallel with its exploration and appraisal of the Carrapateena deposit discovery with temperature data collected in three Carrapateena drill holes. For more information see http://www.teckcominco.com.

Torrens Energy Ltd (ASX Code; TEY) has 21 geothermal licences and five licence applications spread across three areas covering 9,500 km^2 in South Australia. These three areas are located: (1) East of Lake Torrens and north of Port Augusta (GELs 230-235, 278, 285 and 407-410 totalling around 6,000 km^2); (2) The northern Adelaide Plains (GELs 227-229 and 263 totalling 1,963 km^2) and (3) Port Adelaide (GELs 226, 260-262 and GELAs 266 and 293 over a total of 1,868 km^2). The company also has one geothermal exploration permit (GEP) in Victoria. All of Torrens' licence and licence application areas are located close to the National Electricity Market transmission grid and markets. Torrens Energy drilled seven wells to depths ranging 501m to 760m in the northern extent of its licences east of Lake Torrens, in its Parachilna Play in 2007-2008. Determined heat flows ranged between 70-120 mW/m^2, with the results calibrating an inferred in place resource for the Parachilna Play of 780,000 PJ in August 2008.

Torrens next plans to record 2-D seismic and magneto-telluric surveys in its Parachilla Play area and drill at least one shallow well (TKDH-1A) in the central extent of its East of Lake Torrens licences, south of Parachilla and north of Port Augusta, and at least one shallow well (Raitaro-1) in its Port Adelaide play area in 2009. The information gained from wells to < 1 km will be used to locate wells to intermediate depths (to < 2 km) in the Parachilla, north of Port Augusta and Port Adelaide areas. The aim of shallow (to < 2 km) exploration drilling is to delineate heat flow trends as a precedent to locating deep proof-of-concept wells to pre-heat feed-waters for coal and gas fired power stations and desalination. Torrens was awarded a $ 3 million REDI grant (in 2007) to develop, demonstrate and refine a 3-D modelling method for the prediction of Hot Rock plays, and also a $ 100,000 South Australian PACE grant (in 2006) for heat flow exploration in the Adelaide Geosyncline.

In 2008, Torrens Energy entered into an agreement with Australian Gas & Light (ASX Code: AGL) to jointly develop geothermal resources for generation into the National Electricity Market (NEM). This agreement resulted in AGL: owning 10% of Torrens shares; having a first right of refusal to earn 50% of any Torrens geothermal project by funding the completion of a deep confirmation well, and act as a joint venture to find new geothermal opportunities through mid 2012. For more information see: http://www.torrensenergy.com

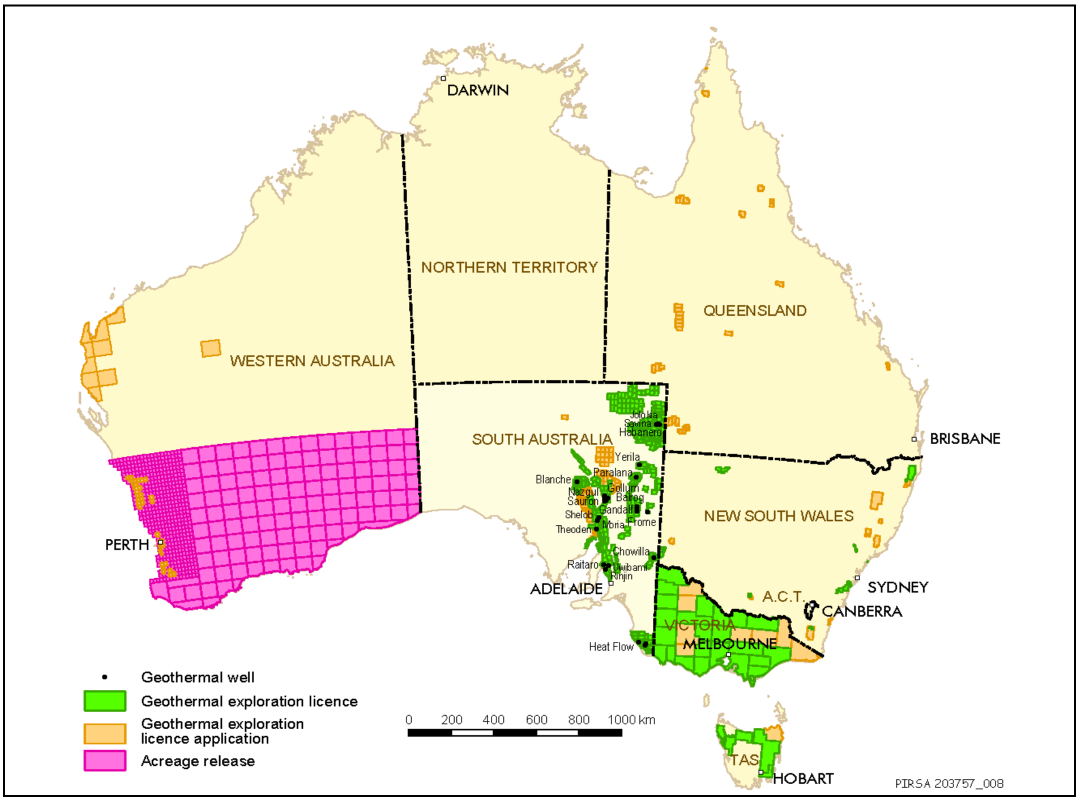

Figure 6.5: Australian geothermal licenses and license application areas to 30 June 2009.

Australian geothermal licenses and license application statistics at year-end 2007 and year-end are shown in Table 6.4.

Table 6.4 Australian geothermal licenses and license application statistics.

Statistics for Australian Geothermal Leases	31 December 2007	31 December 2008
Number of companies with geothermal licences and licence applications	33	48
Number of geothermal licences and licence applications	277	385
Area of licences and licence application	219,000 km^2	359,700 km^2
Estimated actual work program investment in geothermal licences (2002-to specified date)	AUS$ 209,093,158	AUS$ 325,148,424
Estimated actual plus forecast work program investment in geothermal licences (2002-13)	AUS$ 852 million	AUS$ 1,523 million

Appendix C

Table 6.5 Australian Federal and State Government grants awarded for geothermal research, proof-of-concept (including exploration geophysical surveys, drilling and well surveys/tests), and demonstration projects in Australia 2000-June 2009 (sub-tallies for 2008 and 2000-2008 also provided).

Ratio	Grant	Date	Recipient	Project	AUS$ Amount
$:$	Fed. RECP	2000	Pacific Power/ANU	Hunter Valley Geothermal	$790,000
$:$	Fed. START	2002	Geodynamics	Habanero Project	$5,000,000
$:$	Fed. REEF	2002	Geodynamics	Habanero Project	$1,800,000
$:$	Fed. GGAP	Mar-05	Geodynamics	Kalina Cycle to produce 13 MW from waste heat, WA	$2,080,000
$:$	Fed. REDI	Dec-05	Geodynamics	Cooper Basin, SA	$5,000,000
$:$	Fed. REDI	Dec-05	Scopenergy	Limestone Coast, SA	$3,982,855
$:$	PACE 2	Apr-05	Petratherm	Paralana, SA	$140,000
$:$	PACE 2	Apr-05	Scopenergy	Limestone Coast, SA	$130,000
$:$	PACE 2	Apr-05	Eden Energy	Witchellina Project, SA	$21,000
100% of cost	SA Grant	Jun-05	U of Adelaide	Induced seismicity, Cooper Basin	$50,000
100% of cost	SA Grant	Dec-05	Geodynamics	Cost: benefit eval. of hot rocks to reduce national emissions	$40,000
$:$	SA PACE 3	Dec-05	Geothermal Resources	Curnamona Project, SA	$100,000
$:$	SA PACE 3	Dec-05	Green Rock	Olympic Dam Project, SA	$68,000
$:$	Fed. REDI	Jul-06	Geothermal Resources	Frome Geothermal Project	$2,400,000
$:$	Fed. REDI	Dec-06	Proactive Energy	Supercritical cycles to geothermal power	$1,224,250
$:$	SA PACE 4	Dec-06	Torrens Energy	Heatflow expl., Adelaide Geosyncline	$100,000
$:$	SA PACE 4	Dec-06	Eden Energy	Renmark Project, SA	$100,000
$:$	SA PACE 4	Dec-06	Geodynamics	High Temp. borehole imaging, Cooper Basin, SA	$100,000
$:$	Fed. REDI	Feb-07	Petratherm Ltd	Paralana Project, SA	$5,000,000
$:$	SA Grant	May-07	U of Adelaide	Induced seismicity protocols – SA	$50,000
$:$	SA Grant	Jun-07	U of Adelaide	AGEG Research	$250,000
$:$	Fed. REDI	Aug-07	Torrens Energy	3D modelling, hot rocks,, SA	$3,000,000
$:$	Qld Grant	Oct-07	U of Queensland	Qld Geothermal Energy Research Centre of Excellence	$15,000,000
$:$	SA PACE	Feb-08	Petratherm	Shear wave splitting for Hot Rock exploration	$100,000
$:$	SA PACE	Feb-08	Torrens Energy	2D seismic, Adelaide Plains	$100,000
$:$	REDI	Feb-08	KUTh	Tamar Conductivity Zone	$1,800,000
$:$	WA Grant	Mar-08	U of WA	WA Geothermal Energy Research Centre of Excellence	$2,300,000
$:$	SA Grant	Jun-08	U of Adelaide	AGEG Research	$250,000
$:$	NSW	Dec-08	Geodynamics	Drilling in Hunter Valley	$10,000,000
				Sub-tally in 2008 (Includes AUS$ 50 Million GDP)	**$64,550,000**
				Sub-tally 2000 – 2008 (Includes AUS$ 50 Million GDP)	**$110,976,105**
100% of cost	SA Grant	2Q-09	U of Adelaide	Innovative use of Hot Rock power, remote locations	$10,000
$:$	SA Grant	Apr-09	Geodynamics	50% of transmission line from Habanero to Innamincka from SA Regional Development Infrastructure Fund	$630,000
$:$	GDP	Apr-09	Petratherm Ltd	Fed Geothermal Drilling Fund - Paralana, SA	$7,000,000
$:$	GDP	Apr-09	PANAX Geothermal	Fed Geothermal Drilling Fund - Penola, SA	$7,000,000
$:$	GDP	In 3-4Q/09	TBD	Fed Geothermal Drilling Fund	$36,000,000
80% of $1m	SA REF	Jul-09	U of Adelaide	South Australian Geothermal Energy Research Centre of Excellence; $800 000 pa from State and $200 000 pa from the University for 2 years	$2,000,000
Excludes $300 million REDP available for meritorious, commercial-in-scale geothermal, ocean and bio-fuel energy demonstration projects				**Total Government Grants (Includes AUS$ 50 Million GDP)**	**$113,616,105**

Abbreviations:

- RECP (Federal Government's Renewable Energy Commercialisation Program);
- REEF (Federal Government's Renewable Energy Equity Fund);
- GGAP (Federal Government's Greenhouse Gas Abatement Program);
- REDI (Federal Government's Renewable Energy Development Initiative);
- PACE (South Australia's Plan to ACelerate Exploration);

Australian Geothermal Energy Group (AGEG) Members

17 July 09

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

ASX-Listed (Code)

AGEG'S VISION: Geothermal resources to provide the lowest cost emissions- free renewable base load and direct-use energy for centuries to come.

Company Members

1. AGEA (Industry Group)
2. AAA Energy
3. ACILTasman
4. Activated Logic
5. AGL (AGL)
6. Balance Energy
7. Beach Petroleum (BPT)
8. BurnVoir Corporate Finance
9. Callabonna Energy
10. Clean Energy Australasia
11. Deep Energy
12. Earth Heat
13. Earthinsite
14. Earth Solar Power
15. E-Connect
16. Eden Energy (EDE) (Terratherma is a subsid.)
17. Electranet
18. Encom Technology
19. Energycore
20. Ergon Energy - owned by the Qld G'ment
21. Finlayson
22. FrogTech
23. Geodynamics (GDY)
24. Geogen
25. Geopower
26. GHD
27. Google (NASDAQ) - RE<C Team
28. Gradient Energy - Planet Gas subsid (PGS)
29. Granite Power
30. Greenearth Energy (GER)
31. Greenrock Energy (GRK)
32. Geothermal Resources (GHT)
33. Geothermal Advisory Pty Ltd
34. Halliburton (NYSE listed)
35. Hitech HIPPO
36. Hot Dry Rocks Pty Ltd
37. Hot Rock Ltd (HRL)
38. Hot Rocks Tasmania
39. Hydro Aluminium
40. Icon Energy (ICN)
41. Inferus Resources (Southern Gold subsid. (SAU)
42. Intrepid Geophysics
43. KUTh Energy (KEN)
44. KPMG
45. KTM Capital
46. Monaro
47. Macquarie Capital Products Limited (MQG)
48. Marubeni-Itochu Tubulars (Japan)
49. Mitsubishi Heavy Industries (Japan)
50. Near Surface Geothermal Energy
51. New Energy Finance
52. New World Energy
53. Origin Energy (ORG)
54. Osiris Energy (merged with PAX)
55. Panax/ Scopenergy (PAX)
56. Petratherm (PTR)
57. Pacific Sensor Technologies
58. Pacific Hydro
59. Red Hot Rocks
60. RPS Energy
61. Schlumberger (NYSE)
62. Senergy
63. Sinclair, Knight, Merz
64. Snowy Mountain Engineering
65. Strategic Chemistry
66. Stuart Petroleum (STU)
67. Sumitomo (Japan)
68. Syncline Energy
69. Teck Cominco (Toronto Exch)
70. ThermaSource
71. 3D-Geo
72. Terra Therm
73. Torrens Energy (TEY)
74. Tri-Star Energy
75. TRUenergy (Owned by China Light & Power, HK)
76. VEMTEC
77. Weatherford (NYSE)
78. Worley Parsons (WOR)

Research Institution Members

1. Curtin
2. Monash
3. University of Melbourne
4. University of Adelaide
5. University of Newcastle
6. University of NSW
7. University of Queensland
8. University of South Australia
9. University of Sydney
10. University of West Australia
11. University of Tasmania

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1. Fed. Government (RET, GA, CSIRO, EWH&A, CC)
2. South Australia (Chair)
3. Victoria
4. Western Australia
5. Queensland
6. Tasmania
7. Northern Territories
8. New South Wales

97 Members & Growing

Appendix E

Table 6.6 *A list of current commercial, water-loop GSHP installations in Australia.*

New South Wales	**Lithgow Hospital, Lithgow**	**Cowra Shire Council Offices, Cowra**
	NPWS Tourist and Information Centre, Jindabyne	**Wagga Wagga Civic Centre, Wagga Wagga**
	Macquarie University, North Ryde	**Surry Hills Community Facility, Surry Hills**
	Detention Centre, Dubbo	
Australian Capital Territory	**ACTEW Corporation, Canberra**	**Airport Caltex, Pialligo**
	Geoscience Australia, Canberra	**ANU Research Laboratory, Canberra**
	Duntroon Headquarters, Canberra	
Tasmania	**Grand Chancellor Concert Hall, Hobart**	**Antarctic Centre, Hobart**
	Queen Victoria Museum and Art Gallery, Launceston	**Westpac Call Centre, Launceston**
	Southern Cross Homes/Aged Care, Moonah	**Hobart Aquatic Centre, Hobart**
Victoria	**Victoria University of Technology, Werribee**	**Station Pier, Port Melbourne**
	Paynesville Pool, Paynesville	
South Australia	**Royal Adelaide Hospital, North Terrace**	**Coober Pedy Police Station, Coober Pedy**
	Bureau of Meteorology, Kent Town	**Mt Barker TAFE, Mt Barker**
	Garden East Apartments, Adelaide	
Queensland	**University of Southern Queensland swimming pool, Toowoomba**	**Logan Institute of TAFE, Logan**
Northern Territory	**Bureau of Meteorology, Darwin**	

National Activities

Chapter 7

European Commission

The Soultz-sous-Forêts EGS power plant today. (Photo courtesy of Andreas Piontek)

7.0 Introduction

This European Commission contribution covers only a review of EC research activities.

For more general information, please refer to Chapter 8 in IEA Geothermal Energy Annual Report 2007.

7.1 Research Activities

7.1.1 EU Funded Projects and Activities

In the call ENERGY 2008, supported by the EU Seventh Framework Programme, one topic entitled *Increased electricity production from Enhanced Geothermal Systems and from low enthalpy geothermal sources, was opened*.

The aim of this topic was to demonstrate the viability and efficiency of power generation from geothermal fluids of the lowest possible temperature, including hybrid solutions coupling geothermal with additional energy resources (solar, biomass, etc.) for improved efficiency; reduced costs; higher efficiency of energy extraction, conversion and end-use (electricity and heat); and better understanding of plant operation.

Issues to be addressed included production levels and methods in plant operation, e.g. balancing extraction and production rates; managing seismicity and other environmental risks; improving energy conversion efficiency and reducing parasitic loads; increasing the operational life of equipment, etc. Requested in the call was that new or existing facilities should become operational within substantially shorter lead times and should make use of well-known and promising sites. Technologies and systems to be demonstrated should be environmentally sound and well-suited to their site.

All of the six proposals received and analysed by a panel of experts obtained scores under the required thresholds. One possible explanation may be that the current situation for the geothermal sector (for what relates to electricity production), and especially, the prospects for its future developments and replication potential over the next twelve years until 2020, did not correctly address the requirement of the call.

The new European Technology Platform for Renewable Heating and Cooling (RHC-ETP) was endorsed by the European Commission in October 2008. This platform gathers together 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 was recently approved by the board; with the next important objective being to present, by the end of 2009, a shared/common vision about the development of the market by 2020 – 2030, with the preparation of the related Strategic Research.

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National Activities

Chapter 8

France

Figure 8.1 *Soultz-sous-Forêts EGS power plant. (Photo courtesy BRGM)*

8.0 Introduction

Following the implementation of the French Energy Law in 2005 and the large consulting process *Grenelle de l'environnement* launched in 2007, a strong focus has been put on the development of renewable energy sources. These two elements, which establish the structure for the future French energy policy, assign renewable energies, including geothermal resources, an important role and, a priori, the necessary financial resources to allow their real development.

Geothermal energy benefits from an old development in France, for all kinds of geothermal energies, which gives a strong base for a renewed and rapid growth:

- Geothermal heat pumps experienced a first development in the 1980s, and, notably through the presence of French SME, the market has developed again since 2003
- Geothermal district heating already supplies heat for more than 150,000 dwellings, and new operations have been launched since 2007
- Electricity production is especially suitable in our overseas departments, that are not connected to the European grid. The Bouillante plant on Guadeloupe Island has an installed capacity of 15 MW and considers new development, whereas exploration work is to begin in Martinique and la Réunion Island
- Concerning enhanced geothermal systems, after more than 20 years of R&D works, the Soultz project is now operational and provides a worldwide reference for this technology

The year 2008 was marked by some highlights illustrating this context:

- The national policy was deeply marked by the follow-up of *Grenelle de l'environnement*: a law project was presented in parliament in November 2008 in order to endorse the conclusions of the consultation process. The objective of 23% of RES in energy consumption, in line with the objective of the European directive on RES, is written down in this law project.
- Geothermal heat pumps: after a rapid growth, the market of geothermal heat pumps in single houses is stagnant, whereas the market of large heat pumps for collective and tertiary buildings is booming.
- An experimental platform devoted to R&D for geothermal heat pumps was built in BRGM.
- Geothermal district heating: a new well targeting the Dogger aquifer was drilled in Sucy-en-Brie, and several new projects have been launched, whose drillings are planned for 2009.
- Soultz-sous-Forêts: the EGS plant was inaugurated in June 2008, in the presence of French Prime Minister, François Fillon.

8.1 National Policy

8.1.1 Strategy

The French national policy towards renewable energies took a major turn with the *Grenelle de l'environnement*, France's Environment Round Table. The initiative was taken by Nicolas Sarkozy when he was elected president in 2007. For the first time, the consulting process brought together all society's main bodies: unions, local authorities, industry, NGO and administration. For three months, workgroups met to propose concrete action to be implemented at national, European and international levels. In October 2007, these proposals were opened up to debate by a range of public groups. Thus began a stage looking at the technical, legal and administrative aspects, which will serve to assess how best to implement all the measures decided upon. About thirty operational committees met to define guidelines and objectives for operational programs.

A law was presented in the Parliament in November 2008, in order to write down the objectives and to give the framework for an ambitious action plan allowing attainment of these objectives. The law project was voted with quasi-unanimity in Parliament and Senat.

Among the objectives, climate change mitigation is the main one, with the following targets, in line with the European Directive on Renewable Energy sources: to decrease by 38% the building energy consumption, to increase by 20 Mtoe the consumption of Renewable Energy (which is in line with the objective of 23% of RES in energy consumption) and to decrease by 20% GES emissions in transports.

Within this framework, powerful tools were set up, or reinforced, in favour of renewable energies. On 17 November 2008, a declaration was made by the Minister for Ecology, Energy, Sustainable Development and Town and Country Planning for 50 measures for the development of high environmental quality renewable energies. Geothermal energy is concerned in several of them:

- A "Renewable heating and cooling fund" is set up by the finance law 2009-2011 voted in November 2008. This law creates a fund for supporting renewable heating and cooling in tertiary, collective buildings or agricultural/industrial processes. This fund is dedicated to the funding of operational projects, under the following principle: to reach a RES heat price at least 5% lower than conventional heat. For that, an economic analysis is conducted for each project in order to determine the level of subsidy. This fund is granted 1 billion € for the 2009-2011 period, and is designed to gradually reach 800 millions €/year, increasing by a large factor the public money dedicated for RES heating and cooling before. Among the RES, it is foreseen that geothermal energy projects (geothermal heat pumps and direct use) will represent around 130 M€ for 2009-2011 period.

- Tax credits are maintained until 2012 for the purchasing of heat pumps
- R&D work on geothermal heat pumps is supported with two priorities: assessment of the potential of the superficial underground and aquifers for geothermal heat pumps, and the installation of an experimental platform devoted to R&D for geothermal heat pumps in BRGM
- A R&D program will be launched to accompany Soultz-sous-Forêts pilot plant exploitation
- The feed-in tariff for geothermal electricity will be raised

8.1.2. Legislation and Regulation

No specific changes compared with the situation in 2007.

8.1.3 Progress Towards National Targets

Following the *Grenelle de l'environnement*, a working group devoted to RES proposed in 2008 a burden sharing among RES in order to reach the +20 Mtoe/year of RES in 2020. For geothermal energy, the following targets were set up, updating the targets set in the law on energy in 2005:

Table 8.1 For heating (figures in ktoe/year).

	2006	2012	2020
geothermal district heating	130	195	500
large geothermal HP	50	100	250
individual geothermal HP	40	240	550
Total geothermal heating	220	535	1300

Table 8.2 For electricity in overseas departments (in MW installed capacity).

	2006	2020
Guadeloupe	15	90
Martinique	0	40
La Réunion	0	60

8.1.4 Government Expenditure on Geothermal Research and Development

In France, in 2008, a total of 3 M € was spent on geothermal research and development.

8.1.5 Industry Expenditure on Geothermal Research and Development

Industry R&D activity in the field of geothermal heat pumps exists, and has been estimated at about 4 M€ (see Section 8.6.1.2 for more details).

The European Economic Interest Group in Soultz-sous-Forêts dedicated 1.4 M€ for R&D.

8.2 Current Status of Geothermal Energy Use in 2008

8.2.1 Electricity Generation

8.2.1.1 Installed Capacity

Two geothermal plants were installed in 2008.

The installed capacity of the geothermal plant of Geothermie Bouillante in Guadeloupe was 15 MW_e. Due to the pressure drawdown in the field, and to avoid surface manifestations around the plant, which is located in an urban area, the operating capacity was decreased to 11 MW_e from July 2008 onwards. The operating capacity is to stay at this level until partial reinjection of the brine is implemented. The installation of the reinjection facilities will take place before the end of 2009.

The Soultz-sous-Forêts power plant, which was inaugurated in June 2008, has an installed capacity of 2.2 MW (1.5 MW net), but was not commercially operating in 2008.

8.2.1.2 Total Electricity Generated

The electricity production in 2008 was 90 GWh.

8.2.1.3 New Developments During 2008

Soultz-sous-Forêts power plant (net capacity: 1.5 MW), was inaugurated in June 2008 (Figure 8.1).

8.2.1.4 Rates and Trends in Development

No new projects were engaged in 2008, but exploration works are planned.

Geothermie Bouillante plan to drill exploratory wells for the extension of Bouillante plant. An additional capacity of 20-30 MW is expected. Drilling was authorized in December 2008, and could begin by the end of 2009.

In July, Geopetrol obtained an exploration permit in the Auvergne region.

8.2.1.5 Number of Wells Drilled

No new wells were drilled in 2008.

8.2.1.6 Contribution to National Demand

The geothermal installed capacity in France is a very small portion of total national capacity, and geothermal generation was negligible.

8.2.2 Direct Use

8.2.2.1 Installed Thermal Power

In 2008, the total installed thermal capacity was 307 MW_{th} for direct use and 1,300 MW_{th} for geothermal heat pumps.

8.2.2.2 Thermal Energy Used

In 2008, the thermal energy produced was 130,000 toe for direct use and 250,000 toe for geothermal heat pumps (estimate includes the portion given by electricity).

8.2.2.3 Category Use

The categories of direct use in France are provided in the following table:

Table 8.3 Direct use of geothermal energy in France.

	Paris Basin	Aquitaine Basin	Other Regions	Total
District heating	29	5	-	34
Fish farming, greenhouses, etc.	-	4	6	10
Bathing	-	9	3	12
Space heating without urban network	2	-	2	4
				60

8.2.2.4 New Developments During 2008

Since 2007, there has been a renewed interest in geothermal district heating, especially in the Paris Region. Following the drilling of a doublet which replaced an old one in Orly city in 2007, 2008 was marked by:

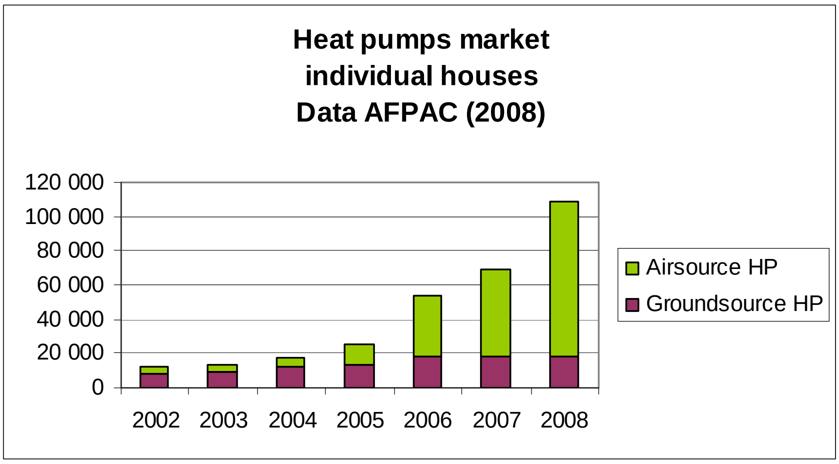
- The drilling of one well in Sucy-en-Brie (Figure 8.2), in order to transform an old doublet into a triplet (the new well being used as production well, and the two old wells as reinjection wells)
- The preparation of a new operation for Paris city district heating, the drilling to be performed in spring 2009
- The preparation of a new operation in Aix en Provence, the drilling to be performed in spring 2009
- Several feasibility studies are engaged for operation in Paris Basin, Alsace and other regions

Figure 8.2 Drilling at Sucy-en-Brie on 10 July 2008. (Photo courtesy of BRGM)

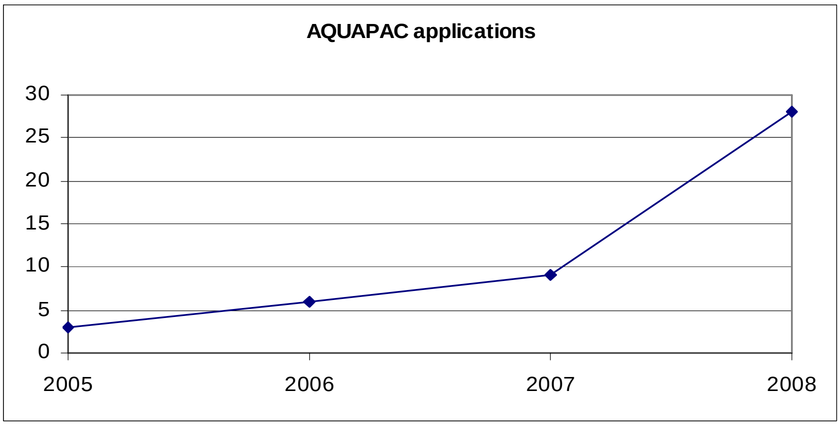
8.2.2.5 Rates and Trends in Development

Direct use- The progress made in the past few years concerned mainly the extension of heating networks, at a pace evaluated around 5,000 toe substituted per year, which means a growth rate of 3.7% per year. New projects are already planned for 2009 and the following years, so the growth rate is expected to increase. The outlook for the next years is to gain, in total, about 9,000 toe/year, which is a growth rate of around 7%/year.

Heat pumps for individual houses- After a fast increase until 2007, the market for geothermal heat pumps for individual houses is stagnant, at around 20,000 units per year. I n parallel, we observe a boom in the selling of air-source heat pumps. The main reason for this is that the tax credit system is largely in favour of air source heat pumps.



In the tertiary and collective buildings, the market for geothermal heat pumps is booming- Groundwater heat pump projects, benefiting from good profitability, represent the quasi-totality of the market. No statistics are available for this market, but profitability is estimated at more than 100 operations per year. The growth of this market can be illustrated by the data from the AQUAPAC guarantee: this public guarantee system covers geological risk for large groundwater heat pump projects. It is used only in areas where the hydrological knowledge is poor, and represents therefore a small part of the market. The evolution of the number of projects that applied to this guarantee is shown below:



The first large operations using borehole heat exchangers are emerging, but until 2008 they were not bankable with the subsidies allocated to such projects, and were therefore limited to demonstration projects. From 2009 on, with the Renewable heating and cooling fund, the situation will change, and one expects to see this market boom as well.

8.2.2.6 Number of Wells Drilled

One production well was drilled in Sucy-en-Brie, targeting Dogger aquifer (2,100 m depth).

8.2.3 Energy Savings

8.2.3.1 Fossil Fuel Savings/Replacement

Geothermal electricity production saved about 26,000 toe; direct use around 130,000 toe; and geothermal heat pumps saved about 150,000 toe (renewable part of thermal energy produced).

8.2.3.2 Reduced/Avoided CO_2 Emissions

Geothermal electricity generation in Guadeloupe avoided production of an estimated 72,000 tonne of CO_2, assuming replacement of fossil fuel with a CO_2 content of about 0.8 t CO_2/MWh.

Direct use avoided production of about 400,000 tonne of CO_2.

An estimate for geothermal heat pumps was not made because no methodology was available to determine the type of energy GHPs substituted for.

8.3 Market Development and Stimulation

8.3.1 Support Initiatives and Market Stimulation Incentives

8.3.1.1 Electricity Generation

New feed-in tariff were established in July 2006. These tariffs are based on the net output production of the geothermal plant, and amount to:

- In mainland France, the feed-in tariff is 120 €/MWh
- In France's overseas departments, it is 100€/MWh

Both tariffs are subjected to an actualisation rate.

It was announced in November 2008 that the feed-in tariff will be revised.

8.3.1.2 Geothermal Heat

There was no new measure taken in 2008, the measures put in force in the previous years are still active.

The creation of the Renewable Heat fund will be in force in 2009.

8.3.2 Development Cost Trends

There is no data available yet to assess the development cost trends.

8.4 Development Constraints

No particular constraints have been reported in France.

8.5 Economics

8.5.1 Trends in Geothermal Investment

The only noticeable investment in 2008 was for the well drilling in Sucy-en-Brie.

8.5.2 Trends in the Cost of Energy

The cost of the heat produced by a conventional geothermal district heating plant serving, for example, 5,000 equivalent-dwellings (as in Paris area) can be estimated at 35 €/MWh (~ US$ 22/MWh) vs 43 €/MWh (~ US$ 27/MWh) for the heat produced with natural gas.

For electricity generation, the Geothermie Bouillante powerplant is selling electricity at a price of 100 €/MWh.

8.5.3 Number of People Employed in the Geothermal Sector

The number of people employed in the geothermal sector is estimated at 600 for conventional activities (such as geothermal district heating plants or geothermal power plants) and approximately 2,000 people for the geothermal heat pump sector.

8.6 Research Activities

8.6.1 Focus Areas

8.6.1.1 Government Funded Research

Public funded activity in R&D on geothermal energy in France is funded principally through:

- Projects funded by the ANR (national agency for research)
- Projects funded by ADEME
- Projects funded by regional authorities
- Contribution of public research institutions, mainly BRGM and CNRS

In November 2008, ADEME decided to finance R&D programs conducted by the BRGM, for the period 2009-2011 on several topics:

- Assess a detailed potential of clastiq (i.e. clayey sandstones) deep aquifers for geothermal exploitation in France (project CLASTIQ 2)
- Modelling of Bouillante geothermal field (project GHEMOD)
- Geological, geophysical and geochemical assessment and monitoring of Bouillante geothermal field (project GEO3BOU)
- Modelling of hydro-thermo-mechanical behaviour of fractured reservoir (GEFRAC MOD)
- Experimental percolation test (GEFRAC EXP)

The main R&D highlights for 2008 are:

- Concerning the integration of geothermal energy in construction design
  - *Creation of an experimental platform for geothermal heat pumps and their underground heat exchangers in Orléans:* In the context of the State-Région

Centre Contract (2007-2013), BRGM and the Centre Regional Council have joined forces to create an experimental platform for geothermal heat pumps and their underground heat exchangers. This platform aims at a global assessment of the performances of heating systems functioning with geothermal heat pumps. The evaluation is based on the three constitutive elements, i.e. the ground, the geothermal heat pump, and the building. On the platform, the heat pump and the building are simulated, and only the heat exchangers are tested.

The platform was inaugurated in December 2008 (Figure 8.3). Horizontal and vertical heat exchangers are driven in a controlled manner, allowing simulation of the heat demand of any heat pump or building. There will be three R&D activity areas for heat exchangers: 1) development of new products, performance qualification of the underground heat exchangers and assessment of their impact on the ground, etc.); 2) evaluation or certification of the systems and 3) installation of a network of demonstrators in order to validate the developed new technologies or new concepts. Moreover, this project involves ADEME, CSTB and some private companies, and will integrate the virtual platform on energy in building developed by CSTB, CNRS and CEA. The amount of funding available is 3.4 M€ for the period 2007-2013.

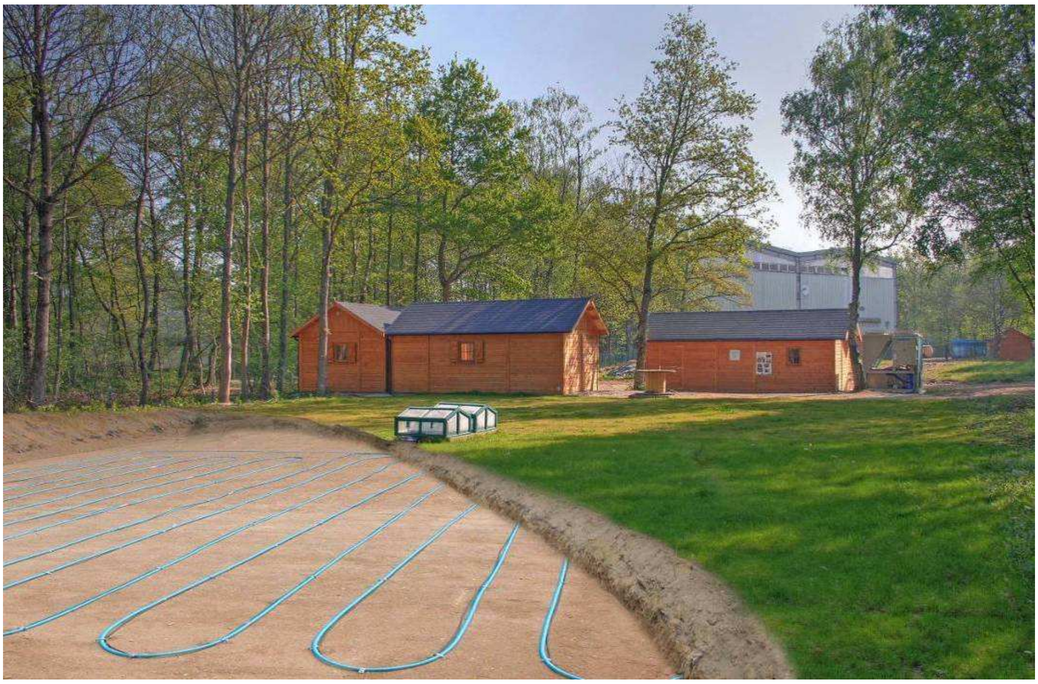


Figure 8.3 *Experimental platform on GBHP underground heat exchangers, BRGM, Orleans. (Photo courtesy of BRGM)*

- Concerning the development of knowledge relating to the geothermal resource:
  - *CLASTIQ : CLAyed SandsTone In Question (2006-2008):* The project aims to estimate the geothermal potential of the clayey-sandstone reservoirs of the Paris Basin and of a few key sectors in mainland France (Figure 8.4). It will review the configurations of geothermal operations carried out on the same type of reservoirs in Europe and also consider the re-injection problems. The partners in this study are: ADEME and BRGM; and the funded amount is 700 k€ for the period 2006-2008.

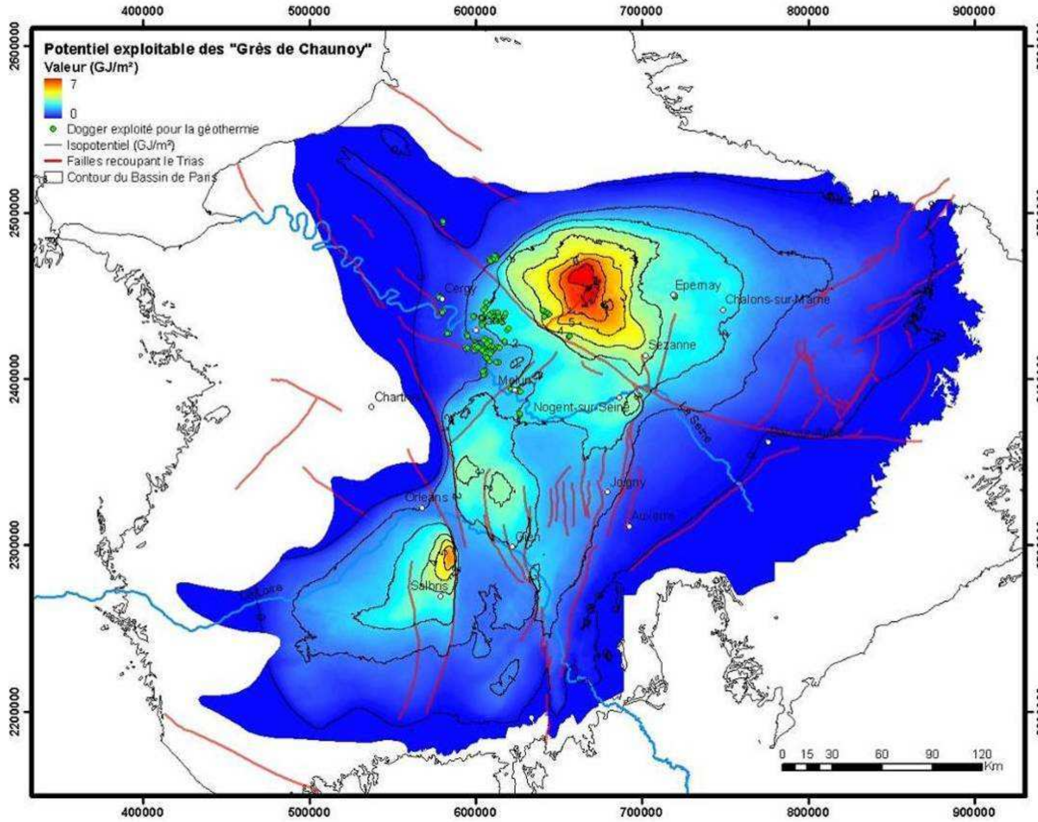


Figure 8.4 Map of geothermal potential of Chaunoy standstone in the Paris Basin. (Courtesy of BRGM)

- *GHEDOM 2 (2005-2008):* The second phase of the GHEDOM project is to develop methods for estimating the geothermal potential of a high-enthalpy field in a volcanic island environment, like that of France's Overseas Departments, and to continue optimizing the surveillance, exploitation and management methods of the Bouillante geothermal field in order to improve and secure the production of electricity. The partners are: ADEME and BRGM, and the funding is 700k€ for the period 2006-2008.
- *GEFRAC 2 (2006-2008):* The first objective is to improve the computing path aimed at describing the hydro-thermo-mechanical behaviour of the geothermal exchangers in a fractured medium. The computing path takes into account conceptual models according to stacked scales ranging from that of the well environment to that of the exchanger dimensions. The aim is to model the access to the exchanger taking into consideration different thermo-hydro-mechanical (THM) couplings based on a realistic geometry of the fracturing. The second objective is to obtain the experimental capability for undertaking fracture percolation tests with the injection of a chemically reactive fluid and to acquire data on the water-rock interactions in the geothermal systems in order to estimate the consequences on the permeability of the fractured medium. Partners in this study are ADEME, BRGM, Itasca and Mines Paris. The amount of funding is 700k€ for the period 2006-2008.

8.6.1.2 Industry Funded Research

R&D activity in the field of geothermal heat pumps exists, but it is difficult to give a good estimate of the expenditures involved. The market in France in 2008 for domestic heat pumps reached 600 M€, only for the equipment production (air-air equipment excluded). Considering that the geothermal heat pumps market represented around 15% of this market and 5% of this part is devoted to R&D activities, the R&D expenditures in the field of geothermal heat pumps could be estimated in 2008 at about 4 M€.

The European Economic Interest Group in Soultz-sous-Forêts dedicated 1.4 M€ for R&D.

8.7 Geothermal Education

There are no education courses dedicated to geothermal energy in France.

An initiative was taken by ADEME and BRGM, who created a 3-day training course for non-technical people on the subject of "management of a GHP project for building". This training course was deployed in 2008.

8.8 International Cooperative Activities

French companies or research institutions were involved in several R&D project funded by the EU, including: Groundreach, Groundhit, Low-bin, HitI (Figure 8.5), I-Get and the Soultz project.

Figure 8.5 *HiTi project- taking measurements on a well in Iceland. (Photo courtesy of BRGM)*

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National Activities

Chapter 9

Germany

Landau geothermal station, Landau, Germany. (Photo courtesy Lothar Wissing).

9.0 Introduction

In 2008, further headway was made in the utilisation of renewable energies, with renewables supplying around 238 billion kWh (2007: approximately 234 billion kWh). However, the share of renewables in the total final energy supply remained about the same in 2008 (9.7 %) as in 2007 (9.8 %). One reason for this was the higher demand for heating, and the consequent increase in final energy consumption (FEC) in 2008 compared to 2007, due to the colder winter. Another contributing factor was the decline in biofuel sales. Due to the mild weather in 2007, the FEC was around 8,585 PJ, significantly lower than the previous year. This led to a disproportionately high renewables share in FEC, which balanced out again in 2008.

The share of renewable energies in the total primary energy consumption in Germany (14,003 PJ) rose from 6.9 % (2007) to around 7.1 % (2008). This result is based on the physical energy content method, with the substitution method estimating the share at 9.7 %.

Developments in 2008 again emphasize that Germany is well on the way to achieving its ambitious targets for the expansion of renewables. With 238 billion KWh, renewable energies already cover

37 % of FEC for private households. Biomass continues to account for most of this, with a share of around 70 %.

9.1 National Policy

9.1.1 Strategy

The 2008 lead study on renewable energies commissioned by the BMU anticipates a positive development for deep geothermal energy in Germany. The study indicates the electricity generation costs of geothermal power plants will decline rapidly up until 2020. Initially, a successful market entry for hydrothermal plants is anticipated, then later for petrothermal (use of hot rock) plants. In this way, it is hoped that the installed geothermal output will rise to 100 MW by 2015, and to 280 MW by 2020, corresponding to an annual electricity production of 1.8 TWh/a. Accordingly, the proportion of geothermal energy amongst the final energy generated from renewable energies would rise to 5% by 2020. As well as electricity generation, the 2008 pilot study shows that use of the waste heat in associated district heating networks is pivotal to the success of geothermal energy development.

9.1.2 Legislation and Regulation

The strong market development for deep geothermal energy in Germany is primarily attributable to the Renewable Energy Sources Act (EEG), which created good economic framework conditions for the operation of geothermal plants as the result of its fee scale. With the adoption of the amended Renewable Energy Sources Act on 6 June 2008, the German Bundestag (Lower House of Parliament) further significantly improved the conditions for geothermal energy in Germany. Whereas the maximum fee was previously 15 €cents/kWh, depending on the size of the plant; under the new provisions, from 1 January 2009, the basic fee has been increased to 16 €cents per supplied kWh (or 10.5 €cents/kWh from a plant capacity of 10 MW). An additional bonus of 4 €cents/kWh is payable for electricity from plants which go live up until 2015.

Operators who use the waste heat from their plants are eligible for a further 3 €cents/kWh. An additional bonus for petrothermal techniques totalling 4 cents/kWh has been introduced to encourage the market launch of innovative technologies. In addition to the CHP bonus under the Renewable Energy Sources Act, the more widespread use of waste heat during geothermal energy generation will now also be encouraged via the Act on the Promotion of Renewable Energies in the Heat Sector (EEWärmeG), or "Heat Act". The Heat Act was adopted by the Bundestag (Lower House of Parliament) on 6 June 2008, and entered into force on 1 January 2009. Under this Act, all owners of new buildings are obliged to purchase part of their heat demand from renewable energy sources.

The BMU's Market Incentive Programme is another tool aimed at developing the market for deep geothermal energy. Under this programme, in 2009, some 400 M€ will be made available to promote renewable energies in the heat market, considerably more than in previous years. As part of the German Government's Integrated Energy and Climate Programme, the BMU has adopted new funding guidelines for the Market Incentive Programme, which offers subsidies for installation of power or heating plants, deep boreholes and heat extraction. The Market Incentive Programme also supports district heating networks that run on regenerative (i.e. renewable) resources.

As part of the Market Incentive Programme and in collaboration with the KfW Bankengruppe, the BMU has created a new loan programme for the long-term financing of deep geothermal drilling. Münchener Rück, (Munich Re Group, en) an insurance group, is supporting the KfW as a cooperation partner. The loan programme helps to hedge the finding risk, i.e. the risk of failing to find sufficient temperatures or water volumes when drilling, and should therefore minimise one of the main barriers to the faster market development of deep geothermal projects. The volume of loans available will be up to 60 M€. Special loans from the KfW will finance up to 80% of the drilling costs of a project, including stimulation measures. In the event of failure to find adequate heat or water, this loan need not be repaid. If heat or water is found, the funding is released and becomes available for use in another project. In order to ensure that the largest possible number of drilling projects can be financed with the loan programme, the default risk is limited by strict application requirements and inspection techniques.

9.1.3 Progress Towards National Targets

In 2008, about 10% of the total energy consumption and around 15% of electricity consumption were met regeneratively, while renewable energies accounted for just over 7.5% of heat consumption. This means that Germany is well on its way to meeting the European Union's expansion targets for renewable energies by the year 2020. By then, Germany aims to be meeting at least 30% of its electricity requirements and 14 % of its heat requirements regeneratively. The EU is hoping to increase the proportion of renewable energies to 20% of total energy consumption. Within this framework, Germany is aiming for a target of 18%.

In 2008, emissions of around 115 million tonnes (Mt) of carbon dioxide (CO_2) were avoided thanks to the use of renewable energies. Under the Kyoto Protocol, Germany undertook to reduce its CO_2 emissions by an average of 21%, relative to 1990 levels, by 2010. This target was exceeded as early as 2007, with a reduction of 22.4%, although the reduction between 2006 and 2007 is partly attributable to special effects.

Emissions were reduced in the waste and agriculture sectors, manufacturing industry, transport and private households. On the other hand, emissions from electricity generation have increased since 1999. This area still offers considerable potential to boost increase efficiency and increase the use of renewable energies.

Germany is also benefiting financially from the expansion of renewable energies. In 2007, sales of renewable energies totalled around 25 billion Euros (B€), and the industry employed around 250,000 people at the end of 2007. For 2008, a rising trend can be assumed. The positive market development was prompted by the Renewable Energy Sources Act (EEG) introduced in the year 2000, which created excellent framework conditions for renewable energies and, in particular, provided investors with the necessary degree of reliability.

9.1.4 Government Expenditure on Geothermal Research and Development

The Advisory Council on Geothermal Research, at its autumn meeting on 2 September 2008, highlighted the accelerating pace of development and implementation for research projects on deep geothermal energy. The scientists stressed that successful projects, such as the geothermal power plant in Landau, were motivating an increasing number of investors to get involved in power plant projects. There is still a high demand for demonstration projects and for research and development. In particular, there is a demand for refinement of detailed exploration techniques, since a precise knowledge of the deep subsurface is pivotal to a project's success. Equally important is the development of powerful deep pumps tailored to the specific requirements of geothermal energy sources. The modified deep pumps from the petroleum mining sector currently available are not designed for aggressive thermal waters with changing load requirements, and in practice, these are often rapidly approaching their technical limitations.

In 2008, the BMU approved a total of 18 new projects with a funding volume of 16.4 million Euros (M€). At the same time, 7.4 M€ were allocated to ongoing projects (Figure 9.1).

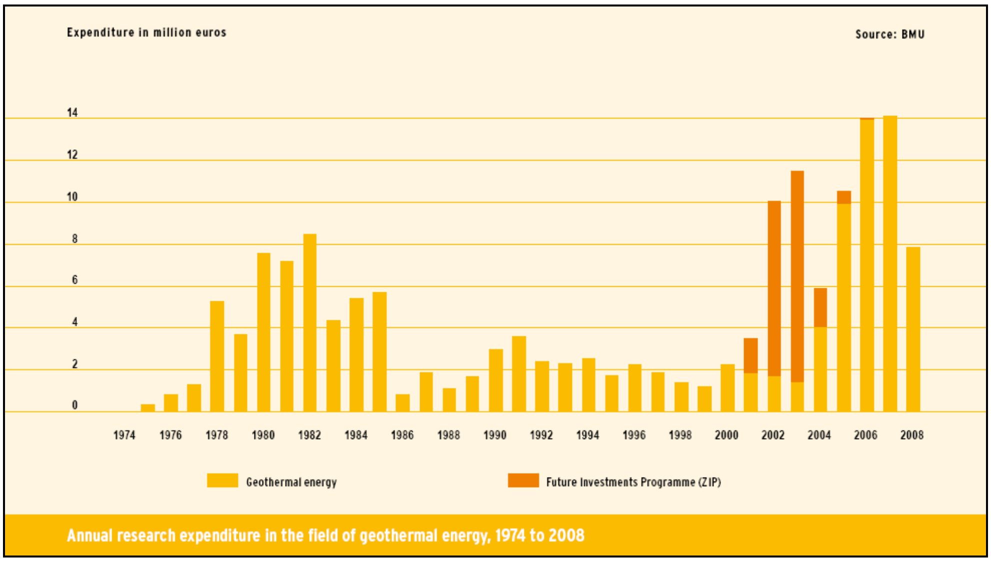

Figure 9.1 Annual geothermal research expenditure. (Source: BMU)

9.2 Current Status of Geothermal Energy Use

9.2.1 Electricity Generation

In November 2003, an organic Rankine cycle plant was installed in Neustadt-Glewe for electricity production (230 kW_e). The second German geothermal power plant began operating in Landau, in 2007; and a third plant, in Unterhaching, also began producing electricity towards the end of 2008. Unterhaching had been generating heat since 2007.

The installed capacity for Landau is 3.0 MW_e and for Unterhaching 3.4 MW_e. This means that Germany currently has a total of 6.6 MW_e of installed geothermal power.

In 2008, the three plants fed 18 GWh into the grid, which is negligible compared to the national demand. More geothermal plants will start operating in the coming years, particularly in southern Germany.

At the end of 2008, there were some 15 geothermal projects underway across Germany, and applications for exploration permits had been submitted for a further 150, or so, sites.

9.2.2 Direct Use

In 2008, the number of heat pumps (all systems) sold in Germany rose to around 62,500, an increase in sales of more than one third compared to the previous year (2007: 44,633 heat pumps). This put the total number of heat pump systems installed in Germany at the end of 2008 at more than 350,000.

The geothermal heat pump figures for 2008 are (*source: Bundesverband Geothermie e.V)*:

- 34,450 newly installed in 2008 (+28.5% compared to 2007)
- 150,000 installed in total

Nevertheless, the share of geothermal energy in total heat generated from renewables is still low, at 2.5%.

In 2008, the total direct use of geothermal energy for near-surface geothermal energy was 2,353 GWh (8.5 PJ), and for deep geothermal energy, 163.0 GWh final energy (0.6 PJ). That means that 2.6% of the heat supply is based on geothermal energy, mainly heat pumps (Figure 9.3).

Geothermal heat supply avoided about 1 Mt of CO_2 in 2008.

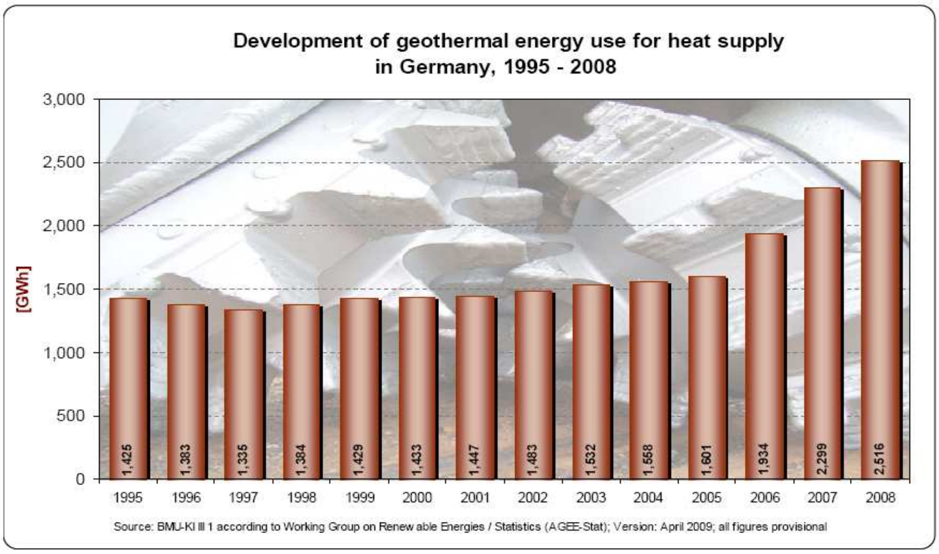

Figure 9.2 Development of geothermal energy use for heat supply in Germany, 1995-2008. (Source: AGEE-Stat)

Table 9.1 Share of renewable energies in total final energy consumption in Germany, 2007/2008 (Source: AGEE-Stat); see also Figure 9.2.

	Electricity		Heat		Fuel		Total		Changes
	2007	**2008**	2007	**2008**	2007	**2008**	2007	**2008**	2007/2008
	[bn KWh]								[%]
Hydropower	21.2	**20.9**	-	**-**			21.2	**20.9**	- 1.4
Wind energy	39.7	**40.4**	-	**-**			39.7	**40.4**	+ 1.8
Biomass*	22.8	**26.0**	94.3	**102.0**	46.4	**37.7**	163.5	**165.7**	+ 1.3
Photovoltaics	3.1	**4.0**	-	**-**			3.1	**4.0**	+ 29.0
Solar thermal energy	-	**-**	3.7	**4.1**			3.7	**4.1**	+ 10.8
Geothermal energy	< 0.1	**< 0.1**	2.3	**2.5**			2.3	**2.5**	+ 8.7
Total	86.8	**91.4**	100.3	**108.7**	46.4	**37.7**	233.5	**237.6**	+ 1.8

Version: April 2009; all figures provisional

Deviations in the totals are due to rounding.

* solid, liquid, gaseous biomass, biogenic share of waste, landfill and sewage gas

Table 9.2 Direct use of heat in Germany 2008. (Source: www.geotis.de)

GeotIS www.geotis.de/vgs

Direct use of heat in Germany 2008

Main use	total installed power	installed power geothermal	Annual production
District heating	161,7 MW_t	57,9 MW_t	205,3 GWh/a
Buildings	1,2 MW_t	1,2 MW_t	0,8 GWh/a
Balneology	44,9 MW_t	44,9 MW_t	372,0 GWh/a
Green houses	-	-	-
others	-	-	-
Total	207,7 MW_t	103,9 MW_t	578,1 GWh/a

Stand 08.04.2009

In die Berechnung wurden die in Bau befindlichen Standorte nicht mit einbezogen.

* Tabellenwerte der Hauptnutzungen auf eine Nachkommastelle gerundet. Summenwerte aus nicht gerundeten Werten berechnet, daher Abweichungen möglich.

** Berechnungen erfolgen nur für die Hauptnutzungen der Standorte. Nebenutzungen werden nicht mit einbezogen.

Source: www.geotis.de

9.3 *Market Development and Stimulation*

In recent years, the steady expansion of renewable energies in Germany has been based on a variety of complementary factors. These include clear political objectives; successful support programmes, such as the Market Incentive Programme; and, in the electricity sector, most especially the investment security provided by the EEG (legal obligation to give priority to the purchase of electricity from renewables, fixed tariffs for a 20 year period).

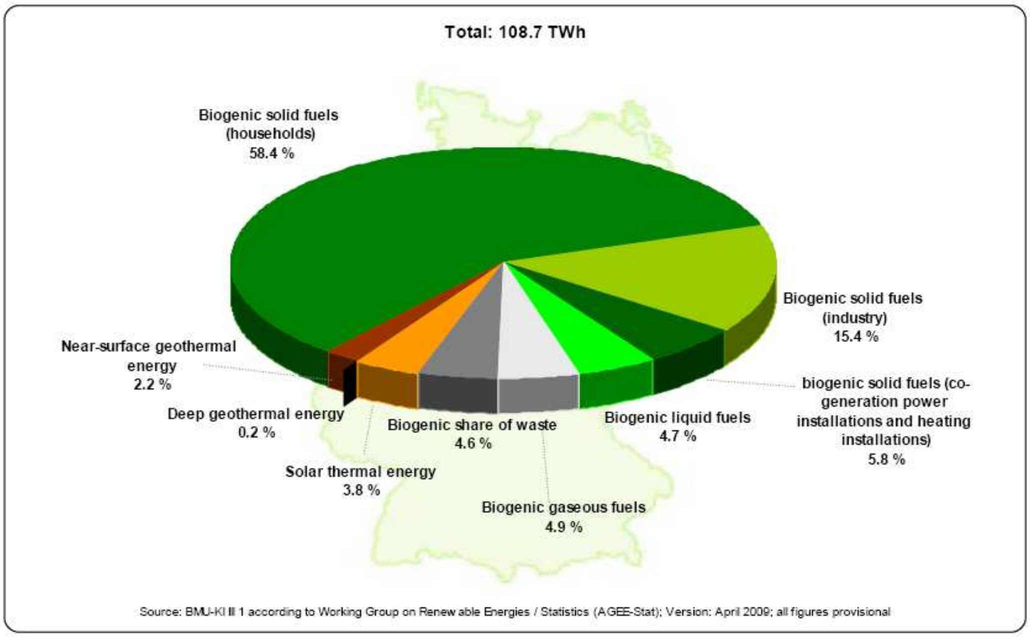

Figure 9.3 Structure of heat supply from renewable energy sources in Germany, 2008. (Source: AGEE-Stat)

The latest decisions of the German Government further improve and update these successful framework conditions. For instance, the new EEG entered into force on 1 January 2009, with significantly more ambitious objectives. Further examples are the introduction of the Renewable Energies Heat Act (EEWärmeG) and substantial topping up of the Market Incentive Programme. In 2008, support funds of 236 M€ resulted in over 150,000 investment projects in the field of heat production from renewables. This is equivalent to an investment volume of 1.6 B€. In 2009, the support volume will rise to 400 M€, and this can be expected to trigger a corresponding increase in investments. The support of renewable energies thus stabilises economic growth- contrary to the general trend.

In 2008, renewable energies gained further momentum in their development into an important economic factor in Germany. An estimate for the BMU shows that total turnover from renewable energies in Germany once more rose compared to the previous year to approximately 29 B€, a rise of around 12.5 %. As recently as 2000, total turnover was only around 7 B€.

This increase in 2008 was particularly apparent in the field of investments in new installations, with growth in photovoltaics, solar thermal power and heat pumps playing a significant role. In all, investments accounted for around 13 B€, and a further nearly 16 B€ was generated by revenues from installation operations. Use of biomass for energy had the strongest turnover at 37%, ahead of solar power (around 34%) and wind energy (around 20%) (Figure 9.4).

Against this background, employment in the renewables sector rose again last year. In an initial estimate for the whole renewable energies sector (including foreign trade and upstream value added stages), an ongoing research project for the BMU puts the gross figure at around 278,000 jobs. This is an increase of nearly 12% compared to the previous year (approximately 249,000 jobs). Thus, since 2004 (approximately 160,500 jobs), employment attributable to renewable energies has risen by about 117,500 jobs, around 73% in just four years.

In 2008, photovoltaics showed the most growth in employment. This branch significantly increased its domestic added value by expanding its production capacities in Germany. The positive developments in the heat market are also fostering employment, with the solar thermal and near-surface geothermal sectors especially benefiting.

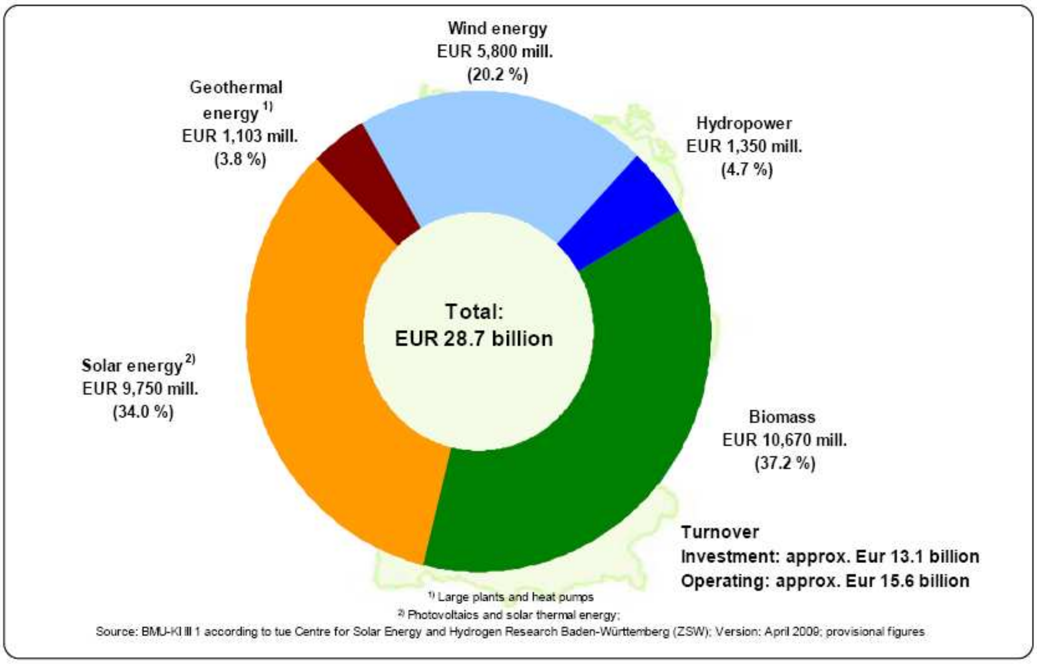

Figure 9.4 Total turnover from renewable energy sources in Germany (Investment and Operating) 2008. (Source: AGEE-Stat)

Biomass continues to make the largest contribution to gross employment, with around 34% (95,800 jobs). This is followed by wind energy with 31% (85,100), solar energy with 27% (74,400), hydropower with 3% (9,300) and geothermal energy with around 3% (9,100). According to a conservative estimate, employment arising from the provision of public and private funds for research and administration was around the same in 2008 as the previous year (about 4,300 personnel), and thus has nearly a 2% share in gross employment.

9.4 Development Constraints

The average geothermal gradient in Germany is 30 °C/km, quiet low for deep geothermal applications. Only in certain regions like the upper Rhine rift valley and the German molasse basin do higher geothermal gradients occur. Therefore, deep drilling down to 3,000-4,000 m is necessary to reach temperature above 100 °C for electricity generation. Associated with this fact are high drilling costs which influence the economic success. Further constraints are the finding risks for such depths and the complicated geological structures in some of the regions of interest. Also, in the northern basin of Germany, the geothermal resources have a high salinity.

Currently, the availability of drilling rigs is poor due to the huge demand of the oil industry. The prices are consequently high for drilling, so some projects are being postponed.

9.5 Economics

2008 was a year with high investments in large geothermal energy plants and heat pumps. The turnover of enterprises engaged in business of construction amounted to 1.1 B€ (Figure 9.5).

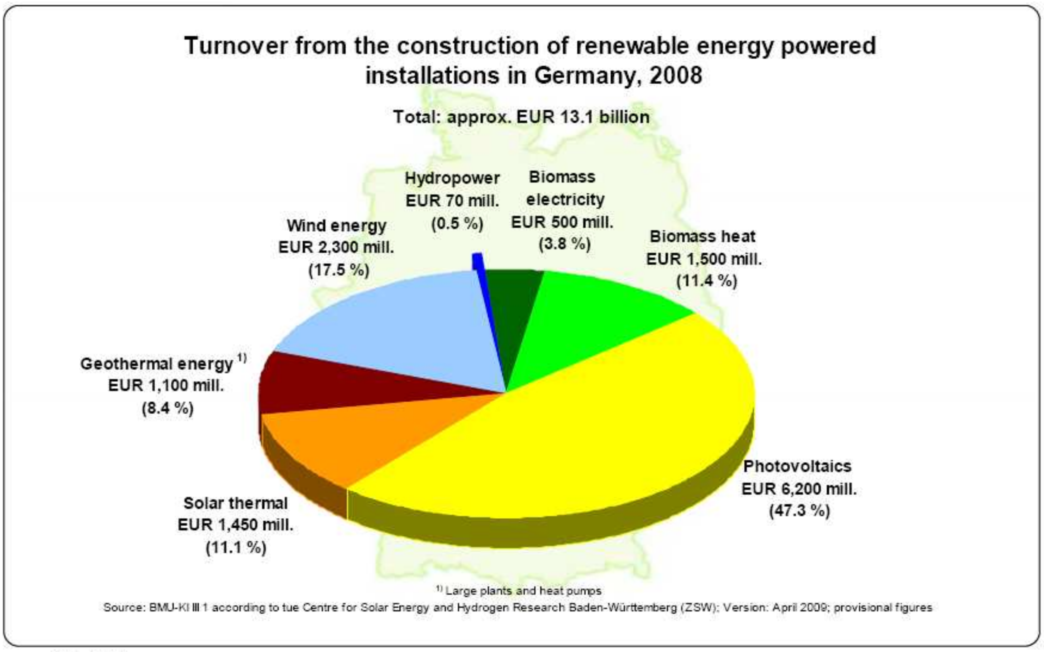

Figure 9.5 Turnover from the construction of renewable energy powered installations in Germany, in 2008. (Source: AGEE-Stat)

Reliable figures for drilling costs, equipment, etc. are not available due to the confidential circumstances of each project.

The production price of conventional generated electricity is about 4-7 €cents/kWh, and the consumer prices are 18-22 €cents/kWh. Prices for energy: oil, gas, coal, electricity depend on the world market prices.

Electricity generation by geothermal techniques is not yet competitive without governmental funding. The simultaneous use of the heat for district heating is essential for the economic success of a project. For this reason, the tendency can be recognized to design projects more for district heating than for electricity generation.

9.6 Research Activities

9.6.1 Focus areas

In its funding announcement of 20 November 2008, the BMU outlined its priority areas for research funding in the field of geothermal energy. The aim is to continuously reduce the cost of extracting and using heat and electricity from geothermal reservoirs. For this reason, the following topics and tasks are a particular focus of funding:

- Development of methods and techniques to minimise the finding risk for drilling within the context of exploration
- Development of measurement techniques and equipment capable of supplying reliable data, while drilling under the high temperatures, high pressures and corrosive

conditions that typify geothermal projects; and for storage-management purposes, and which can also be used for forecasting and storage models

- Development and improvement of drilling techniques used specifically for tapping into geothermal reservoirs
- Development and improvement of methods and techniques to optimise reservoir management and influence productivity, such as stimulation techniques, fracing techniques, and monitoring systems
- Development of equipment, apparatus and machinery capable of reliable, low-maintenance operation under the high temperatures, pressures and corrosive conditions that typify geothermal applications
- Investigation, optimization and development of methods and techniques for converting geothermal energy (hot water and steam) into usable heat and electricity, e.g. cogeneration of power/heat/ cooling, ORC (Organic Rankine Cycle) and Kalina process or innovative techniques; also in combination with other renewable energies
- Addressing fundamental technical issues related to the incorporation of geothermal energy into local supply systems (heat/electricity), also in combination with other renewable energies, with a high multiplication potential

9.6.1.1 Government Funded Research

Preparation and planning- The finding risk remains one of the main barriers to the use of hydrothermal geothermal energy. The finding risk for geothermal drilling is defined using the anticipated volumetric flow, the temperature of the thermal water, and the required pump capacity. As the volumetric flow (known as delivery) and the temperature of the water cannot be reliably predicted, a risk remains. The BMU supports a variety of projects aimed at minimising this risk.

The project *Evaluation of geothermal technology methods and tools for the supply of electricity and heat* by Helmholtz-Zentrum Potsdam, Deutsches GeoForschungsZentrum (GFZ), aims to represent quality improvements in geothermal technological developments in the form of a learning curve. The learning effects and empirical data from geothermal reference projects, such as the GFZ project Groß Schönebeck and other projects, both within Germany and abroad, are incorporated and evaluated. Exploratory geothermal techniques help to minimise the finding and exploration risk of a geothermal resource, and to optimise planning at every stage, right through to design of the reservoir. The available methods are not uniform, but are instead always tailored to the geology of a region. In Germany, the three large-scale geological structures currently in use are Norddeutsches Becken, Oberrheingraben and Molassebecken. To each of these large-scale geological structures several exploration techniques, approaches to work and experiences exist, which must be compared with one another and related to the specific characteristics of the structure. The outcome of the project should be to define the *status quo* of technological development, and devise new scientific approaches to boost efficiency and to minimise costs and risks. Forthcoming research requirements should also be highlighted, aimed at ensuring the efficient use of our domestic geothermal resources. The main criteria are finding forecasting, reservoir design and system reliability of geothermal plants, offering major optimization potential (BMU funding total: approximately 1.5 M€).

In order to improve the project-planning quality of geothermal plants and minimise the finding risk, the Leibniz-Institut für Angewandte Geophysik (LIAG, Leibniz Institute for Applied Geophysics), formerly the Institut für Geowissenschaftliche Gemeinschaftsaufgaben (GGA/Institute for Applied Geosciences) in Hanover, has developed a unique information system. The geothermal information system GeotIS is a compilation of data and information on deep aquifers (water-carrying strata) in Germany that could potentially be very useful for geothermal. GeotIS could be described as a digital version of a geothermal atlas. It is largely scale-independent and always up-to-date. The system provides both basic geoscientific data and current findings and results, which are continuously added to. The main data is provided from more than 30,000 boreholes in Germany, predominantly petroleum and natural gas boreholes, together with mining, geothermal,

thermal and mineral water boreholes. The system also draws on a variety of available databases and studies by the six project partners. Despite offering a wide range of up-to-date data, GeotIS is no replacement for a local feasibility study.

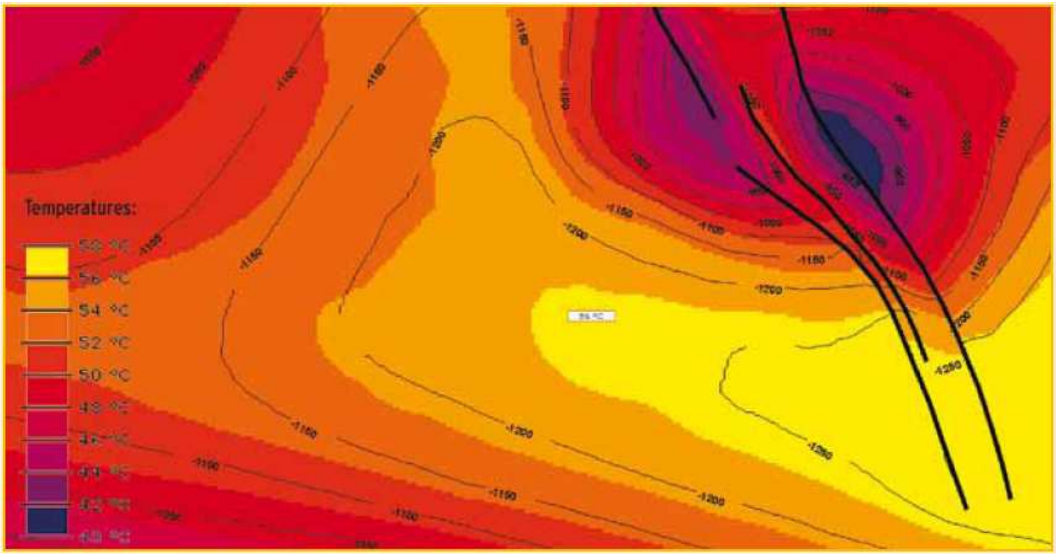

Figure 9.6 Sample application in the geothermal information system: the image shows a depth contour plan of a stratigraphic unit, with temperature distribution shown in colour. (Source: geotis.de)

All searches on GeotIS are internet based. As soon as the test and development phase is complete, the system will be made available free of charge at www.geotis.de. The search interface supports the dynamic generation of interactive maps combining technical information with topographic and statistical data. Dynamically generated vertical and horizontal sections provide a detailed insight into the subsurface, up to a depth of 5,000 m. Essentially, the vertical section is a geological profile. As well as showing geothermally relevant rock strata, it also highlights boreholes in the vicinity. The temperature patterns can also be superimposed in the form of isolines. The horizontal section allows users to view both the temperature distribution over area, and the sequence of layers at a certain depth. Temperature distribution at the base or top of a layer of rock may also be represented (Figure 9.6).

The project was launched in January 2006, and will be activated officially in May 2009 (BMU funding total: approximately 2.3 M€).

Technological development- In view of the comparatively low temperatures (about 110-150°C) of geothermal resources in Germany, special power plant processes are needed to generate electricity, such as the Kalina or ORC process.

The research project *Power plant optimisation – Optimisation of electricity generation* at Hamburg-Harburg Technical University is devoted to the optimization of these power plant processes. Simulations are used to optimize various process circuits and tools, which make allowance for power consumption as well as electricity and heat generation. A number of circuit variants in the Organic Rankine Cycle (ORC) have already been optimized with various operating fluids and simple ORC circuits, with and without thermal recovery, as well as with mixed pressure processes. Research has also been conducted into circuits with inorganic materials. As well as Rankine circuits with pure materials, researchers have also simulated Kalina circuits with fluid mixtures. Simulated Kalina circuits with water and ammonia are used to compare and to optimize assorted circuit variants in terms of the overall efficiency of the plant. All experiments make allowance for both the power consumption of the power plant and that of the thermal water circuit in the overall balance. The studies evaluate the various power plant processes and the optimized circuits with a view to energy-efficient, cost-effective geothermal electricity generation in Germany (BMU funding total: around 160,000 €).

Demonstration projects-

- **Landau** Germany's first industrial, year-round geothermal power plant began operation in Landau, in November 2007 (Figure 9.7). The power plant has an electrical output of around 3 MW, and is capable of supplying around 6,000 households with electricity. The surplus heat generated will be sufficient to heat around 300 households, which could be increased to around 1,000 households. Electricity is generated using ORC (Organic Rankine Cycle) in which the heat is transferred to an organic solvent with a higher steam pressure than water. The solvent circulates in a sealed secondary circuit. It is used to produce electricity in a steam turbine at temperatures of around 90°C.

Figure 9.7 ORC plant in the Landau geothermal power plant. (Source: PTJ-EEN)

- **Unterhaching** Geothermie Unterhaching GmbH & Co. KG provides a combination of geothermal heat and electricity supply in this community to the south of Munich. Around 38 MW of thermal energy is available all year round at temperatures of 60-122°C. Depending on the weather conditions, this can be used either to produce district heating or electricity (up to 3.4 MW), or a combination of both. This is Germany's largest geothermal deep drilling project to date. From a depth of more than 3,300 m, the plant is capable of supplying up to 150 l/s of hot thermal water to the surface. By the end of 2008, the connected load for the district heating network, with its 27 km of pipework, is expected to be around 31.5 MW, equivalent to the supply of 1,700 individual houses, or 3,900 apartments. A plant based on the Kalina technology (Siemens AG) is used to generate electricity. Geothermie Unterhaching calculates that by substituting conventional electricity and heat production plants, more than 30,000 tonnes of CO_2 emissions per annum will be avoided. The long-term aim is to supply a connected load of 70 MW_{th}.

- **Soultz-sous-Forêts** On 13 June 2008, a 1.5 MW power plant for generating electricity from geothermal energy was officially opened in Soultz-sous-Forêts, Alsace (Figure 9.8). This project has received financial support from Germany, France and the EC over a period of many years. Since 1987, experts at this site have been developing the technique for extracting energy from hot, dry, plutonic rock. The site, 50 km north of Strasbourg, is at the centre of a thermal anomaly, where temperatures of 200°C are found at a depth of 5,000 m. The power plant in Soultz is operated by the European Economic Interest Grouping (EEIG) "Heat Mining", whose purpose is to accumulate experience in the management and long-term behavior of a heat exchanger in the deep subsurface, based on this research project. French Prime Minister Francois Fillon and representatives of the BMU attended the official opening of the power plant. The next phase of the project will be to evaluate and optimize the system's operating behavior.

Figure 9.8 *Part of the ORC plant at the geothermal power plant in Soultz-sous-Forêts, Alsace, France. (Source: PTJ-EEN)*

9.7 Geothermal Education

Education with the focus on geothermal issues is offered by universities like University of Bochum, RWTH Aachen, Technical University Berlin and University of Potsdam. Additionally, seminars and lectures are held by several institutions and associations involved in geothermal energy.

9.8 International Cooperative Activities

The Federal Ministry for Environment, Nature Conservation and Nuclear Safety Focus supports the project in Soultz-sous-Forêts and participation in the IEA as a member of the Geothermal Implementing Agreement.

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National Activities

Chapter 10

Iceland

Figure 10.2 Steam rising at the geothermal field Brennisteinsfjöll on Reykjanes peninsula. The field is one of the proposed power project sites under consideration in the Master Plan. (Photo courtesy Jonas Ketilsson)

10.0 Introduction

During the 20th Century, Iceland has emerged from one of Europe's poorest countries, dependent upon imported oil and coal, to a country with one of the highest standards of living where practically all stationary energy, and 82% of primary energy, is derived from indigenous renewable sources with near carbon-free electricity production. This is the result of an effective policy in making renewable energy a long-term priority in Iceland. Nowhere else does geothermal energy play a greater role in providing a nation's energy supply. Geothermal primary energy consumption contributed 62% in year 2008, equivalent to 140 PJ (see Figure 10.1). The principal use of geothermal energy is for space heating, with 89% of houses heated with geothermal energy.

10.1 Highlights for 2008

Reykjavik Energy installed an additional two 45 MW_e high-pressure turbines in autumn 2008, increasing the total capacity of Hellisheidi geothermal power plant to 213 MW_e. Currently, eight geothermal power plants of total estimated 785 MW_e installed capacity are under formal consideration as can be seen in Table 10.1, of which at least 90-180 MW_e will be installed in 2010-

2011. The geothermal industry, e.g. Iceland GeoSurvey, have for quite some time served as consultants in various geothermal projects around the world.

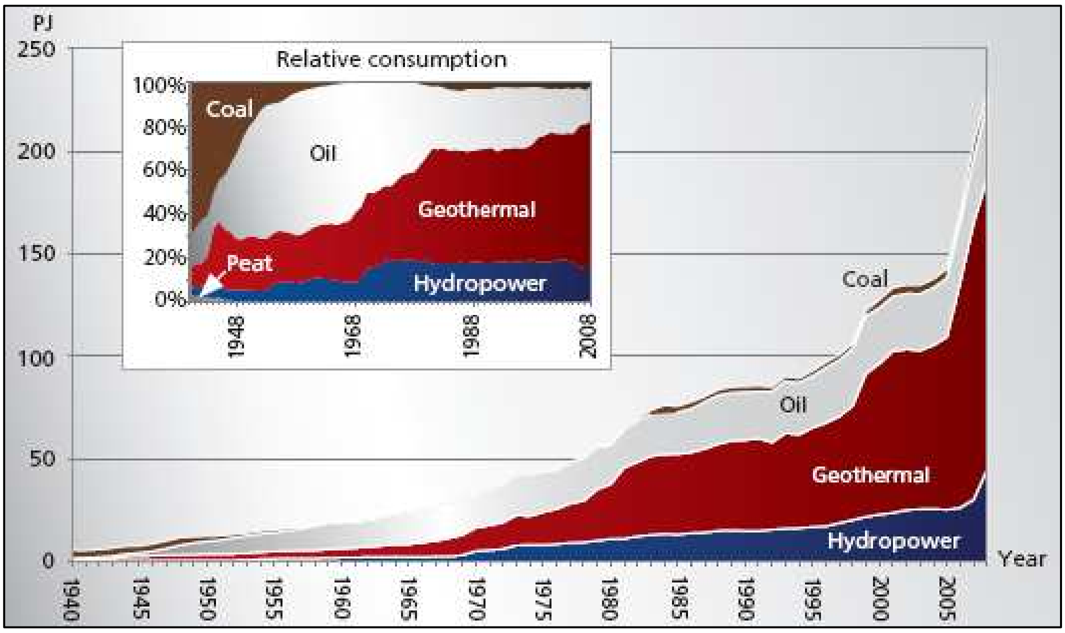


Figure 10.1 Primary energy consumption in Iceland 1940-2008.
(Source: Energy Statistics 2009, Orkustofnun)

10.2 National Policy

It is the policy of the Government of Iceland to increase utilization of the renewable energy resources even 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 are being evaluated and categorized on their energy efficiency and economics, and also on the basis of the impact that the power developments would have on the environment. The Master Plan is to be presented to the Icelandic Parliament for formal consideration in 2010. There has, as well, been a government 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 presented in Figure 10.3.

In Iceland, ownership of resources is associtated with the ownership of land. However, exporation and utilization is subject to licensing. Three major amendments have recently been made to the energy legal framework in Iceland: (1) the ownership of resources can no longer be sold by the state or municipalities, although utilization rights can be leased to a developer for up to 65 years, with a possibility of extension; royalties for the utilization are determined by the Prime Minister; (2) producers of electricity compete on an open market in Iceland. Therefore CHP power plants are obliged to keep separate accounts for heat and power production to prevent cross subsidization of electricity; (3) the National Energy Authority can grant licenses on behalf of the Minister of Industry.

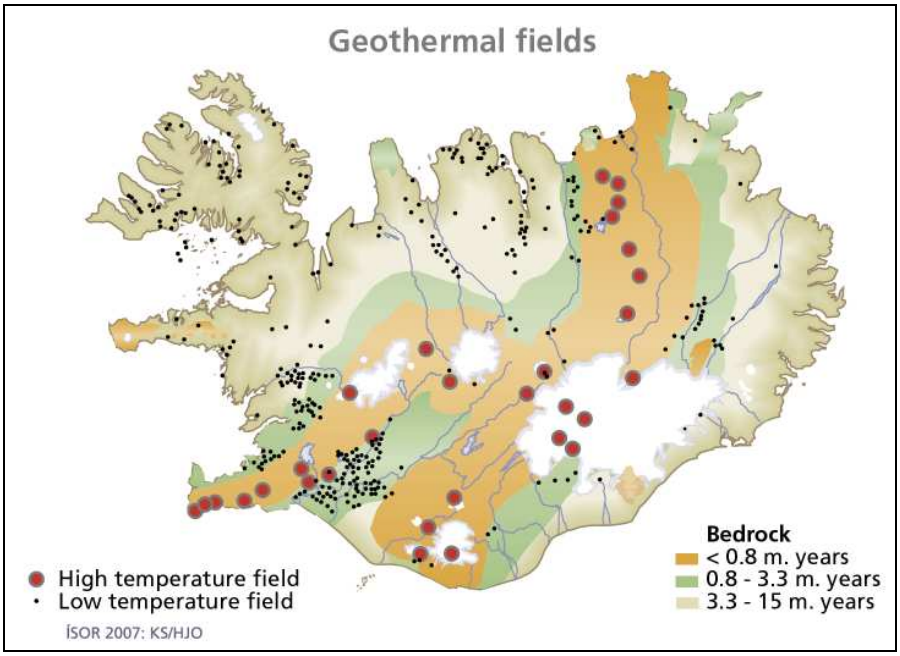


Figure 10.3 Location of high temperature geothermal fields in the volcanic zones of Iceland and clusters of low temperature springs on the flanks of the volcanic zones. Iceland is located on both a hotsport and the Mid-Atlantic Ridge, which runs right through it. This combined location means that geologically, the island is extremely active. (Energy Statistics 2009, Orkustofnun)

10.3 Current Status of Geothermal Energy Use in 2008

10.3.1 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 575 MW_e at the end of year 2008. Electricity generation from geothermal power plants was 4.0 TWh in 2008, but is predicted to increase to 4.6 TWh in 2009 (see Figure 10.4).

Table 10.1 Installed and planned electric capacity in August 2009. (Source: Orkustofnun)

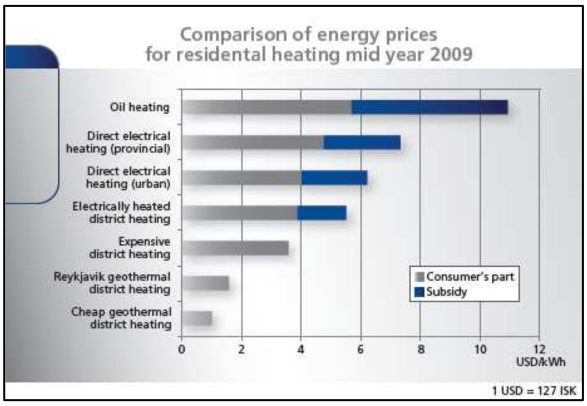
Geothermal Field [MWe]	2005	2006	2007	2008	Licensing	EIA completed	EIA started	Future	Total
Bjarnaflag	3	3	3	3	-	90	-	-	93
Krafla	60	60	60	60	-	-	150	30	240
Þeistareykir							200	40	240
Húsavík	2	2	2	2	-	-	-	-	2
Hengill area	120	210	243	333	180	135	-	90	648
Svartsengi	46	46	76	76		-	-	44	120
Reykjanes		100	100	100	-	100	-	20	200
Other fields	-	-	-	-	-	-	-	1720	1720
TOTAL	*232*	*422*	*485*	*575*	*180*	*325*	*350*	*1994*	*3263*

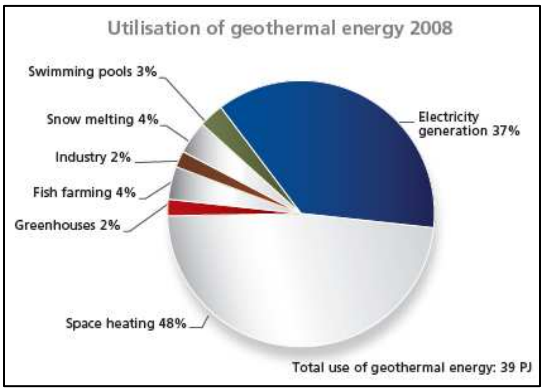
10.3.2 Direct Use

The total direct use of geothermal energy in 2008 was estimated to be 25 PJ, of which 19 PJ was for space heating. Currently, 89% 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 10%, 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 163 geothermal swimming pools in Iceland, at 134 sites, with a total surface area of 33,800 m². 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 920,000 m². There has been no increase in direct industrial uses of geothermal energy in Iceland during the last years, and in 2004, the diatomite plant at Lake Myvatn closed down (it had consumed 444 TJ/year). A seaweed processing plant at Reykhólar, west Iceland, uses about 250 TJ/year for drying. A plant for the commercial production of liquid CO_2 has been in operation at Haedarendi in south-west Iceland since 1986. Geothermal water is also used for heating greenhouses and for small scale timber and fish drying. Various energy statistics can be found in Figure 10.4.

10.3.3 Energy Savings

In 2008, the total CO_2 emission from geothermal power plants was 185,140 tonnes, as can be seen in Table 10.2. Geothermal utilization was equivalent to 4.638 Mtoe in year 2008 (IEA conversion factors: 1163 GWh/Mtoe for electric generation and 20,921 TJ/Mtoe for direct use).





The main district heating companies in Iceland

	Number of wells 2008	Population 2008	Distribution 1000 m³ 2008
Reykjavik Energy *geothermal*	93	204.208	85.626
HS veitur	13	24.932	14.621
geothermal		21.332	13.320
electricity / oil		3.600	1.301
Nordurorka hf. *geothermal*	18	19.039	9.088
Skagafjardarveitur *geothermal*	10	3.516	4.092
Selfossveitur *geothermal*	7	7.821	3.700
All heating services	**330**	**294.176**	**140.000**

Installed capacity in power station

	2008		2007	
	MW	%	MW	%
Hydro	1.879	73,0	1.758	68,3
Geothermal	575	22,3	485	18,8
Fuel	120	4,7	120	4,7
Total	**2.574**	**100,0**	**2.363**	**91,8**

Electricity production

	2008		2007	
	GWh	%	GWh	%
Hydro	12.427	75,5	8.394	70,1
Geothermal	4.038	24,5	3.579	29,9
Fuel	3	0,0	3	0,0
Total	**16.468**	**100,0**	**11.976**	**100,0**

Figure 10.4 *Energy Statistics in Iceland. (Source: Energy Statistics 2009, Orkustofnun)*

Table 10.2 Emission of CO_2 in year 2008 per electric and heat production. (Source: Orkustofnun)

Geothermal Field	Emission (tonnes/a)	Emission per electricity production (g/kWh)	Emission per CHP production (g/kWh)
Reykjanes	24,310	28.1	
Svartsengi	61,182	108.8	39.3
Hellisheiði	32,937	29.2	
Nesjavellir	20,904	21.4	6.5
Námafjall	1375	86.7	
Krafla	44,272	90.8	
TOTAL	*185,140*	*Weighted average: 45.9*	

10.4 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 77% of the total consumption in year 2008. 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.

10.5 Development Constraints

Development constraints are mostly due to environmental issues, 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 government subsidies, amounting to 951 M ISK in 2008, to communities where there is no access to geothermal water for space heating (see Figure 10.3). The subsidies, although effective for regional development, can decrease interest in search for geothermal resources.

10.6 Economics

Geothermal power is competitive with hydro in Iceland; providing reliable base load, green energy and favorable prices: 8 ISK/kWh + VAT for 3.5 MWh/year consumption, but can get considerably lower for the power intensive industry due to very high load factor. For residential heating see Figure 10.4.

10.7 Research Activities

10.7.1 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 out of hydrothermal systems at supercritical conditions. 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 troubles 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, and is waiting for testing and analysis. The decision on where to drill the next well has not yet been made. 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 installments.

10.7.2 Government Funded Research

Orkustofnun represents the government on a steering committee of the IDDP. The total amount from Orkustofnun will be at maximum 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 theyears 2007-2009, 172 M ISK were granted to exploration in 29 places, of which total cost is estimated to be 300 M ISK. The Icelandic International Development Agency (ICEIDA) is involved in stimulating geothermal utilization in

***Figure 10.5** Recently opened geothermal wells at Hellisheiði power plant which Reykjavik Energy operates. (Photo courtesy Jonas Ketilsson)*

developing countries like e.g. Nicaragua. The cost of just the Nicaragua-project as a whole is estimated to be just over US$ 4 M. ICEIDA has also participated in a joint project with six states in northwestern Africa. 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 (ARGeo).

10.7.3 Industry Funded Research

The three major power companies in Iceland each grant US$ 1.4 M for R&D in 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 Reykjavik Energy granted, in 2008, 99 M ISK to 39 projects. The energy fund of Landsvirkjun Power granted, in 2008, 40 M ISK to various energy projects.

10.8 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, amounting to US$ 5 M/year.

The School for Renewable Energy Science (RES) in Akureyri and Reykjavik Energy Graduate School of Sustainable Systems (REYST) both started their first academic year in 200,8 offering education in the field of renewable energy, emphasizing on geothermal.

Figure 10.6 *Fellows of the UNU Geothermal Training Programme in Iceland 1979-2007. (Source: Orkustofnun)*

10.9 International Cooperative Activities

Iceland is a member of IEA-GIA and leads the Annex VIII and Task E of Annex I. It is a member of the International Geothermal Association, with two BoD Members, and now hosts the IGA Secretariat, having done so since September 2004. Iceland is also a Member of the World Energy Council, cooperates within the EU, and is a partner of the Enhanced Geothermal Innovative Network for Europe (ENGINE) and HiTi-project, designing high temperature instruments for supercritical geothermal reservoirs which both are partly funded by the 6th EU Framework Programme. Orkustofnun hosts the UNU-GTP, and ICEIDA is involved in stimulating geothermal utilization in developing countries. The first Workshop on International Partnership on Geothermal Technology was held in Iceland 27-28 August 2008.

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

10.10 References

Orkustofnun (2009) Energy Statistics-2009.

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Italy

Figure 11.2 A view of the 40 MW Nuova San Martino power plant installed in the southern area of the Larderello field. (Photo courtesy Guido Cappetti, ENEL)

11.0 Introduction

In Italy, the geothermal resources are mainly exploited for the purposes of generating electricity. An overview on the development of the activities carried out in the year 2008 is presented in this chapter.

All of the plants in operation are located in Tuscany, in the two *historical* areas of Larderello-Travale and Mount Amiata. In 2008, with the installed capacity of 810.5 MW (711 MW operating capacity) the gross electricity generation reached 5,500 GWh.

Though this represents only 1.8% of Italy's total domestic generation, it meets about 25% of the electricity demand in Tuscany, the Italian region where all the geothermal plants are located.

Besides the electricity generation, geothermal fluids are used as heat sources, mainly for spas, space and district heating, greenhouses and fish farming. In 2008, the supply of thermal energy totalled about 8,000 TJ.

11.1 The Electricity Market in Italy

In accordance with the liberalization process of the electricity market in Italy, Enel was obliged to reduce its quota of electricity generation below 50% (it was 73% in 1998), so 15,057 MW of its generating capacity were sold to other operators in the period 2001-2003. As a consequence, several international competitors are now present in the Italian electricity market and Enel, which is still the main operator, now has a quota of about 30% of electricity generation.

Since 1 April 2004, the Italian Power Exchange has been operating, and in the same year an independent private company, called TERNA, was established for the ownership and management of the national high voltage electric grid (transmission network).
In the year 2007 (2008 data not available at time of writing) the electricity needs in Italy reached 360,200 GWh, with a domestic contribution of 87.2%, with the remaining 12.8% imported.

As regards the 314 TWh of domestic electricity generation, 82.5% comes from fossil fuels, 12.2% from hydro and 5.3% from geothermal, biomass, wind and solar (*Figure 1*). Even if the contribution of geothermal electricity generation is only 1.8% of the whole Italian generation, it covers about 25% of the electricity needs in Tuscany, giving a substantial contribution to the green energy generation in this Region.

11.1.1 Enel Green Power

In response to the growing demand for renewable energy, recorded in recent years as a result of commitments signed by many governments aimed at reducing CO_2 emissions, a new company, Enel Green Power, fully owned by Enel Group, was established in December 2008.

This company draws its strength from Enel expertise and experience in geothermal, small-hydro, wind, biomass and solar power generation, and is dedicated to developing and managing energy generation from renewable resources both in Italy and abroad (Europe and American continent).

At present, Enel Green Power operates in sixteen Countries and is the world leader in this sector, with 17.2 TWh produced (covering the energy consumption of 6.5 million families and avoiding 13 million tons of CO_2 emissions every year). The installed capacity is around 4,500 MW, and there are over 500 plants currently in operation, or under construction, around the world.

11.2 Current Status of Geothermal Energy Use

11.2.1 Electricity Generation

All geothermal plants in operation are located in Tuscany, in the areas of Larderello/Travale-Radicondoli and Mt. Amiata (Figure 11.1).

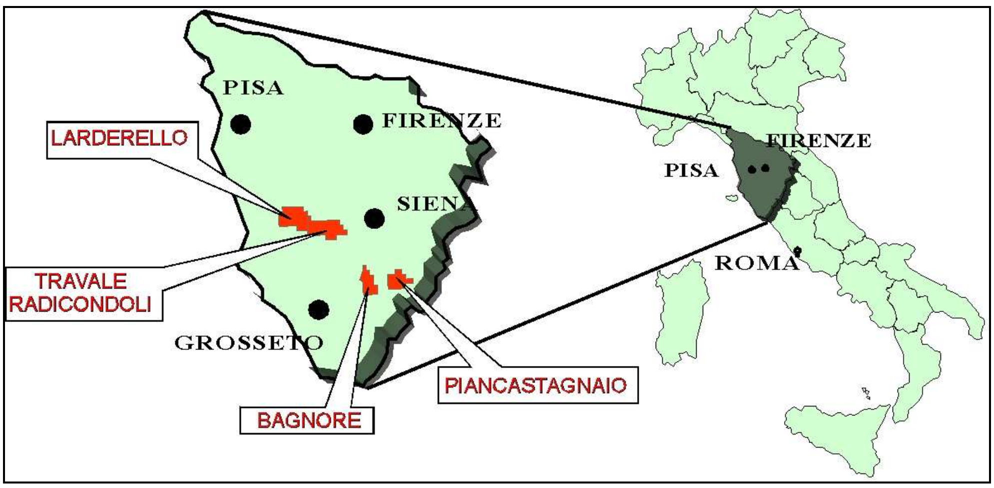

Figure 11.1 *Location of geothermal fields in Italy.*

As of 31 December 2008, 244 production wells were in operation, with a steam network of 184 km total length. In addition, 30 reinjection wells were in operation, with a total water network of 242 km.

32 units (with capacities in the range 10-60 MW) were in operation, with a total installed capacity of 810.5 MW gross and a maximum running capacity of 711 MW gross.

The net electricity generation in 2008 was 5,181 GWh, of which 88% was in the Larderello/Travale – Radicondoli area and 12% in the Mount Amiata area.

11.2.1.1 Drilling Activities

The following drilling activities were carried out in the course of 2008:

- Drilling and completion of 4 production wells and 1 reinjection well
- Workover/deepening activities in 4 wells
- Drilling and completion of 1 deep exploratory well (the last in the frame of the "Deep Exploratory Program" launched in 2003 in the area of Larderello/Travale-Radicondoli)

A total of 14,261 m were drilled in 2008.

11.2.1.2 Power Plant Construction

Nuova San Martino- The 40 MW Nuova San Martino is the most recent power plant built in Italy. It was put in operation at the end of 2005 (Figure10.2, chapter title page). In 2008, there were no new power plants commissioned, but the construction of two 20 MW units has begun, and the commissioning is expected in 2009.

AMIS plant construction- The AMIS abatement plants have been designed by Enel to remove H_2S and Hg from plant emissions. This technology makes it possible to substantially reduce the environmental impact of the generation park, with a consequent acceptability improvement from the local population. It will eliminate the bad smell of H_2S present in the geothermal areas, which represents a real nuisance for the people living near the plants. In addition, Hg removal will prevent possible effects of mercury build up in soils, water and food chain in the long-term operation of the plants. A picture of the AMIS plant installed at the Nuova Gabbro plant (20 MW) is given in Figure 10.3. Four additional AMIS plants were installed in 2008.

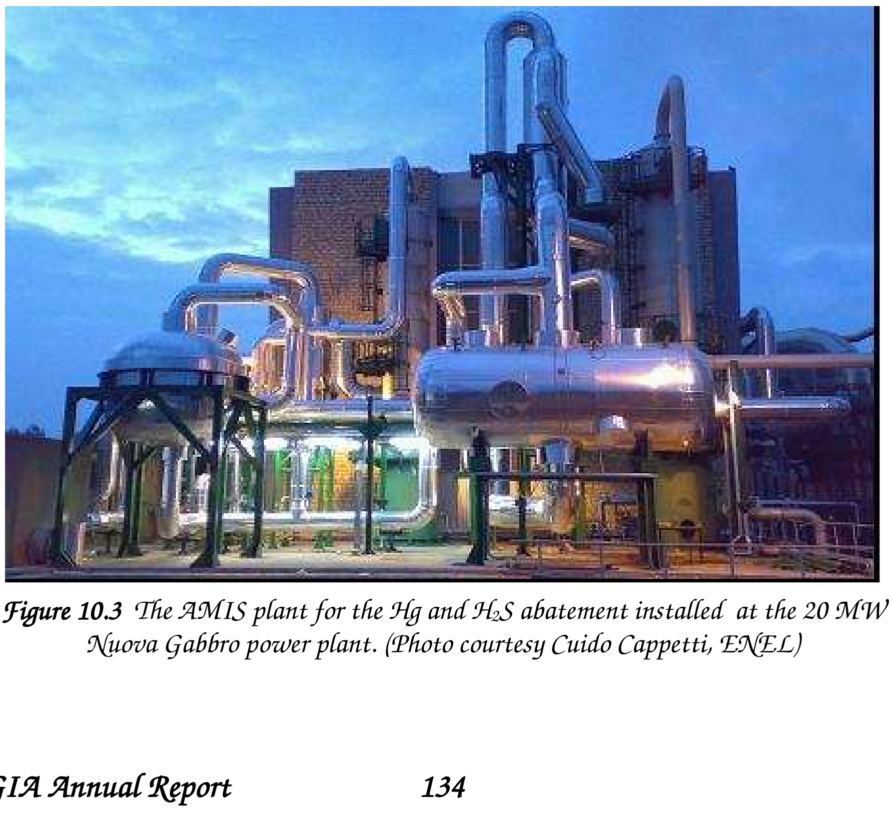

Figure 10.3 *The AMIS plant for the Hg and H_2S abatement installed at the 20 MW Nuova Gabbro power plant. (Photo courtesy Cuido Cappetti, ENEL)*

11.2.2 Direct Uses

Besides electricity generation, the geothermal fluids are also used in Italy as thermal sources. The yearly average of the total heat supply was about 8,000 TJ/y in 2007.

Most of the applications (60% of the supply) are devoted to bathing (temperatures less than 40°C), which has a long tradition in Italy, dating back to Etruscan and Roman times. There are also several other uses including space and district heating, fish farming, greenhouses and industrial process heat.

Enel is engaged in geothermal direct uses, supplying the equivalent of about 1,100 TJ/y of geothermal heat. In addition, Enel is also selling about 36,000 t/y of nearly pure CO_2, produced from a deep well located in the Torre Alfina field (Latium) that is used, after purification, in the food industry.

11.2.3 Avoided Emissions

The utilization of geothermal fluids for electricity generation and direct uses provides a saving of about 1.5 Mtoe (million tons of oil equivalent); avoiding, at the same time, the emission of about 3 million tons of CO_2 into the atmosphere.

It should be noted that the exploitation of steam-dominated fields reduces the amount of CO_2 naturally emitted from the ground in the geothermal areas, so that the total CO_2 emission (natural plus power plant emission) remains unchanged. For this reason, the CO_2 emission has not been included by ARPAT (the Italian Agency for the protection of the environment and the territory) in the GHG inventory.

11.3 Market Development and Stimulation

Specific policies for supporting the development of renewable resources have been adopted in Italy. From the year 2001, all of the operators (importers and producers of electricity from non-renewable sources) have to supply a quota of their input into the grid from renewable sources within the following year. This quota was initially, i.e. from the year 2002, set at 2% of the total energy produced or imported, exceeding 100 GWh (excluding cogeneration, auxiliary consumption and exports).

The conceived mechanism provides a great deal of flexibility: operators are allowed to meet their obligations either by generating directly or by purchasing from others some or all of the necessary "green" energy, or simply their rights (as in the spirit of the *Green Certificates*).

According to a Decree Law issued in January 2004, the initial quota of 2% was increased to 2.35% for the year 2005, to 2.7% for 2006 and to 3.05% for 2007, to keep up with international commitments for the CO_2 emission reduction. With a subsequent law in 2007, the quotas were updated to 3.80% for 2007, and a yearly increase of 0.75% per year was fixed up to 2012, giving a final quota of 7.55% for this year.

The value of the *Green Certificates* was modified at the end of 2007, making it equal to the difference between 18 €cent/kWh and the average market price of the electricity; a multiplying coefficient (different for each renewable energy source; it is 0.9 for geothermal) has then to be applied to this difference. Small power plants (typically below 1 MW) are allowed a fixed price (again, differentiated by source; it is 20 €cent/kWh for geothermal).

The calculation mechanism may be updated every three years.

Green Certificates are awarded to new power plants in operation after April 1999, and for a period that was initially 8 years and subsequently extended to 12 years. For plants in operation after January 2008, they are awarded for 15 years.

In 2008, the average market price of the electricity was approximately 7 €cent/kWh. The value of the net kWh generated from new or recent geothermal power plants awarded with *Green Certificates* is around 17 €cent/kWh; this incentive makes it possible to proceed in Italy with the exploration, development and utilization of deep geothermal resources, up to 3,500-4,000 m depth, which requires the drilling of very expensive wells.

State incentives for the direct use of heat from geothermal sources are also provided. They consist of:

- Incentive to the end users of 10.33 €/MWh_t on a permanent basis plus 15.49 €/MWh_t to be confirmed every fiscal year
- Incentive to the developers for new supplies or for increasing the existing ones, that is 20.66 €/kW_t

11.4 Environmental/Acceptability Aspects

The strong interaction occurring between geothermal activities and territory, taking into account that we operate in Tuscany, has placed serious hindrance to developing new projects.

Aiming at the retrieval of a constructive and mutually beneficial relation with the territory, Enel has initiated a number of initiatives to reduce the environmental drawbacks and increase the acceptability.

New design solutions have been adopted to reduce the noise and visual impact of drilling pads, gathering systems and power plants. Moreover, an innovative plant for the abatement of mercury and hydrogen sulphide (AMIS) was designed and put in operation with very positive results, improving significantly the acceptability by local population.

11.5 Royalties and Contributions

The royalties for the exploitation leases are 1186.2 €/km^2.

In addition, it should be noted that, by law, Enel must pay royalties for every kWh generated from geothermal resources to the municipalities and to the District where the plants are located. For the year 2008 the royalties have been:

- 0.12752 €cent/kWh to the affected municipalities
- 0.19123 €cent/kWh to the Tuscany District Authority

From 2008, Enel must also pay, for the new plants that will be commissioned, a contribution of 650,000 €/MW of installed capacity to the municipalities where the plants are located. The contribution is spread over 10 years.

11.6 Economics

The geothermal projects developed in recent years in Italy are concerned with deep resources, with relevant huge investments in drilling activities (wells up to 3,000-4,000 m), and therefore the total capital cost for a new development project is around 4 million €/MW_e installed, depending on the well depths, productivities, chemical composition of the fluids.

Accordingly to the above mentioned consideration, the development of new projects is still feasible thanks to of the presence of *Green Certificates*.

11.7 Research Activities

Research activities have been focused both on the implementation of advanced methodologies (3-D seismic) aimed at reducing the mining risk of deep drilling and on the methodologies aimed at solving/mitigating the corrosion problems in the wells, the gathering systems and the power plants caused by the presence of chlorine in the steam produced from deep wells.

These activities have been carried out in collaboration with universities and research institutions both in Italy and in Europe.

11.8 International Activities

Enel has been engaged in several exploration and development programs in Central, South America and in USA. In El Salvador, as partner of La Geo, Enel has completed the further development of the Berlin field with the drilling of wells and the construction of a 44 MW power plant, that began commercial operation in February 2007.

Exploration activities have been started in some areas of Chile, Nicaragua and Guatemala. In the USA, development programs for about 140 MW of binary units have been initiated in four different areas of Nevada, Utah and California.

In Nevada, 9 wells have been drilled in the two areas of Stillwater and Salt Wells, and construction of the power plants was started in 2008.

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National Activities

Chapter 12

Japan

Figure 12.8 Production test of the well N19-IK-1 in the east of Ikedako, Kagoshima Prefecture, Japan, on 18 November 2008. (Photo courtesy of H. Muraoka)

12.0 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 43 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 phase 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 of 0.22 MW_e in 2006. This pessimistic trend will soon be changed by the "New Energy Law", revised in 2008 to reintroduce geothermal energy into "New Energy".

12.1 Highlights for 2008

The year 2008 was marked by some highlights:

- Geothermal energy was included back into "New Energy" in Japan from April 2008, though it was virtually restricted to only binary-cycle plants
- The New Energy and Industrial Technology Development Organization (NEDO) adopted two new fields for the Geothermal Development Promotion Surveys: Shimoyu (Aomori) and Otari-mura (Nagano)
- National Institute of Advanced Industrial Science and Technology (AIST) made the GIS-base hydrothermal resource assessment in Japan, estimating 23,470 MW_e for shallow-depth hydrothermal resources above 150°C for all of Japan
- The Japan International Cooperation Agency (JICA) prepared the Master Plan Study for Geothermal Power Development in Peru

12.2 National Policy

12.2.1 Strategy

The Agency for Natural Resources and Energy (ANRE), the Ministry of Economy, Trade and Industry (METI), is in charge of Japan's energy policy. METI states that the promotion of the geothermal energy development is extremely important, because it is one of the alternative energies to oil; it is a clean and stable domestic power supply that answers a social request like the mitigation of global environmental problems. Therefore, the inducement at the early stage of geothermal power generation development, where private entrepreneurs aim for potential geothermal power, is extremely useful.

To adjust the environmental contribution statistics of the international standard "Renewable Energy", the New Energy Committee of ANRE under METI proposed that it would be better if small-scale hydro and geothermal energy should be included back into the Japanese-specific category "New Energy" on 24 March 2006. This motion was positively discussed in the following two meetings of the Committee, and adopted as an express statement, 26 May 2006. This was legally enacted on "the Special Measures Law for the Promotion of Utilization of the New Energy" (so-called the New Energy Law) in April 2008.

12.2.2 Legislation and Regulation

The "Law Concerning Promotion of the Development and Introduction of Alternative Energy" was enacted in 1980, and the promotion strategy for geothermal energy was described. While the "Special Measures Law for the Promotion of Utilization of the New Energy (so-called New Energy Law)" was launched in 1997, geothermal energy was excluded from definition of New Energy which needs governmental support. Then the "Renewable Portfolio Standard Law" was enacted in 2003, where geothermal energy was included as renewable energy in this law but realistically restricted to binary-cycle plants.

There is no stand-alone geothermal legislation that defines geothermal resources and governs their use and development in Japan. F or example, an application for geothermal drilling is governed by the Hot Spring Law and its implementation is approved by hot spring deliberation committees in local governments.

12.2.3 Progress Towards National Targets

The numerical target for geothermal electrical capacity has remained 535 MW_e for the electricity power industries since FY2000. This means that the objective for the moment is only to maintain the current state. However, geothermal energy is expected to promote developments, considering the mitigation of regional environmental impact by its clean nature, improvement of economy and reduction of the risks of energy security by its purely domestic origin. On the other hand, no target is given for the direct use of geothermal energy, either qualitatively or quantitatively.

12.2.4 Government Expenditure on Geothermal R&D

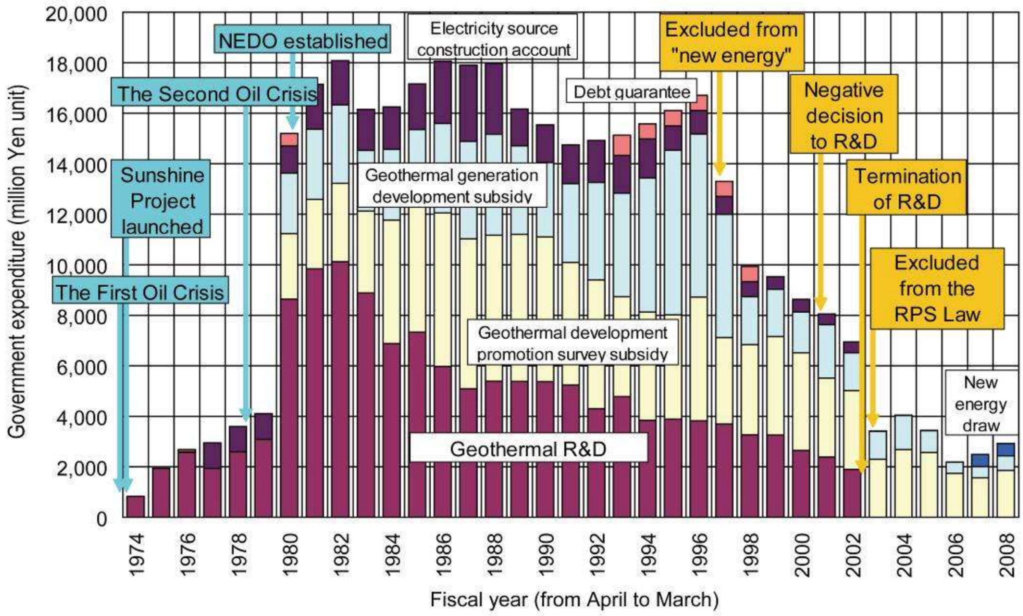

Figure 12.1 A chronological change of annual geothermal budgets in Japan.

A chronological change of government expenditure on geothermal development in Japan, including the geothermal R&D as well as the market stimulating subsidy, is shown in Figure 12.1 (Thermal and Nuclear Power Engineering Society, simplified as TENPES hereinafter, 2009).

The government expenditure has been drastically decreasing during the last decade, reflecting that the geothermal energy was excluded from "New Energy" in 1997. In particular, the national geothermal R&D projects ceased in FY2002.

12.2.5 Industry Expenditure on Geothermal R&D

In the current, less incentive situation, the market for geothermal power generation developments in a private sector is inactive except for those of overseas investment by trading companies and those of plant facility exports by turbine and generator makers.

12.3 Current Status of Geothermal Energy Use in 2008

12.3.1 Electricity Generation

12.3.1.1 Installed Capacity and Electricity Generated

The total installed electricity generation capacity for geothermal energy at the end of March 2008 was 535.26 MW_e, including that of the companies' own private use power plants (TENPES, 2009; Figures 12.2 and 12.3 and Table 12.1).

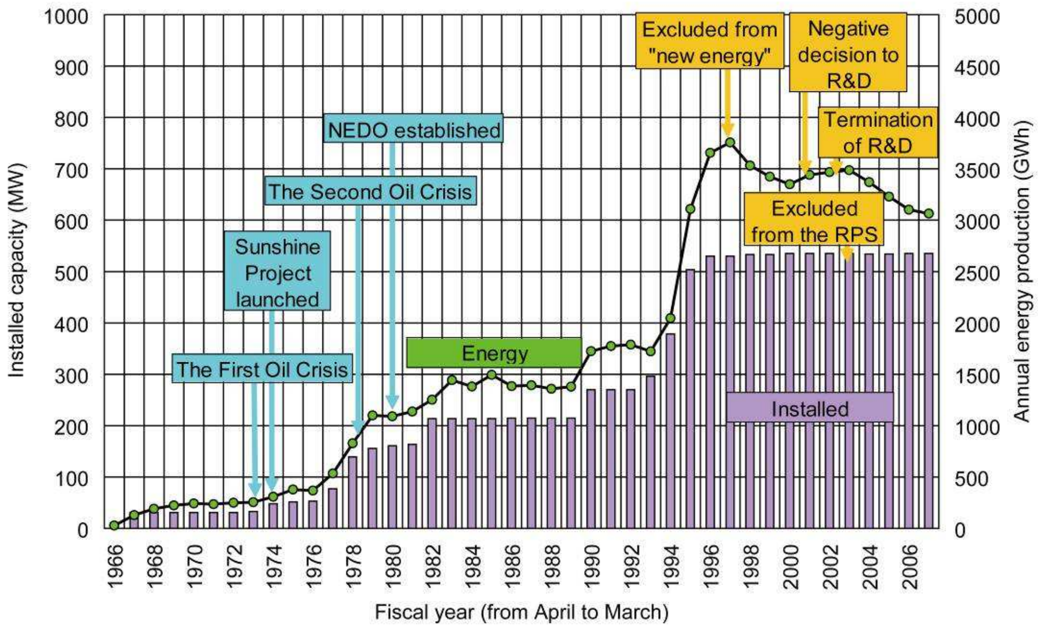

Figure 12.2 A chronological change of installed capacity and annual energy production of geothermal power plants in Japan.

The total electricity generation from geothermal energy in Japan during FY2007 (from April 2007 to March 2008) was 3,064 GWh (TENPES, 2009; Figure 12.2 and Table 12.1).

12.3.1.2 New Developments in 2008

The installed capacity of geothermal power generation in Japan increased slightly from 534.24 MW_e in March 2006, to 535.26 MW_e in March 2007, with a gain of 1.02 MW_e. This is ascribed to the following activity in the three plants (TENPES, 2009). Kyushu Electric Power Co., Inc. built a 2,000 kW_e binary power plant inside the Hatchobaru Geothermal Power Plant in February 2004 for the purpose of evaluating the cost and performance of the facility. After the two years' satisfactory demonstration, the plant was approved as a commercial plant and was put into operation since April 2006. Suginoi Hotel abandoned the former 3,000 kW_e plant in January 2006 and replaced it with a new 1,900 kW_e plant since April 2006. Kirishima Kokusai Hotel abandoned the former 100 kW_e plant in May 2006, and replaced it with a new 220 kW_e binary plant in August 2006.

12.3.1.3 Rates and Trends in Development

Japan's geothermal power market has lost in the last decade since geothermal energy was excluded from "New Energy" in 1997. Although geothermal energy will be back into "New Energy" in 2008, the future trend is still obscure. Investment in large-scale power plants is too risky in present circumstances; this inevitably focuses activities on the realistic option of developing small-scale power plants for the next few years.

12.3.1.4 Wells Drilled

During the year 2008, 1 production well was drilled at Sumikawa power station, and 4 reinjection wells were drilled at 3 other power stations (Otake, Hatchobaru and Yamakawa).

2 exploratory wells were drilled in Ikedako, 1 exploratory well was drilled in Sado, and 1 exploratory well was drilled in Shimoyu.

12.3.1.5 Contribution to National Demand

ANRE reported statistics on the details of national electricity generation capacity for FY 2007 (from April 2007 to March 2008) in the Energy White Paper 2009 on its Web site (ANRE, 2009). The total installed electricity generation capacity for the country at the end of March 2008 was 234,073 MW_e, where LNG power accounted for 24.3 %, nuclear power 20.8 %, oil and other fire power 19.5 %, coal power 15.8 %, pumping-up power 10.7 %, hydro power 8.7 % and geothermal power 0.2 % (Figure 12.4).

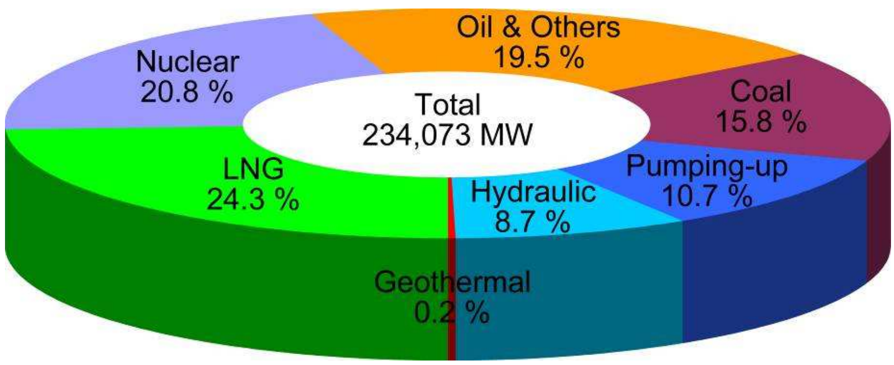

Figure 12.4 Share of installed capacities by individual generation sources in Japan from April 2007 to March 2008. (Source: ANRE, 2009)

The national electricity generation is again adopted from the Energy White Paper 2009 (ANRE, 2009). The total annual electricity generation for the country at the end of March 2008 was 1,004,622 GWh, where LNG power accounted for 27.4 %, nuclear power 25.6 %, coal power 25.3 %, oil and other fire power 13.8 %, hydro power 6.6 %, pumping-up power 1.0 % and geothermal power 0.3 % (Figure 12.5).

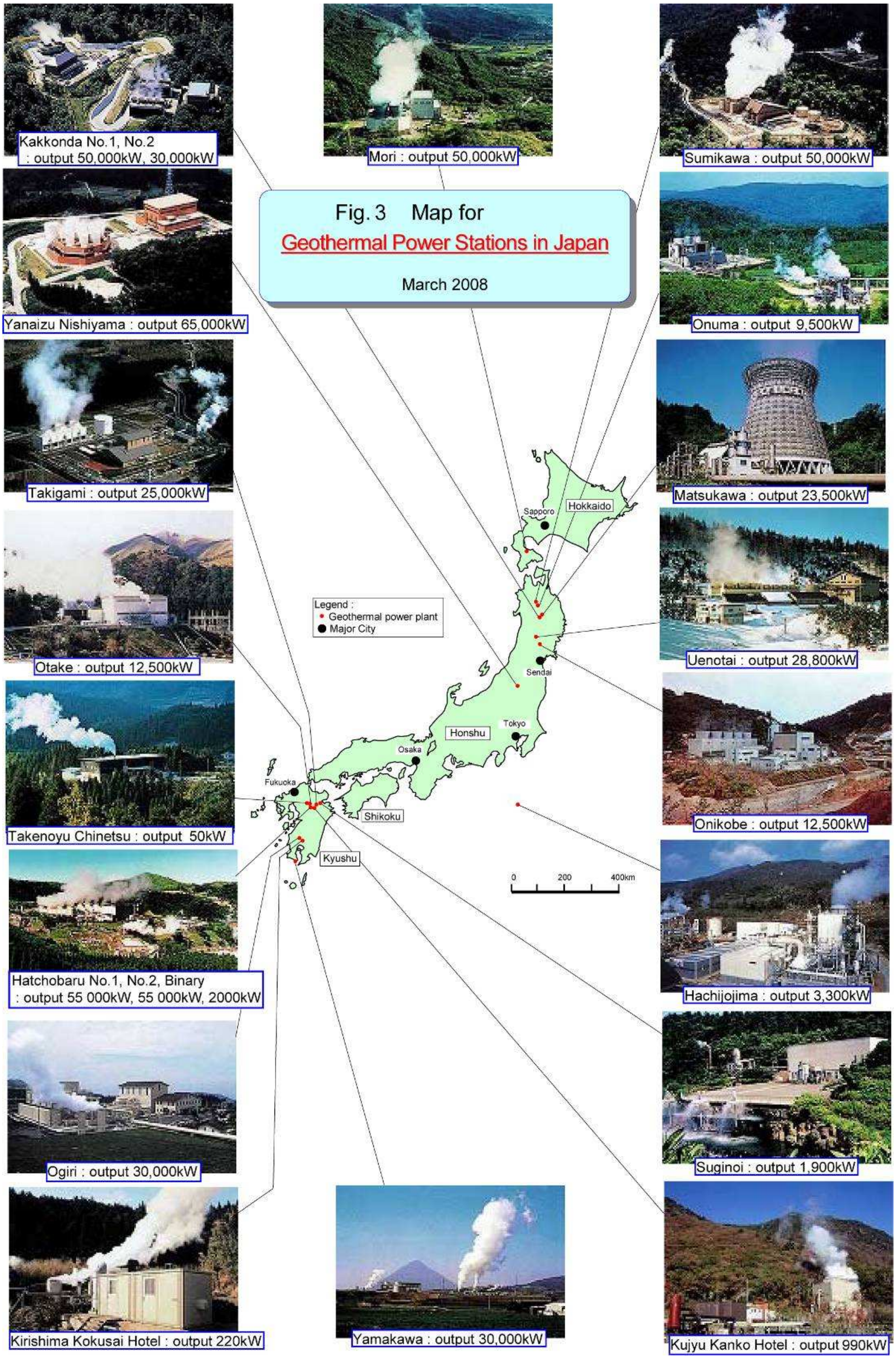

Figure 12.3 *Map of geothermal power plants in Japan.*

Table 12.1 Operating geothermal power plants in Japan from April 2007 to March 2008.

Name of power plant	Power plant operator		Authorized output (MW)	Annual energy production (MWh)	Start of operation
	Power generator	Steam supplier			
Mori	Hokkaido Electric Power Co., Inc.	Hokkaido Electric Power Co., Inc.	50.00	114,620	Nov. 1982
Sumikawa	Tohoku Electric Power Co., Inc.	Mitsubishi Materials Corporation	50.00	337,871	Mar. 1995
Onuma	Mitsubishi Materials Corporation	Mitsubishi Materials Corporation	9.50	59,932	Jun. 1974
Matsukawa	Tohoku Hydropower & Geothermal Energy Co., Inc.	Tohoku Hydropower & Geothermal Energy Co., Inc.	23.50	124,728	Oct. 1966
Kakkonda 1	Tohoku Electric Power Co., Inc.	Tohoku Hydropower & Geothermal Energy Co., Inc.	50.00	200,109	May 1978
Kakkonda 2			30.00	122,394	Mar. 1996
Uenotai	Tohoku Electric Power Co., Inc.	Akita Geothermal Energy Co., Ltd.	28.80	170,112	Mar. 1994
Onikobe	Electric Power Development Co.	Electric Power Development Co.	12.50	104,034	Mar. 1975
Yanaizu - Nishiyama	Tohoku Electric Power Co., Inc.	Okuaizu Geothermal Ltd. Co.,	65.00	362,796	May 1995
Hachijojima	Tokyo Electric Power Company	Tokyo Electric Power Company	3.30	14,171	Mar. 1999
Suginoi	Suginoi Hotel	Suginoi Hotel	1.90	11,655	Mar. 1981
Kuju	Kuju Kanko Hotel	Kuju Kanko Hotel	0.99	8,380	Dec. 2000
Takigami	Kyushu Electric Power Co., Inc.	Idemitsu Oita Geothermal Co., Ltd.	25.00	215,796	Nov. 1996
Otake	Kyushu Electric Power Co., Inc.	Kyushu Electric Power Co., Inc.	12.50	82,726	Aug. 1967
Hatchobaru 1	Kyushu Electric Power Co., Inc.	Kyushu Electric Power Co., Inc.	55.00	351,007	June 1977
Hatchobaru 2			55.00	425,820	June 1990
Hatchobaru Binary			2.00	10,705	Apr. 2006
Takenoyu	Hirose Trading Co., Ltd.	Hirose Trading Co., Ltd.	0.05	0	Oct. 1991
Ogiri	Kyushu Electric Power Co., Inc.	Nittetsu Kagoshima Geothermal Co., Ltd.	30.00	224,296	Mar. 1996
Kirishima Binary	Daiwabo Kanko Co., Ltd.	Daiwabo Kanko Co., Ltd.	0.22	694	Feb. 1984
Yamakawa	Kyushu Electric Power Co., Inc.	Kyushu Electric Power Co., Inc.	30.00	121,654	Mar. 1995
Total			**535.26**	**3,063,500**	

12.3.2 Direct Use

To summarize geothermal direct use in Japan, special attention should be given to its huge number of hot springs for bath use. As often discussed, the energy saved by the hot springs for bath use in Japan is difficult to estimate because of the huge numbers of hot springs; but these hot springs are economically more important than any other geothermal resources for direct use in Japan.

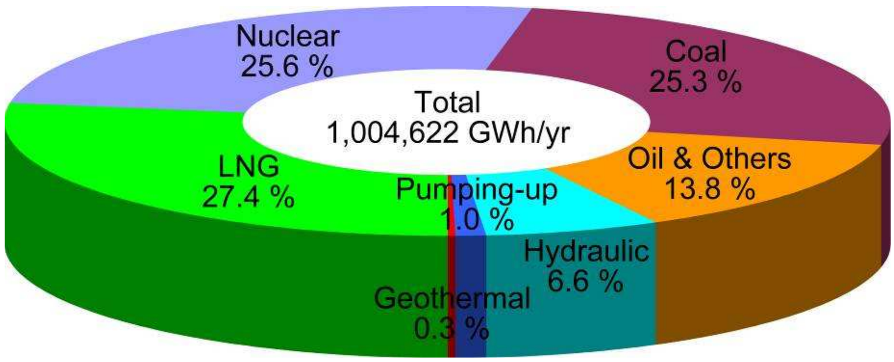

Figure 12.5 *Share of electricity production by individual generation sources in Japan from April 2007 to March 2008. (Source: ANRE, 2009)*

Geothermal resources for direct use are classified here into three categories: hot water for thermal uses excluding bath use, geo-heat use including geo-heat pumps, and hot springs for bath use. Estimating the energy contribution by hot spring bath use is a long-pending project in Japan. Lund, *et al*. (2005) stated "...who do not keep accurate records of temperatures and flow rates of more than 25,000 hot spring sources in Japan". This is true; however, we started to try to make estimates of the energy contribution by hot springs for bath use as described on the 2006 Japan Country Report (GIA, 2009). We here introduce this category by the latest paper (Sugino and Akeno, 2010, in press).

12.3.2.1 Installed Thermal Power

Installed thermal power is described here for the three categories described above. The New Energy Foundation (NEF) in Japan has periodically conducts a questionnaire survey on hot water for thermal uses to individual municipalities in Japan since 1990. The latest survey (the 8th) was carried out in the year 2006 (NEF, 2007).

Questionnaires for hot water thermal uses, excluding bath uses, were sent to 267 municipalities in Japan, and answers were returned from 116 of them. The number of facilities for the various hot water uses in Japan as of March 2006 was 697 (NEF, 2007). The facilities are generally dominant in northern and colder areas, but are also known in southern Kyushu. Installed capacity of hot water uses in Japan as of March 2006 was 400.7 MW_{th} (Sugino and Akeno, 2010 in press; Table 12.2). The largest application of hot water utilization is for road snow melting and it is followed by house heating and welfare facilities heating.

A questionnaire survey for geo-heat uses including geo-heat pumps was also conducted by NEF in 2006. The number of geo-heat use facilities in Japan as of March 2006 was 638, of which geo-heat pumps in a narrow sense are restricted into 116 and the others are more primitive types using soil air circulation. They are mostly used for house heating, followed by snow melting. Installed capacity of geo-heat uses in Japan, as of March 2006, is 13.4 MW_{th} (Sugino and Akeno, 2010 in press; Table 12.2).

Estimating the energy contribution from hot spring bath use is a long-pending project in Japan. First of all, it should be noted that the Japanese commonly prefer thermal water at a temperature

42°C for bathing. In fact, the Japanese are heating water up to the temperature 42°C in most of their home baths using fuels or electricity. Therefore, this provides a baseline for saving energy by hot spring bath uses in Japan.

A method to estimate the fuel alternative energy by hot spring bath use was described by Muraoka in Ehara et al. (2008). To conservatively estimate, hot spring sources less than 42°C are neglected here, with those higher than 42°C only counted, because some of hot springs less than 42°C save a small amount of fuel energy but others rather consume fuel energy for heating to 42°C, almost compensating each other. Then, the fuel alternative energy by hot spring bath use can be estimated as the thermal energy between the mean ground surface temperature in Japan (15 °C) and the bath use temperature 42°C on all the hot springs that are higher than 42°C. Excess thermal energy higher than 42°C is not effectively utilized in the way of bath use so that this should not be counted for the fuel alternative energy.

Based on this method and 24,807 hot spring data, the Sustainable-Zone Research Group recently estimated the fuel alternative energy by hot spring bath use to be 1,685.5 MW_{th} (Sugino and Akeno, 2010 in press; Table 12.2).

12.3.2.2 Thermal Energy Used

As of March 2006, the total hot water thermal energy used for thermal use, excluding bath use, was 4,900.4 TJ/yr (Sugino and Akeno, 2010, in press; Table 12.2). Hot water supply is the largest type of hot water utilization, and its capacity factor is relatively high because it is for all-seasonal uses. The weighted-average capacity factor for hot water use is 0.39.

The total thermal energy used for geo-heat applications in Japan, as of March 2006, was 67.9 TJ/year (Sugino and Akeno, 2010 in press; Table 12.2). The average capacity factor for geo-heat uses is 0.16.

For hot spring bath use, even if bath tubs are always filled with hot water, its utilization (capacity) factor depends on visitors' soaking hours, and this is not known. According to the data from fiscal year 2005, the number of hot spring accommodations was 15,024, the accommodation guest capacity was 1,413,088, and the annual guest accommodation was 136,613,954 man-days. This means that the mean guest capacity of a hotel is 94.1 persons and an average hotel has 24.9 guests every day through the year. Even if there is some seasonal bias and popularity bias from one hotel to another, its utilization (capacity) factor is expected to be very high. However, to conservatively estimate, the annual day utilization factor related to the seasonal and popularity biases is assumed to be 0.75. In addition, most of bath tubs are cleaned every day so that the hourly utilization factor is assumed to be 0.52. Then, 0.75 multiplied by 0.52 makes 0.39, a very conservative assumption for the utilization (capacity) factor.

We obtain the annual fuel alternative energy from hot spring bath use is 20,729.7 TJ/year (Sugino and Akeno, 2010, in press; Table 12.2). The utilization (capacity) factor is here assumed to be 0.39 for a conservative estimate. This will improve the statistical data of direct use in Japan (Lund, *et al.*, 2005).

The grand total of the three categories of the used thermal energy for direct use in Japan is 25,697.9 TJ/year (Table 12.2).

12.3.2.3 Comment on Categories of Use

We here summarize the direct use in Japan (Table 12.2). We have conservatively estimated the fuel alternative energy from hot spring bath use for heating water up to 42°C. Nevertheless, as seen in Table 12.2, the hot spring bath use represents the largest contribution, 80.67 % of the direct use in Japan. Hot water use, excluding bath use, is 19.07 %, or one magnitude less than bath use; and geo-heat use including geo-heat pumps is 0.26 %, three magnitudes less than bath use. In other words, there is plenty of room for development in the other categories such as geo-heat pumps.

Table 12.2 Summary of direct use in Japan (Sugino and Akeno, 2010, in press).

Category		1							2	3	Total	Total
Contents of category		Hot water for thermal uses excluding bath use							Geo-heat use including geo-heat pumps	Hot springs for bath use		
Subdivision of category		Green-house Heating	Fish breeding	Industrial process heat	Space heating	Hot water supply and swimming pool	Snow melting and air conditioning (cooling)	Total of category 1	Ground heat uses (including heat pump)	Fuel-alternative energy by hot spring bath use		
Unit		(MWt)									(MWt)	(TJ/y)
WGC2005 (Statistics on the year 2003)	Total (MWt)	43.11	16.91	1.10	103.59	106.47	138.17	409.35	3.99	0.02	413.36	
	Total (TJ/y)	428.50	212.34	27.34	1409.98	2583.68	476.49	5138.33	22.35	0.38		5161.06
	Capacity Factor	0.32	0.40	0.79	0.43	0.77	0.11		0.18	0.60		0.4
WGC2010 (Statistics on the year 2006)	Total (MWt)	36.92	7.91	1.24	77.37	124.73	152.54	400.71	13.36	1685.46	2099.53	
	Total (TJ/y)	451.73	141.86	30.92	969.49	2790.11	516.27	4900.38	67.86	20729.70		25697.94
	Capacity Factor	0.39	0.57	0.79	0.40	0.71	0.11		0.16	0.39		0.39

12.3.2.4 New Developments in 2008

As has been mentioned, NEF periodically conducts a questionnaire survey on two categories of direct use: hot water thermal use without bathing and geo-heat use including heat pumps. The two most recent surveys were carried out in 2002 and 2006 (NEF, 2003; 2007). Therefore, we can only compare four years' results between 2002 and 2006. The hot water thermal use without bathing decreased from 5,138.3 TJ/year in 2002 to 4,900.4 TJ/year in 2006. The main reason for this result is ascribed to the recoverability of the questionnaire surveys- they decreased from 147 replies/260 recipients in 2002 to 116 replies/267 recipients in 2006. The geo-heat use including geo-heat pumps increased from 22.4 TJ/year in 2002 to 67.9 TJ/year in 2006, more than a factor of three during the four years. Hot springs for bath use are constantly developed every year. The number of hot spring sources for bath use increased from 27,644 in March 2005 to 27,866 in March 2006, i.e. by 222, or 0.8 % annually. The discharge rate of hot springs for bath use increased from 2,712,140 l/min in March 2005 to 2,761,300 l/min in March 2006, an increase of 49,160 l/min, or 1.8 % annually.

12.3.2.5 Rates and Trends in Development

The hot water thermal use, excluding bathing, apparently decreased from 2002 to 2006 due to the recoverability of the questionnaire surveys, but this category may not have changed much. The geo-heat use, including geo-heat pumps, increased at factor of about three during the four years. This is equivalent to the rate of the 32.1 % every year. Although the present market for geo-heat use is still small, this rate is promising a rapid expansion in the near future. The numbers of hot springs for bathing were 13,079 in FY1962 and 27,866 in FY2005. If we simply apply a linear trend, the mean annual increment is 344 (Figure 12.6). The discharge rate of hot springs for bathing was 930,110 l/min in FY1963 and 2,761,300 l/min in FY2005. If we simply apply a linear trend here, the mean annual increment is 43,600 l/min. This must be the largest and steadiest direct use market in Japan.

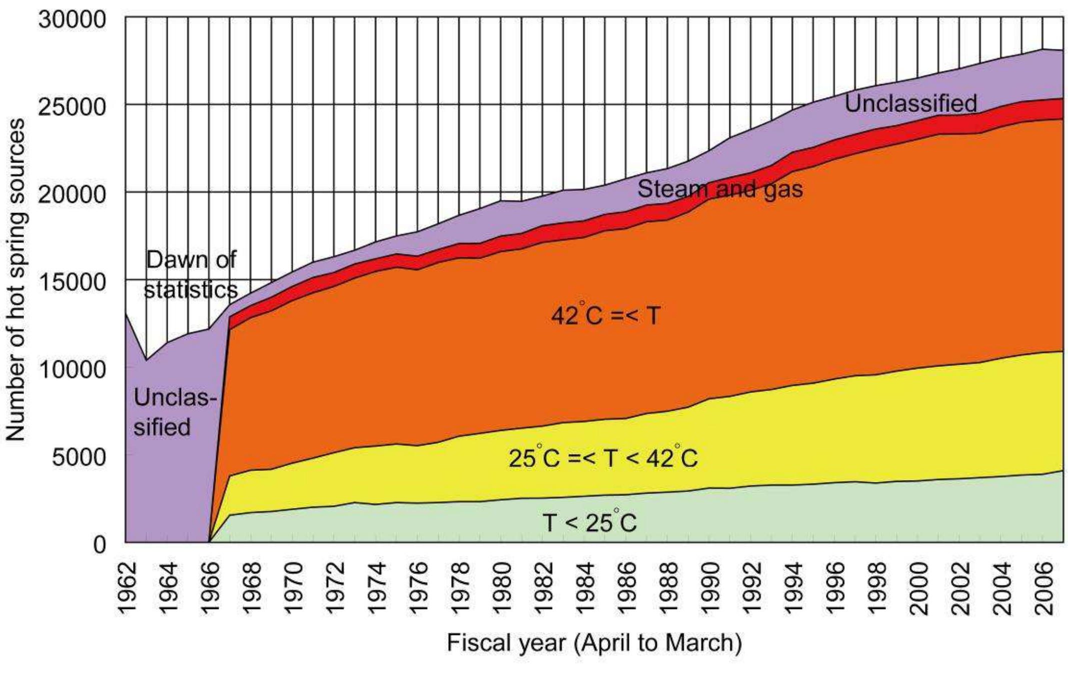

Figure 12.6 Expanding Japanese hot spring market. (Source: Ministry of Environment, 2009)

12.3.2.6 Number of Wells Drilled

The recent increase of hot spring sources for bathing is almost entirely performed by drilling. Therefore, the numbers of drilled wells are roughly the same as the increment number of hot spring sources 222 in FY2005. The numbers of drilled wells for the hot water uses and geo-heat uses are not given in the results of the questionnaire surveys (NEF, 2007). In some cases, development may be from drilling one well for hot water use; while for other cases, development may be by drilling several shallow wells, such as for geo-heat pump use. However, it seems clear that the number must be larger than the increment number of the facilities. The numbers of facilities of hot water uses increased from 692 in 2002 to 697 in 2006, and the increment was only 5 during the four years. The numbers of facilities of geo-heat uses increased from 276 in 2002 to 638 in 2006, and the increment was 362 during the four years.

12.4 Energy Savings

12.4.1 Fossil Fuel Savings/Replacement

The total geothermal electricity produced in Japan saved 776,418 toe/yr (toe = tons of oil equivalent) in FY2007, based on the IEA-GIA conversion factor 1 GWh = 253.4 toe in produced electricity (Mongillo, 2005).

The total direct use energy produced in Japan saved 904,567 toe/yr in FY2005, based on the IEA-GIA conversion factor 1 TJ = 35.2 toe in produced heat (*ibid.*).

The direct use energy produced in Japan must have increased from FY2005 to FY2007. Therefore, although the statistics of direct use is taken from FY2005, in the grand total of geothermal power and direct use, Japan was saving at least 1,680,985 toe/year, in FY2007.

12.4.2 Reduced/Avoided CO_2 Emissions

When we assume the oil thermal power plants as a baseline, the total geothermal electricity produced in Japan results in avoidance of 2,503,288 tonnes of CO_2/year in FY2007, based on the IEA-GIA CO_2 factor 817 kg/MWh in produced electricity (Mongillo, 2005).

When we assume the oil thermal power plants as a baseline, the total direct use energy produced in Japan avoids CO_2 emissions by 2,919,572 tonnes/year in FY2005, based on the IEA-GIA CO_2 factor 409 kg/MWh in produced heat (*ibid.*).

The direct use energy produced in Japan must have increased from FY2005 to FY2007. Therefore, although the statistics of direct use are taken from FY2005, in the grand total of geothermal power and direct use, Japan avoided CO_2 emissions of at least 5,4221,860 tonnes/year, in FY2007.

12.5 Market Development and Stimulation

12.5.1 Support Initiatives and Market Stimulation Incentives

NEDO initiated “Geothermal Development Promotion Surveys” in prospective geothermal areas where investigation is hampered by survey risks, thereby expediting the development of geothermal power generation by private-sector companies. This program started in 1980. The survey program is composed of Surveys A, B and C, varying the scale and content depending upon regional potential and existing data. Surveys had been completed in 65 areas at the end of FY2008. Since 1999, NEDO has carried out Survey C intensively, aiming at a further reduction of survey risks and development lead-time for private-sector companies to construct geothermal power plants based on preliminary results. Therefore, geothermal reservoir evaluation using large-bore production wells for long-term production tests is included. The five areas selected for the surveys FY2008 are considered to have potentials suitable for binary power plants smaller than 10 MW_e. Although the capacity is rather small, each area has particular characteristics that may promote further utilization of geothermal energy in the area.

Figure 12.7 *Production test of the N19-HA-1 well, Hachimantai, Iwate Prefecture, Japan, on 22 May 2008. (Photo courtesy of H. Muraoka)*

Figure 12.9 *Well N20-SY-1 in Shimoyu, Aomori Prefecture,Japan, on 17 September 2008. (Photo courtesy of H. Muraoka)*

In Hachimantai, the area of the third year, two production wells were drilled last year. One of them succeeded in the temporary production of steam (Figure 12.7). In the east of Ikedako, the area of second year, one production well and one reinjection well were drilled (Figure 12.8). In Sado, the area of second year, one production well was drilled; however, geothermal development was finished because the permeability did not reach the targeted value. In Otari-mura, a newly selected area, the removal of the pit scale has been confirmed as a result of scale dredging work and the cleaning work for existing well. In Shimoyu, a newly selected area, one production well was drilled; however, geothermal development was stopped because the permeability did not reach the targeted value (Figure 12.9).

The Japanese government has taken a leading role in the development of geothermal energy resources. The government has introduced a compensation system for geothermal developers that provides compensation for interest on bank credits to support developers undertaking well drilling, a process that requires a large investment at an early stage. 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%. These systems started in 1983. Beginning in 2002, binary facilities in geothermal power generation systems were rewarded with a subsidy ratio of less than one-third.

The actual subsidy record for FY 2008 was:

- Production wells were drilled at: Sumikawa, 1 well
- Reinjection well was drilled at: Otake, 1 well; Yamakawa, 1 well; Hatchobaru, 2 wells
- Facilities : new pipe laying at Sumikawa

12.5.2 Development Cost Trends

The latest construction of the conventional steam turbine type geothermal power plant was in Hachijojima in 1999. There are no recent statistics on the development cost, so that it is difficult to determine the development cost trends. During the last ten years' stagnancy, the trend of geothermal power plant design is shifting from a large-scale to a relatively small-scale. Therefore, the total cost of construction tends to decrease, but the unit construction cost is increasing.

12.6 Development Constraints

The recent reduction of political supports to geothermal development is a primary constraint to geothermal market promotion in Japan. Internationally, geothermal energy is categorized as a renewable energy together with solar, wind, hydro and biomass energy. However, in Japan, only solar and wind were classified as "New Energy" that enjoyed protection under the Special Measures Law for the Promotion of the Use of New Energy enacted in 1997. Geothermal energy was not included. Moreover, in 2001, biomass was added to the list of "New Energy" to be promoted by the New Energy Subcommittee of the Advisory Committee for ANRE, but geothermal energy was not. According to the Energy Supply and Demand Outlook presented by the government, future growth in geothermal energy is assumed to be zero. Consistent with this perspective, in 2001, the METI decided to cut the entire budget for geothermal energy research and development (Figure 12.1). This decision was purely political. However, geothermal energy was legally included in the category of "New Energy" in 2008, and this should help reduce constraints on development.

12.7 Economics

Japan's economy entered a serious deflation recession stage beginning 1991, after a long-lasting growing stage since 1955. Particularly, it has come to be more serious by sliding down to minus growth since the Asian currency crisis in 1997. This has dramatically made governmental tax revenues shrink and the government has withdrawn a variety of incentives from many fields, including geothermal R&D. Japan's economy has been recovering gradually since 2002, but the Lehman shock again attacked Japan, prolonging its economic recovery.

12.7.1 Trends in Geothermal Investment

Geothermal power generation is economically marginal in Japan, and therefore, investment to geothermal power developments is risky in the current situation where governmental incentives are not fully available. The investment to geothermal power development in the private sector is currently inactive except for those overseas investments by trading companies and those of product improvement investment by turbine and generator makers.

12.7.2 Turbine, Project, Well Drilling and O&M Costs

Reliable data for most of these items are not available, partly due to their confidential nature and partly due to too few references in the current inactive geothermal market. One of the reference data for the drilling cost is available from the cost estimation of conventional geothermal power developments in Japan (NEDO, 2002), where the drilling cost for a large-diameter production or reinjection well is assumed to be 230,000 Yen/m. This is equivalent to US$ 2,150/m and US$ 4.3 M for drilling a 2,000 m depth well. This is still expensive, more than the world standard, but the recent drilling cost may have improved.

12.7.3 Trends in the Cost of Energy

Cost of energy is seldom published, even by the government, because of difficulty in the equal-base comparison under the different levels of political supports. It is old, but ANRE (2001MS) estimated costs of a variety of energy sources as of 1999 that show 7.3 Yen/kWh (6.8 US cents/kWh) for fire power averaged from oil, coal and LNG, 5.9 Yen/kWh (5.5 US cents/kWh) for nuclear power, 66.0 Yen/kWh (61.7 US cents/kWh) for photovoltaic power and 11.5 Yen/kWh (10.7 US cents/kWh) for wind power.

The cost of geothermal power at the nearest year can be referred to NEDO (2002). NEDO (2002) estimated costs of conventional geothermal power developments in 31 target geothermal areas without incentives from the Geothermal Development Promotion Surveys and drilling subsidy. The cost varies from 10.0 to 24.0 Yen/kWh, and most of them range from 10 to 14 Yen/kWh (from 9.3 to 13.1 US cents/kWh). This range indicates a general cost of geothermal power in Japan. However, the traditional cost regime was drastically changed by the recent steep rise in the crude oil price.

As Japan is an oil-importing country, the recent steep rise in the crude oil price is changing the energy market regime. Geothermal power generation has been economically marginal in Japan, but, if the crude oil price will further rise, geothermal power generation will soon come to be competitive in cost to the hydrocarbon thermal power generation.

12.7.4 Geothermal Sector Employment

There is no reliable data on geothermal sector employment, but the Geothermal Research Society of Japan has about 550 members, which gives a reference number of people employed in the geothermal sector in Japan, because a number of non-geothermal employee members of the society may be roughly comparable with that of geothermal employees outside the society.

12.8 Research Activities

There have been no full-scale national projects for geothermal R&D in Japan since April 2003. However, the Geothermal Research Society of Japan still has about 550 members, preserving a high-level of motivation for geothermal R&D. Research activity is individually performed by national universities, national institutes and the private sector with their own budgets.

12.8.1 Focus Areas

Many researchers who are concerned with enhanced geothermal systems, or engineered geothermal systems (EGS), are cooperatively participating in the Cooper Basin Project in Australia, including those from the Graduate School of Environmental Studies in Tohoku University, the Civil Engineering Research Laboratory (CERL) in the Central Research Institute of Electric Power Industry (CRIEPI) and the Institute for Geo-Resources and Environment (GREEN) in the National Institute of Advanced Industrial Science and Technology (AIST).

Geo-heat pump systems are currently one of the key research issues in Japan, mainly investigated by the Faculty and Graduate School of Engineering in Hokkaido University, Tohoku University, the Graduate School of Engineering in Kyushu University and AIST.

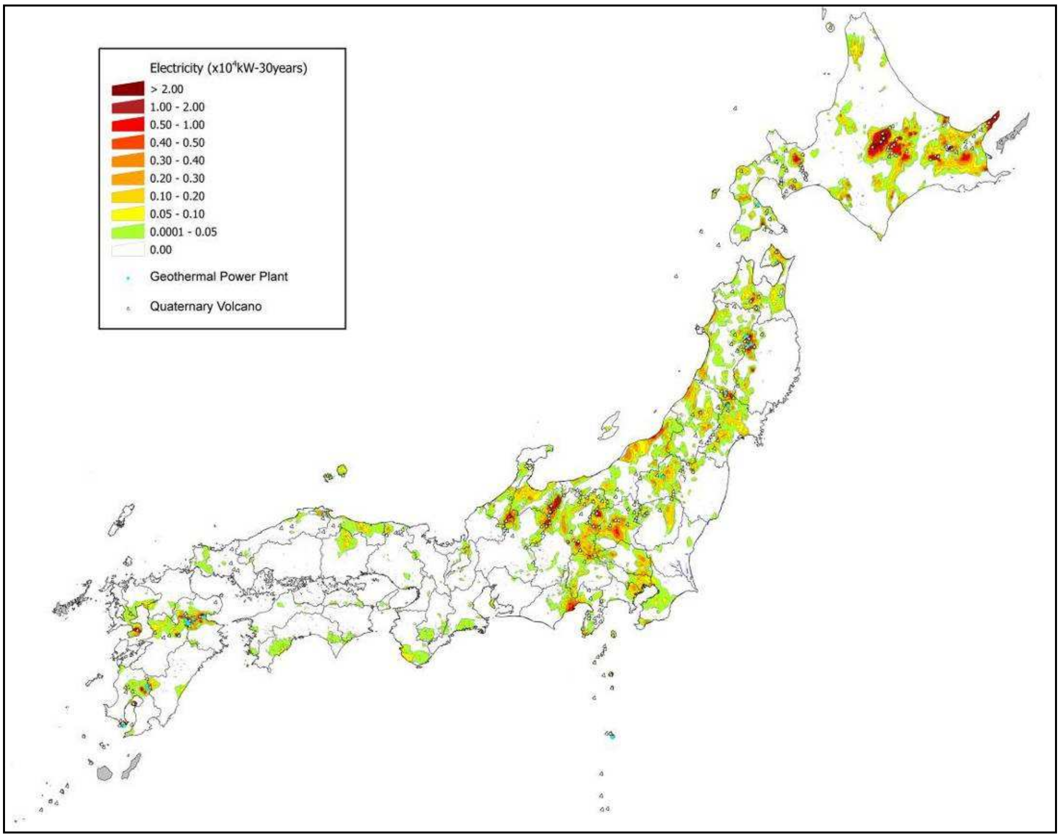

Figure 12.10 Distribution of the shallow-depth hydrothermal resources above 53 °C (Muraoka et al., 2008).

Geothermal reservoir engineering is mainly carried out by Kyushu University and AIST. Geothermal exploration techniques are mainly studied by Tohoku University, Kyushu University, Akita University and AIST. Nationwide geothermal resource assessments and databases are mainly conducted by AIST. AIST did the first GIS (Geographic Information System) base geothermal resource assessments in Japan in 2008 (Figure 12.10; Muraoka et al., 2008). Shallow-depth hydrothermal resources above 150°C were estimated to be 23,470 MW_e in Japan.

Numerous hot springs used to be one of the main obstacles for geothermal power development in Japan. However, Kalina-cycle, a current low-temperature power generation technique, enables us to generate electricity from waste thermal energy of high-temperature hot springs above the bath use temperature. The hot spring power generation also enables cooling of the high-temperature hot springs down to an adequate bath use temperature without dilution of balneological constituents. To open the new market for the hot spring power generation, the Geothermal Energy Research & Development Co., Ltd. (GERD) and GREEN, AIST, proposed the "Development of the Hot Spring Ecogene (ecology + co-generation) System" project to the competitive grant "Project to Support Innovative New Energy Technology Ventures" in NEDO. This proposal was adopted as the phase I (feasibility stage) in August 2007, and adopted as phase II in March 2008. A 50 kW_e class Kalina-cycle power generation system adequate for the hot spring power generation market will be completed in March 2010.

12.8.2 Government Funded

Geothermal research at national universities and AIST is supported by grants from the government. The amounts used in geothermal research, in FY2008, in Kyushu University and Tohoku University are approximately 60 million Yen and 30 million Yen, respectively. The amount used in geothermal research at AIST is dispersed among several research groups and is approximately 20 million Yen in FY2008.

12.8.3 Industry Funded

Information about funding for geothermal R&D in the private sector is not necessarily open to public and is difficult to estimate. Japan's turbines and generators still have a 50% share in the world geothermal power plants and these makers may be investing in these R&D fields. For example, the new 220 kW_e binary plant at Kirishima Kokusai Hotel, installed in August 2006, is a R&D demonstration facility owned by the Fuji Electric Systems Co., Ltd. The electric companies and their institute, CERL in CRIEPI, are funding geothermal R&D, but the amounts are unknown.

12.9 Geothermal Education

Geothermal education is mainly conducted by Kyushu University, Tohoku University and Akita Universit,y at both undergraduate and graduate levels. Recently, Kyoto University also began geothermal education at the graduate level. The Geothermal Research Society of Japan holds a forum on the geothermal energy for its enlightenment and dissemination to citizens once a year.

A new geothermal course was initiated at Kyushu University in October 2002 following the end of the JICA international geothermal course. It is a doctoral program in the Graduate School of Engineering entitled "International Special Course on Environmental Systems Engineering". Twenty students are admitted each year into the Graduate School of Engineering, ten of which are awarded with MEXT (Ministry of Education, Culture, Sports, Science and Technology) Scholarships. Participants in this course study under five advanced departments of the Graduate School of Engineering: Earth Resources Engineering, Civil and Structural Engineering, Urban and Environmental Engineering, Applied Quantum Physics and Nuclear Engineering and Maritime Engineering. Due to the international nature of this course, all the education is conducted in the English language.

12.10 International Cooperative Activities

Japan International Cooperation Agency (JICA) dispatched a preparatory survey mission to Peru in 2008 for initiating the "Master Plan Study for Development of Geothermal Energy in Peru" at the request of the Peru government (Figure 12.11).

In spite of numerous volcanoes along Andes, no geothermal power plants are working in South America since the Copaue plant stopped in Argentina. One reason is that South American countries are blessed with fossil fuels. Among them, Peru is enthusiastic for geothermal development. For example, Peru established the Geothermal Law in 1997, earlier than any other countries in the world. The Peru government decided to develop a variety of renewable energy sources, including geothermal energy. If every condition is satisfied, the Master Plan Study will start from FY2009.

The mission also visited two representative geothermal fields; Borateras (Figure 12.12) and Calientes (Figure 12.13) on a high plateau, called Altiplano, southern Peru. Thick sinter terraces in both fields promise subsurface hydrothermal reservoirs.

Figure 12.11 *Courtesy visit to INGEMMET (Instituto Geologico Minero y Metalurgico), Rima, Peru, on 26 November 2008. (Photo courtesy of H. Muraoka).*

Figure 12.12 *Borateras geothermal field, 4,386 m high, southern Peru on 29 November 2008. (Photo courtesy of H. Muraoka)*

Figure 12.13 Calientes geothermal field, 4,409 m high, southern Peru on 30 November 2008. (Photo courtesy of H. Muraoka)

Figure 12.14 Group photograph of the 8th Asian Geothermal Symposium in Hanoi City, Vietnam on 10 December 2008. (Photo courtesy H. Muraoka)

The 8th Asian Geothermal Symposium was held in Hanoi City, Vietnam, on 9-12 December 2008 (Figure 12.14), sponsored by the National Institute of Advanced Industrial Science and Technology (AIST), the Vietnam Institute of Geosciences and Mineral Resources (VIGMR) and the Korean Institute of Geoscience and Mineral Resources (KIGAM). The theme of the Symposium was "Geothermal Energy: emerging issues and its role in energy security and environmental protection for Asia". Over fifty participants from nine countries attended this Symposium.

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Figure 13.26 Sixty geothermal heat pumps heat and cool a large university building.

13.0 Introduction

13.0.1 Background

Direct use geothermal utilization in Korea has been quite active for the last five years, especially geothermal heat pump installations. The rapid increase in geothermal heat pumps is mainly due to active government subsidizing programs for renewable energy deployment; but recently, the private investments on geothermal heat pump installations, without subsidies, are also increasing. There are several areas producing hot spring water with discharge temperatures higher than 60 °C, which originates from circulation through deeply extended fractures in crystalline rocks. This hot water has been utilized for floor heating in a hot spring areas for more than 20 years. In other places, a small-scale district heating scheme and greenhouse heating using hot spring water was started in 2008.

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". 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 to have new and renewable energy's share of 11% of total primary energy supply and of 7.7% of electricity generation by 2030.

13.0.2 Major Highlights for 2008

- The first geothermal district heating and greenhouse heating has been realized in Korea
- Total cumulative installed capacity of geothermal heat pumps in Korea exceeded 100 MW_t at the end of 2008
- Government subsidized more than US$ 70 million for geothermal heat pump installations, for greenhouse heating and cooling of 90 MW_t in rural villages; these will come into operation in 2009

13.1 National Policy

13.1.1 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-E's; 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 to have new and renewable energy's share of 11% of total primary energy supply and of 7.7% of electricity generation by 2030. Among the new and renewable energy, photovoltaic (PV), wind and hydrogen/fuel cells are of primary concern. 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 cells. This project will help geothermal heat pump installation continue to increase in the future.

13.1.2 Legislation and Regulation

From 2004, the *Mandatory Public Renewable Energy Use Act* has come into effect and states that "in construction of all public buildings bigger than 3,000 m^2 in area, more than 5% of total budget must be used to install renewable energy equipment." Geothermal heat pump installations are now being accelerated in public sector with this act.

13.1.3 Progress Towards National Targets

The total use of new and renewable energy at the end of 2007 reached 5.61 million ton of oil equivalent (Mtoe) accounting for only 2.40% of the total primary energy consumption (234.07 Mtoe). According to the *Second Basic Plan for the Development, Use and Supply of New and Renewable Energy Technology (2003-2012)*, renewable energy's share would have reached 3% by 2006. However, by 2007, this goal has not been reached, which is the main reason why Korean Government has set up a new policy in 2008: *The Third Basic Plan on New & Renewable Energy Technology Development, Utilization and Diffusion (2009-2030)*. Renewables' share in 2008 was around 2.6%.

The status and prospects of geothermal energy in the national target still does not seem significant because government program focuses on the three major items for electricity generation: photo voltaic, wind power and fuel cell. Fortunately, however, the importance of geothermal utilization is being acknowledged by the government and the public sector, and geothermal's share of market stimulating incentive has become significant. Therefore, we expect some remarkable progress can be made in the next five years.

Increases of geothermal heat pump installations and energy use are presented in Table 13.1. The values are based on the officially reported installations and we expect the actual number of installation is bigger than reported.

Table 13.1 Geothermal heat pump installation and energy uses (2004-2008).*

	2004	2005	2006	2007	2008**
Installed Capacity in MW_t (Cumulative)	6.22 (9.31)	8.20 (17.51)	35.2 (52.7)	20.5 (73.2)	32.2 (105.4)
Annual Energy Used in Toe (TJ)	1,355 (57.7)	2,558 (109.0)	6,208 (264.5)	11,114 (473.5)	18,394 (772.5)

* From report of New & Renewable Energy Center, Korea Energy Management Corporation (KEMCO)
** Estimated from the installer's report to Korea New & Renewable Energy Association (KNREA)

13.1.4 Government Expenditure on Geothermal Research and Development

In 2008, total investments by government amounted to some US$ 6.9 million (M) (assuming a currency exchange rate of US$ 1 = 1,000 KRW) including:

- Development of deep-seated, low-temperature geothermal resources: US$ 2.2 M
- Information system of geothermal resources distribution and utilization: US$ 0.6 M
- Various geothermal heat pump utilization and demonstration programs: US$ 4.1 M (9 subjects)

Government R&D expenditure has decreased in 2008 compared to the former years, reflecting that government investment is more focused on subsidizing deployment programs for geothermal heat pumps than R&D. Table 13.2 shows the statistics of the last five years.

Table 13.2 Geothermal R&D expenditure for the period 2004-2008,
In Thousand US$ (1US$ = 1,000 Won).

	2004	2005	2006	2007	2008
Government	5,505	5,979	6,943	7,792	6,914
Industry	758	881	1,148	1,800	1,383
Total	6,263	6,860	8,091	9,592	8,297

13.1.5 Industry Expenditure on Geothermal R&D

Industry expenditure is still quite small, and mainly a type of matching funds to government R&D funding, which amounts 15-50% of the total budget, depending on the size of the participating industry's business. In 2008, the total amount is estimated to be some US$ 1.4 M.

13.2 Current Status of Geothermal Energy Use

13.2.1 Electricity Generation

There is no geothermal power generation in Korea.

13.2.2 *Direct Use*

13.2.2.1 *Installed Thermal Power*

At the end of 2008, the installed thermal power was 149 MW_t, mainly for geothermal heat pumps and hot spa usage (see Table 13.3).

Table 13.3 Geothermal direct heat uses, fossil fuel saving and avoided CO_2 emission in Korea as of December 2008.

Use	Installed Capacity (MW_t)	Annual Energy Use ($TJ/yr=10^{12}J/yr$)	Capacity Factor	Fossil fuel saving (toe/yr)	Avoided CO_2 emission (tonne)
Individual Space Heating	8.66	53.43	0.20	2,554	6,070
District Heating	2.21	31.28	0.45	1,495	3,554
Greenhouse Heating**	0.17	-	-		
Bathing and Swimming	32.56	507.61*	0.49	24,264	57,670
Geothermal Heat Pumps	105.4	772.5	0.23	36,926	87,764
Total	149.0	1,364.8		65,239	155,058

* Σ [(supplying water temp.: 42 – leaving water temp.: 27)×flow rate × operating time]
** installed at the end of 2008, so no energy use

13.2.2.2 *Thermal Energy Used*

Thermal energy used in 2008 is estimated to be 1,365 TJ, with capacity factors: 0.2, 0.45, 0.49 and 0.23 for individual space heating, district heating, hot spas and heat pump, respectively (see Table 13.3). Note that the first greenhouse heating facility with geothermal water was completed at the end of 2008, so there is no thermal energy used.

13.2.2.3 *Category of Use*

Direct use in Korea includes individual space heating with hot spring water, a small scale district heating scheme (21 households), one greenhouse, bathing (hot spa) and geothermal heat pump (see Table 13.3).

13.2.2.4 *New Developments During 2008*

There are several artesian wells, with discharge temperatures of some 70°C on the small island of Seokmo-Do, in the Yellow Sea, close to Incheon (the 3rd largest city in Korea), near Seoul, the capital city of Korea. Some drilled wells, several 100 m deep, struck deeply-connected fractures in Jurassic granite and a large amount of brine water flows from them. One of the wells has been drilled down to depth of 1,280 m according to the interpretation result of the magnetotelluric data acquired by KIGAM in 2005.

A small scale district heating scheme for 21 households started operation in 2008, and will expand to several hundred houses on the island in 2009. A greenhouse heating facility was completed at the end of 2008 and will become into operation in 2009. The greenhouse is 1,155 m^2 in size; the inlet temperature of geothermal water is 68°C, and it is cooled down to 56°C through a plate heat exchanger; the average flow rate is designed to be 6 m³/hr. No performance data is available yet. After heating the greenhouse, the cooled geothermal water is supplied to a public bath.

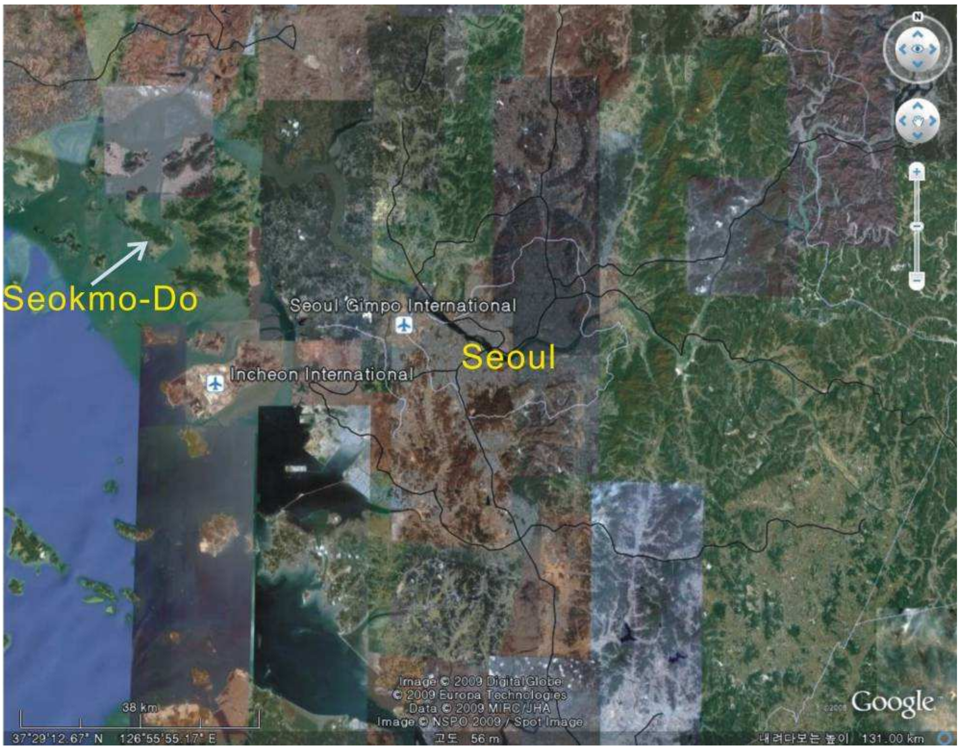

Figure 13.1a *Location of the Seokmo-Do (island), location of Korea's first geothermal heated greenhouse (see following photos).*

Figure 13.1b *Artesian well and the greenhouse on Seokmo-Do.*

Figure 13.1c *Plate heat exchanger for use of geothermal water.*

Figure 13.1d *Vegetables and fan coil units inside of greenhouse.*

Figure 13.1e Polyethylene tube for heating the soil covering peak load.

Another new development is a huge borehole heat exchanger system for heating and cooling the total building area of a new private university. The system consists of the 245 boreholes, each 150 m deep, equipped with double U-tubes, which provides for an area of 95,854 m^2, including entire classrooms, labs, offices and dormitories. Total heating and cooling loads amount to 6,230 kW_t, provided for by 60 heat pump units of 122 kW_t. It is notable that investment for this installation was private, without government subsidy. This is the biggest geothermal heat pump system in Korea, followed by another private university equipped with geothermal heat pump system of 5,451 kW_t using standing column well types.

13.2.2.5 Rates and Trends in Development

No data available

13.2.2.6 Number of Wells Drilled

No wells have been drilled in 2008, except hot spring developments for which detailed information is not available.

13.2.3 Energy Savings

Fossil fuel savings and CO_2 emission reductions are included in Table 13.3, following IEA and GIA conversions.

Figure 13.2a Photo of the big university building being heat and cooled by a 60 geothermal heat pump system of 5,451 kW_t. Heat pump system shown in Figure 13.2b (chapter title photo).

Figure 13.2c Layout of 245 borehole heat exchangers for the heating/cooling system of the university building in Figure 13.2a.

13.3 Market Development and Stimulation

13.3.1 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 installation through various renewable energy spreading programs amounted US$ 81.5 M in 2008, which supported new installations of more than 100 MW_t with half of total cost, almost eight times that of the previous year (see Table 13.4).

Table 13.4 Subsidies for geothermal heat pump installation for the period 2005-2008, In Thousand US$ (1US$ = 1,000 Won).

	2005		2006		2007		2008	
	Capacity (MW)	Subsidy (1,000 USD)	Capacity (MW)	Subsidy (1,000 USD)	Capacity (MW)	Subsidy (1,000 USD)	Capacity (MW)	Subsidy (1,000 USD)
Deployment Subsidy Program	5.84	3,643	16.69	9,541	15.37	8,351	14,11	7,689
Rural Deployment Program	3.10	3,105	3.74	4,239	2.63	1,998	89.55	73,728
Total	8.93	6,748	20.42	13,780	18.01	10,349	103.66	81,417

* Note: Data correspond to year of subsidy support, so actual operations are to be one or two years later.

This big increase is because of the special rural deployment program supporting rural villages to save energy costs by implementing geothermal heat pumps for heating and cooling small greenhouses. The special deployment program was a temporary one to make rural agriculture competitive. Installations subsidized through the special rural deployment program will be completed in 2009, and thus, total cumulative installed capacity is expected to exceed 200 MW_t by the end of 2009.

13.3.2 Development Cost Trends

No data available.

13.4 Development Constraints

13.4.1 Technical and Social Barriers

A barrier to the progress of geothermal heat pumps from technical and scientific points of view may be explained by relative lack of understanding of the importance of accurate information for the thermal properties of subsurface materials and lack of scientific knowledge on hydro-geological conditions influencing heat extraction/injection rates. 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 unnecessary concern about running out of the resources without understanding the natural water cycle.

Also, the general perception that geothermal heat pump systems are of high initial cost, while there are not sufficient guaranteed examples of performance yet. Therefore, people tend to consider that a natural gas or an oil boiler is cheaper in initial stage and long-lasting. The most serious problem is still the lower public awareness level than that of wind or photovoltaic, even some government officers and energy authorities think that geothermal is nothing but heat pumps.

13.4.2 Environmental Issues

The *Groundwater law* states that the depth and purpose of all boreholes must be reported prior to drilling. Also, if someone plans to use groundwater, an environmental impact assessment must be performed, and submit the results. It is also necessary for groundwater thermal utilization, even though subject to re-injection. The heat pump business society claims that heat extraction from groundwater will not affect the quality of the water, and thus, thermal utilization should be free from such regulation.

13.5 Economics

13.5.1 Trends in Geothermal Investment

Government investment in geothermal has steadily increased since 2003. I nvestment from industry has also increased, as a matching fund to government R&D budget. Government investigation is being made though R&D expenditure and various subsidizing programs; statistics are available in Table 13.2 and Table 13.4, respectively. Once more, there was a huge subsidy through the rural deployment program, which amounted some US$ 70 M and more than 90 MW_t of new installations. However, this special program is a temporary one, and the total subsidy in 2009 will reduce to less than 2007.

13.5.2 Trends in the Cost of Energy

Because 97% of energy resources are imported, the energy cost in Korea reflects recent high oil prices. The price of electricity, however, does not change much, partly due to the high portion of nuclear power generation (~40% of total generation) and partly due to government policy. The average electricity price is about US 7.8 cents/kWh. But an increase in the electricity price is very possible in 2009 because of abnormally high oil prices.

13.5.3 Number of People in Geothermal Sector

The number of people working in the geothermal sector is continuously increasing thanks to active geothermal heat pump business. There are some 60 people in universities and research institutes, including graduate students. In the industry sector, around 60 people are working on geothermal heat pump system design and installation (borehole heat exchangers).

13.6 Research Activities

13.6.1 Focus Areas

R&D activities in Korea are focused on 1) exploration and exploitation of low-temperature geothermal water for district heating, 2) characterization of geothermal resources, 3) sampling and measurement of subsurface thermal properties for borehole heat exchangers, resulting in big databases, 4) simulation of T-H-C coupled behavior with borehole heat exchangers with groundwater flow, and 5) utilizing groundwater thermal energy along with aquifer thermal energy storage (ATES). Almost all of the research activities are initiated by government funding.

There was no notable progress in terms of research activities in 2008. Instead, some practical applications based on acquired R&D results were made, such as the first district heating and greenhouse heating applications on a small island (see Figure 13.1), and the huge geothermal heat pump installations in private universities (see Figure 13.2).

13.6.2 Government Funded R&D

R&D in geothermal investigations, exploration and exploitation is 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 Group of KIGAM is leading the two major government funded R&D programs: 'Development of deep-seated, low-temperature geothermal resources' and 'Information system of geothermal resources distribution and utilization', and the grants for these amounted to 41% of total government R&D or RD&D funding in 2008. These research subjects also include collaboration with some universities through subcontracts.

RD&D programs on various geothermal heat pump applications are funded by the New & Renewable Energy Center, Korea Energy Management Corporation (KEMCO). In 2008, no new R&D projects were granted for geothermal developments. Instead, two policy topics were granted on the possibility of geothermal power generation and on small-scale geothermal heat pump systems for individual houses.

13.7 Geothermal Education

There is no regular curriculum for geothermal at university level yet. Public recognition, however, is increasing and there are special lecture courses for HVAC and architectural engineers to introduce general geothermal topics and state-of-the-art heat pump technologies once a year. Also, there are many small seminars about general geothermal topics reflecting increasing public recognition thanks to recent high oil prices.

13.8 International Cooperative Activities

The major international cooperative activity of KIGAM is participating IEA GIA ExCo and Annex Ⅷ. KIGAM also maintains research collaboration with Institute for Geo-Resources and Environment (GREEN) of AIST, Japan, in geophysical exploration of geothermal resources and other geothermal related topics.

The Korean Technology Center for Geothermal Energy (KORGE) was established in 2006, aiming to foster geothermal utilization. KORGE opens the Accredited Installer Workshop in conjunction with International Ground Source Heat Pump Association (IGSHPA).

13.9 Websites

- Geothermal Resources Division, KIGAM: http://geothermal.kigam.re.kr
- Korean Technical Center for Geothermal Energy: http://www.korge.org

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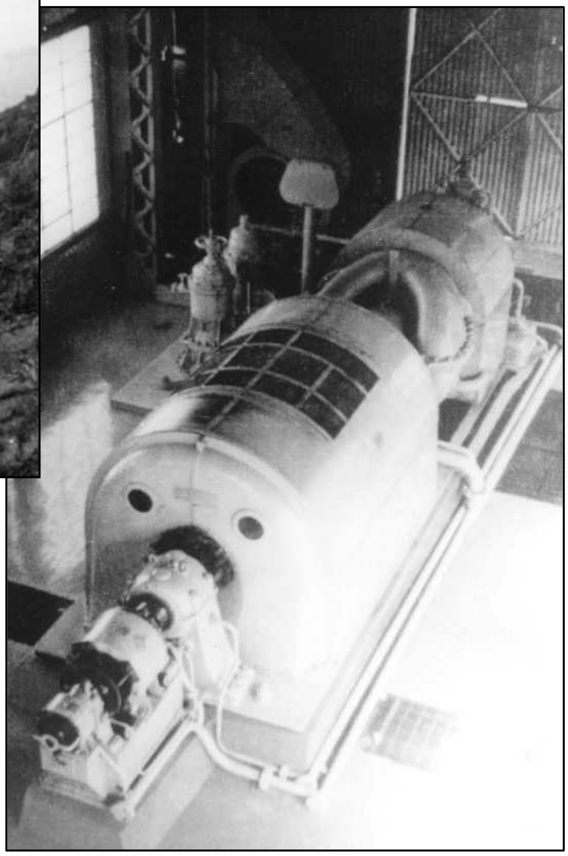
National Activities

Chapter 14

Mexico

First geothermal power house at the Pathé Geothermal Field.
(From GRC Bulletin September-October 2003, p. 205)



The Pathé Geothermal Field geothermal turbine- the first to generate geothermal power in the Americas.
(From GRC Bulletin September-October 2003, p. 205)

14.0 Introduction

Geothermal energy is, by far, the most important non-conventional renewable energy source utilized in Mexico, followed by wind energy. 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). By December 2008, the geothermal-based installed capacity for electricity generation was 958 MW_e, placing Mexico in fourth place worldwide.

14.1 National Policy

About 77% of the installed capacity for public-service electricity generation belongs to the two government-owned utilities, namely the Comisión Federal de Electricidad (CFE) and Luz y Fuerza del Centro (LFC). The remaining 23% belongs to private-owned companies. CFE 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, and it is set to compete on the same bases as fossil-fuel, conventional hydro and nuclear technologies.

CFE has launched two international bids to increase the installed capacity and replace some of the older power plants. The aim is to replace two old 37.5 MW_e units with two 50 MW_e units in the Cerro Prieto Field, using the same amount of steam. This is the project CP-V. The other project under bidding is Los Humeros II, which is going to increase the current 40 MW_e installed capacity to 46 MW_e in the Los Humeros Field. CFE is also taking steps to install 75 MW_e in the partially developed Cerritos Colorados Field and undeveloped areas with geothermal potential (see below). Also, CFE is currently doing feasibility studies for the following projects: 1) 50 MW_e in binary power plants in Cerro Prieto Field; 2) replace seven 5 MW_e units in Los Azufres Field with two units, one of 50 and one of 25 MW_e, for a net increase of 40 MW_e using the same amount of steam; and 3) Research and Development of Hot Water (brine) Injection System in Cerro Prieto Field.

14.2 Current Status of Geothermal Energy Use

14.2.1 Electricity Generation

14.2.1.1 Installed Capacity, Electricity Generated and New Developments

The installed capacity is 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).

The total electricity generated with geothermal steam in 2008 was 7,056 GWh.

The eighth power unit of 5 MW_e in Los Humeros was officially commissioned in April 2008, making the installed capacity 40 MW_e in this field, and 958 MWe nationwide.

14.2.1.2 Number of Wells Drilled and Work over Jobs

During 2008, CFE drilled 11 geothermal production wells in the Cerro Prieto field, with a combined length of 29,942 m, an average depth of 2,722 m for each one; and 3 production wells in Los Azufres with a combined length of 6,600 m, an average depth of 2,200 meters for each well. There were no new wells drilled in the Los Humeros and Las Tres Vírgenes fields, or in other areas.

There were 229 production wells and 23 injection wells in operation in 2008, as national average in the four operating fields.

14.2.1.3 Contribution to National Demand

Electricity generation from geothermal sources represented around 3% of total generation for public service in Mexico. In 2008, the geothermal contribution to electricity generation (3%) was almost 1.6 times higher than its contribution to the installed capacity (1.9%), reflecting the high capacity factor of geothermal electric plants.

14.2.2 Direct Use

The installed thermal power in 2008 was estimated to be about 155.8 MW_t.

Balneology, the main use, amounted to some 155.3 MW_t, at around 160 sites distributed in 19 states.

14.3 Market Development and Stimulation

Support Initiatives and Market Stimulation Incentives: At present there are no economic incentives for geothermal development in Mexico. CFE, the larger of two national utilities, increased its installed capacity for power generation with geothermal sources from 953 to 958 MWe in the year 2008, and this is the only substantial increase expected throughout 2009, although studies for possible new developments and expansions in developed fields are underway (see below). In 2008 it was passed a renewable-energies law which is expected to support the further development of this type of energies, including geothermal energy.

14.4 Development Constraints

As mentioned above, power generation with geothermal energy is considered conventional in Mexico, and thus it must compete on the same bases 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 compared with the modern fossil-fuel generation technologies. It is expected that a new renewable-energy act could support the geothermal development.

14.5 Economics

14.5.1 Trends in Geothermal Investment

As mentioned above, international bids are underway by CFE for future developments in the order of 46 MW_e in Los Humeros, and 100 MW_e in Cerro Prieto that will replace two of the older units (75 MW_e). CFE is working also on the development of 75 MW_e in Cerritos Colorados, 50 MW_e in binary power plants in Cerro Prieto, and for replacing seven old 5 MW_e units in Los Azufres field with two units: one of 50 MW_e and one of 25 MW_e. CFE is also exploring new fields in Acoculco, Pue., and Tulecheck, BC, and has plans to conduct more exploratory studies in San Pedro, La Soledad and the Chichonal Volcano among other zones with geothermal potential.

14.5.2 Trends in the Cost of Energy

The increase of the average price for electricity has accelerated in the last few years (ca 5.4% from 2000 to 2001, 14% from 2001 to 2002 and higher increases after 2002), reflecting in good measure the trend of fossil fuel prices. This trend is changing due to the international recession crisis and the drop of oil prices.

14.6 Research Activities

Most geothermal research activities in Mexico are focused on 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. In 2009 the federal government plans to implement a fund for research on Energy Sustainability which promises to lead to a substantial increase of research activities related to geothermal and other renewable energy sources.

14.7 Geothermal Education

CFE has trained some of their engineers through the geothermal programs offer by Iceland (the United Nations University), New Zealand (the Geothermal Institute of the University of Auckland) and, in the past, by the Baja California university (UABC), who used to offer a Geothermal Training Program (10-month program).

During the last year, CFE has sent young engineers for training to Japan, under an agreement between JICA and the Mexican government, and CFE is planning to do the same in the coming years. For the most part, mechanical, electrical, chemical and geological engineers are trained on the job, as part of their professional development in CFE and the Instituto de Investigaciones Eléctricas (IIE). Periodic professional meetings (congresses, seminars, etc.) provide a basis for continued education of geothermal personnel.

14.8 International Cooperative Activities

Mexico, through IIE and CFE, has participated in the activities of Annex I (Environmental Impacts of Geothermal Energy Development) and Annex IV (Deep Geothermal Resources), and is participating now in Annex VII (Advanced Geothermal Drilling Technologies) of the International Energy Agency Geothermal Implementing Agreement.

In 2008, IIE continued a project for the evaluation of low and intermediate enthalpy geothermal resources in Mexico and Central America, with the aim of promoting direct uses of this energy source. This project is partially supported by the International Atomic Energy Agency.

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Newly installed Kawerau 100 MW_e power plant, August 2008. (From White, 2008)

15.0 Introduction

15.0.1 Background

In New Zealand, over the 2008 year, there has been a continuing growth in geothermal development, with installation and commissioning of new generation, exploration and production drilling, and firm plans to build several new geothermal power plants. Growth has confirmed earlier predictions that more than 600 MW_e of additional geothermal generation, on top of the existing 600 MW_e, is looking feasible and commercially attractive over the next five years. Geothermal heat pumps remain slow to become established, but this an area for considerable future growth, along with other direct use applications. The New Zealand Government is dedicated to the greater use of renewable low-emission energy forms (including geothermal energy). New Zealand commercial operators (especially Mighty River Power and Contact Energy) are selecting geothermal as the best renewable, low-carbon-emitting option for new generation because of significant cost advantages (even without subsidies, feed-in tariffs or carbon taxes). These cost advantages are partly the result of low-risk drilling (>80% success) in "brown-field" resources because of previously acquired knowledge gained from historic, government-funded, exploration drilling.

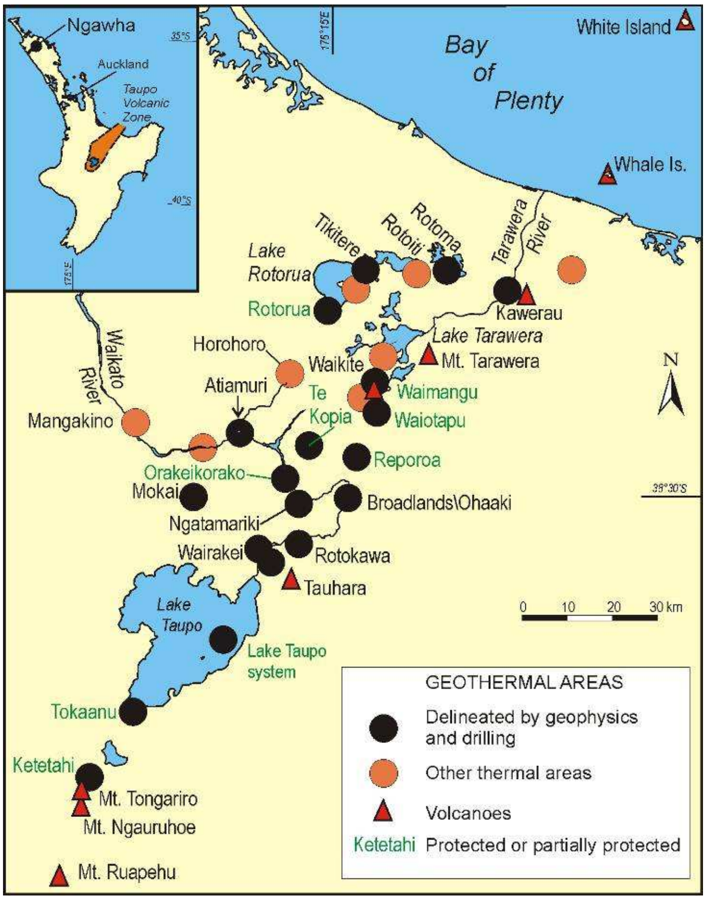

Figure 15.1 Map of New Zealand geothermal system.
(From Hochstein and Bromley, 2009)

15.0.2 Major Highlights for 2008

Existing power plants (with installed capacity at end of 2008) at Mokai (114 MW_e), Rotokawa (35 MW_e), Wairakei (175 MW_e + 55 MW_e), Ngawha (25 MW_e) and Kawerau (122 MW_e) have all been operating normally at full load. Ohaaki has been operating at improved outputs of 60-75 MW_e (104 MW_e installed) due to successful makeup drilling (Figure 15.1). The other major highlights for 2008 include the successful commissioning (ahead of schedule) of 100 MW_e generation capacity at Kawerau, 8 MW_e at KA24 (also at Kawerau) and 15 MW_e at Ngawha. Also, in 2008, the commencement of construction of the world's largest geothermal turbine (132 MW_e, triple flash) at Nga Awa Purua (Rotokawa) and a new 23 MW_e binary plant at Tauhara. Additional exploration drilling at Tauhara geothermal field (linked to Wairakei) has revealed proven steam reserves sufficient for 100 MW_e and adequate inferred resource for a proposed 250 MW_e of new capacity. New drilling at Ngatamariki (north of Rotokawa) has delineated a resource area sufficient for at least 130 MW_e. This acceleration in development activity has been supported by intense drilling activity in most of the high enthalpy resource prospects of the Taupo Volcanic Zone that are ear-marked for power development (about 27 new wells per year).

15.1 National Policy

15.1.1 Strategy

The New Zealand Government energy strategy (see: www.med.govt.nz) favours renewable energy sources. This strategy is benefiting from the economic reality that geothermal investment is currently competitive with a wide range of alternative generation sources and so presents an investment opportunity (even without renewable energy subsidies or carbon credits). A factor is that wholesale gas prices for thermal generation have more than doubled because of dwindling reserves. Furthermore, it is widely known that the equivalent of an additional 1000-1,200 MW_e of geothermal resources is probably available, at competitive long-run marginal costs, even after disregarding environmentally protected geothermal fields from consideration. Therefore, geothermal projects alone could meet more than a decade of anticipated electricity demand growth (about 700 GWh/yr). Existing projects are costing about NZ$ 3-4 million/MW_e. Near-term future projects will probably have a total capital cost of around NZ$ 4 million/MW_e. The anticipated expansion in geothermal generation equates to an expected NZ$ 4 billion development programme over the next 10 years.

15.1.2 Legislation and Regulation

Geothermal was recognised as a resource vital to New Zealand's future energy mix and is economically competitive at the current average wholesale electricity cost of about NZ$ 70/MWh (about US$ 50/MWh). Spot market prices vary with demand and hydro-lake capacity fluctuations. Long-run marginal costs for new geothermal developments are in the range of NZ$ 73-93/MWh (www.med.govt.nz), currently amongst the cheapest of all new generation options.

The New Zealand Government has legislated a carbon emissions trading scheme that is expected to be implemented in 2010. This will provide an additional financial incentive to help boost economically-marginal renewable energy projects (for both electricity generation and direct use), and reduce the use of fossil fuels. The long term strategy is to encourage the transport industry and the public to use more electric vehicles, and to provide the additional energy needed in the form of new, economically-viable, base-load geothermal electricity generation for off-peak recharging of vehicle batteries.

15.1.3 Progress Towards National Targets

Several recent measures have been introduced to stream-line consenting procedures for large renewable energy projects, including a "calling-in" of resource consent applications, to be held before a single Board of Enquiry under the Ministry of Environment, with tight timelines for submissions and decisions. This has already achieved some shortening of the normal consenting process for new geothermal projects (e.g. Te Mihi, Wairakei consents which were finalised in September 2008).

In October 2007, the Government set targets for 2025 of 9.5 PJ/yr of additional direct use renewable energy (mostly geothermal or wood biomass), 90% of all electricity from renewables, and fast uptake of electric vehicles. Progress towards the target in geothermal direct use is slow, but for electricity, the renewable percentage of total generation has increased from about 60% to 70%, and is on target for 90% in less than 10 years. Geothermal is expected to contribute about 20%, wind about 15% and hydropower about 55% (Figure 15.2). Variability in seasonal hydro and wind generation means that some standby capacity and peak load capacity will need to be maintained, and it is envisaged that fast-start gas-fired turbines will probably continue to play this role.

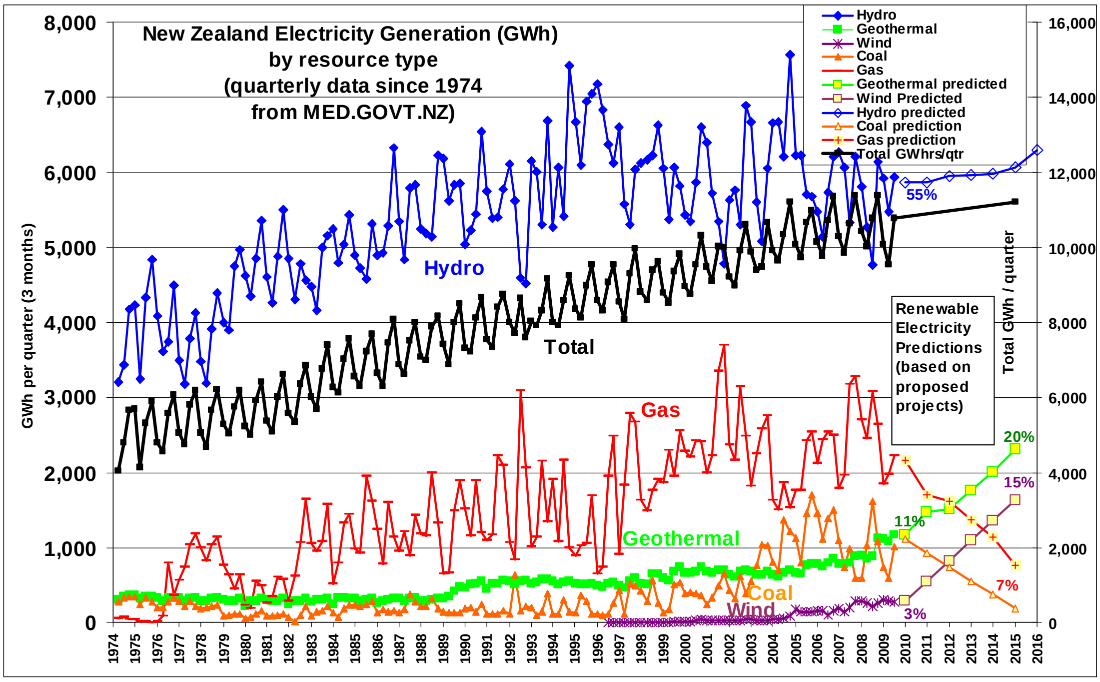

Figure 15.2 Comparison of NZ electricity generation per quarter by type: history and predictions.

However, it is possible that some surplus geothermal capacity (especially units supplied by production from easily-controlled steam-zone wells) could contribute to load-following generation in the future, if economically viable.

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

Government R&D expenditure is presently about NZ$ 3M/yr (US$ 2M/yr). Key topics of geoscientific research include the potential of deeper and more-marginal resources, improved simulations of long term reservoir performance, avoidance of adverse environmental effects, and enhancement of knowledge regarding resources and technologies suitable for direct use.

15.1.5 Industry Expenditure on Geothermal R&D

The major geothermal operators, Mighty River Power and Contact Energy, between them, intend to spend more than NZ$ 2 billion in developing geothermal resources over the next 10 years. A small proportion of this is targeted at research to improve resource knowledge and reduce development costs. Specific applied research projects are linked with longer-term government-sponsored research programmes. Other significant developers of geothermal energy in New Zealand include Top Energy (Ngawha), Bay of Plenty Energy (Kawerau), and Tuaropaki Power Company (Mokai). At public forums, such as the annual New Zealand Geothermal Workshop, and consent hearings, these companies often release the results of commissioned research and exploration work undertaken on these fields in order to contribute to the wider geothermal knowledge database. It is difficult to quantify the cost and value of such "in-kind" contributions to research outcomes, but it is substantial.

15.2 Current Status of Geothermal Energy Use in 2008

15.2.1 Electricity Generation

Comprehensive information about New Zealand's electricity generation may be found on the New Zealand Ministry for Economic Development website at: www.med.govt.nz.

15.2.1.1 Installed Capacity

New Zealand's geothermal installed capacity at the end of 2008 was 632 MW_e, up some 40% from 452 MW_e in 2007.

15.2.1.2 Total Electricity Generated

The total electricity generated with geothermal energy in 2008 was 3,962 GWh, up from 3,272 GWh in 2007. Generation is expected to increase to about 4,700 GWh in 2009, a 9% per annum growth rate.

The average generating capacity factor was ~ 85**%.**

15.2.1.3 New Developments During 2008

In 2008, a total of 123 MW_e of new generation was commissioned; with 108 MW_e at Kawerau (a 100 MW_e dual flash steam turbine, and at well Ka24 an 8 MW_e binary plant) and a 15 MW_e binary plant at Ngawha.

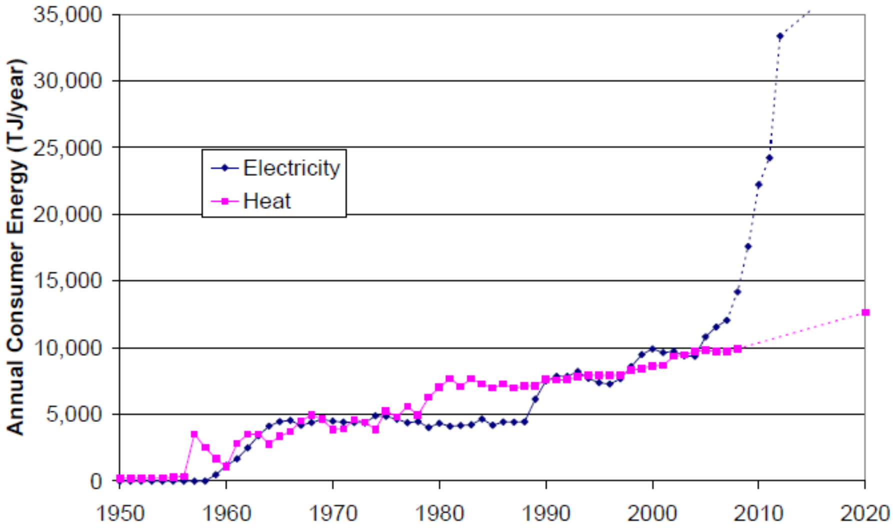

Figure 15.3 Historic trends and projected growth in NZ geothermal electricity and direct use. (From White, 2008)

15.2.1.4 Rates and Trends in Development

Under construction- At Rotokawa geothermal field, the Nga-Awa-Purua (Rotokawa II) extension is incorporating a 132 MW_e triple flash turbine, with completion expected in early 2010. At the Tauhara geothermal field, the first development, a 23 MW_e binary plant identified as Centennial Drive or Tauhara I, is currently being built and is expected to be completed in mid-2010.

Projects committed, consents granted and designs/equipment contracts well advanced- The Te Mihi 234 MW_e development is planned to replace the current Wairakei 162 MW_e power station with a more efficient plant. Construction has been delayed, with priority shifting to Tauhara.

Future projects at an early stage of planning-

- Ngatamariki (100-130 MW_e, exploration drilling has been successful, and a consent application was lodged in 2009)

- ➢ Rotoma 1 (35 MW_e, consent application lodged 2009)
- ➢ Tauhara II (250 MW_e, delineation drilling successful, consent application to be lodged early 2010)

Possible future projects under consideration-

- ➢ Rotokawa III (67 MW_e)
- ➢ Mokai IV (40 MW_e)
- ➢ Tikitere and Taheke (?)
- ➢ Tokaanu (?)
- ➢ Rotorua (?)

As a consequence, there is a high probability of more than doubling the geothermal production in New Zealand within 5 years.

Table 15.1 *New Zealand geothermal power projects, current, under construction and planned.*

Table of New Zealand Geothermal Power Generation as of January 2009						
Geothermal System	Start date	Capacity	Direct Use	Constructing	Planned	Notes
		MWe	MWth	MWe	MWe	
Wairakei	1958-2006	176			234-162	Te Mihi (delayed)
Poihipi	1996	55				Part load-following
Tauhara Tenon	2007		25			Timber drying
Centennial Drive				23		2010 Binary
Tauhara II					250	2013-14
Kawerau (NTG)	1958	14	200			
Kawerau	2008	100				2008 August
Ka24	2008	8				2008 September
Ohaaki (105 MW)	1989	105				June2008-75MW
Rotokawa- Nga Awa Purua	1997	35		132		2010 June
Mokai	1999-2007	114				
Ngawha	1998-2008	25				
Ngatamariki					100	2012 ?
Rotoma-Tikorangi					35	2012 ?
TOTAL		**632**	**225**	**155**	**457**	

15.2.1.5 Number of Wells Drilled

In 2008, 27 wells were drilled.

15.2.1.6 Contribution to National Demand

Geothermal installed capacity contributes 6% of the total New Zealand national capacity; while generating 10-11% of the national electricity in 2008-2009.

15.2.2 Direct Use

In 2008, the total primary thermal power discharged was about 22 PJ/yr; with some 10 PJ/yr thermal energy used. The average capacity factor was 43%, with capacity factors for industrial process heating and commercial bathing of 44% and 39%, respectively.

15.2.2.1 Categories of Use

Approximately 55% of the direct use of geothermal energy in New Zealand is industrial use at the Kawerau Pulp and Paper Mill (~200 MW_{th}). The balance is mostly bathing and space heating facilities, kiln drying facilities at two sites, a geothermal tourism business, horticulture (e.g. tomato/capsicum glasshouses at Mokai, orchids at Wairakei) and aquaculture (e.g. Prawn Park at Wairakei).

15.2.2.2 New Developments and Wells Drilled in 2008

At Tauhara geothermal field, a ~ 50 MW_{th} waste-wood pellet-drying facility for producing pellets for use in domestic pellet-burning heaters is in the planning stages.

The number of new wells drilled for direct use is not recorded.

15.2.2.3 Rates and Trends in Development

Rates of growth in direct use have been relatively static over recent years, but are predicted to improve in the next 10 years. Geothermal tourism is growing; this involves commercial visits by domestic and overseas tourists to geothermal parks or reserves, and bathing at hot spring resorts.

15.3 Energy Savings in 2008

15.3.1 Fossil Fuel Savings/Replacement

Fossil fuel savings/replacement for 3,962 GWh (14.26 PJ) of geothermal electricity generation in 2008 was 1.0 Mtoe/yr, assuming 70.4 toe/TJ.

Fossil fuel savings/replacement for 10 PJ of geothermal direct heat use in 2008 was 0.35 Mtoe, at 35.2 toe/TJ.

15.3.2 Reduced/Avoided CO_2 Emissions

Reduced/avoided CO_2 equivalent (CO_{2-eq}) emissions (in tonnes of CO_{2-eq} /yr) for 3,962 GWh of electricity (using average of 806 t CO_{2-eq}/GWh net) is 3.19 Mtonnes (Mt) CO_{2-eq}/yr.

Reduced/avoided CO_{2-eq} emissions (in tonnes of CO_{2-eq}/year) for 10 PJ of direct heat use (using average of 114 t CO_{2-eq} /TJ net) is 1.1 Mt CO_{2-eq}/yr.

Using published data on gas content in discharged steam, the calculated actual CO_{2-eq} (including methane) emissions from all NZ geothermal power plants (at a weighted averaged rate of 93.7 t CO_{2-eq}/GWh) producing 3,962 GWh in 2008 was 0.37 Mt CO_{2-eq}. This would have avoided CO_{2-eq} emissions from an equivalent (Huntly-sized) coal-fired power station (3,962 GWh at 900 tonnes CO_{2-eq} /GWh) of 3.56 Mt $CO2_{eq}$, leaving a calculated net benefit from geothermal of 3.19 Mt $CO2_{eq}$ (same as above). Such a calculation ignores the long-term effects of steam production on natural CO_{2-eq} emission rates through the ground.

15.4 Market Development and Stimulation

15.4.1 Support Initiatives and Market Stimulation Incentives

At present, the NZ government does not support geothermal directly in the form of renewable energy feed-in tariffs or subsidies. Normal market forces are deemed sufficient to drive investment in geothermal. However, New Zealand participates in the Clean Development Mechanisms programme under the Kyoto Protocol, and a carbon emissions trading scheme has been finalized in legislation and regulation ready to be implemented in 2010.

15.4.2 Development Cost Trends

Total capital costs of generation from new geothermal plant now average about NZ$ 3-4 M/MW$_e$ installed. Prior to 2008, drilling costs increased significantly to about NZ$ 4M per 2 km deep well, due to a shortage of rigs, shortage of skilled manpower and increasing consumable costs (steel and cement). Prices and costs have since been quite variable, mainly as a result of the global financial crisis, commodity price swings and changes in the availability of rigs and operators.

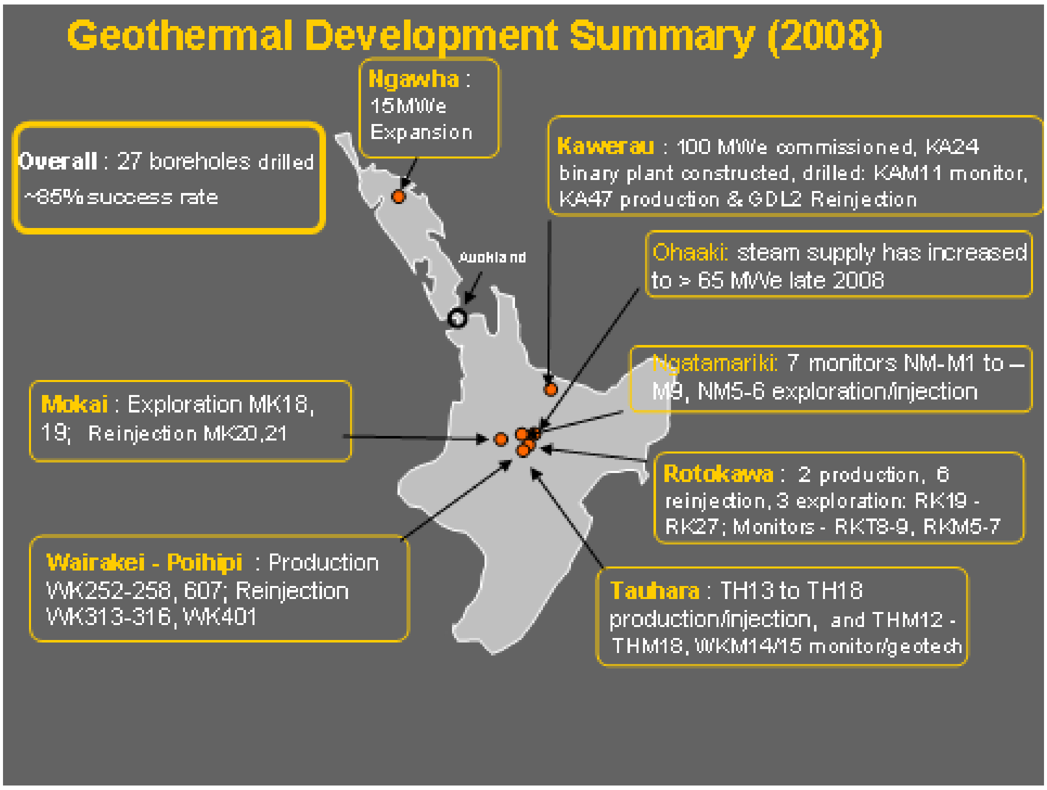

Figure 15.4 Map of recent NZ geothermal well drilling and development activities. (From Bignall, 2009)

15.5 Development Constraints

Significant constraints on the potential for future geothermal energy development in New Zealand are the issue of environmental effects and consideration for tourism and natural feature preservation. In the Waikato Region alone, about 50% of the estimated economically accessible resources are categorised by the regional authority (Waikato Regional Council) for *protection* due to outstanding natural characteristics. Others are only available, at present, for small *research* takes or *limited development* as a precautionary measure. Resources that are located near cities (e.g. Rotorua and Taupo) are subject to stricter control of fluid take and injection rates (with more stringent conditions on resource users) in order to minimize the risk of possible adverse effects on urban environments (such as subsidence, hydrothermal eruptions or pressure interference between bore users).

15.6 Economics

15.6.1 Trends in Geothermal Investment

A growth trend in geothermal investment in New Zealand is very apparent, with significant drilling activity, new resource consent applications and power plant construction. Geothermal drilling in known NZ geothermal resources over the past 3 years is achieving ~85% success rate in terms of commercially viable production or injection wells. This has reduced the perception that geothermal drilling is a risky venture, and has encouraged new investment.

Figure 15.5 (from MED, 2009, with assumption as given) shows that geothermal power is expected to be the cheapest option for most of the proposed projects up to 900 MW_e of new capacity. Although the geothermal heat is *free*, these long-run marginal new generation costs include the costs of interest on capital, operations and maintenance, and anticipated make-up drilling.

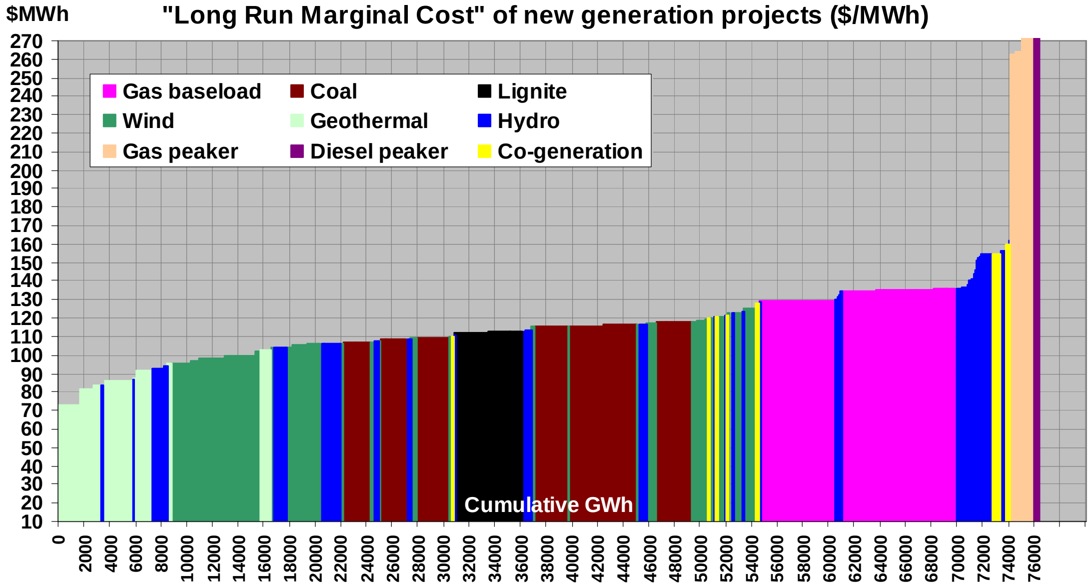

***Figure 15.5** Example of long-run marginal cost curve (NZ$) for identified future NZ generation projects versus cumulative GWh in cost order (Electricity LRMC model.xls, in www.MED.govt.nz). Assumes 8% discount rate, US$ 0.6/NZ$ and NZ$ 25/tonne CO_2 charge. Geothermal predominates up to 8,000 GWh.*

15.6.2 Turbine, Project, Well Drilling and O&M Costs

Typical project costs (including drilling) for new green-field developments in New Zealand were recently presented in a report for the NZ Geothermal Association (Barnett and Quinlivan , 2009). In summary, for resources in the temperature range of 275-300 °C and a power plant size of about 50 MW_e, the total capital costs would range between NZ$ 3.4 M/MW_e and NZ$ 4.6 M/ MW_e (in 2007 $), and the long-run marginal cost is expected to range between NZ$ 70/MWh and NZ$ 90/MWh (for the next 1,000 MW_e). For lower enthalpy resources and smaller power plants, the costs will be greater.

Recent drilling-inclusive, new-project, capital-costs have been NZ$ 3 M/MW_e total for the Kawerau 100 MW_e project, NZ$ 3.2 M/MW_e for the Nga-Awa-Purua (Rotokawa II) 132 MW_e project and about NZ$ 4 M/MW_e for the Tauhara 23 MW_e binary plant. Well drilling costs are currently about NZ$ 4 M each for 2 km deep wells.

O&M costs are typically NZ$ 8.5/MWh (for power plant and steam field) plus a long-term average of NZ$ 2.5/MWh for make-up well drilling (although this varies significantly between fields).

15.6.3 Trends in the Cost of Energy

Average wholesale electricity cost at source is presently about NZ$ 80/MWh (US$ 50/MWh), although the average delivered price for large industrial users in 2008 was NZ$ 106.5/MWh, and this has increased 71% per year since 2000 (3 times the rate of inflation). New geothermal generation cost is about NZ$ 70/MWh for the best resources. Older geothermal generation costs (e.g. 25-50 year-old turbines) are much lower (estimate ~NZ$ 15/MWh) because capital costs have been written down (although maintenance costs increase with age).

15.6.4 Geothermal Sector Employment

The number of people (i.e. full-time-equivalents) employed in the NZ geothermal sector was estimated to be about 280 in 2005, and about 320 in 2008.

15.7 Research Activities

15.7.1 Focus Areas

Research focus areas include: geophysical studies (MT, seismicity), environmental issues (subsidence, hot spring/vegetation effects), deep resource delineation, production sustainability, and shallow hot water resources for direct use.

Figure 15.6 Example of environmental studies: Otumuheke Spring at Tauhara; a steam-heated spring located inside a subsidence bowl which historically increased in temperature due to deep pressure drawdown increasing steam upflow.

15.7.2 Government Funded Research

Government funded geothermal research undertaken by GNS Science and Auckland University, receives about NZ$ 3M/yr, for the 6-year research cycle which began in October 2007. In addition, supplementary research projects for deep geothermal resource exploration and for enhanced direct use of lower enthalpy resources were commenced in 2008.

15.7.3 Industry Funded

Industry funded research was pursued in several topic areas, including: silica scaling issues for specific power plants; arsenic removal from separated brines; geotechnical drilling, core analysis and modelling to investigate causes of subsidence anomalies; and micro-seismicity studies.

15.8 Geothermal Education

The New Zealand Geothermal Association and the University of Auckland continue to provide relevant annual seminars, the annual New Zealand Geothermal Workshop (held in November), and short courses. In 2008 and 2009, Auckland University (Institute of Earth Science and Engineering [IESE]) continued the international post-graduate training course (a 5-month course from July to November). One-day geothermal information seminars are organised annually by GNS Science for the benefit of members of indigenous Maori Trusts. The New Zealand Geothermal Association also hosts specialised 1-day workshops with invited speakers on topics of interest as required. In 2008, this involved a visiting speaker on reservoir management, Dr. Cedric Malate, from PNOC-EDC (Philippines).

15.9 International Cooperative Activities

New Zealand scientists and engineers collaborate with geothermal projects throughout the geothermal world including: EGS (USA, Australia) and International Deep Drilling Project (IDDP) high temperature drilling (Iceland). Consulting by New Zealand based geothermal specialist companies (e.g. SKM, PB Power, GNS Science, IESE) is undertaken in all geothermal countries.

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National Activities

Chapter 16

Spain

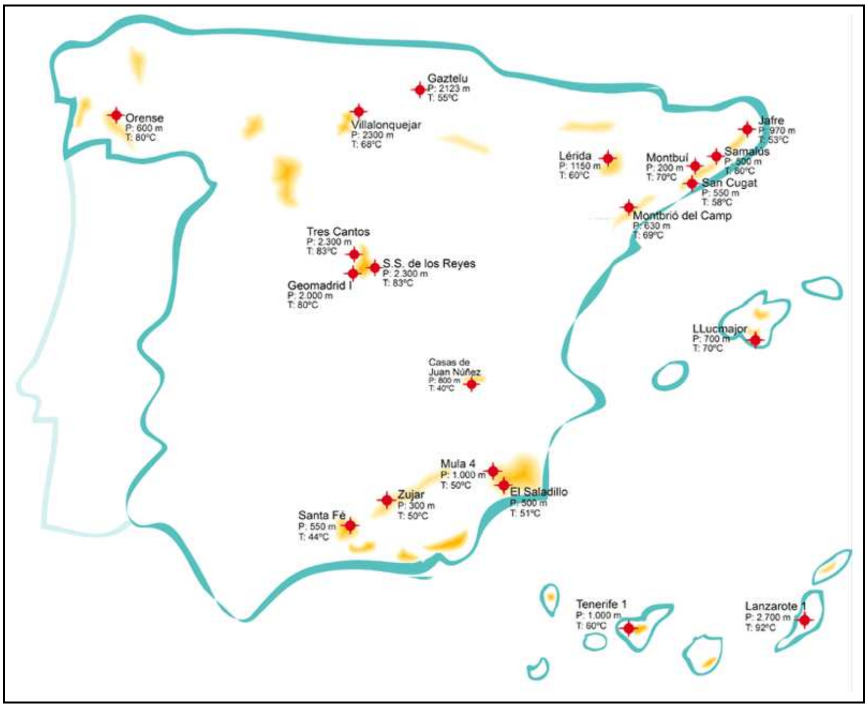

Figure 16.1 *Spanish geothermal potential areas and geothermal investigation wells.*

16.0 Introduction

Spain joined the IEA-GIA at the end of 2008. Consequently, this is the first country annual report produced by Spain for IEA-GIA, and will thus include a brief overview of the geothermal potential in Spain.

At present, geothermal energy in Spain still has a low penetration in our energy balance, despite the importance of Spanish geothermal resources, as demonstrated by the extensive studies and investigations undertaken during the 1970s-1980s. Since a couple of years, a great interest in geothermal energy in our country has been awoken again.

There is currently no reliable assessment of the geothermal energy potential in Spain. However, from studies conducted in the 1970s and 1980s, mainly carried out by the Spanish Geological Survey (IGME), there are indeed recognized and identified several areas with significant potential.

Geothermal resource exploration, assessment and evaluation started in Spain in the 1970s, with a general geological and geochemical survey of known thermal springs and areas showing signs of thermal activity. The most interesting sites were then selected, based on geological criteria, with the results of the surveys showing locations in the south-east (Granada, Almería and Murcia), north-east (Barcelona, Gerona and Tarragona), north-west (Orense, Pontevedra and Lugo) and centre (Madrid) of the Iberian Peninsula. Other, minor areas located in Albacete, Lérida, León, Burgos and Mallorca, have also been investigated. The evaluation of geothermal resources was based on low temperatures, and the exploration boreholes are not more than 2,300 m deep.

The geothermal resources evaluated in all these cases exhibit low temperatures, 50-90°C. The only area where high-temperature fluids might possibly exist at depth lies in the volcanic archipelago of the Canary Islands. Hot dry rock resources have been evaluated on the islands of Lanzarote and La Palma. On the island of Tenerife, the presence of high-temperature areas has been investigated, but no commercially viable geothermal reservoirs have been found. Low-temperature geothermal sites are currently being exploited on a small scale. For example, geothermal fluids are being used for heating and to provide hot water to spa buildings in Lugo, Arnedillo (in La Rioja), Fitero (in Navarra), Montbrió del Camp (in Tarragona), Archena (in Murcia) and Sierra Alhamilla (in Almería). In Orense and Lérida, geothermal waters are being used to heat homes and schools. Greenhouses are being geothermally heated at Montbrió del Camp (Tarragona), Cartagena and Mazarrón (in Murcia), and Zújar (in Granada); these facilities are identified in Figure 16.1.

Within the framework of the Spanish Renewable Energy Plan 2011-2020, necessary studies are being planned to complete this knowledge and to have a better assessment of the geothermal potential in Spain.

The contribution of Renewable Energy Sources to Primary Energy Consumption in 2007 reached 7%, as compared to 6.4 % from 2006. Biomass, wind energy and hydro contributed with the 4.9%. In the sector diagram below, showing the Contribution of RES to primary energy consumption, geothermal energy is a significantly lower contributor than the other renewable energies.

With respect to global results, it should be noted that the primary consumption of renewable energy increased over this period by some 1 million ton oil equivalent (toe) (growth of 11% from 2006), reaching a total of 10.2 million toe. Thus, renewable energy has surpassed for the first time, the goal of 10 million toe.

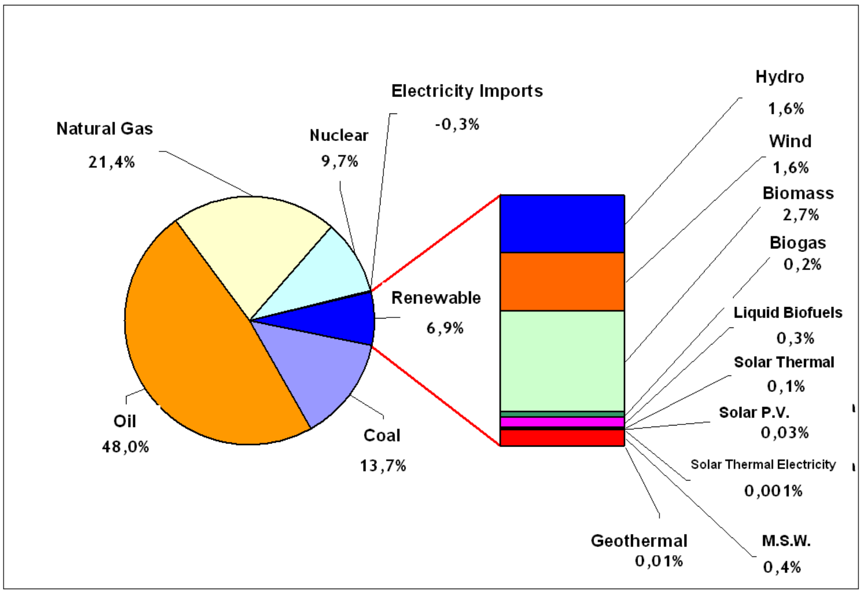

Figure 16.2 Spanish contribution of RES to primary energy consumption, 2007.

16.1 Highlights for 2008

The year 2008 was marked by several highlights illustrating the geothermal situation:

- In order to enhance its involvement in geothermal energy, The Institute for the Diversification and Saving of Energy (IDEA) created a new section (at the end of 2007) devoted to geothermal energy in the Hydroelectric and Geothermal Department. This new section takes over the whole activity linked with geothermal energy. Moreover, it shall promote geothermal energy and its different uses together with the Spanish geological survey The Instituto Geológico y Minero de España (IGME).

Concerning the different types of geothermal activities the main highlights are the following:

- Diffusion activities
  - IDAE published the first *Geothermal Manual* and an institutional video about geothermal energy and all different uses
  - Celebrated the First Geothermal Energy Congress (GEOENER 2008) in Madrid
  - At the end of 2008, the first steps to set the Spanish Geothermal Energy Platform, GEOPLAT, were completed
- Important resources and imminent exploitation
- Geothermal heat pumps: There is an emerging market (GHPs for individual houses). There is an emerging application area of low-temperature geothermal energy for heating, cooling and WSW, mainly through geothermal heat pumps, which are enabling the development of an industrial network which is important to enhance the quality and the specific knowledge of this technology, to avoid market distortions and to ensure high quality products and services to final consumers
- Geothermal district heating: there are some initiatives in this field (some companies are initiating geothermal exploration, with production expected in 2011 and power generation in 2013)
- High temperature resources in evaluation: there is a great expectation for high-temperature geothermal energy exploitation and deep uses such as EGS/HDR, because now the use of this energy is not limited to areas with favourable geological conditions. Spain is starting this way, though it will be necessary to increase the knowledge of the subsurface and to investigate advanced new drilling technologies.

16.2 National Policy

16.2.1 Strategy

The Spanish Renewable Energy Plan (REP) 2005-2010 represents a revision of the Spanish Promotion Plan for Renewable Energies 2000-2010 enforced in 2005:

- A revision of the old Spanish Promotion Plan for Renewable Energies is necessary as a consequence of the growing consumption of renewable energies, which though significant, was insufficient in helping reach the goal of 12% by 2010.
- In fact, the growth, which was more than estimated, of the total consumption of primary energy, made it difficult to comply with the relative increase of renewable energy.
- Also, it was necessary to define the goals of the Directive in regards to renewable energy (29.4% of the consumption of renewable electricity for the gross electric production) and of the Directive on biofuels (5.75% of the total gasoline and gasoils in

2010). These Directives were approved following the approval of the previous Plan and therefore, their objectives had not been completely defined.

- On the other hand, there was also the need to adopt new commitments on the environment derived from the National Plan of Emissions Allocation Rights (PNA), contributing with clean energies to the reduction of the greenhouse gas emissions.

The new Plan revised the objectives of the previous one, particularly in areas of wind power (up to 20,000 MW in 2010), solar photovoltaic (up to 400 MW), solar thermoelectric (up to 500 MW) and biofuels (up to 2.2 million tons oil equivalent).

16.2.2 Legislation and Regulation

In Spain, with little tradition and experience in the use of geothermal resources, the legislation is poorly developed, especially in regards to low temperature geothermal energy. The exploitation of geothermal resources is mainly covered by the mining legislation, because of its nature of energy mineral resources.

- Law 22/1973, of July 21, Mine (amended by Law 54/1980, of November 5). Geothermal resources appear covered in Section D, together with the energy resources of interest
- Regulations for the General System of Mining (Decree 2857/1978, of August 25)
- Regulation of Mining Safety Standards (RD 863/1985, of April 2), developed through Complementary Technical Instructions.

Currently, the autonomous areas are the administrative management of the mining system, according to the law of transfer of functions and services relating to industry, energy and mines.

In the general regulation for prospecting and exploitation of these resources (high temperature), there are three different and distinct permits: Permissions for exploration, research permits and exploitation concessions:

- Exploration permit, to be allowed to search for the geothermal deposits (resources)
- Exploitation permit that gives the owner an exclusive right on the resource in the perimeter of the permit
- Exploitation Concessions: Legal Right to use geothermal resources, to a certain extent, for a period of 30 years, and extendable up to 90 years

16.3 Current Status of Geothermal Energy Use

16.3.1 Electricity Generation

16.3.1.1 Installed Capacity

There are currently no geothermal plants in Spain.

16.3.2 Direct Use

Currently, in Spain, there are only geothermal heating projects for spa facilities, greenhouse heating and geothermal house heating.

The main exploitation projects of low temperature geothermal energy at present are limited to greenhouse heating in the Mediterranean area (Murcia, Alicante, Tarragona). A few projects in Galicia and Lerida use geothermal energy for both domestic and school heating.

There are other projects associated with thermal springs and balneological applications. The geothermal energy is mainly used to heat spa buildings.

There are some initiatives for geothermal district heating projects which have already begun the exploration phase.

16.3.2.1 Installed Thermal Power

In 2008, the total installed power of geothermal heat pumps was 5976.95 kW_t, according to data registered by the Spanish Autonomous Regions.

16.3.2.2 Category of Use

Figure 16.3 shows the various direct use operations in Spain.

Figure 16.3 Direct use in Spain.

16.4 Market Development and Stimulation

16.4.1 Support Initiatives and Market Stimulation Incentives

16.4.1.1 Electricity Generation

The Royal Decree 661/2007, established the feed-in tariffs for the production of electricity for Renewable Energy Sources.

- **Category a)-** Producers using cogeneration or other ways of electricity production from waste energy
- **Category b)-** Installations using any of the non-consumable renewable energies, biomass or any kind of biofuel as primary energy, whenever their titleholder does not carry out production activities under the ordinary scheme

  Group b.3- Installations that only use as primary energy: geothermal energy, wave energy, tidal energy, energy from hot dry rock, ocean thermal, and the energy of sea currents

- **Category c)-** Power plants that use waste with energy recovery not stated in category b) as primary energy

Geothermal Energy in the Spanish Regulation (Royal Decree 661/2007) presents two sale options:

- Article 36: Sets the tariffs and premiums (updated tariffs 2007 ITC-3801):
  - To the distributor at the regulated tariff (% of average electricity tariff, as set by RD 1432/2002). Option know as feed-in tariff.
    - In the first 20 years: 68.90 €/MW
    - After the first 20 years 65.10 €/MW
  - Free market sale: price set by the market (calculated on hourly basis) + premium (% of average electricity tariff, as set by RD 1432/2002) + incentives+ complements.
    - In the first 20 years: 38.44 €/MW
    - After the first 20 years 30.60 €/MW
- Article 39: additional prime specific for each project during the first 15 years.

16.4.1.2 Geothermal Heat

Several initiatives were taken concerning district heating and geothermal heat-pumps.

16.4.1.3 Financial Initiatives

Financial incentives will be considering the inclusion of subsidies for geothermal heat pump and district heating for next year.

16.4.3.4 Geothermal Heat Pump Incentives

In 2008, geothermal projects have been subsidized for low temperature heat pump, at regional level, included in the subsidies of the Saving and Efficiency of the Renewable Energy Plan for the 2005-2010 period.

The amounts of the grants were:

- 490 €/kW for open circuit geothermal installations
- 1.000 €/kW for closed circuit with horizontal drilling
- 1.400 €/kW for closed circuit with vertical drilling

16.5 Economics

16.5.1 Trends in Geothermal Investment

There was not significant investment in 2008. For the next year, geothermal projects (district heating and geothermal heat pumps) will be included in the subsidies of the Renewable Energy of the Renewable Energy Plan for the 2005-2010 period.

16.5.2 Development and O&M Costs

Geothermal energy is emerging in Spain, but there are currently no reference costs.

16.5.3 Employment in Geothermal Sector

The number of people employed in the geothermal sector, mainly in geothermal heat pump sector, is not significant for this year.

16.6 Research Activities

16.6.1 Focus Areas

- The development of knowledge relating to geothermal resources: IDAE and the Spanish Geological Survey has a Cooperation Agreement to promote and foster the development of geothermal energy in Spain: low, medium, and high temperature and also HDR.
- In 2008, IDAE (The Institute for the Diversification and saving of Energy) is initiating the preparation and preliminary studies to initiate the evaluation of geothermal potential in Spain to be conducted throughout the year 2009.

16.6.2 Government Funded Research

In 2008, there was no national funded for geothermal energy R&D activities in Spain.

16.7 Geothermal Education

There are currently no education courses dedicated to geothermal energy in Spain.

Additionally, congresses, seminars and lectures are held by several institutions and associations involved in geothermal energy.

16.8 International Cooperative Activities

The Government of Spain has designated The Institute for Diversification and Saving of Energy (IDEA), to participate in the IEA as member of the International Energy Agency Geothermal Implementing Agreement.

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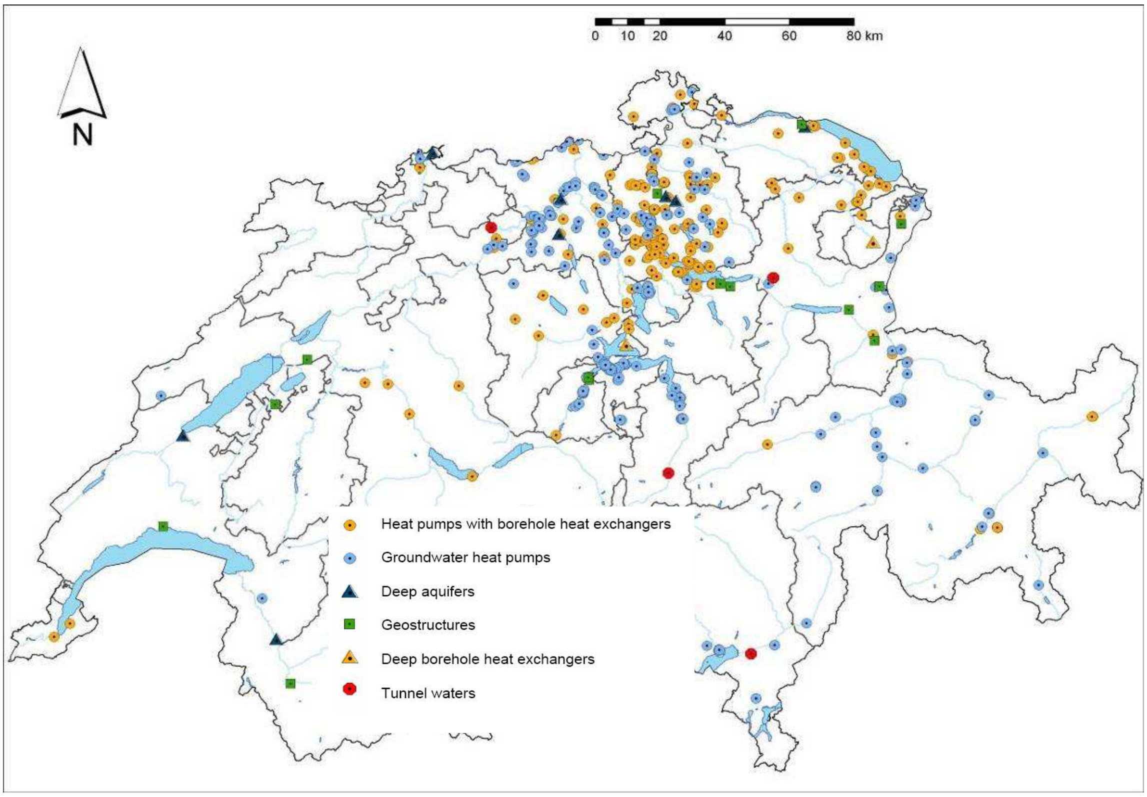
National Activities

Chapter 17

Switzerland



Large (>100kW) geothermal installations in Switzerland. (Source: Swiss Geothermal Association)

17.0 Introduction

17.0.1 Background

Switzerland continues to move towards the wide-spread use of renewable energies and energy-efficient technologies to satisfy its domestic demand for energy. A national energy program (SwissEnergy) and corresponding cantonal (21 cantons make up the Swiss confederation) programs provide the framework for continued uptake of sustainable and environmentally less harmful energies and technologies. Historically, the programs have relied more heavily on incentives and voluntary measures than compulsory measures.

17.0.2 Major Highlights and Achievements in 2008

The main achievement is the steady growth of geothermal direct use, mainly due to the advance of geothermal heat pump systems. Such systems are increasingly installed in larger complexes for space heating, cooling, and domestic hot water production. In addition they are deployed in the course of renovating old building stock.

17.1 National Policy

17.1.1 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 the advance the use of renewable energies. Five focus areas have been 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
- Energy efficient and low emission mobility.

17.1.2 Legislation and Regulation

The energy article in 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 the instruments for defining a sustainable and modern Swiss energy policy. In addition to these legal instruments, the energy policies of the federal government and the cantons are also 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 the municipal, cantonal and federal levels.

Since 1990, all cantons have drawn up their own 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 received through the adoption of 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.

Building on the Energy and the CO_2 Acts, the Federal Council has launched the program SwissEnergy in 2001. By means of voluntary agreements with trade and industry, and with the aid of information campaigns, the program's aim is to realize Switzerland's energy and climate objectives, slow down the increase in energy consumption, promote the use of new renewable forms of energy and decrease the use and dependence on fossil fuels.

17.1.3 Progress Towards National Targets

National targets comprise:

- The goal of Switzerland's climate policy to reduce CO_2 emissions by 10% by 2010 and to stabilize other greenhouse gas emissions compared to their values of 1990
- 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 have, by the end of 2008, declined by only 1.6% when compared to 1990.

Switzerland's electricity consumption amounted to 58,729 GWh, about 12.1% more than in 2000 (52,373 GWh), of which renewable energy sources (excluding hydropower) contributed 1,285 GWh. The latter figure compares to 847 GWh for the year 2000. In 2008, 11,153 GWh of heat were derived from renewable energy sources compared to 8,314 GWh in 2000.

17.1.4 Government Expenditure on Geothermal Research and Development

For this purpose, government expenditure covers not only research and development (R&D) in the strict sense, but also contributions to pilot and demonstration projects. The Swiss Federal Office of Energy, the Swiss State Secretariat for Research and Education, the Board of the Swiss Federal Institutes of Technology, the Swiss Innovation Promotion Agency, and the majority of individual Swiss cantons have contributed funds to a number of R&D and pilot and demonstration projects. Although not a member state, Switzerland has a range of bilateral agreements with the European Union (EU) that include research activities and allow cooperation with and integration into EU-wide R&D activities.

Figures for 2008 are only available for funds that have been provided by the Swiss Federal Office of Energy; for Research and Development some CHF 0.7 Million (M), for pilot and demonstration some CHF 0.2 M, and for support of the Swiss Geothermal Association some CHF 0.5 M.

17.1.5 Industry Expenditure on Geothermal Research and Development

It is not possible to obtain reliable figures. In many instances, industry R&D funds are co-mingled and include all energy related activities. Actual expenditures are likely to range from CHF 1-3 M; the funds derive mostly from Switzerland's main utility companies and their research vehicle (swiss*electric* research), member funds used for Switzerland's Center for Geothermal Research (CREGE or Centre de recherche en géothermie) based in Neuchâtel, funds that small and medium sized enterprises contribute, and funds from semi-private regional and local utility companies. Towards the end of 2008, the local utility company, ewz, of Zürich, has committed CHF ~20 M towards drilling a exploratory geothermal well for research and development of the deep subsurface in the region of Zürich.

17.2 Current Status of Geothermal Energy Use

17.2.1 Electricity Generation

There was no power production from geothermal resources in 2008. 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.

17.2.2 Direct Use

The Swiss Geothermal Association (www.geothermie.ch) publishes annual statistics on the use of geothermal energy in Switzerland (Signorelli et al., 2009 in preparation). In 2008, some 2.1 TWh of heat were produced from geothermal systems (Table 17.1) of which 1.6 TWh were directly attributable to geothermal energy. 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 0.3 TWh of produced heat in Switzerland (Figure 17.1).

Table 17.1 Installed capacity for direct use and associated total heat production for 2008.

Geothermal System	Installed Capacity (MW_{th}) 2008	Compound Annual Growth Rate (2000-2008)	Annual Total Heat Production (GWh) 2008	Compound Annual Growth Rate (2000-2008)
Heat pumps with borehole heat exchangers, horizontal collectors	861.2	11%	1573.7	12%
Groundwater heat pumps	143.0	5%	221.8	6%
Energy piles («geostructures»)	10.4	14%	21.5	14%
Deep borehole heat exchangers	0.2	0%	0.8	2%
Deep aquifers for district heating	5.0	0%	15.5	-2%
Tunnel waters	2.4	1%	4.3	3%
Spas, wellness facilities	34.9	-1%	290.4	-1%
Total	1057.0	10%	2128.1	9%

Source: http://www.geothermie.ch/data/dokumente/miscellanusPDF/Publikationen/GeoStatisikCH_2008.pdf

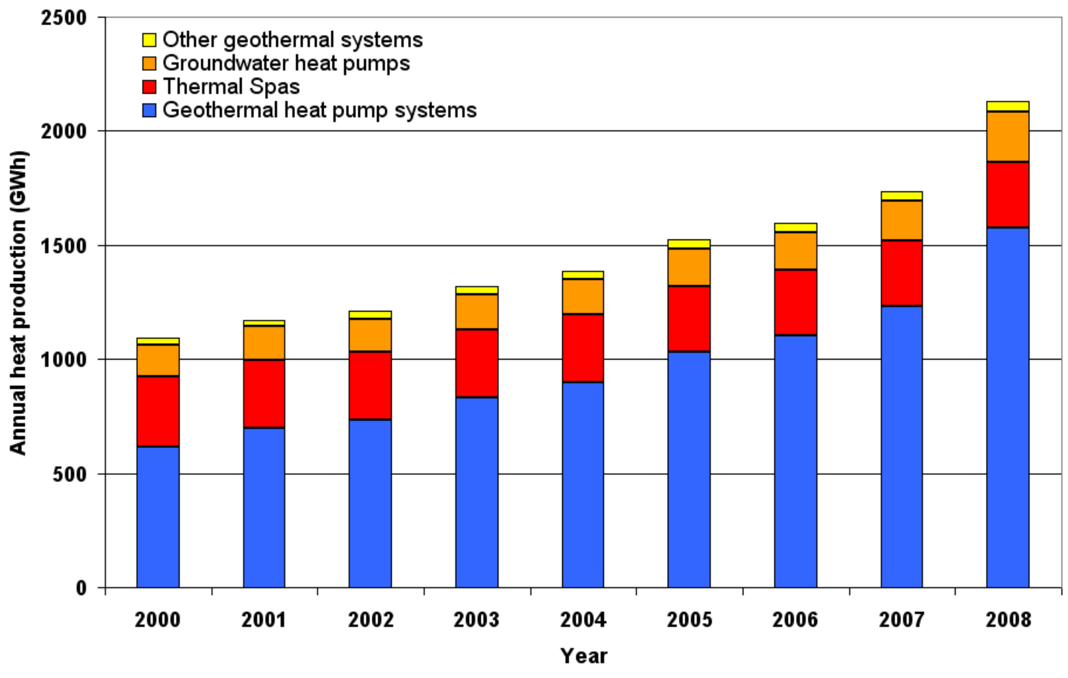


Figure 17.1 Development of heat production of Swiss geothermal installations 2000 – 2008 (Source: Swiss Geothermal Association).

17.2.3 Energy Savings

The total heat production of 2,128 GWh (7.7 PJ) in 2008 corresponds to a savings of some 183,000 toe/year. Assuming an emissions factor of 3.18 tonnes of CO_2 per tonne of heating oil, an estimated 581,000 tonnes of CO_2/year were not emitted. This figure is likely to be an upper limit to the actual figure. Of the 581,000 tonnes, an estimated 17% are a reduction owing to the use of geothermal energy in renovated building stock and some 83% have been avoided owing to newly constructed buildings that otherwise are likely to have been heated using heating oil. Switzerland's own electricity production (~60 % hydro, ~40 % nuclear) is almost free of CO_2 emissions. But, there is very active pan-European power trading which on occasion results in the import of fossil-fuel derived electricity. This contribution would actually lower the amount of reduced and avoided CO_2 emissions.

17.3 Market Development and Stimulation

2008 saw a continuation of the boom in the utilization of geothermal heat pumps. During the years 2000-2008, borehole heat exchanger systems were deployed mostly in newly constructed real estate. However, as most of Switzerland's building stock is old and in need of renovation, the rate of deployment in renovated building stock has correspondingly accelerated over the last few years. A closely correlated marker is the meters drilled for borehole heat exchanger-coupled geothermal heat pumps (Figure 17.2). Whereas the 2000-2008 compounded annual growth rate of meters drilled for such systems in newly constructed real estate amounted to 21%, the rate of growth for such systems in renovated building stock was 38% (http://www.fws.ch/dateien/Statistiken_2008.pdf).

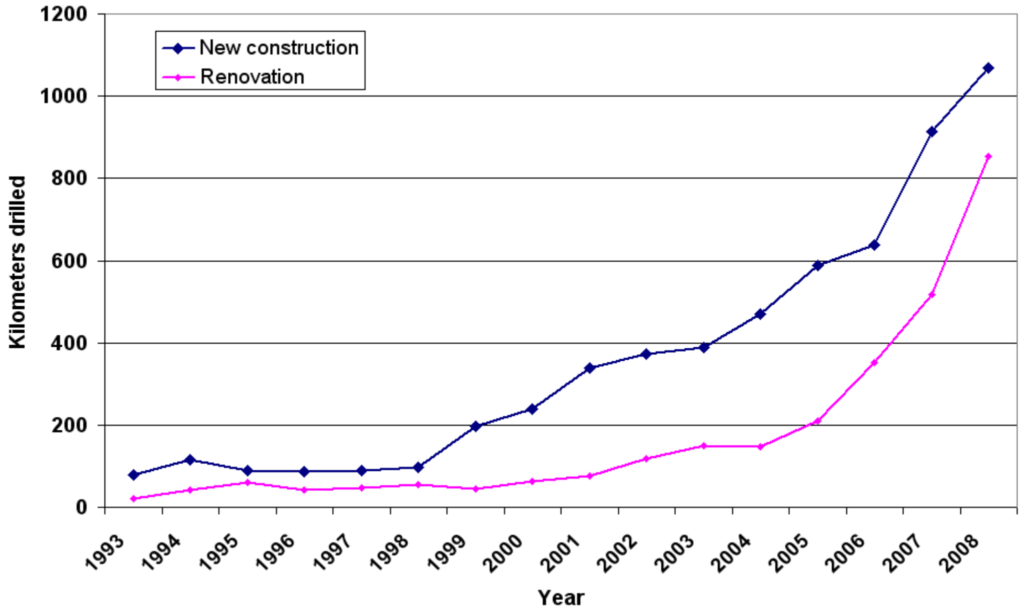


Figure 17.2 Kilometers drilled – an indicator for market development for geothermal heat pump systems. In recent years geothermal heat pumps systems are increasingly deployed in the renovation of Swiss building stock. (Source: www.fws.ch – last accessed on 17 July 09)

To allow for more wide-spread deployment of geothermal heat pump systems particularly in densely built-up environments, the Swiss Federal Office of Energy has sponsored the construction of a mini-rig for drilling shallow geothermal wells to depth of around 100-120 m depth (Figure 17.3). The rig is expected to meet the growing demand of customers with limited and difficult-to-access space for geothermal heat pump systems. The small dimensions (a width of 1.00 m) and the light weight allow for fast deployment.

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 seminar on a regular and as-needed basis. A few hundred technical and engineering professionals have taken part in those 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.

Figure 17.3 Light and compact mini-rig to drill shallow (100-120 m deep) wells for deployment of geothermal heat pumps systems. (Source: Terra AG and J. Wettstein)

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 up to 0.6 Swiss cents per kWh has been levied on high-voltage grid transmission costs, resulting in up to CHF 320-340 M per year of funds available for feed-in tariffs (Table 17.2).

Table 17.2 Feed-in Tariffs for electricity produced from geothermal resources; tariffs decrease by 0.5% per year beginning 2018 (1 USD ≈ 1.10 CHF).

Nominal Capacity (MWe)	Tariff (CHF/kWh)
≤ 5	0.30
≤10	0.27
≤20	0.21
>20	0.17

Source: http://www.admin.ch/ch/d/sr/7/734.71.de.pdf

Total feed-in allocations are limited for individual renewable energy technologies to prevent costly technologies from draining a disproportionate share of the overall feed-in funds to ensure that the ultimate objective of adding 5.4 TWh of renewable electricity by 2030 is not at risk. Almost 5,000 applications totaling CHF 295 M/year of feed-in tariffs were filed in 2008. But only CHF 258 M was approved for financing through the grid levy, which for 2009, has been set at 0.45 Swiss cents per kWh. The number of PV applications exceeded the available maximum by a factor of 3. In contrast, all wind energy projects qualified. Small hydro and biomass applications did not exhaust the maximum amount of money available. There were no applications for geothermal projects.

In addition to the feed-in tariffs there exists a risk guarantee for geothermal power projects. If project developers 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).

17.4 Development Constraints

Geothermal heat pump systems have a high market penetration for new buildings, and increasingly considered for larger systems (>100 kW capacity, see chapter photo). The high density of buildings poses, at times, an accessibility constraint 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 when advancing projects. 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.

EGS projects are currently on-hold until a next phase in the Basel EGS Project has been identified and approved for execution. The decision is expected in 2010.

17.5 Economics

As in years prior, the installation cost of geothermal systems did not significantly decrease in 2007. 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). There is a base price depending on the installation size and a variable price for heat, cooling and warm water delivery. Neither unit technical costs nor retail prices are known.

The average retail electricity price in Switzerland for 2007 was CHF 145/MWh (1 USD ≈ 1.10 CHF). This price is an average value obtained from 110 companies in the power sector and is therefore deemed an accurate number.

There continue to be no statistical data about employment in the Swiss geothermal sector. Previous estimates are likely to remain unchanged with some 150-200 people working in the sector, most of them in drilling or engineering companies.

17.6 Research Activities in 2008

17.6.1 Focus Areas

Shallow geothermal energy has proven to be successful in the market place and is therefore deemed less of a priority in terms of R&D. Instead, public funds for research and development of geothermal energy are increasingly focused on advancing hydrothermal systems for direct use and power, and on pursuing further research into Enhanced Geothermal Systems (EGS).

17.6.2 Publicly Funded Research and Development

A number of smaller research projects (each between CHF 20,000-50,000 Swiss Federal Office of Energy share) focus on measurement campaigns associated with large and complex geothermal heat pump systems, and establishing best practice manuals on using borehole heat exchangers both for heating and cooling. In the same category, a collaborative project has resulted in the construction and deployment of the light mini-rig for drilling shallow geothermal wells (Figure 17.3).

Significant funds have been spent on maturing hydrothermal projects in St. Gall, Zürich, Brigerbad, Lavey-les-Bains, and in the Lausanne-Nyon region of the Canton of Vaud. Public funds have also been utilized to perform some investigative work in preparation for a well workover near Geneva. A database of geothermal springs in Switzerland has been compiled and ported to GoogleEarth (Figure 17.4). Each of the projects has a scope of CHF 10,000-200,000 (Swiss Federal Office of Energy share).

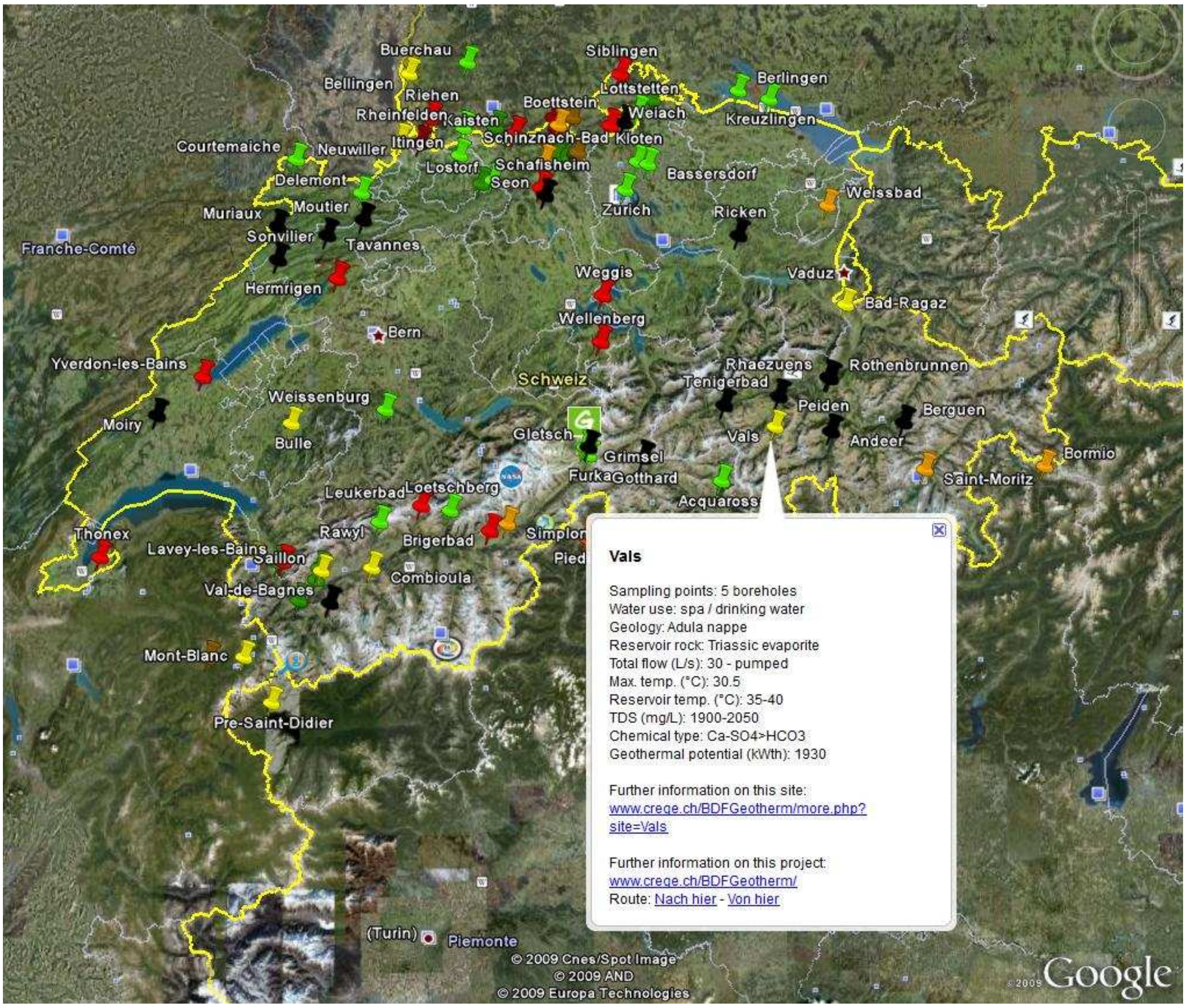


Figure 17.4 Geothermal fluid data of Switzerland visualized on Google Earth. (Source: CREGE)

A large portion of available funds has been made available to Swiss researchers working on the French-German EGS Project in Soultz-sous-Forêts (France). The Swiss Federal Office of Energy, the

Swiss Federal Office of the Environment, the Canton of Basel City, and the (private) owner of the EGS Basel Project have funded the on-going risk analysis study for induced seismicity around the EGS Basel Project. In addition, funds have been made available to contribute to the cost of a temperature profile of the EGS Basel deep well (Figure 17.5). The total amount of research into EGS amounts to approximately CHF 400,000.

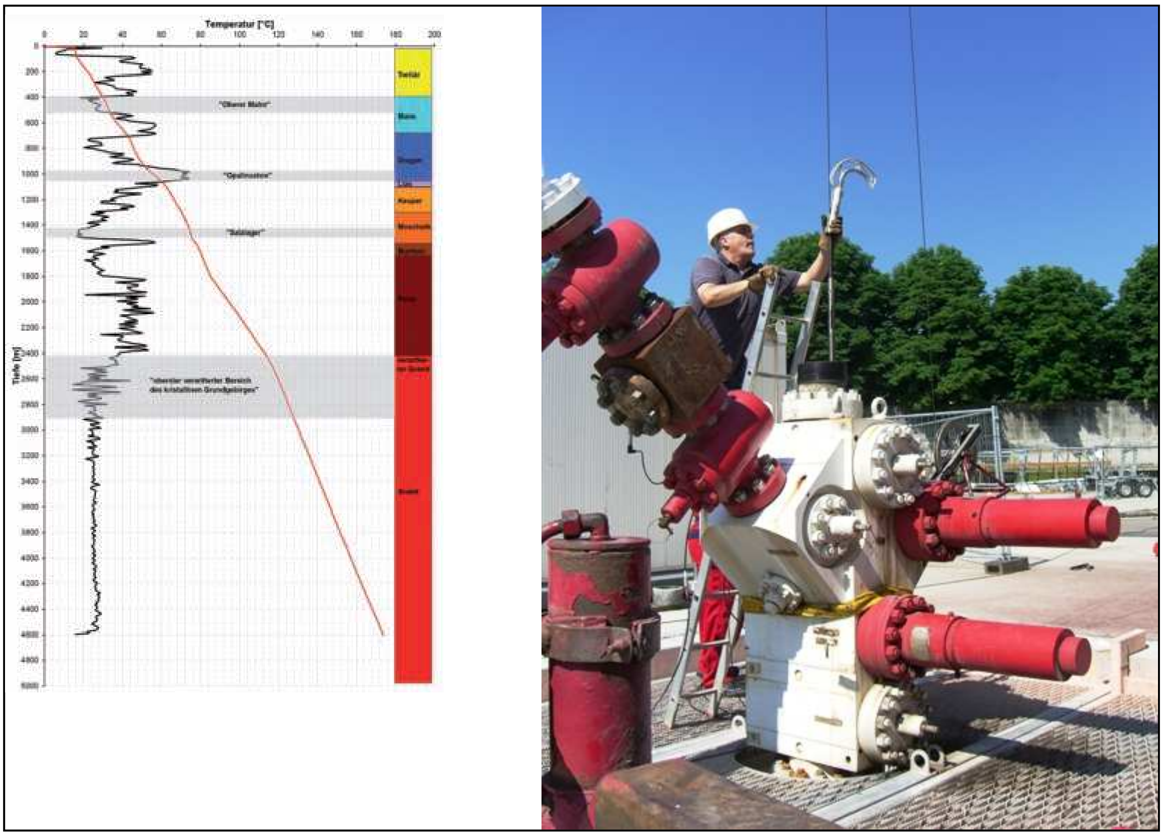


Figure 17.5 Temperature profile of the deep Basel EGS borehole. (Source: Geopower AG and Geothermal Explorers Ltd.)

17.6.3 Industry Funded Research and Development

As no reliable figures are available, it is safe to assume that at least similar amounts of funds have been made available in all R&D projects. Of particular mention is a 2008 research project that swiss*electric* research has funded (CHF 416,000) at the Swiss Federal Institute of Technology into the fundamentals of thermal spallation drilling (Figure 17.6).

17.7 Geothermal Education

The bulk of geothermal education in Switzerland has been managed by the Swiss Geothermal Association. 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.

In 2008, the University of Neuchâtel, in the French-speaking part of Switzerland, has established a geothermics chair which has been filled by Eva Schill. Formal university-level courses in geothermal energy will be offered in the near future and a research group are currently being established.

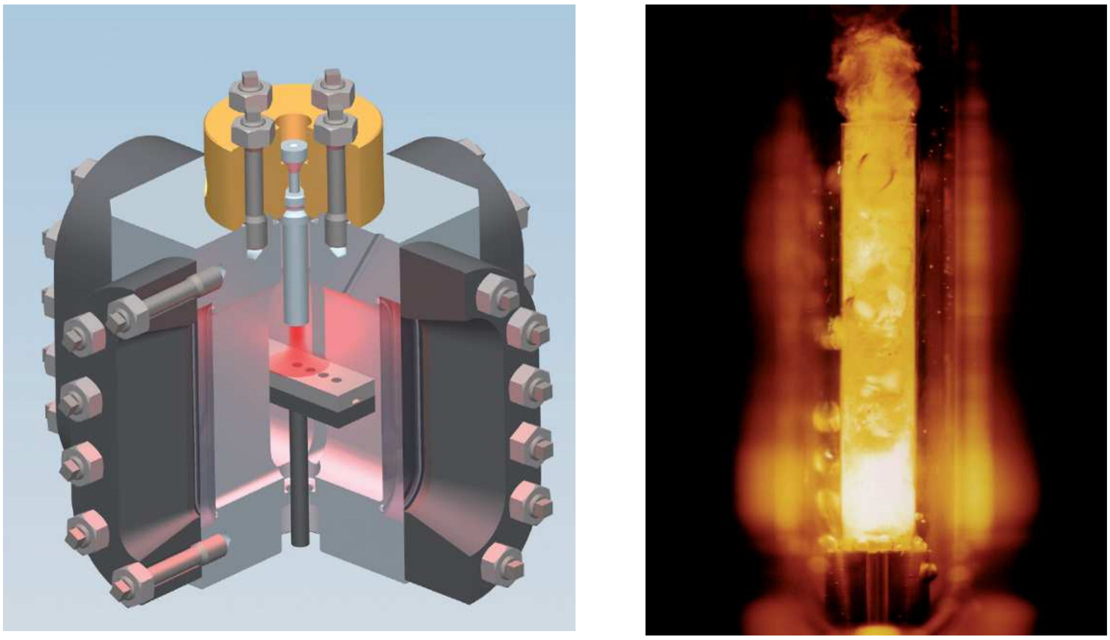


Figure 17.6 Supercritical water oxidation (SCWO) system with stable hydrothermal flame - thermal spallation drilling reseach at ETH Zurich. (Source: T. Rothenfluh, ETH Zurich)

17.8 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 (e.g. ENGINE, I-GET).

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Figure 18.3 Raser's Hatch Power Plant in Beaver Creek, Utah.
(Source: Raser Technologies)

18.0 Introduction

18.0.1 Background

The development of geothermal energy regained significant momentum in the United States during 2008. In 2006, the Massachusetts Institute of Technology (MIT) released the results of a study concluding that Enhanced Geothermal Systems (EGS) could provide the United States with 100,000 MW_e of capacity by 2050 (MIT, 2006). Combined with rising energy prices and climate change concerns, the report led to a resurgence of interest in geothermal energy as a clean, renewable solution to address the nation's growing electricity demands. The U.S. Department of Energy's (DOE) Geothermal Technologies Program (GTP) received significant new funding and shifted its emphasis to the advancement of EGS technologies, with a commitment to achieve technology readiness by 2015.

In September 2008, the U.S. Department of the Interior's United States Geological Survey (USGS) released the first national geothermal resource assessment in 30 years. The assessment focused on electricity generation in the western United States, and estimated 39,090 MW_e of mean resource potential from conventional hydrothermal reservoirs, with an additional 517,800 MW_e potential from EGS (USGS, 2008). While successful development of EGS technologies could set the stage for a long-term, nationwide expansion of geothermal energy, near-term capacity additions are expected to come from conventional moderate to high-temperature hydrothermal reservoirs, new projects that utilize fluids co-produced with oil and gas, and low-temperature resources. At the lower-end of the geothermal temperature spectrum, geothermal heat pumps (GHPs) continued to experience strong market growth during 2008.

18.0.2 Major Highlights and Achievements for 2008

- **Google Invests in EGS**- On 19 August 2008, tech giant Google's philanthropic arm, Google.org, announced its decision to invest US$ 10.25 M in advanced EGS technologies. Funding was provided for two geothermal companies, AltaRock Energy and Potter Drilling, as well as a grant for Southern Methodist University's Geothermal Laboratory.
- **International Partnership for Geothermal Technology**- In order to enhance collaboration and information sharing, avoid blind alleys and duplication of efforts, and hasten the development of advanced geothermal technologies, the United States, Iceland, and Australia formed the International Partnership for Geothermal Technology (IPGT). On 28 August 2008, the DOE Acting Assistant Secretary for Policy and International Affairs, Katharine Fredriksen; Australian Ambassador to Iceland, Sharyn Minahan; and Icelandic Minister of Industry Energy and Tourism, Ossur Skarphedinsson, signed the IPGT Charter document.
- **Co-Produced Fluids**- The Ormat Energy Converter, developed by Ormat Technologies and installed at the Rocky Mountain Oilfield Testing Center (RMOTC) in Wyoming, successfully generated electricity from fluids produced during oil and gas extraction, or co-produced fluids (Figure 18.2). Since September 2008, the plant has been producing 150-250 kW gross power. The RMOTC project is one of two geothermal co-production demonstrations supported by the DOE. A second project is in development at the Jay Oil Field, Florida.

Figure 18.2 Ormat's OEC producing power from co-produced fluids in Wyoming. (Source: DOE Office of Fossil Energy)

- **Geothermal Assessment of 13 Western States**- In September 2008, the USGS released a geothermal energy assessment which estimated 39,090 MW_e of potential from conventional hydrothermal resources. This figure includes 9,057 MW_e from identified sources, and a mean estimated power production potential from undiscovered geothermal resources of 30,033 MW_e, distributed over 13 states. The undiscovered resource estimates are based on an analysis of the local geology and the calculated thermal potential of current discovered resources in the states examined. The resource assessment predicts an additional 517,800 MW_e of potential to come from implementing EGS technologies in high temperature, low permeability rock formations (USGS, 2008). Geothermal systems located on closed public lands, such as national parks, were not included in the assessment. GTP is currently funding a broader study encompassing all 50 states to be prepared by the USGS.

- **U.S. DOE Funding Opportunity Announcement (FOA) Awardees**- In October 2008, 21 applicants were awarded a combined total of US$ 43.1 M over four years from the DOE for research, development and demonstration (RD&D) associated with EGS. The awards represent the greatest number of new recipients, and of first-time recipients (13 of the 21), in the history of the program.
- **Rapid Power Plant Construction**- Raser Technologies developed a modular construction approach for its binary cycle geothermal power generating units. This technique enabled the company to construct the Hatch Plant in Utah in just six months rather than the typical three-year timeframe typically required for traditional plant designs (Figure 18.3, chapter photo).
- **Land Lease Sales**- Bureau of Land Management (BLM) held a competitive auction of lease parcels on 5 August 2008 in Reno, Nevada, offering 35 parcels encompassing a total of 105,211 acres. The lease sale brought in a record US$ 28.2 M in bids for geothermal energy development. A second lease sale was held in December 2008, offering 61 parcels totaling 196,377 acres in the states of Utah, Oregon, and Idaho. Cumulativel,y the two sales totaled 301,588 acres and generated more than US$ 34.5 million in revenue.
- **Western Renewable Energy Zones (WREZ)**- The WREZ, an initiative launched in May 2008 by the Western Governors' Association and the DOE, seeks to identify the most cost-effective and environmentally sustainable areas within the western United States to develop renewable energy resources and facilitate their delivery to major load centers. The project promotes stakeholder collaboration and information exchange between state and Federal governments and non-governmental organizations with a regional approach to energy development. Eleven states, two Canadian provinces, and areas in Mexico that are part of the Western Interconnection, are currently participating in the project.

18.1 National Policy

18.1.1 DOE Strategy and Progress

With geothermal energy considered an essential component of the nation's future renewable energy portfolio, the DOE is working with industry to demonstrate the technical feasibility of EGS by 2015. However, the technologies necessary to exploit EGS resources are not yet commercial-ready. In 2008, GTP refocused its long-term technology development goals to address this state of affairs. GTP seeks to demonstrate the ability to create an EGS reservoir capable of producing 5 MW_e by 2015, and eventually improve EGS technology so that the private sector has the tools and knowledge to install 50 GW_e by 2030. While pilot EGS reservoirs of limited size have been designed, built, and tested for short periods in various countries, many technical obstacles remain in reservoir creation, operation, and management. Program activities are focused on the research and development (R&D) needed to reduce barriers and address these technology hurdles. GTP is also actively supporting RD&D efforts to generate electricity economically using co-produced fluids from the nation's oil and gas wells, and facilitating continued development of low-temperature geothermal resources.

GTP promotes the advancement of EGS through an integrated portfolio of cost-shared research and field demonstrations. The strategy involves working with cost-sharing partners at existing geothermal fields or greenfield areas to develop, test and improve the tools needed to drill and maintain wells, fracture hot rock and manage heat extraction. Most of these projects will be conducted in test wells as some novel technologies may be too risky for commercial wells, and this will allow the DOE to control site operations and scheduling, an ability which is not available at commercial fields.

Periodic technology evaluations will be performed by experts from geothermal and allied industries such as the petroleum service sectors. GTP is also working with the BLM to simplify permitting processes and will coordinate with additional Federal agencies as the need arises.

GTP has four primary performance target benchmarks related to its focus of EGS technologies (see Table 18.1).

Table 18.1 *DOE performance goals for EGS technologies.*

Year	DOE Performance Goal
2009	Determine actual pre-stimulation reservoir flow rate for at least one EGS field site.
2010	Model a 10 percent increase in flow rate for an EGS field site demonstration.
2015	Demonstrate the ability to create an EGS reservoir capable of producing 5 MWe.
2020	Validate the ability to sustain an EGS reservoir capable of producing at least 5MWe.

Source: DOE, 2009

Because EGS may allow for an eastward expansion of geothermal power production, an energy corridor is under consideration for the eastern states, replicating West-wide Energy Corridor efforts under the West-wide Energy Corridor Programmatic Environmental Impact Statement (PEIS). The PEIS evaluates potential impacts associated with the proposed action to designate corridors on Federal land in 11 western states (Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming) for oil, gas and hydrogen pipelines and electricity transmission and distribution facilities.

18.1.2 Legislation and Regulation

18.1.2.1 The Emergency Economic Stabilization Act (EESA) of 2008

The EESA, signed by President Bush on 3 October 2008, extended PTCs for electricity produced by geothermal facilities (as well as other renewable energy sources) by two years, pushing the sunsets of these credits to the end of 2010. This brought a renewed sense of certainty to the investment market, as these tax credits were set to expire at the end of 2008. The legislation also instituted a 30% individual tax credit for qualifying GHPs, capped at US$ 2,000.

18.1.2.2 The American Recovery and Reinvestment Act of 2009 (Recovery Act)

In February 2009, President Obama signed the Recovery Act, designed to stimulate the economy, create and retain jobs, support infrastructure improvements and major investments in renewable and efficient energy technologies. The Recovery Act also extended timelines and flexibility associated with the various tax credit options available to geothermal developers. The law extended the Production Tax Credit (PTC) through 31 December 2013, allowed geothermal developers to claim the Investment Tax Credit for the first time, and required the Department of the Treasury to issue grants in lieu of tax credits to support geothermal and other renewable energy projects. The latter provision was designed to address the decline of tax equity as a major source of capital for renewable project developers. The Recovery Act also removed the US$ 2,000 tax credit cap for geothermal heat pump installations installed from 2009 onward.

18.1.2.3 ROD Expands Geothermal Leasing

On 17 December 2008, the BLM released its Record of Decision (ROD) for its Geothermal PEIS. The ROD makes approximately 190 million acres of Federal land available for leasing and potential geothermal development in 12 western states: Alaska, Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Washington, and Wyoming. The ROD:

- Classifies BLM lands as open or closed for geothermal leasing, and identifies those National Forest System lands that are legally open or closed to leasing
- Develops a reasonably foreseeable development scenario that indicates a potential for 12,210 MW_e of generating capacity from 244 power plants by 2025, and additional direct uses of geothermal resources
- Adopts stipulations, best management practices, and procedures for geothermal leasing and development (BLM, 2008)

18.1.3 Government Expenditure on Geothermal Research and Development

The DOE GTP received an operating budget of US$ 20 M for FY 2008 and US$ 44 M for FY 2009. Though the FOA awardees announced in October 2008 (see Highlights section above) will have access to a total of US$ 43.1 M over four years, the 2008 contribution was US$ 12.4 M (US$ 8.7 M for component technologies R&D and US$ 3.7 M for systems demonstrations).

18.1.4 Industry Expenditure on Geothermal Research and Development

Collectively, 2008 public-private investments totaled US$ 78 M. The aforementioned FOA awards included cost-share agreements with industry contributions totaling US$ 34.9 M for the year.

18.2 Geothermal Energy Use in 2008

18.2.1 Electricity Generation

Electricity generated from geothermal energy in 2008 remained limited to the western U.S. The vast majority of resources exploited were conventional, high-temperature hydrothermal reservoirs. However, low temperature geothermal resources, including energy derived from geo-pressured and co-produced fluids, are also expected to contribute to the United States' geothermal portfolio in the coming years. This is based on recent improvements made in binary-cycle technology, the successful commercial Ormat power production unit at RMOTC, and studies that suggest substantial untapped potential in co-produced resources.

18.2.1.1 Installed Capacity

In 2008, geothermal electric power was generated in eight U.S. states: Alaska, California, Hawaii, Idaho, Nevada, New Mexico, Utah, and Wyoming (see Table 18.2). The total installed capacity was 3,040.27 MW_e (GEA, 2009).

Table 18.2 Existing geothermal capacity by state (MWe).

Alaska	California	Hawaii	Idaho	Nevada	New Mexico	Utah	Wyoming	Total
.68	2605.3	35	15.8	333	.24	50	.25	3,040.27

Source: GEA, March 2009

18.2.1.2 Total Electricity Generated

According to the Energy Information Administration (EIA), electricity generation within the United States for 2008 totaled 4,114.9 TWh, of which renewable energy accounted for 373.5 TWh, or approximately 3% (EIA Electric Power Monthly, March 2009). Electricity generation from geothermal resources totaled 15.0 TWh. (1 TWh = 1 billion kWh). This represents just 0.37% of overall electricity and 4% of all renewable production generated in the United States.

18.2.1.3 New Developments During 2008

Co-Produced Fluids- On 18 October 2008, at the Naval Petroleum Reserve No. 3 (NPR3), Ormat Technologies and RMOTC were the first to successfully generate electricity using geothermal fluids co-produced from existing oil infrastructure. The ORMAT developed technology has been generating 150-250 kW gross power since its inception. The RMOTC project is one of two geothermal co-production demonstrations supported by the DOE. The other is located at the Jay Oil Field in Florida. There are numerous oil and gas wells in the United States that produce hot water as well as hydrocarbon products. I n fact, an average of 40 billion barrels of heated water is co-produced annually from oil and gas wells within the United States. These co-produced fluids have an estimated generation potential of 3,000-14,000 MW_e, depending on their temperature (MIT, 2006) and represent a large untapped geothermal resource. Improvements in Organic Rankine cycle technology allow for cost-competitive power generation from resources as low as 74°C in some locations, and utilizing existing oil and gas infrastructure minimizes drilling and well-completion costs.

Modular Power Plant Design- December 2008 marked the completion of Raser Technologies' first modular geothermal electricity plant. The Hatch Power Plant, formerly named Thermo, consists of 50 UTC Power/Pratt & Whitney PureCycle® power systems, each with a nameplate capacity of 250 kW (0.25 MW_e). This gives the facility a cumulative nameplate of 14 MW_e and a net output total of 10 MW_e. Raser's modular design approach allowed the Hatch Plant to be completed in just 6 months, rather than the more typical timeframe of 3 or more years.

New Geothermal Plant Capacity Added in 2008- In 2008, power developers added an estimated 110.29 MW_e of new nameplate capacity in the United States (see Table 18.3). Of this total, 10 MW_e came from flash steam plants and the remaining 100.29 MW_e was produced by binary plants.

18.2.1.4 Rates and Trends in Development

Low Temperature Production Advances- Recent advances in binary-cycle technologies have expanded the resource base for geothermal power by allowing for the exploitation of lower temperature geothermal fluids. Until recently, resource temperatures lower than 93°C (200°F) were considered uneconomical for electrical production. It was recently discovered that certain environments with extremely low ambient air temperatures may allow power generation from significantly lower temperature fluids. Since 2006, a UTC Power/Pratt & Whitney PureCycle® power system at Chena Hot Springs in Fairbanks, Alaska has been generating electricity from geothermal fluids as low as 74°C (165°F). This is the lowest resource temperature ever used for commercial production.

Capacity Under Development- GEA reports that 126 confirmed and unconfirmed projects with 3,638-5,650 MW_e of capacity are currently under development (Figure 18.4). Projects closest to completion are in their fourth phase of development; that is, drilling is underway and/or the facility is under construction. As of March 2009, 10 projects have reached phase four with a conservative estimate of 329 MW_e of capacity. Projects under construction will bring geothermal energy production to five additional states, including Arizona, Colorado, Oregon, Washington and Florida (GEA, 2009).

Table 18.3 New geothermal power plants online in 2008.

Start Year	State	Power Plant	Nameplate (MW_e)	Additional Information
2008	Idaho	Raft River	15.8	Went online during January 2008. Net output is currently between 10.5 and 11.5 MW_e.
2008	Nevada	Galena	20.0	Created as an addition to the Steamboat Complex, with annual net output at 17 MW_e.
2008	New Mexico	Lightning Dock	0.24	Raser Technologies installed a PureCyle® power system at Lightning Dock in New Mexico as a pilot plant during July 2008. Raser is expected to increase capacity by adding more PureCycle power systems, eventually creating a second 10 MWe modular plant.
2008	Utah	Hatch	14.0	Went online in December 2008, net output currently 10MW. Low-temperature modular design. Utilizes 50 modules (PureCycle® power systems) in all to create the plant. Completed in just six months. Original name of plant was Thermo. Started power delivery to Anaheim during April 2009.
2008	Wyoming	NPR3	0.25	Online in September at the RMOTC, specifically the Naval Petroleum Reserve No. 3. First successful production of electricity from coproduced fluids using a Ormat Energy Converter system. Generates between 150-250 kWh.
2008	California	Herber South	10.0	A new edition to the Herber Complex.
2008	California	North Brawley	50.0	According to Ormat's Fourth Quarter Results for 2008, it has successfully reached the start up phase and can expect to ramp up gradually to full capacity by second quarter of 2009.
Total		**100.29**		

Source: GEA, March 2009

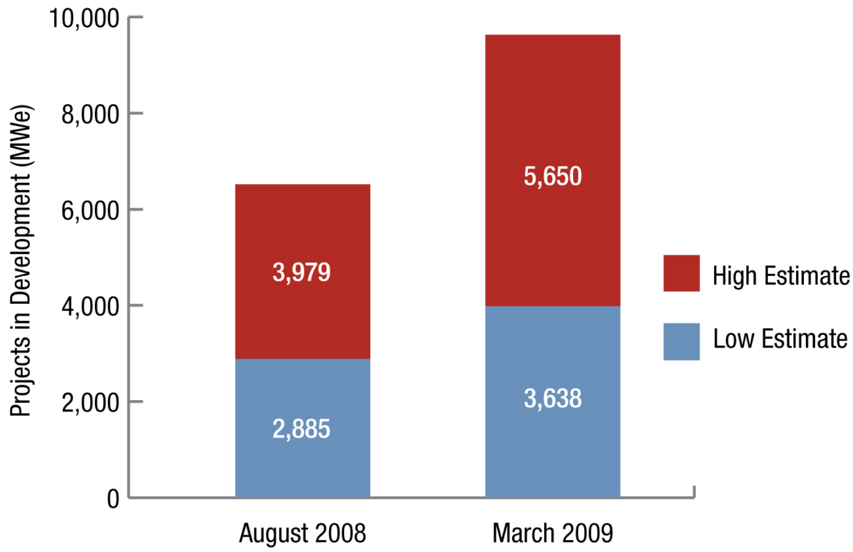

Figure 18.4 *The U.S. geothermal project pipeline (200802009).*
(Source: Geothermal Energy Association, U.S. Geothermal Power Production and Development, August 2008 and March 2009)

Number of Wells Drilled- Summary information is not available for production, injection and gradient wells drilled for geothermal electric power in the United States. However, a few states do provide limited information on well-related activities. The California Geothermal Annual Report (www.conservation.ca.gov/dog/Pages/Index.aspx), is an excellent source for wells drilled, completed, redrilled or deepened, and plugged and abandoned in that state. Utah's website (www.geology.utah.gov/geothermal/interactive/index.html) offers an interactive map of the state's geothermal wells and springs, and Nevada's Bureau of Mines and Geology has links to databases on well chemistry, siting, and other data (www.nbmg.unr.edu/geothermal/gthome.htm).

18.2.1.5 Contribution to National Demand

Existing U.S. generation capacity for 2008 has yet to be published by EIA. In 2007, the nameplate capacity totaled 1,087,791 MW for all energy types (EIA, Electric Power Annual 2007, released January 2009). Geothermal accounted for 3,233 MW, which was 0.30% of the total (see Table 18.4). In 2008, geothermal electricity generation was 15 TWh, which was 0.36% of the total U.S. electrical generation of 4,114.9 TWh. Geothermal electricity generation accounted for 4% of all renewable production, which totaled 373.5 TWh, including conventional hydropower.

Table 18.4 *Existing capacity (MW) by Energy Source for 2007. (Source: EIA, January 2009)*

Energy Source	Number of Generators	Generator Nameplate Capacity
Coal	1,470	336,040
Petroleum	3,743	62,394
Natural Gas	5,439	449,389
Other Gases	105	2,663
Nuclear	104	105,764
Hydroelectric Conventional	3,992	77,644
Wind	389	16,596
Solar Thermal and Photovoltaic	38	503
Wood and Wood Derived Fuels	346	7,510
Geothermal	224	3,233
Other Biomass	1,299	4,834
Pumped Storage	151	20,355
Other	42	866
Total	17,342	1,087,791

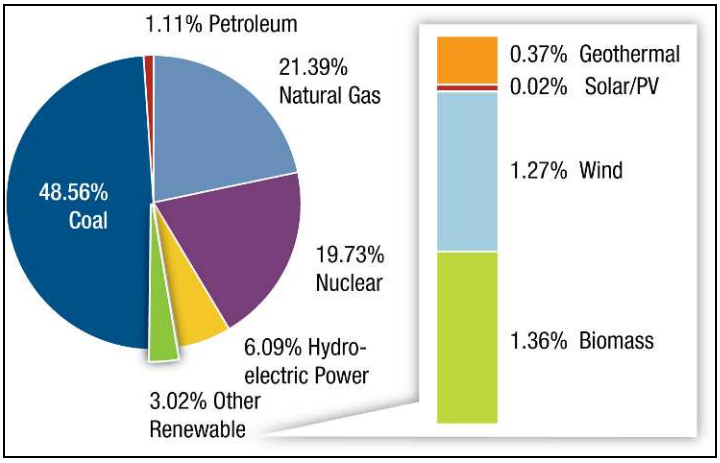

Figure 18.1 *U.S electricity generation by type.*
(Source: DOE Energy Information Administration, March 2009)

18.2.2 Direct Use

18.2.2.1 Category Use

Geothermal energy is used for a variety of direct use applications within the United States, including aquaculture, greenhouses, industrial and agricultural processes, pools and spas, and space and district heating.

18.2.2.2 Installed Thermal Power and Use

The installed direct use capacity in 2007 was 11,146 MW_t, with an annual energy use of 43,362 TJ/yr (12,041 GWh/yr) (DOE). Given the values of installed thermal power and annual energy use from previous years, the capacity factor for all direct use applications combined is approximately 12%. Based on this assumption, the total installed capacity for 2008 is estimated to be about 12,037 MW_t and direct use geothermal consumption totaled 46,831 TJ/yr (13,004 GWh/yr) (Lund et al, 2005).

18.2.2.3 Rate and Trends in Development

The U.S. GHP industry has experienced double-digit annual growth for each of the last four years (EIA, 2009). Shipments exceeded 71,000 units in 2008, indicating strong demand despite souring economic conditions (AHRI, 2009) (see Table 18.5). The tax credits extended and enhanced by EESA of 2008 and the Recovery Act of 2009 are expected to support continued marketplace adoption despite declines in the U.S. housing and real estate markets and the economy as a whole.

Table 18.5 Geothermal Heat Pump Shipments (1999-2008).

1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
41,679	35,581	N/A	37,139	36,439	43,806	47,830	63,682	86,396	71,000*

*Source: EIA, *AHRI manufacturer survey data, 2009.*

18.2.2.4 Number of Wells Drilled

Summary information is not available for the number of wells drilled for direct uses in 2008.

18.2.3 Energy Savings

Geothermal's baseload capability sets it apart from other renewable sources. Given its high capacity factor, a geothermal power plant of 1 MW_e can generate as much electricity as a 3 MW_e wind plant or a 5 MW_e solar plant. Typical capacity factors for these resources are 30% for wind, 18% for solar and 90% for geothermal.

18.2.3.1 Fossil Fuel Savings/Replacement

Power Plants- In 2008, 15 billion kWh (54,000 TJ) of electricity was generated from geothermal energy in the United States. One metric ton of oil equivalent (1 toe) is equal to 0.042 TJ; and 1 TJ = 23.8 toe. Given that fuel oil generates electricity at a 0.35 efficiency factor, 1 TJ = 68 toe. Given these assumptions, geothermal energy production displaced approximately 3.672 Mtoe.

Direct Use- Annual thermal energy use for 2008 was estimated at 46,831 TJ/year, which equates to a fuel oil savings of 3.185 Mtoe. Fuel oil savings associated with GHPs and other direct uses have been estimated at 2.524 Mtoe and 0.703 Mtoe (0.727 Mtoe), respectively, based on 2008 energy consumption values of 37,124 TJ/yr for GHPs and 10,332 TJ/year for other direct uses.

18.2.3.2 Reduced/Avoided CO_2 emissions

Power Plants- According to EIA's 2009 *Annual Energy Outlook*, the electric power sector accounted for 2,433 million metric tons of carbon dioxide (CO_2) emissions in 2007 (2008 data are not yet available) (EIA, 2009). The amount of CO_2 offset by geothermal electricity generation is dependent upon the utility fuel mix it is replacing, which is approximately 193 kg CO_2/MWh for natural gas, 953 kg CO_2/MWh for coal and 817 kg CO_2/MWh for oil (Lund, 2005). Therefore, emission offsets from the 15 billion kWh of electricity generated via geothermal could range from 2.9 to 14.3 million metric tons.

Direct Use- The annual thermal energy consumed during 2008 from direct use technologies was estimated at 46,831 TJ/year (13,004 GWh/yr). Based on the above assumptions, direct use geothermal energy could offset from 2.51 to 12.39 million metric tons of CO_2, depending on which generation fuel is displaced.

18.3 Market Development and Stimulation

18.3.1 Support Initiatives and Market Stimulation Incentives

The primary market development incentives for geothermal energy development include tax-based policy incentives and state renewable portfolio standard (RPS) requirements (Figure 18.5). GHPs also benefit from tax incentives at the national level, as well as a variety of state grant programs and utility rebates.

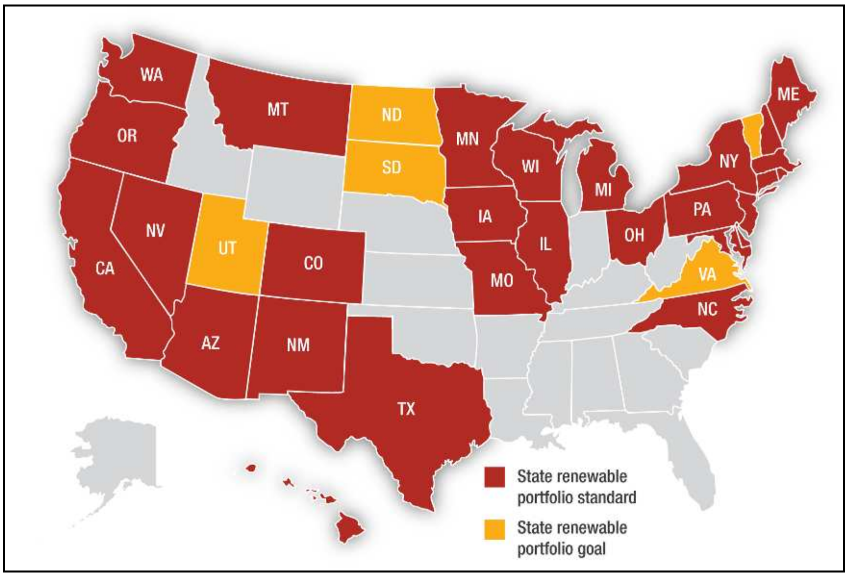

Figure 18.5 States with Renewable Portfolio Standards and Policies. (Source: Database of State Incentives for Renewable Energy, May 2009)

18.3.1.1 Tax Incentives for Geothermal Development

Federal tax subsidies amount to a large share of development financing for a variety of types of renewable energy plants, including solar, wind and geothermal. Geothermal projects qualify for the PTC under Section 45 of the U.S. Internal Revenue Code, a 2.1%/kWh credit claimed on the electricity generated by the geothermal plant for up to 10 years. In addition, the Modified Accelerated Cost-Recovery System (MACRS) allows the power plant developer to depreciate a geothermal property over five years. Under MACRS, intangible drilling costs can be deducted immediately and depletion can be claimed on the investment in the reservoir. In sum, a substantial portion of the cost of developing the geothermal project can be covered by these tax benefits. Recent legislation, including the EESA of 2008 and the Recovery Act of 2009, renewed and enhanced tax incentives available to geothermal developers, and individuals and firms that install GHP systems. The Recovery Act also included substantial new investments in renewable and energy efficient technologies. The law included US$ 16.8 billion for the DOE's Office of Energy Efficiency and Renewable Energy, with US$ 400 M devoted specifically to geothermal activities.

18.3.1.2 Importance of Renewable Portfolio Standards

RPSs are widely considered an essential driver for development of geothermal and other renewable energy technologies. An RPS mandates that utilities provide a certain percentage or set amount of power from renewable sources. Currently RPSs exist only at the state level in the United States. The diverse set of authoring entities has resulted in a disparate set of policies governing geothermal technologies. Many of the state RPSs target small-scale or residential geothermal projects, but do not provide adequate incentives for large-scale exploration or plant development. As of May 2009, 32 states and Washington, D.C. have implemented RPS guidelines that are either mandatory or goal-oriented, a 28% increase from 2007 figures. As of September 2009, a national RPS is currently under consideration in Congress, contained within the American Clean Energy & Security Act.

18.3.2 Development Cost Trends

Geothermal development costs include all expenditures associated with exploration, drilling, permitting, construction, and ancillary investments such as transmission costs. Actual costs can vary based on factors such as time delays, geology, environmental restrictions, project size, and transmission access (DOE, 2008). After years of steady increases in plant construction costs, 2008 saw a decline of 5%. According to Cambridge Energy Research Associates (CERA), the trend is due to sharp cost reductions for raw materials, including steel and copper. After steep increases in costs towards the beginning of 2008, steel prices fell nearly 30% in the fourth quarter. Availability of equipment, such as drilling rigs, labor, engineering and management services, has also improved due to new plant construction delays and cancellations. Additional declines of approximately 7-10% are projected for 2009 under present economic conditions (CERA, 2009).

18.4 Development Constraints

Geothermal energy development in the United States is constrained by a variety of factors, including the geographical location of resources, technological limitations, availability of reliable information for developers and investors, potential environmental considerations, a limited geothermal-focused workforce, the 2008 economic downturn, permitting issues and substantial financial risk and complexity.

18.4.1 Geothermal Project Financing in 2008

Geothermal development entails steep upfront investment and risk associated with initial exploration and drilling activities needed to verify and tap the subsurface resource. Activities such as the drilling of exploratory wells may prove unsuccessful even if geological data are favorable. Additionally, cost and risk increase proportionally with drilling depth. As the project moves toward the production phase, this risk begins to decline and financing options are more readily available. Geothermal developers require risk-tolerant investment partners at the early stages of the project, including large institutional investors that can utilize tax equity generated by the project.

Unfortunately, the financial crisis that started during the third quarter of 2008 reduced investment in, and capital available to, the entire renewable energy sector. Crucial tax equity financing was largely eliminated after several large financial companies reduced or eliminated their participation in the renewable energy space. Despite some high-profile investments in geothermal energy technology, such as Google's funding for EGS, investment stagnated by year end. Furthermore, tighter capital markets mean that private equity investors will gravitate towards operating and late-stage projects which are already producing cash returns or feature limited development risk to advance to that point.

This state of affairs threatens or complicates the financing picture for exploration stage projects and will impact smaller geothermal developers with limited assets and project portfolios with which to attract equity investors. Early stage projects, which will not be completed in time to address current utility portfolio targets, will not be able to attract investors with signed power purchase agreements either. As a result, some projects could be delayed or suspended indefinitely. Several provisions in the recent Recovery Act (described above) were meant to address these concerns.

18.4.2 Geographical Considerations

Prior to successful commercial EGS deployment and excepting low-temperature and direct-use opportunities, the development of geothermal energy resources will remain geographically concentrated in the western states, which boast the most desirable high-temperature hydrothermal reservoirs. Furthermore, geothermal resources are generally located great distances from major load centers requiring new investments in transmission infrastructure. This increases power delivery costs and the additional capital requirement represents a disincentive for utilities considering the addition of geothermal to their generation portfolios. EGS technologies hold the key to mitigating these barriers because they afford additional flexibility in siting plants in closer proximity to existing transmission infrastructure and may open the entire country to geothermal development.

18.4.3 Availability of Reliable Resource Information

Aside from such geographical concerns, geothermal development in the United States is hindered by a lack of accurate and reliable resource data, which also acts as a deterrent to potential geothermal investors. The vast majority of information available is from private lands while most of the identified geothermal resources exist on Federal lands. For this reason, the DOE GTP is developing a National Geothermal Data System to serve as a central, map-based repository for nationwide geothermal resource data, including the DOE EGS demonstration projects and links to historical geothermal resource data. Data will be organized with metrics established by the geothermal community that will assist developers and investors to make the best decisions when they evaluate potential project sites and investment opportunities.

18.4.4 Environmental Concerns

Geothermal energy development may also encounter new environmental challenges with the advent of EGS, including increased water consumption and induced seismicity. Power generation from high-temperature hydrothermal resources consumes minimal water, approximately 5 gallons/MWh according to the GEA (GEA, 2007). This is because geothermal production can be accomplished through an existing heat carrier medium (water or steam) produced on-site. By comparison, natural gas facilities require the import of as much as 361 gallons of water per megawatt hour produced. EGS development presents some new and unique contingencies in this area. Large quantities of water may be needed to create the reservoirs and maintain electricity production. In addition, the processes associated with EGS development have been shown to cause micro-seismic effects. GTP is working closely with EGS project partners to mitigate these concerns as technologies and resources are developed.

18.4.5 Permitting, Leasing and Environmental Assessments

With approximately 90% of known geothermal resources located on Federal lands in the United States, geothermal developers must address a variety of Federal permitting and leasing requirements along with state-level regulations governing the development process. These requirements bring additional complexity and expense to the building of the U.S. geothermal energy portfolio and represent a development constraint. Developers may encounter delays because the Federal government and individual states each treat mineral and water rights, resource ownership, and permitting requirements in a different manner. Though the BLM has increased the frequency of lease sales and opened additional land to development, there is still a large backlog of lease nominations. The BLM made progress in addressing these concerns with the ROD, which made additional lands available for geothermal development, and the PEIS, which serves to streamline the Federal permitting process.

18.4.6 Workforce Development

Substantial growth in the U.S. geothermal industry will require an educated and trained workforce to locate new resources, create new reservoirs, and build and administer power plants. Though strong academic programs do exist, the U.S. geothermal industry could benefit from greater efforts in this area, including the development of new targeted curricula, student exchanges, scholarships, and training programs. Training programs do not currently exist in disciplines specific to geothermal energy development, such as drilling technology, exploration and characterization technologies, reservoir management/enhancement, power plant operation, and power transmission.

18.5 Economics

18.5.1 Trends in Geothermal Investment

At a cost of roughly US$ 4 M/MW$_e$, the current pipeline of U.S. projects in development, not including the DOE's EGS projects, will require roughly US$ 15 billion for completion, of which US$ 1.5 billion will likely be required in 2009 and an additional US$ 2.7 billion by 2010 (Glitnir, 2008).

Over the past few years, the geothermal industry has experienced significant investment growth and seen many new market entrants, including new developers and technology firms. This trend has continued into 2008 despite the economic downturn. Public market (Figure 18.6), project acquisitions, venture capital and private equity have shown a marked increase from 2005-2008 (Figure 18.7). In 2007 and 2008, as the number of geothermal industry players grew, so did total investments in the sector (New Energy Finance, 2009).

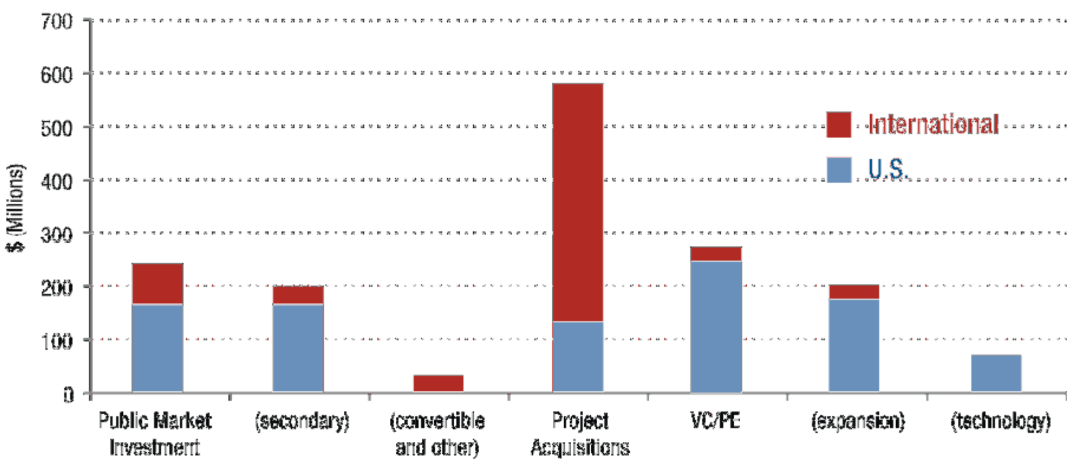

Figure 18.6 U.S. and international geothermal investments in 2008.
(Source: New Energy Finance (January 2009)

Figure 18.7 Trends in U.S. geothermal investments during 2005-2007.
(Source: New Energy Finance, January 2009)

18.5.2 Costs (turbine, project, well drilling, and operations and maintenance)

The Geothermal Resources Council (GRC) reported an installed cost of US$ 4,000/kW (US$ 4 M/MW) for a 20 MW_e geothermal power plant (Table 18.6). A subsequent analysis conducted by New Energy Finance estimates overall development costs at US$ 3,650 per installed kW (US$ 3.65 M/MW) for a larger 50 MWe power plant (Table 18.7). Construction of the power plant and other surface facilities accounts for the largest portion of overall plant costs due to the high historic prices of raw materials such as steel. Exploratory and production drilling represent the next most significant cost for the power developer, estimated by GRC and New Energy Finance at roughly 35-42% of the total plant cost.

Table 18.6 Estimated development costs for a typical 20 MW_e geothermal power plant.

Development Stage	Cost (US$/kW)	Overall Cost (%)
Exploration drilling and resource assessment	400	10
Well field (Production) drilling and development	1,000	25
Power plant, surface facilities, and transmission	2,000	50
Other development costs (fees, reserves, and contingencies)	600	15
Total	4,000	100

Source: GRC, 2008

While these models are useful for determining rough estimates, true costs vary and are dependent on several factors, such as site (geography), geology, reservoir size, geothermal temperature, and plant type. Time delays frequently generate the most significant additions to delivered cost- as much as US$10-20 or more per MWh, and are most likely to occur during the first two stages of development, when the risks and the cost of capital are the greatest (DOE, 2008).

Low-temperature reservoirs typically use binary power plants, while moderate- to high-temperature reservoirs employ dry steam or flash steam plants, depending on whether the production wells produce primarily steam or water, respectively. Recent cost comparisons between flash, dry steam and binary plants do not demonstrate a clear winner (California Energy Commission, 2007).

Table 18.7 Estimated development costs for a 50 MWe geothermal power plant.

Development Stage	Cost ($/kW)	Overall Cost %
Exploration	14	<1
Permitting	50	1
Steam Gathering	250	7
Exploratory Drilling	169	5
Production Drilling	1,367	37
Plant and Construction	1,700	47
Transmission	100	3
Total	3,650	100

Source: New Energy Finance, 2009

18.5.3 Trends in the Cost of Energy

Though geothermal power production is capital intensive with high first-cost and risk, it boasts fairly low operating costs and a high capacity factor, making it the most attractive baseload generation option available among renewables. On a levelized cost of energy (LCOE) basis, which provides an apples-to-apples comparison of generation options, geothermal is very competitive with other renewable and conventional energy technologies (Figure 18.8). Most recently, Lazard, the financial advisory and asset management firm, calculated LCOE for various alternative and conventional electric generating technologies. With tax incentives included, it estimated geothermal LCOE of US$ 0.042-0.069/kWh. Without the PTC included, Lazard estimated costs of US$ 0.082-0.116/kWh, which emphasizes the critical importance of Federal tax incentives (Lazard, 2008). By way of comparison, LCOE for wind ranged from US$ 0.044-0.091 with tax incentives, and US$ 0.089-$1.50 without subsidies added (Figure 18.9).

Figure 18.8 Levelized cost of energy per MWh for various generation options. (Source: Lazard, 2008)

Figure 18.9 Levelized cost of renewables with and without tax incentives. (Source: Lazard, 2008)

18.5.4 Employment in the Geothermal Sector

Several studies have examined the employment and economic benefits of U.S. geothermal energy development. In 2008, the GEA estimates that the geothermal industry employed about 18,000 people, including 5,000 direct jobs in operating, construction and manufacturing and an additional 13,000 indirect and supporting jobs (GEA, 2009). According to the Calpine Corporation, the construction of a single 50 MW plant requires 160 employees and a combined 33 months of labor. Because the United States added approximately 110 MW of new capacity in 2008, and many new projects also entered the development pipeline, it is likely that several hundred new positions were created in the geothermal sector.

These figures do not incorporate the manufacturing and installation jobs generated separately by the GHP industry. According to the EIA, direct employment in the GHP manufacturing sector accounted for 1,219 person-years in 2007, the most recent year for which data is available (EIA, 2009). GHPs are a labor-intensive product to manufacture and install. Based on estimates generated by WaterFurnace, each GHP requires 24 hours of manufacturing labor and 32 hours of installation labor, and a permanent job is created for every 18 installations. GHPs require a wide range of expertise, with up to 30 individuals involved with each project (WaterFurnace, 2008).

18.6 Research Activities

18.6.1 Focus Areas

Geothermal R&D activities conducted by government agencies and private industry were heavily focused on EGS during 2008.

18.6.2 Government Funded

Geothermal energy R&D in the United States regained momentum in 2008 with significant new investments by the DOE. GTP awarded US$ 43.1 M to 21 applicants over four years for EGS R&D and demonstration projects in October. EGS R&D is expected to provide technological tools and information that will enable the private sector to create commercial-scale EGS reservoirs. Field demonstrations with the private sector and academic institutions via competitive solicitations will validate technologies and the commercialization potential of EGS.

18.6.2.1 Research and Development

Over the course of the 2008 fiscal year, GTP awarded US$ 8.7 M to fund 17 component technology R&D projects. The recipients of the cost-shared awards include a variety of organizations from private industry, the DOE National Laboratories and academia. Component R&D topic areas include a wide variety of component technologies and modeling tools, including: an ultrasonic borehole televiewer; high-temperature submersible pumps; seismic monitoring techniques; measurement tools for temperature, flow, pressure, and seismicity; reservoir stimulation models; wellbore tools and reservoir engineering approaches; improved reservoir characterization techniques; and absorbing tracer technologies.

18.6.2.2 Demonstration Projects

GTP awarded roughly US$ 11.1 M to four demonstration projects focused on EGS reservoir creation, development, management and successful power production. These are located at sites where existing data indicate a favorable target for potential EGS development and electricity production. Accessibility to the grid, cooperative industry partner(s) with available land and a favorable environmental setting were all critical for site selection. In order to share infrastructure, these projects are located on the fringes of conventional geothermal fields with pre-existing power generating capabilities. Two field projects are located at The Geysers Geothermal Field in northern California, which is run by AltaRock Energy and Calpine Corporation. A third project is located in Brady's Hot Springs, Nevada, led by Ormat Technologies, and the fourth is in Raft River, Utah, managed by the University of Utah.

18.6.3 Industry Funded

Aside from a few high-profile investments, industry geothermal R&D activities in 2008 were largely joint projects conducted with the DOE funding support. Google's philanthropic arm, Google.org, provided more than US$ 10.5 M in August 2008 to three EGS development initiatives. AltaRock Energy received US$ 6.25 M to develop an EGS project in The Geysers; Potter Drilling received US$ 4 M to develop their breakthrough drilling technology, hydrothermal spallation; and the SMU Geothermal Laboratory received nearly US$ 500,000 to improve geothermal resource assessment techniques and update the Geothermal Map of North America.

18.7 Geothermal Education

18.7.1 Industry Associations

Geothermal Resources Council- The GRC is a tax-exempt non-profit educational association with members in 30 countries. It serves as a primary professional educational association for the international geothermal community, convening special meetings, workshops, and conferences on a broad range of topics pertaining to geothermal exploration, development and utilization. In addition, the GRC periodically schedules a basic introductory course about geothermal resources and development. (http://www.geothermal.org/)

Geothermal Energy Association- The GEA is a trade association of U.S. companies supporting the expanded use of geothermal energy and developing geothermal resources for electrical power generation and direct-heat uses. In order to achieve this goal, the GEA compiles statistical data surrounding the geothermal industry and conducts various education and outreach projects. In 2008, a number of publications were released for public access providing invaluable information regarding current geothermal technologies and trends in developments. (http://www.geo-energy.org/)

Geothermal Education Office- The Geothermal Education Office (GEO) promotes public understanding of geothermal resources. The GEO produces and distributes geothermal educational materials to schools, energy and environmental educators, libraries, industry, and the public. The GEO collaborates with education and energy organizations with common goals, and, through its website, responds to requests and questions from around the world. (http://geothermal.marin.org/)

International Ground Source Heat Pump Association- The International Ground Source Heat Pump Association (IGSHPA) is a non-profit organization established in 1987 to advance GHP technology at the local, state, national and international levels. IGSHPA is headquartered on the campus of Oklahoma State University in Stillwater, Oklahoma, and is primarily known for its GHP system design and installation curriculum and related course offerings. The organization is an excellent source of information and a research center for GHP technology. (http://www.igshpa.okstate.edu/)

18.7.2 Academic Institutions

Several U.S. universities and academic institutions provide crucial support to the geothermal industry through scientific research and the development of new technologies that will allow the United States to achieve its geothermal energy goals. Leading organizations include:

- Nevada's Desert Research Institute (http://www.dri.edu/)
- The Oregon Institute of Technology's Geo-Heat Center (http://geoheat.oit.edu/)
- Southern Methodist University's Geothermal Laboratory (http://smu.edu/geothermal/)
- Stanford University's Geothermal Program (http://pangea.stanford.edu/ERE/research/geoth/)
- University of California – San Diego (http://www.ucsd.edu/)
- University of Nevada, Reno (http://www.unr.edu/)
- The University of Utah (http://www.utah.edu/).

18.8 International Cooperative Activities

Representatives from Australia, Iceland and the United States signed the Charter Agreement for the International Partnership for Geothermal Technology (IPGT) on 28 August 2008 in Keflavik, Iceland. The IPGT provides a forum for government and industry leaders to coordinate their efforts and collaborate on projects. Partners share information on results and best practices to avoid blind alleys, limit unnecessary duplication, and efficiently accelerate geothermal technology development. The IPGT relies on small groups and substantive, technical projects to further the development of advanced geothermal technologies, including EGS, worldwide.

Additionally, the United States is a part of International Partnership for Energy Development in Island Nations (EDIN). Current partners include Iceland and New Zealand. EDIN aims to advance the deployment of renewable energy and energy efficiency technologies (including geothermal) in islands across the globe.

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Canadian Geothermal Energy Association

South Meager Creek project, Canada. (Photo courtesy CanGEA)

19.0 Introduction

The Canadian Geothermal Energy Association joined the IEA-GIA in 2008, marking the beginning of greater participation in the international geothermal community. Although Canada has embraced low-temperature geothermal technology through the growth of heat pump installations, Canada's vast high-temperature resources remain to be developed due to challenging circumstances in policy and legislation.

Since 1986, there has been a virtual absence of government support and attention towards development of high-temperature geothermal resources. The dearth of government participation has largely precluded exploration and development of indigenous Canadian geothermal resources. Currently in Canada, only 1 high temperature geothermal project has completed an exploration drilling program and there is no geothermal power on the Canadian electrical grid. Although Canada is home to several well-known geothermal power companies, their operations are almost exclusively focused internationally and Canada remains an unspoiled frontier for high-temperature geothermal resource development.

Heat pump installations have seen steady growth in Canada over the past decade, backed by financial incentives from government and favourable legislative attention. It is estimated that 55,000 heat pump installations were in operation in Canada as of 2008.

19.1 Highlights for 2008

- Through the support of the BC Provincial Government and the Canadian Geothermal Energy Association (CanGEA), a comprehensive white-paper on the policy best-practices for Canadian geothermal energy development was published.
- The BC Provincial Government established a Geothermal Task Force to update current geothermal regulations in that Province, in anticipation of a geothermal lease sale.
- Testing at the South Meager Creek hydrothermal project, owned by Western GeoPower Corporation, independently verified Canada's first potentially commercial geothermal reservoir for electrical generation.

19.2 National Policy

19.2.1 Strategy

A targeted national strategy for geothermal energy in Canada does not presently exist. However, the Canadian government has instituted several goals and policies aimed at strengthening Canada's portfolio of renewable energy technologies. In 2008, the Canadian Federal Government presented the goal of deriving 90% of Canada's renewable energy from "non-emitting" sources by 2020. Presently, Canada generates 70% of its electricity from non-emitting sources, although 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. The Canadian Geothermal Energy Association, which represents the high-temperature geothermal industry in Canada, maintains that with proper legislation and support, 5,000 MW of geothermal power could be harnessed feasibly by 2015.

19.2.2 Legislation and Regulation

Regulations and standards for geothermal heat pumps have been established under the jurisdiction of Natural Resources Canada, a Federal Ministry and the Canadian Geo-Exchange Coalition, the largest industry organization for heat pumps in Canada.

As of 2008, only one Canadian Province, British Columbia (BC), had passed legislation which defines and regulates high-temperature geothermal energy as a resource. In this legislation, geothermal resources are broadly defined as any terrestrial heat resource over 80°C from which value can be derived. The BC *Geothermal Resources Act* also specifies terms for leasing, permitting and developing these resources, although only 1 geothermal lease has ever been issued by the BC government. Due partly to the fact that Canada's highest-temperature geothermal resources are situated in the western Provinces, the Federal Government and many Provincial Governments have not adopted legislation pertinent to high-temperature geothermal resources.

19.2.3 Progress Towards National Targets

The Federal Government goal of producing 90% of Canada's electricity from non-emitting sources by 2020 is currently focused on technologies such as nuclear power, wind power, and fossil-fuel generation with carbon capture and storage (CCS) technology. In 2008, geothermal energy was not identified as priority item in this initiative, although some estimates suggest that Canada's conventional hydrothermal resource could supply up to 5% of the total Canadian consumption of electricity.

In 2008, there was no geothermal electrical power on the Canadian grid, although it is forecasted that by 2010, the South Meager Creek Project will enter into production and establish Canada's first geothermal power plant.

19.2.4 Government Expenditure on Geothermal Research

In 2008, the British Columbia government funded a project through the Canadian Geothermal Energy Association to establish policy best practices for the development of geothermal energy. Aside from this initiative, government support of geothermal research was virtually absent. Canadian Governments do not employ nor support any full-time geothermal researchers.

19.2.5 Industry Expenditure on Geothermal R&D

Canada's geothermal industry is not positioned to fund research and development initiatives. Relative to other European countries and the United States, who are financially supporting R&D in geothermal energy, Canada has not yet developed a favourable climate for research in this field. Research in geothermal energy has historically migrated to countries with well-established geothermal industries and robust government support, which Canada is soon hoping to develop.

19.3 Current Status of Geothermal Energy Use in 2008

19.3.1 Electrical Generation

There is currently no geothermal electricity produced in Canada.

19.3.2 Direct Use (and Heat Pumps)

Estimates regarding the direct-use of geothermal power are difficult to substantiate in the absence of a comprehensive, nationwide study. This has been identified as an area for study in future compilations of Canadian geothermal data.

19.3.2.1 Installed Thermal Power

It is estimated that 1750 MW_t of direct-use geothermal energy capacity (including ground-source heat pumps) is installed in Canada.

19.3.3 Energy Savings

Relative to conventional heating and cooling methods, an estimated 550,000 tonnes of greenhouse gas emissions are prevented in Canada through direct-use geothermal installations.

19.4 Market Development and Stimulation

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 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 $10/MWh direct subsidy from the Federal Government, which has paid out C$ 254 M between 2002 and 2007. As of 2008, geothermal power had not been recognized in any of these subsidy programs, and the establishment of equal subsidy for geothermal power is a priority initiative in the Canadian geothermal community.

19.5 Development Constraints

In 2008, the largest constraint on the development of the Canadian geothermal industry was the absence of favourable policy in the high-temperature sector to stimulate activity in Canada's indigenous geothermal resources. Through the efforts of the Canadian Geothermal Energy Association, progress was made at high levels of government in 2008 to educate policy makers on the vast potential of geothermal energy, and to demonstrate the economic benefits that will be realized through the development of high-temperature geothermal resources.

Additionally, a need has been recognized for a comprehensive technical assessment of the Canadian geothermal resource base. The most detailed work in Canadian geothermal resource assessment was completed in 1986 and is limited in both in scope and geographic breadth. Other energy resources have benefited from government funded resource assessments, as they establish areas of favourability and significantly de-risk exploration activities for industry.

Geothermal energy is a capital intensive industry and the need for confidence in regulation and reporting is paramount to attracting investment. To overcome this development barrier, Canada has taken a leading role in developing a reserves and reporting code for high-temperature geothermal resources. The hopeful implementation of this code on the Toronto stock exchange will help improve the metrics for value in the geothermal industry, thereby mitigating some of the uncertainty that has precluded greater investment.

19.6 Economics

19.6.1 Trends in Geothermal Investment

The Canadian stock market in Toronto supports approximately $ 280 Million of market capital in the geothermal industry as of December, 2008. Investors are aware that the Canada is one of the leading equity markets in the world for geothermal energy companies. This trend is likely to increase in 2009 as several companies prepare to make public offerings on the Toronto stock exchange. Government investment in the geothermal energy industry was absent in 2008, marking the 22nd consecutive year in which geothermal energy has received no Government funding in Canada.

19.6.2 Development and O&M costs

There are currently no reliable data available on development or O&M costs associated with geothermal energy in Canada.

19.6.3 Trends in the Cost of Energy

Canada is self-sufficient in the production of fossil-fuels and electricity. Retail electricity prices in Canada are low relative to other countries, owing to an abundant and well-diversified supply of power. On average, Canadian households paid C$ 70/MWh in 2008. Canadians, like others around the world, were adversely affected by high oil prices for much of 2008.

19.6.4 Employment in the Geothermal Sector

In 2008, approximately 1,000 people were employed in the ground-source heat pump industry in Canada, and 100 people are employed by the high-temperature geothermal industry.

19.7 Research Activities

2008 research activity in the geothermal industry was largely restricted to the policy realm, which has demonstrated the greatest need for attention. Some small technical research initiatives related to the geothermal potential of western Canadian geothermal basins were completed in 2008.

19.8 Geothermal Education

The Canadian Geothermal Energy Association maintains an outreach program to provide educational resources on high-temperature geothermal energy. The outcome of the 2008 outreach program has been positive, through the development of internet internet-based resources, and speaking opportunities at several leading energy conferences in Canada.

Currently, only 1 Canadian university features curricular material on geothermal energy, and the development of post-secondary material on geothermal energy is a goal for the CanGEA outreach program in the near future.

19.9 International Cooperative Activities

In addition to joining the GIA in 2008, CanGEA has worked closely with the Australian Geothermal Energy Association and the Australian Geothermal Energy Group in the development of a reporting code for geothermal reserves. CanGEA has also represented Canada at a number of leading international geothermal events in 2008 including the Final Engine Conference, the 2008 AGEA/AGEG conference, the 2008 GRC Annual Meeting, and the 2008 SMU Conference on Geothermal Energy Utilization. CanGEA also hosted delegates from around the world at the 2008 CanGEA conference in Vancouver, British Columbia.

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Sponsor Activities

Chapter 20

Geodynamics

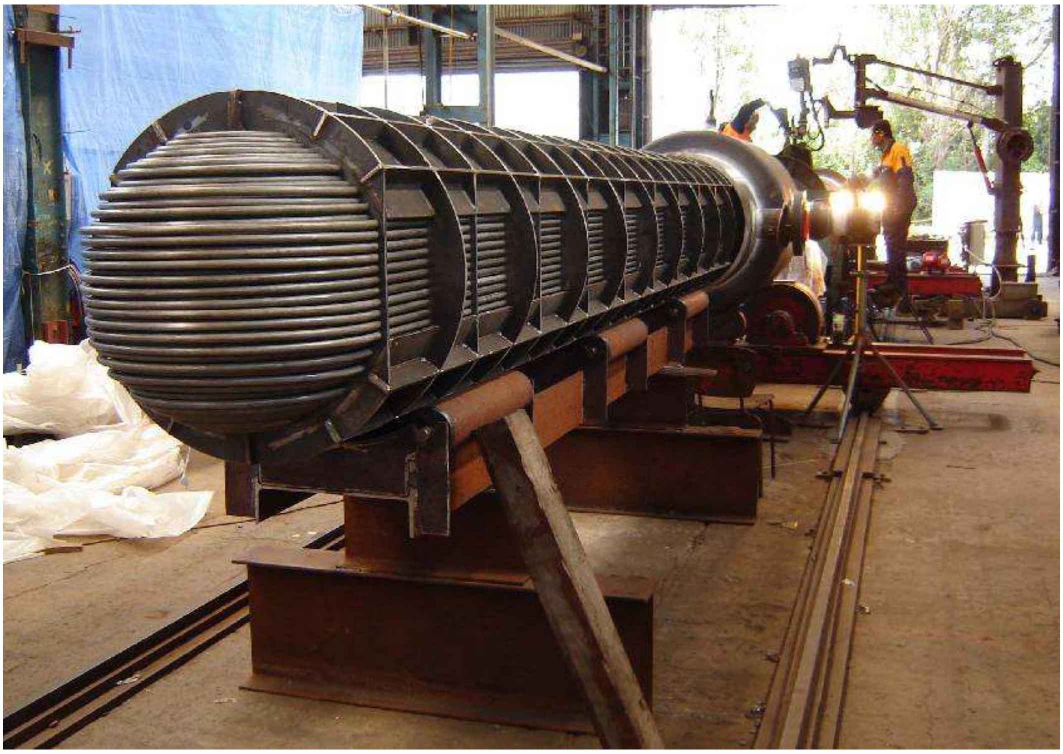

Figure 20.1 One of four high pressure heat exchangers being manufactured for the 1 MWe Habanero power station. (Photo courtesy Geodynamics)

20.0 Introduction

The history and aims of the company have been previously reported in the 2007 GIA Annual Report. Geodynamics continues as Australia's largest geothermal company, and the company remains with a specific focus on the economic extraction of heat from hot rocks using enhanced geothermal systems (EGS) technology. I n particular it is focused on drilling into fractured granite 3.6-4 km below the surface at Cooper Basin, in northern South Australia, where the temperature at the top of the granite is in the order of 230°C.

Geodynamics vision is to become a world-leading geothermal energy company supplying competitive zero-carbon energy and base load power to the Australian market. The company will also operate internationally where its capacity and expertise warrant and where the economic potential is high.

20.1 Highlights for 2008

20.1.1 Habanero Flow Testing

In early March 2008, open flow testing commenced from the Habanero 3 well. The flow testing took place from an EGS reservoir stimulated from the Habanero 1 well located 560 m to the SW. The reservoir is located at approximately 4,200 m depth and the temperature measured at the main fluid entry point into the well at 4,181 m is 244°C. Stable flow rates of 18 kg/s at 208°C and 27.5 MPa flowing wellhead pressure were achieved.

In late March 2008 an open flow test between Habanero 3 and Habanero 1 wells resulted in slightly higher productivity from Habanero 3. In this test, the Habanero 3 output increased to 20 kg/s at 27.5 MPa surface pressure, and the surface temperature reached 212°C. The open flow test involved flowing to a pit then flocculating silica from the water and re-pressurizing the water before injecting it into Habanero 1 well. The open flow test phase was completed by the end of March 2008.

In late April 2008, Habanero 3 was flowed at 27 kg/s with the flowing pressure limited to not less than 15 MPa. In order to better connect the Habanero 3 well to the reservoir, a high pressure stimulation was carried out over a 3-day period from 17-19 April, in which 2,173 m^3 of water was pumped into the well. During the stimulation, the acoustic monitoring network detected 276 events, of which 254 were located. All events were clustered around Habanero 3 and extended out into the main reservoir up to 200 m from the well.

Closed loop circulation between Habanero 3 and Habanero 1 was first achieved on 1 August 2008 along a high pressure pipeline. The circulation was achieved using a high pressure air cooler and a horizontally mounted multi-stage centrifugal re-injection pump. However, the mechanical seal on the inlet to the pump failed during the August 2008 operations, and the loop had to be shut down. The pump needed to be refurbished in Singapore, delaying commencement of the closed loop circulation until December.

The closed loop testing and chemical tracer test, programmed to run for 6 weeks, began on 17 December 2008. The test was successfully completed on 24 February 2009, after more than 50,000 tonnes of brine was circulated through the reservoir. The chemical tracer returns (naphthalene tri-sulphonate) were analysed by Energy & Geoscience Institute, University of Utah. The reservoir has a mean pore volume of 18,500 m^3 between the two wells. This volume is consistent with measured volumes in other granite EGS projects (Soultz and Hijiori) when the well spacing is taken into account.

Construction of a 1 MW power station began in mid-2008. It is based on transferring subsurface heat from Habanero 3 brine flow via four high pressure heat exchangers (Figure 20.1) into a surface loop using demineralised water. By March 2009, the power station construction was virtually complete and almost ready for commissioning.

20.1.2 Jolokia 1 Development

The well Jolokia 1 spudded on 18 March 2008, at a location 10 km west of the Habanero reservoir. The aim was to develop a second EGS reservoir at the new locality.

Five new micro-seismic monitoring stations (100 m wells) were installed up to 5 km from the Jolokia 1 well in June 2008, ready for the Jolokia 1 stimulation. Two stations from the Habanero micro-seismic network were also joined to the Jolokia network.

By 1 July 2008, the Jolokia 1 well had reached the granite basement at a depth of 3,702 m, set 9-5/8 inch casing to 3,776 m and drilled into an overpressured fracture in the granite at 3,805 m. The overpressure in the fracture confirmed that the overpressured condition persisted across the granite from the Habanero field 10 km east. The overpressured fracture was successfully cemented up so that drilling could continue with a heavy barite-weighted drilling mud. The target depth of Jolokia 1 was extended from 4,250 m to 5,000 m.

Jolokia 1 was completed at a depth of 4,911 m on 21 September 2008. The rig was mobilised 10 km west to a new well Savina 1. Savina 1 was to be drilled to 4,300 m for the development of another EGS reservoir and to allow expansion of reserves.

20.1.3 Savina 1 Development

Savina 1 spudded on 18 October 2008 and reached the granite basement at 3,615 m in early January 2009.

The well intersected a highly productive overpressured fracture at 3,700 m but the drill pipe became stuck high in the sedimentary section which had not been cased off at the time. Attempts to wash over the stuck section, though initially successful, were eventually abandoned and the well was suspended above 2,640 m with two cement plugs on 5 March 2009. The fracture overpressure was determined to be almost identical to the overpressure in the reservoir at Habanero 20 km east.

In March 2009, the Savina microseismic monitoring network was installed. It consists of six new stations (100-200 m deep wells) and will incorporate one station from the Jolokia network. Geodynamics now has an extensive monitoring network of eighteen permanent stations covering an area of about 160 km^2 across the central part of the buried granite. The network is continually operating with the stations powered by solar panels and linked by digital radio transmitters.

20.1.4 Investments

In April 2008, The Sentient Group and Sunsuper Pty Ltd agreed to become a joint cornerstone investor in Geodynamics. Sentient and Sunsuper will collectively subscribed for 11.8% of the Company's issued share capital, or 25 million fully paid ordinary shares in Geodynamics at an issue price of A$ 1.50 per share.

In June 2008, Geodynamics announced that it had formally agreed to a swap of its 25% shareholding in Exorka International Limited (Exorka) to a 3.2% shareholding in Exorka's much larger parent company Geysir Green Energy ehf.

Also in June 2008, Geodynamics announced it had successfully raised A$ 33.5 M from its Share Purchase Plan (SPP) following the issue of 22.3 million shares at a price of A$1.50. More than 55% of shareholders participated in the SPP. Following completion of the SPP, the Company's share capital expanded from 236.6 million shares to 258.9 million shares.

In July 2008, Origin Energy confirmed the achievement of the open loop circulation test as a key milestone of the joint venture in South Australia with Geodynamics. Origin committed a further A$ 9.6 M to project expenditure, bringing Origin's total commitment to approximately A$ 150 M. At the time of the announcement, it was stated that the development of the Cooper Basin geothermal resources encompasses three stages: (1) Announcing 'Proof of Concept' and the development of a 1MW Pilot Plant to power the joint venture operations and the local township of Innamincka. (2) The design and construction of a 50MW demonstration plant, the drilling of a further nine wells and the completion of transmission infrastructure for the plant. (3) The replication of the demonstration 50MW power plant to achieve commercial baseload power generation. A further nine plants will be built to produce an overall capacity of 500MW.

Tata Power agreed, in September 2008, to become a third cornerstone investor in Geodynamics. Tata Power subscribed for 11.4% of the Company's issued share capital or 29.4 million fully paid ordinary shares in Geodynamics at an issue price of A$ 1.50 per share.

Also in September 2008, Geodynamics announced it would buy a second heavy duty drilling rig at a cost of US$ 38.3 M. The rig chosen was a National Oilwell Varco (NOV) 2000 HP AC, 15,000 psi rig contracted to be built in Edmonton, Canada. The rig will have the capacity to drill to 6,000 m.

Geodynamics announced, in November 2008, the award by the NSW Government of A$10 M in funding for the development of the Hunter Valley Geothermal Project. The funding was awarded under the NSW Climate Change Fund Renewable Energy Development Program following a competitive 2 stage process and forms part of an overall A$27 M award to 7 renewable energy projects. The funding will be staged over the life of the project with the full amount expected to be received following the commissioning of a small geothermal power plant in the Hunter Valley. The award of the funding will allow Geodynamics to accelerate the exploration and development of its resource in the Hunter Valley. The first stage of this will be the drilling of a 2k m exploration well in 2010 to confirm temperature gradients.

Following completion of analysis of the Habanero circulation and tracer test, on 31 March 2009, it was announced that Geodynamics had achieved "Proof of Concept". The key elements were:

- Resource definition
- Ability to drill and complete wells
- Ability to hydraulically stimulate fractures
- Ability to develop a substantial reservoir volume
- Achievement of well productivity and injectivity
- Confirming fluid circulation between production and injection wells
- Forecasting resource degradation
- Mitigation of currently identified operational constraints
- Absence of adverse environmental impacts

The Company's cash position at the end of December 2008 stood at A$ 119.8 M.

Figure 20.2 Bit being replaced at Savina 1. (Photo courtesy Geodynamics)

Figure 20.3 Steam flow from Habanero 3 on 19th June 2008.
(Photo courtesy Geodynamics)

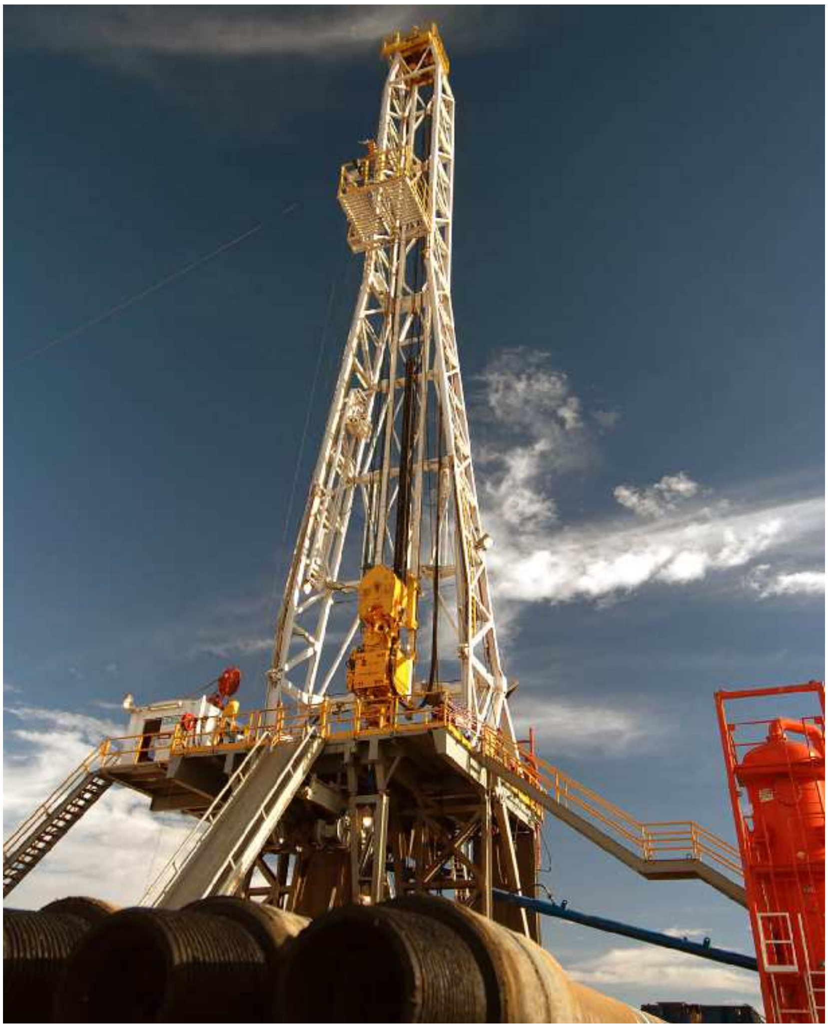

Figure 20.4 Geodynamics rig drilling at Jolokia 1.
(Photo courtesy Geodynamics)

20.2 Status of Company's Geothermal Activities in 2008

As outlined in the highlights (above), Geodynamics is now operating geothermal development programs as well as drilling programs. The development at the Habanero field was to achieve *Proof of Concept* to demonstrate circulation in an EGS reservoir in the target granite. This was achieved by March 2009 after six years of field operations.

The drilling program at Jolokia and Savina was aimed at extending the field development to other parts of the 1,000 km^2 buried granite body. This has resulted in proving that the high granite temperatures, fracture conditions and overpressures extend between the Habanero field and the Savina field, a distance of 20 km.

20.3 Planned Activities for 2009 and Beyond

Despite a very active and successful year in 2008, a number of setbacks have delayed the Geodynamics development program. The problems with the re-injection pump at Habanero delayed the circulation test and the start-up of the 1 MW station. More recently, the Habanero 3 well casing rupture in April 2009 has been a major set-back. The analysis of the failure has not been completed and the program of work for recommencing the Habanero circulation system has not therefore been properly defined. Only after the circulation is re-established will the 1 MW plant be commissioned and in operation.

The Geodynamics drilling rig has been relocated from Savina back to Jolokia 1 in preparation for the Jolokia stimulation. Initially there will be some logging work including possible running of a high temperature borehole imaging log. The stimulation will follow the deployment of a completion string to isolate the upper part of the granite above 4,400 m so that the lower part (to 4,911 m) is targeted for stimulation. The stimulation program consists of injection of 20,000 m^3 of fresh water into the open hole section below 4,400 m. The water is already stored in an adjacent dam, and further water is available from shallow bores.

The Jolokia stimulation is an important step in the development of the Commercial Demonstration Plant (CDP). Geodynamics has completed a grant application with the Federal Government's Renewable Energy Demonstration Program (REDP) for A$ 90 M for the CDP. The A$ 435 M REDP is part of the federal government's A$ 500 M Renewable Energy Fund (REF). It is expected that grant offers will be made available to successful applicants by late 2009. The Geodynamics activities will see a number of directional wells drilled from the Jolokia 1 lease to intersect deep fracture systems extending out from the Jolokia 1 well. The program is predicated on the ability to develop reservoirs at Jolokia similar to the reservoir already proven at Habanero. The Jolokia reservoir will be targeted at a deeper level in an area known to be about 10°C hotter at the same depth than that at Habanero.

Beyond 2009, the plans still remain to build multi-well platforms of wells from the one location and power stations of approximately 50 MW net.

20.4 Comments on the Geothermal Market; Opportunities and Constraints (from Company's Point of View)

20.4.1 Marketing Initiatives and Market Stimulation Incentives

The renewable energy initiatives continue to enlarge in Australia, particularly with Federal Government's Renewable Energy Demonstration Program, and its carbon pollution reduction scheme (CPRS). Geodynamics remains with the weight on its shoulders to deliver results. However other companies are now also commencing drilling programs.

20.4.2 Development Cost Trends

As a result of the slow-down related to the 2008 financial crisis, procurement difficulties and cost pressures have abated. However there still remains a major focus to reduce costs, particularly drilling costs so that EGS becomes competitive with fossil fuel electricity generation.

20.5 Company's Research Activities (where they can be disclosed)

20.5.1 Focus Areas

In April 2009, Geodynamics announced it would provide A$5 M over 5 years for technology advancement. This has been called its Geothermal Technology Plan. Subsurface technologies of drilling performance improvement, high temperature logging, fracture understanding and stimulation optimization are a focus. However a number of surface technological improvements to increase generation efficiency are also being targeted.

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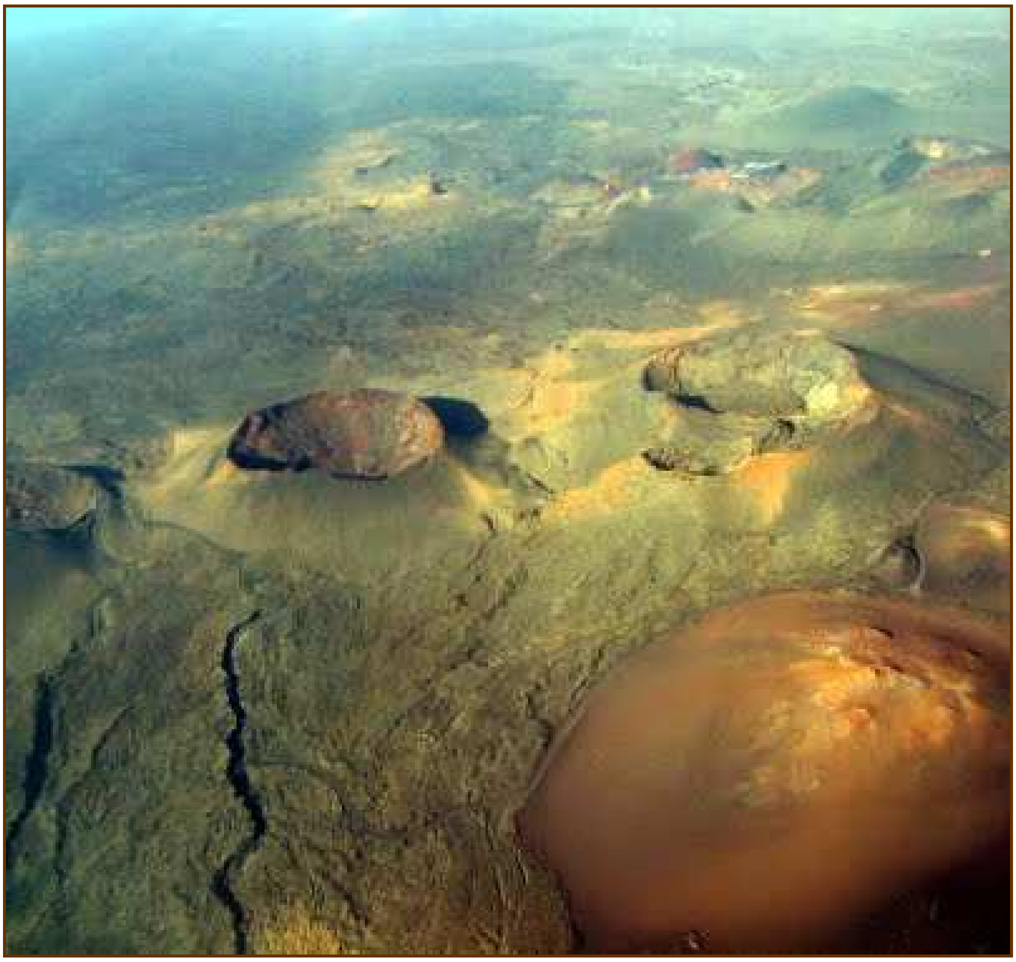
Sponsor Activities

Chapter 21

Geothermal Group-
Spanish Renewable Energy Association



Timanfaya National Park, Canary Island, Spain.

21.0 Introduction

The Spanish Renewable Energy Association, APPA, is a National Association that represents close to 500 producers, businesses and other associations in the Spanish renewable energy sector. Its role is to coordinate, to represent and to look after 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. It has a representation in the Spanish National Energy Commission, CIEMAT (Center for Environmental and Energy Technology Research), Committee of Agents of the Electricity Market and in other public entities (i.e. Energy Agencies of the Autonomous Communities). APPA has presence in Europe as well. It is a member of ESHA (European Small Hydropower Association), EWEA (European Wind Energy Association), AEBIOM (European Biomass Association), EGEC (European Geothermal Energy Council) and EU-OEA (European Ocean Energy Association).

APPA is divided into nine departments, covering all the renewable technologies: biofuels: bioethanol and biodiesel, biomass and biogas; wind energy: small-scale wind installations; 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.

21.1 Mission Statement and Strategic Objectives

According to APPA companies the strategic objectives for the low and high enthalpy departments are:

Low Enthalpy Geothermal Department objectives:

- To boost and to spread geothermal technologies in institutions
- To coordinate the different Spanish Autonomous Regions with the aim that they have similar requirements
- To have 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 study Spanish geothermal resources status
- To define basic exploration lines to improve the resource
- To define specific investigation lines and financing mechanisms
- To study the legal framework applicable to the geothermal development
- To define the appropriate financing mechanisms and feed-in tariffs to make geothermal business attractive
- To contribute to the Spanish Geothermal RAP objectives

21.2 Highlights for 2008

Geothermal energy, despite the importance of Spanish geothermal resources, as demonstrated by the extensive studies and investigations undertaken during the 1970s-1980s, at present still has a low penetration in the Spanish energy balance.

Figure 21.1 indicates the geothermal potential of Spain as determined from the results of several drilled wells; these indicate high enough temperatures to consider geothermal energy as a viable source of energy in Spain.

Spain presents several favourable areas with potential to hold volcanic convective hydrothermal, conductive sedimentary and enhanced geothermal systems suitable to generate electricity (see Table 21.1 and Figure 21.2). There are also a significant number of medium/low temperature resources distributed throughout Spain. Some are available to provide direct heat to the most important (in terms of population) cities in Spain: Barcelona and Madrid, which makes them propitious for the direct heat uses and the development of geothermal district heating schemes.

Regarding the very low enthalpy geothermal resources, where heat pumps allow their use, they are spread over the whole of Spain.

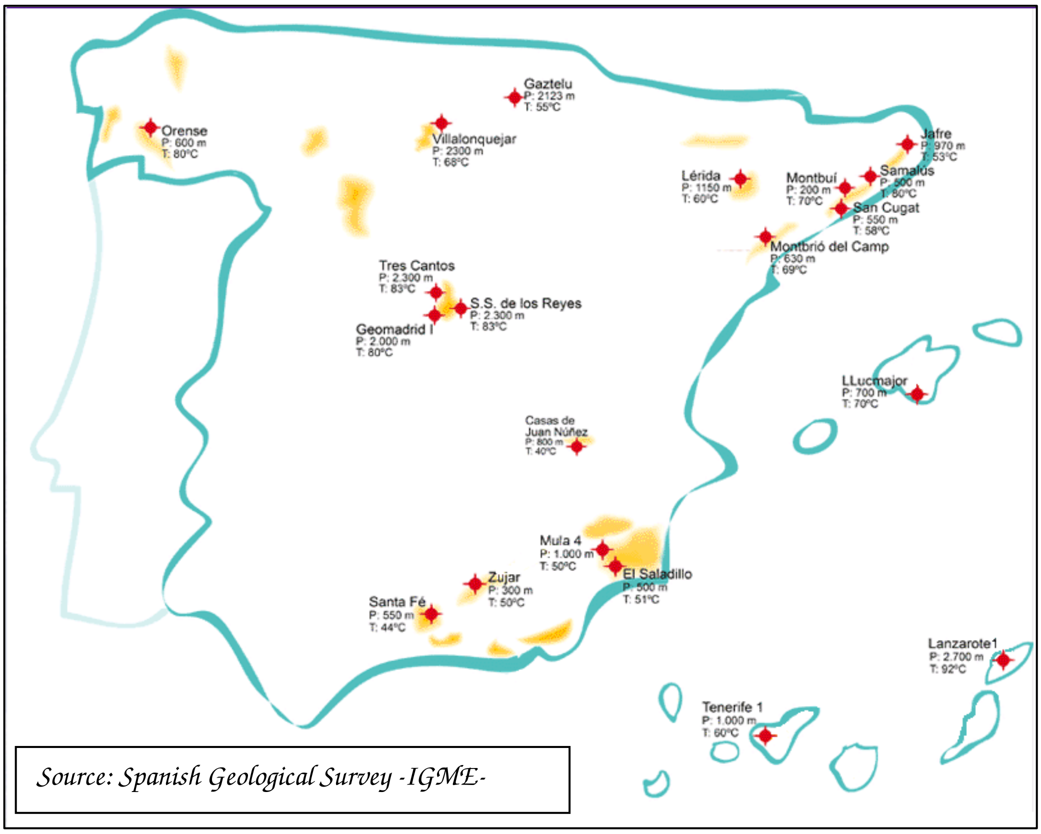


Figure 21.1 Geothermal wells undertaken in Spain in the past century.
(Source: Spanish Geological Survey, IGME)

Table 21.1 Classification of geothermal systems in Spain. (Source: modified from IGME (2005)).

Conventional Geothermal Volcanic Systems		**Canary Islands**
Hydrothermal Sedimentary Systems	**Main Cenozoic Basins**	Tajo Basin: Madrid Duero Basin: León, Burgos, Valladolid Guadalquivir Basin
	Small-Medium basins	Catalonian ranges: Vallés, Penedés, La Selva, Ampurdán Betic range internal basins: Granada, Guadix, Baza Pirinees internal basins: Jaca-Sabiñánigo
Enhanced Geothermal Systems		Associated with crystalline granitic basement of the described basins Hercinian thermal active granites associated to deep fault connective systems: Galicia

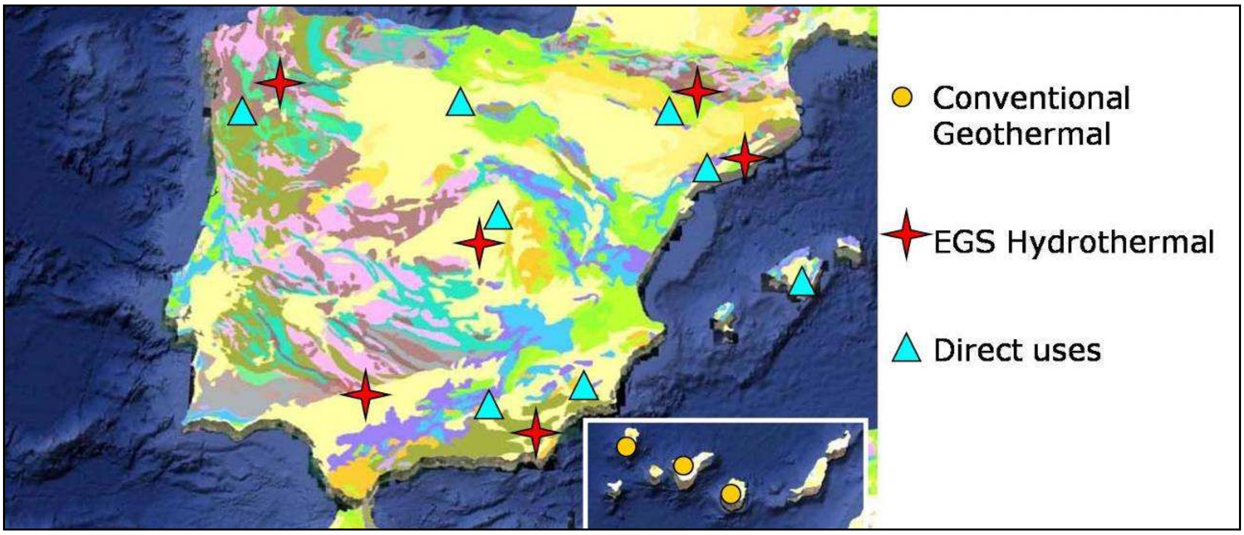


Figure 21.2 Location of the different types of geothermal energy in Spain.

The progress of geothermal energy in Spain will require further exploration drilling and the development of new investigation and exploration techniques to discover the geothermal potential in areas having minimal information (see Figure 21.3). This will involve a combined effort of both National and Regional governments, and private initiative.

Currently, in Spain, there are only geothermal heating projects for spas facilities, greenhouse heating and geothermal house heating. The total installed power of geothermal heat pumps subsidized by Government is around 8400 kW_t, according to data registered by the Spanish Autonomous Regions in 2008.

The main highlights in 2008 concerning geothermal activities carried out in Spain to develop and deploy geothermal energy are the following:

- More than 50 geothermal exploration and investigation licenses have been applied for by private initiatives, covering an area of about 7,500 km^2
- More than 10 M€ to be spent by the companies in the next three years destined for early exploration programs
- Some of these companies are initiating geothermal exploration activities, with the first geothermal district heating production expected for 2011, and power generation for 2013
- Feasibility study carried out by Petratherm SL to develop a geothermal district heating in Madrid (Figure 21.4)
- According to Low Enthalpy Geothermal Department of APPA, its companies have 276 installations of GSHP, which represents approximately 8386 MW_t
- Collaboration between the Spanish Renewable Energy Association (APPA) and the European Geothermal Energy Council (EGEC) to prepare and develop the following documents:
    - Research Agenda for Geothermal Energy. Strategy 2008-2030, developed by EGEC
    - Geothermal Regulation Framework: legal guidelines and financial incentives to set a regulatory framework for the geothermal sector in Europe

Figure 21.3 Summary of Spains geothermal areas.

Figure 21.4 GEOMADRID well inspection undertaken by Petratherm España in July 2008

21.3 National Policy

21.3.1 Strategy

The new Directive on renewable energy sets ambitious targets for all Member States, such that a total 20% of EU electricity consumption to come from renewable sources by 2020. Specifically, in Spain, this target is equivalent to the 42% of electricity generated by renewable energies.

Each EU Member State must develop an action plan which must be submitted to the European Commission before the 30 June 2010.

In Spain, the current Spanish Plan for Renewable Energy, PER 2005-2010, sets targets for areas, with the objective to cover in 2010 at least 12% of total primary energy demand with renewable energy sources. Geothermal energy was not considered in PER 2005-2010, and there are no official specific objectives established for its technologies.

Currently, a new Spanish Plan for Renewable Energy, PER 2011-2020, is being prepared by the Government at the same time as a new Law on Energy Efficiency and Renewable Energy.

Concerning energy efficiency, Spain has become a point of reference with regard to the development of some renewable energies, and it has also significantly increased the resources used for energy efficiency. Despite this, deeper changes are required to achieve the new targets established by the European Union.

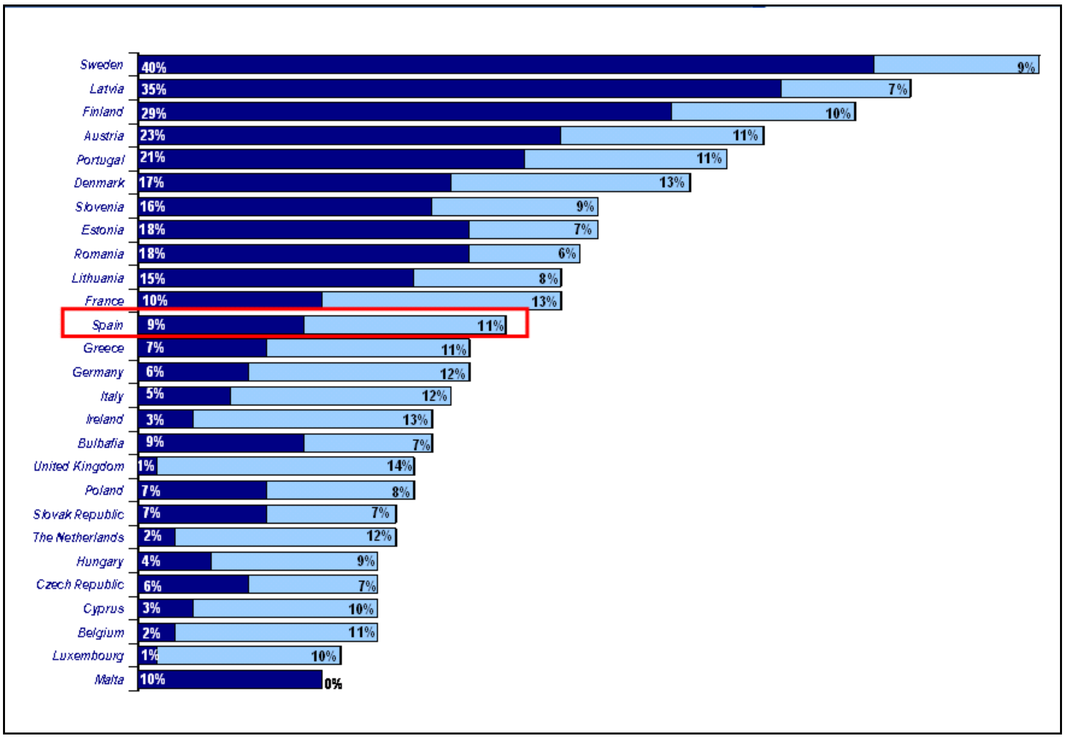


Figure 21.5 Spanish target by 2020. (Source: Spanish Institute for Diversification and Saving of Energy, MITYC (IDAE)).

The new PER 2011-2020 will go into consolidated areas in depth, and it will incorporate other new ones, such as geothermal energy and its concrete objectives (thermal and electric objectives) by 2020.

An important priority for APPA is to influence on the Spanish Government to include geothermal objectives in the next PER 2011-2020 and in the RAP.

21.3.2 Legislation and Regulation

The use of geothermal resources is mainly regulated by the Spanish Mining Law, due to the resource nature:

- Law 22/1973 (Mining Law approved the 21st July 1973): geothermal resources included in Section D of this Law
- Decree 2857/1987 (25th August 1987): General Regulations for Mining Regime
- Royal Decree 863/1985 (2nd April 1985): General Regulations of Mining Healthy and Safety Rules

Nowadays, Regional governments have the authority in legislative development and execution of basic national legislation with regard to the Mining and Energy Regime. Therefore, there is no specific regulation to cover all the possibilities that geothermal energy provides; thus, general regulation is being applied with excessive requirements in some cases.

In relation to electricity generation, the Royal Decree 661/2007 regulates the activities of electricity generation in a special regime defining feed-in tariffs, administrative procedures, etc. Facilities that use geothermal energy as primary energy are included within this Royal Decree in Group b.3.

21.3.3 Permits for Use of Geothermal Resources

There is a legal framework to obtain exploration, exploitation and research permits, depending on the type of geothermal resource and its use.

Deep geothermal resources for electricity generation and thermal uses:

- **Mining Regulation-** Mining rules establish different authorisations for prospecting and use of geothermal resources, such as exploration permits, research permits and exploitation concessions
- **Environmental Regulation-** The specific characteristics of drilling require a previous evaluation from the relevant authority with regard to environment, according to the Law of Environmental Impact Assessment (approved by the Royal Legislative Decree 1/2008)
- **Industry Regulation-** Royal Decree 1955/2000 which establishes the procedure for the authorisation of electricity facilities. For facilities building administrative permit, project approval and exploitation authorisation are required.

Shallow and very low geothermal resources for thermal uses; a very low geothermal energy facility for heating, SHW or heating & cooling, must fulfil the following legal requirements:

- **Mining Regulation-** Drilling could require an authorisation related to mining safety and an evaluation from the relevant environmental authority who will determine the needed procedures
- **Water Regulation-** For open geothermal systems, concessions for water extraction and dumping are needed. For closed geothermal systems, an authorisation is needed if the drilling affects the aquifer
- **Industry Regulation-** The facility for thermal uses or WSW must be registered following the same standards as a facility which uses conventional energy sources.

21.3.4 Progress Towards National Targets for Renewable Energy and Emissions

The Spanish Government has:

- Signed the Kyoto Protocol to reduce emissions to not exceed 332.79 Mt CO_2 equivalent during the period 2008-2012)
- Set a target according to the Emission Trading System. In relation to this point, greenhouse emissions decreased 6.5% in Spain, in 2008, with respect to the previous year
- Agreed to the National Allocation Plan of CO_2 emissions allowances, set by the European Commission, which establish an annual assignment of 152.3 Mt CO_2 for the period 2008-2012
- Set a Volunteer Agreement to reduce greenhouse gases, which is included in the Spanish Strategy for Climate Change and Clean Energy, Horizon 2007-2012-2020, as an urgent measure against climate change. Its objective is to reduce greenhouse emissions from private sector activities that are not subject to Emissions Trading System. This joint initiative between the Environment Ministry and the Sustainability Observatory in Spain (OSE), value a reduction of 60,454 Mt CO_2 equivalent during the period 2008-2012

21.4 Current Status of Geothermal Energy Use in 2008

21.4.1 Power Generation

21.4.1.1 Installed Capacity

In Spain, there is no installed capacity for electricity generation yet, but according several studies mainly carried out by the Spanish Geological Survey (IGME) in the 1970s and 1980s, there are indeed several recognized and identified areas with significant potential.

There is a great expectation for high-temperature geothermal energy exploitation and deep uses such as EGS or HDR, since the use of this energy is not limited to areas with favourable geological conditions. Spain is starting this way, though it will be necessary to increase the knowledge of the subsurface and to investigate advanced new drilling technologies.

21.4.2 Direct Uses

21.4.2.1 Installed Thermal Power

In 2008, the installed capacity was about 22.3 MW_t for thermal uses (spas facilities, greenhouse heating and geothermal house heating).

The total installed power of geothermal heat pumps is 8,415 kW_t, according to data registered by the Spanish Autonomous Regions in 2008.

The categories of use are presented in Figure 21.6.

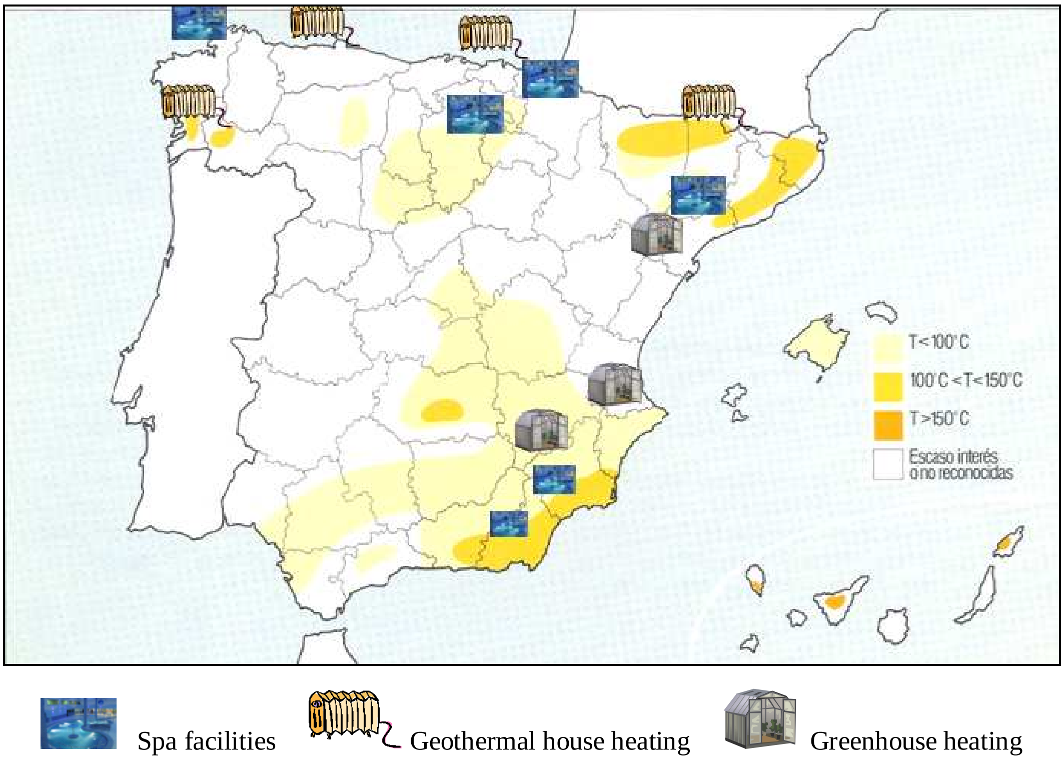


Figure 21.6 Category of geothermal resource use in Spain. (Source: Spanish Institute for Diversification and Saving of Energy, MITYC (IDAE))

21.5 Research and Development Activities

21.5.1 Spanish Geothermal Technology Platform- GEOPLAT

During the last couple of years, a great interest in geothermal energy has awoken in Spain again. With the aim of identifying and developing sustainable strategies for the promotion and marketing of geothermal energy in Spain, at the end of 2008, the first steps were taken to set the Spanish Geothermal Technology Platform-GEOPLAT- (www.geoplat.org).

GEOPLAT is a scientific-technical sector coordination group consisting of all relevant stakeholders in geothermal energy sector in Spain. All the activities carried out within the Spanish Geothermal Technology Platform aim to provide a framework within which all sectors involved in the development of geothermal energy (lead by industry) work together in a coordinated way to ensure the commercial settlement of this renewable energy and its continuous growth, in a competitive and sustainable form.

GEOPLAT covers all R&D activities in terms of identification and evaluation of resources, as it covers the use of this renewable energy and its technology.

The activities of the Spanish Geothermal Technology Platform are subsidized by the Spanish Science and Innovation Ministry. Also, it has the support of the Spanish Institute for Diversification and Saving of Energy- MITYC (IDAE) and the Spanish Center for Industrial Technology Development (CDTI). The GEOPLAT Secretariat is managed by the Spanish Renewable Energy Association (APPA) within its two geothermal departments (High and Low Enthalpy Geothermal Departments).

21.5.2 Government Funded Research

Geothermal energy R&D activities in Spain are funded principally through:

- Projects funded by the Spanish Science and Innovation Ministry
- Support of the Spanish Institute for Diversification and Saving of Energy-MITYC (IDAE)
- Support of the Spanish Center for Industrial Technology Development (CDTI)

21.6 Development Constraints

Whilst geothermal energy resources in Spain have a high potential, geothermal facilities are not yet price-competitive. It is necessary to consolidate geothermal energy as an asset for the future due to its undoubted environmental benefits, its renewable nature and its economic benefits, in terms of creating a new industrial network and the possibility of having a competitive source of energy for society.

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Sponsor Activities

Chapter 22

Green Rock Energy

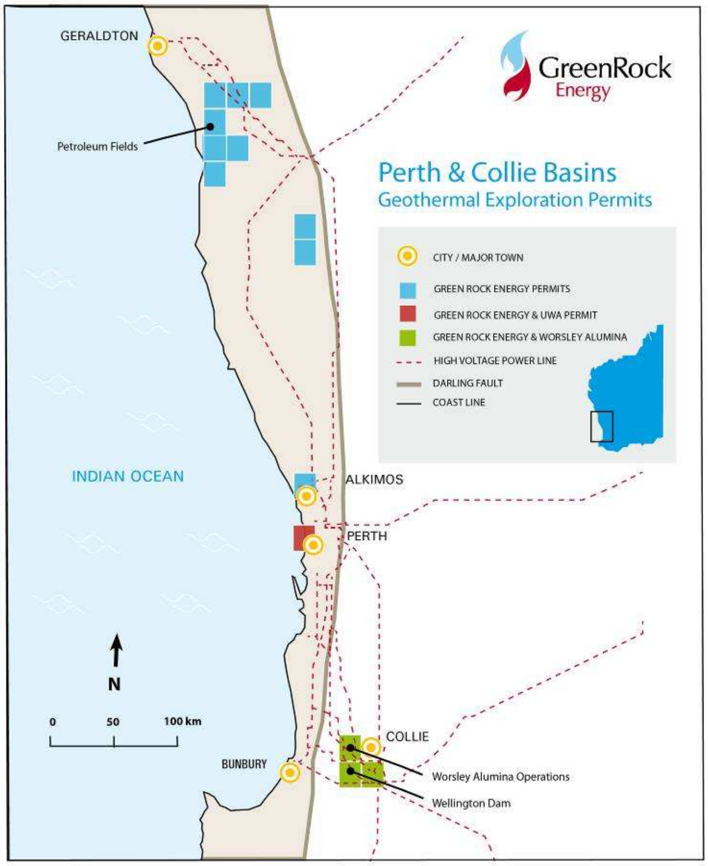

Figure 22.1 Perth and Collie Basin Permit Map.

22.0 Introduction

Green Rock Energy Limited, a sponsor member of GIA, is a public company listed on the Australian Securities Exchange with the purpose of evaluating and developing geothermal resources in Australia and abroad. The Company has a portfolio of projects in diverse geological environments.

Over the next three years the Company is focussing on developing two commercial demonstration projects in sedimentary aquifers in each of Australia and Hungary, and one engineered geothermal system (EGS) project in a thermally anomalous granite at Olympic Dam in South Australia. All three projects are located at markets, and given success with drilling and flow testing, can be commercialised quickly.

The chief challenges for both types of geothermal resources relate to: drilling to depths with sufficient temperatures for the end uses (2,000-5,000 m); finding or engineering sustainable permeability at reasonable cost; proving the capacity of the geothermal reservoir to deliver enough energy at the surface to justify the investment. To assist in resolving these issues, Green Rock Energy is participating in GIA Annexes III (Enhanced Geothermal Systems), and VII (Advanced Geothermal Drilling Techniques). The Company is also involved in Annex VIII (Direct Uses).

22.1 Geothermal Energy Projects

22.1.1 Australian Projects

22.1.1.1 Perth Basin, Western Australia

In July 2009, Green Rock Energy was awarded the Western Australia's first geothermal exploration permits (GEP) to be granted in the State. These were in the Perth Basin which where most of Western Australia's population reside. The first Permit, GEP1, is held jointly with the University of Western Australia in the city of Perth and the other three are held solely by the Company. Perth, the capital of Western Australia, has recently been Australia's fastest growing city, a city of approaching 1.7 million people (Figure 22.2).

In August 2009, Green Rock accepted the grant of a 100% interest in another six Permits in the northern Perth Basin in an active oil and gas production area and another three Permits in the Collie Basin held jointly with Worsley Alumina (Figure 22.1). A substantial proportion of the city of Perth's electricity supply is generated from power stations in the Collie Basin. Worsley Alumina is one of the world's largest and most efficient alumina refineries and is a joint venture operation with majority ownership held by BHP Billiton.

The Perth Basin is a 1,000 km long extensional rift, or half graben, containing a thick sequence of sediments in places up to 15 km deep. The rift was initiated when Australia split from India. The Basin has potential for both hydrothermal energy resources hosted in thick permeable sandstone aquifers and for enhanced geothermal systems in basement rocks.

In the northern Perth Basin, the heat flow is high with many petroleum wells in the company's permits having values over 100 mW/m^2. In this part of the Basin, temperatures are expected to be sufficient at reasonable depths for commercial generation of electricity provided sufficient permeability can be proven.

Near the city of Perth, temperatures are generally lower at equivalent depths and only suitable for direct heat uses rather than electricity generation. Geothermal water recovered from around 750 m deep is being used to heat a number of major aquatic centres in Perth including the Challenge Stadium where the World Swimming Championships have been held twice in the last decade (Figure 22.3).

Figure 22.2 Perth, Australia.

22.1.1.2 *Challenge Stadium*

Green Rock is the first industry participant of the Geothermal Centre of Excellence, which is comprised of the UWA Curtin University and the CSIRO, Australia's premier science and industrial research organisation. The Centre formed recently and is funded by the Western Australian Government. Green Rock is funding some students at UWA who are doing geothermal research on the Perth Basin.

Figure 22.3 *Challenge Stadium, Perth, Australia.*

22.1.1.3 *Perth Urban Direct Heat Project*

The first commercial demonstration project the Company plans is at the main campus of The University of Western Australia (UWA) in the Perth metropolitan area (Figure 22.4). Green Rock plans to drill one production and one injection well at the UWA campus to around 2-3 km deep to recover geothermal energy from fluvial sandstone aquifers where the temperature is expected to range between 75-100°C. The project is designed to replace a significant portion of the UWA's Crawley Campus' electricity powered compression chillers that produce cold water for air-conditioning with geothermal powered absorption chillers. All of the cooled water will be returned without contamination to the underground aquifers.

Figure 22.4 *University of Western Australia.*

The project aims to establish the commercial viability of replacing a portion of the air-conditioning and heating capacity at the main Campus and then the replication of the process through the Perth metropolitan area in commercial and industrial buildings and at two new residential developments intended to be carbon-neutral.

The first development will be a high density suburb of Perth to house 30,000 people. The second is a brand new suburb about 40 km from Perth named Alkimos, where Green Rock holds the exclusive geothermal energy rights. The State Government wants to develop a carbon neutral suburb at Alkimos housing 60,000 people within the next few years.

22.1.1.4 Olympic Dam

At Green Rock's 100% owned Olympic Dam EGS project in South Australia, the Company plans to drill one production and one injection well and carry out fracture stimulation to connect them at depths ranging from 3.5 km to 5 km in the thermally anomalous granite near our Blanche No 1 well. A major technical advantage of this project was the presence of granite only 720 m deep at the site of Blanche No 1. This enabled the Company to drill Blanche No 1 over 1,000 m into the hot granite to determine its amenability to fracture stimulation. Mini hydro fracture stimulation in Blanche No 1 was successful and gives confidence that fracture stimulation at production depths ranging from 3,500-5,000 m can be successful. This is a major technical advantage over other EGS projects in Australia, where the drilling depth of the target rocks is so deep it precludes sampling prior to undertaking expensive and deep drilling to determine the suitability of the target reservoirs for fracture stimulation and temperature measurement.

A major commercial advantage of this project is that it is located at a major market where the Olympic Dam mine currently consumes 130 MW of electricity, and only a few kilometres from a 275 kV power line connected to the national power grid.

Green Rock Energy is now seeking funding by way of a farmin before it commences the deep drilling, fracture stimulation and flow testing to prove the commercial viability.

22.1.2 Hungary

The second commercial demonstration project is intended to be carried out by Central European Geothermal Energy (CEGE), in Hungary, at depths in Triassic sediments generally around 3,000 m, where geothermal water temperatures are sufficient for commercial electricity production. In Hungary, most geothermal energy production is generally from shallower Pannonian age sediments where temperatures do not exceed 100°C and is only used for direct heat purposes.

Figure 22.5 *CEGE signing ceremony, Hungary.*

In August 2008, CEGE was formed by MOL, Green Rock and Enex of Iceland (see Figure 22.5: signing ceremony at MOL's office in Budapest). In January 2009, MOL and Green Rock acquired Enex's one third interest in CEGE so that both parties each hold a 50% interest in CEGE.

CEGE's aim in Hungary is to produce electricity from geothermal water recovered from existing petroleum wells using conventional Organic Rankine Cycle power plants. In Hungary, a feed-in-tariff applies to electricity produced from geothermal energy and a network of transmission lines is well established. CEGE's technical team has identified a number of potential wells which could be re-entered and flow tested for power production. CEGE is also investigating potential investments in direct heat projects in Hungary.

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Sponsor Activities

Chapter 23

Ormat Technologies, Inc

27.5 Gross MW Galena III Geothermal Power Plant, installed in 2008. Part of the 104 Gross MW Steamboat Complex, which supplies sufficient electricity for all households in Reno, NV. (Photo courtesy of Ormat Technologies)

23.0 Introduction

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 25 years of 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 July 2009, Ormat owns and operates 515 MW (including the 50 MW North Brawley project in California, which is in start up phase) of geothermal and recovered energy generation (REG) facilities in six countries, including 350 MW of geothermal and 37 MW of REG in the United States. In total, Ormat has built more than 1,200 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 over 1,000 employees worldwide, with approximately 450 in the United States.

23.1 New Projects

Ormat continues its rapid growth in the United States and abroad. In 2008 and early 2009, Ormat added approximately 187 MW of gross geothermal capacity and 50 MW of gross REG capacity worldwide; approximately 75% of which is owned and operated by Ormat.

Beyond 2009, Ormat expects to add to its portfolio approximately 200 MW of new geothermal power plants in California and Nevada.

In addition, during 2008 and early 2009, Ormat has signed US$ 230 M in contracts with third parties for power plants in Nevada, New Zealand, Turkey and Costa Rica.

The same type of ORMAT ORC power technology is used for both geothermal and REG. Examples of some of the 2008 and 2009 projects are shown in Figures 23.1 and 23.2.

Figure 23.1 *35 MW Phase II of Olkaria III Geothermal power plant at Kenya, installed in 2008. (Photo courtesy of Ormat Technologies)*

Figure 23.2 *The 4 MW OREG 4-Peetz Recovered Energy Generation power plant is the first REG plant in Colorado. (Photo courtesy of Ormat Technologies)*

23.2 Revenues

Revenues were US$ 345 M in 2008, an increase of 16.5% over 2007, and we expect 2009 annual revenues to reflect a growth of between 9% and 15% over 2008. Figure 23.3 shows revenue growth in recent years.

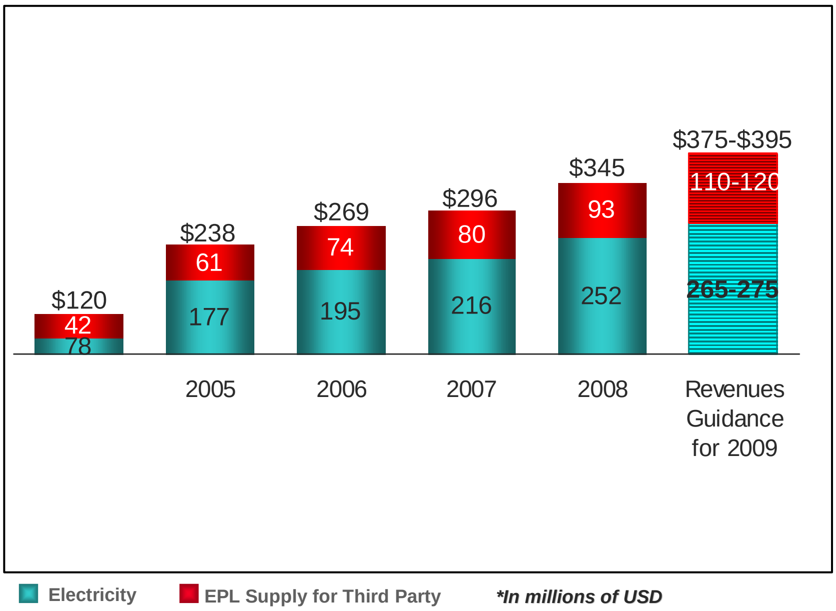

Figure 23.3 Ormat revenue growth.

23.3 Resource and Project Development

Ormat has a dedicated staff of geologists, resource managers and drilling engineers to confirm and develop new geothermal fields.

Ormat has geothermal leases and rights for future development covering approximately 220,000 acres, most of which were acquired during 2008. The geothermal leases in the United States are located in Alaska, California, Nevada, Hawaii, Oregon, Idaho and Utah. We are actively pursuing additional land in these and other states where prospective geothermal resources remain untapped.

Ormat's in-house drilling company, GeoDrill, has over 90 employees and four rigs (Figure 23.4) with capability to drill down to 18,000 ft (~ 5,500 m).

23.4 Research and Development

23.4.1 Co-production of Electricity at Oil and Gas Fields

Ormat, in 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 marks the first of its kind by providing on-site fuel free power that will increase the productivity and possibly extend the longevity of existing US oil fields.

Figure 23.4 *Ormat drill rig. (Photo courtesy of Ormat Technologies)*

The oil fields in the United States could provide an additional 200-5,000 MW of electricity through this technology, according to United States Senator Mike Enzi (Wyoming). The Ormat ORC unit being used (Figure 23.5) 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.

Figure 23.5 *Hot water co-produced from oil wells at the Rocky Mountain Oilfield Testing Center (RMOTC), Wyoming, USA (2008). (Photo courtesy of Ormat Technologies)*

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.

23.4.2 Enhanced Geothermal Systems (EGS)

23.4.2.1 Desert Peak

Ormat is also working with research institutions to create an engineered geothermal system (EGS) at our Desert Peak geothermal field in Northern Nevada. Ormat currently operates an 11 MW geothermal power plant at Desert Peak. Heat flow through the field is significant and temperatures in excess of 200°C have been measured at relatively moderate depths. However, these heat anomalies lack interconnectivity with the existing geothermal reservoir. Thus, much of the heat energy in the field cannot be captured through conventional hydrothermal technology. For this reason, this project serves a dual purpose: to move forward scientific understanding and applied technology by employing and practicing advanced methods to help commercialize EGS technology. Because this project is being tested at an existing geothermal field, a successful EGS could be quickly adapted to additional generation capacity for commercial sale.

23.4.2.2 Brady

The US Department of Energy (DOE) has once more chosen Ormat to demonstrate the viability of Enhanced Geothermal Systems (EGS) with a grant for US$ 3.4 M to improve hot, non-commercial wells located within a stress environment and in formations favorable for permeability enhancements using EGS techniques.

Ormat, the DOE, GeothermEx Inc. and other stakeholders will apply EGS stimulation techniques at Ormat's Brady facility near Reno, Nevada, to develop fracture networks that will enable currently non-commercial wells to communicate with the productive reservoir and enhance generation.

23.4.2.3 Landau, Germany

Ormat technology has been applied to another commercial project with EGS injection in Landau, Germany, where a 3.2 MW power plant has been in operation for more than a year (Figure 23.6).

Figure 23.6 *The 3.2 MW Landau Geothermal Power Plant is the first commercial plant in Germany, and the first implementation of EGS technology in an injection well. (Photo courtesy of Ormat Technologies)*

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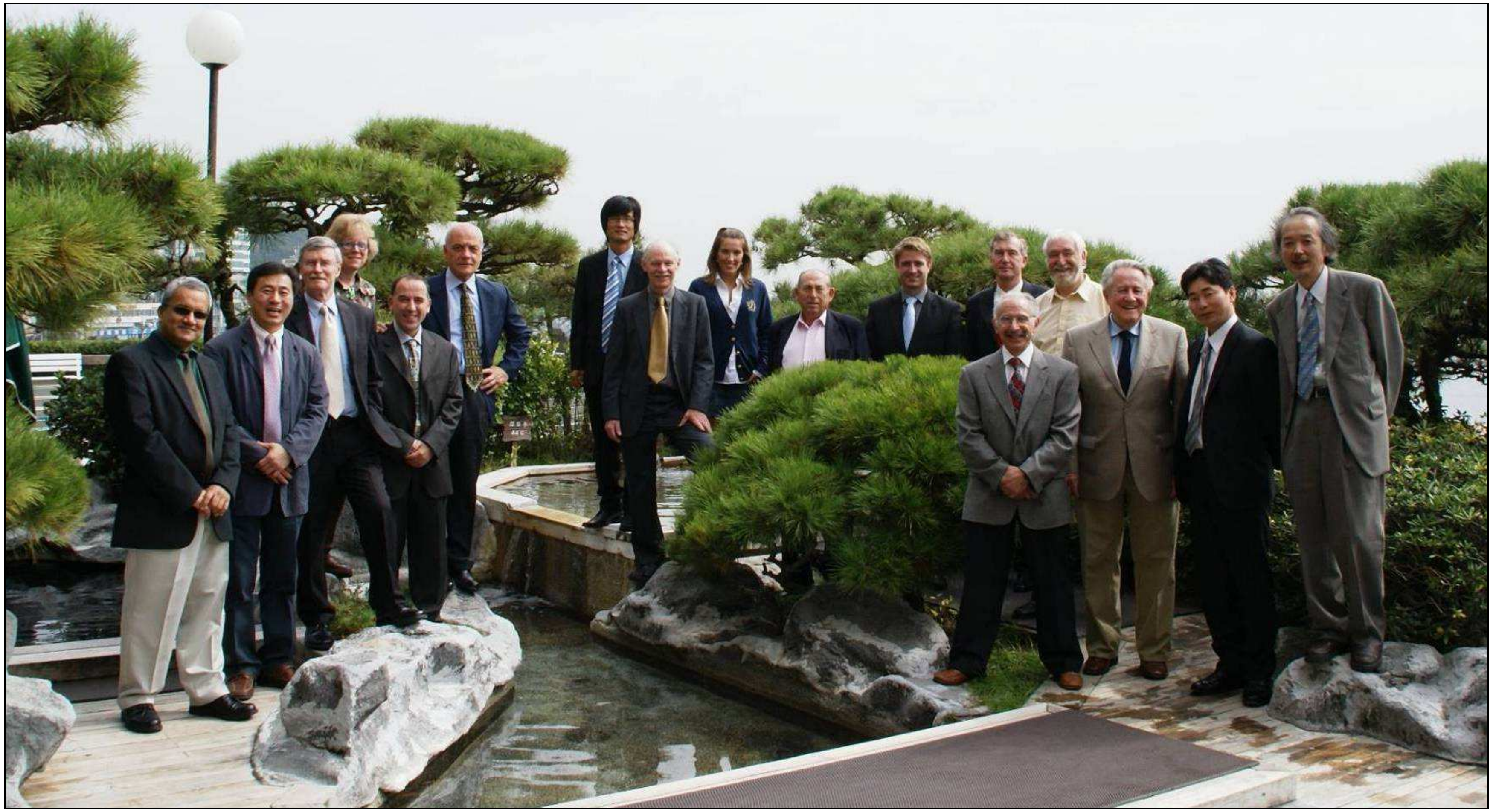

(Photo courtesy Hirofumi Muraoka)

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