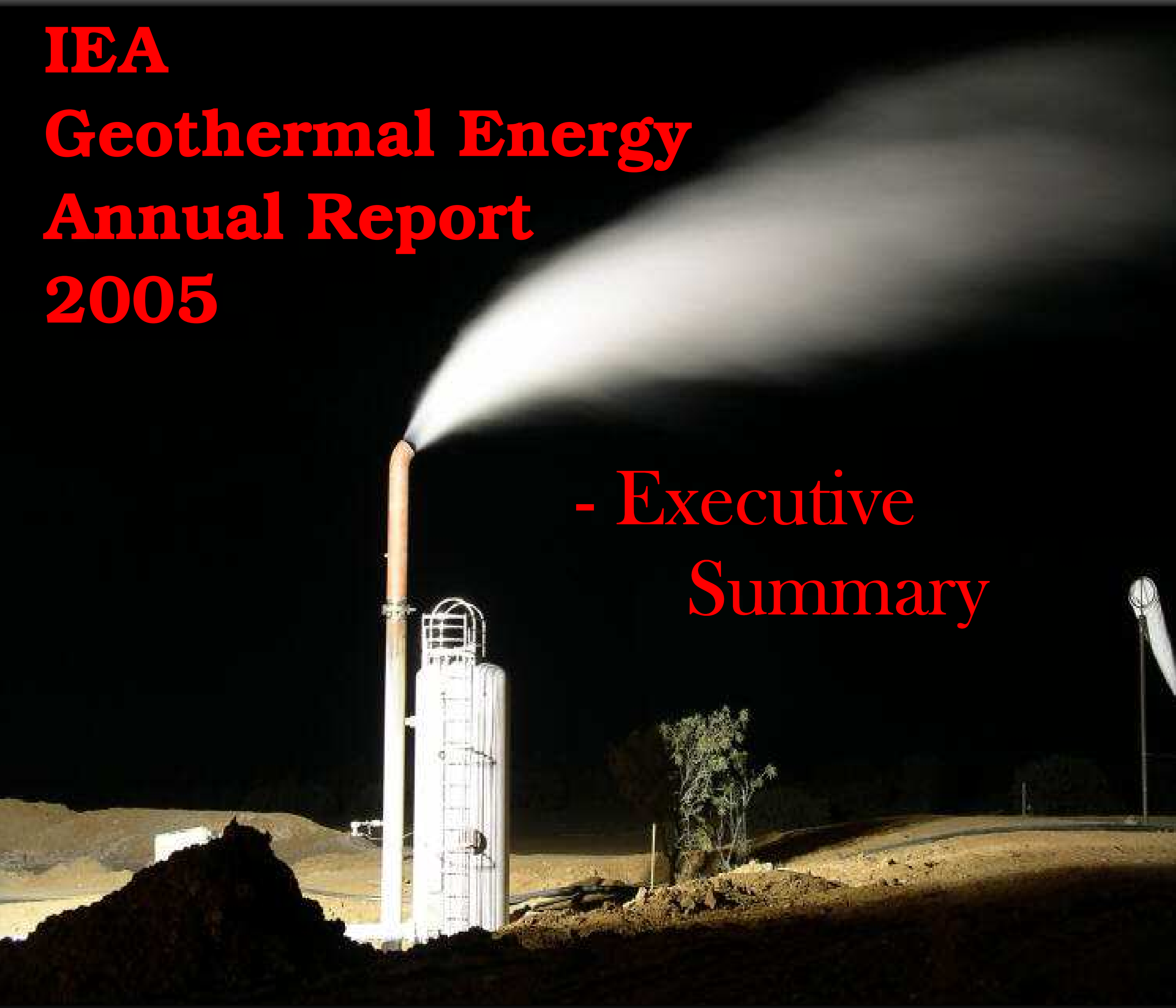
INTERNATIONAL ENERGY AGENCY

IEA Geothermal Energy Annual Report 2005

- Executive Summary



International Energy Agency
Implementing Agreement
for Cooperation in
Geothermal Research and Technology

November 2006

CONTENTS

Page

EXECUTIVE SUMMARY

Introduction... 1

The IEA-GIA- Its Mission and Objectives.. 3

Collaborative Activities............................. 4

National Activities.. 7

Plans for 2006 GIA.. 8

References.. 8

To Find Out More

If you are interested in finding out more about the IEA Geothermal Programme, or you wish to join the GIA:

Contact the IEA GIA Secretary

Dr Mike Mongillo
IEA GIA Secretary
c/o GNS Science
Wairakei Research Centre
Private Bag 2000
Taupo
NEW ZEALAND

Tel: +64-7-378-9774; +64-7-374-8211
Fax: +64-7-374-8199
E-mail: mongillom@reap.org.nz

OR

Visit the IEA GIA Website

www.iea-gia.org

Photograph: Well Habanero 2 Steam Separator, April 2005, Cooper Basin, Australia. The well is flowing at 12 kg/sec with a wellhead temperature of 160 °C. During testing in May 2006, the well flowed up to 25 kg/sec with a wellhead temperature of 210 °C at maximum output. (*Photo by Ralph Weidler of Q-Con GmbH; courtesy of Geodynamics Limited).*

Executive Summary

INTRODUCTION

In 2005, the IEA Geothermal Implementing Agreement (GIA) continued its successful efforts to support and advance the worldwide use of geothermal energy through international collaborative activities. This 2005 Annual Report describes these activities and the major achievements of the Participants in IEA Geothermal for the year. The current status of the Member Countries' geothermal energy policies, uses, market situation, economics, research activities, education and international activities is also discussed.

This Executive Summary begins with a brief introduction to the world's current energy situation and the part that geothermal resources can potentially play in it, in order to set the context in which the IEA-GIA operates. It includes a very brief description of the GIA and a synopsis of the information described in detail in the Annex and Member Country reports provided in Chapters 2-6, and 8-18, respectively. The contributions and highlights of the GIA Member Countries' activities for 2005 are described, and the major achievements of the GIA's research activities are reviewed. Finally, the GIA's plans for 2006 are outlined.

Geothermal Energy in the World Energy Scene

The accelerating demand for energy worldwide and the increasing awareness of global warming issues have led to a growing worldwide desire to use clean and renewable energy sources. Providing affordable, clean energy to meet these rapidly expanding needs is an enormous challenge, and geothermal energy can be a very significant part of the solution.

In 2004, the worldwide total primary energy use was estimated to be about 463 EJ/y (IEA, 2006). Current estimates indicate that economic exploitation of geothermal resources could provide about 150 EJ/y for electricity generation and 350 EJ/y for direct uses. Consequently, geothermal has the potential to make a considerable contribution towards meeting the world's current and future energy needs. Geothermal energy also has characteristics which make it extremely valuable for both electricity generation and direct heat use: extensive global distribution, environmentally friendly, independent of season, immune from weather effects, indigenous nature, contributes to development of diversified power, effective for distributed application and can provide sustainable development. Though geothermal usually operates as a baseload provider of electricity with load factors typically well above 90%, it can also operate in a load-following capacity, albeit at lesser efficiency.

Status of Worldwide Geothermal Energy in 2005

At the start of 2005, 24 countries worldwide were producing electricity from geothermal resources, with a total installed capacity of 8,900 MW_e and electricity generation of 56,800 GWh (Bertani, 2005) (Table ES1). Over the past 25 years, geothermal installed capacity has increased by a factor of about 2.3, at a very steady rate of about 200 MW/y; 11.6%, or about 2.3%/y, during the past 5 years. Electricity generation has grown by 50% since 1995; 15% in the past 5 years, averaging 3.1%/y growth (*ibid.*) (Table ES2, Figure ES1). Geothermal energy provides a major contribution to the national generation of many countries, with six countries now obtaining more than 15% of their electricity from geothermal (Table ES1). In 2005, the average contribution to national installed capacity for the 18 countries with 'non-negligible' installation/generation was 8.4%, the corresponding average contribution to national generation being about 9.2%. The 2005 geothermal generation resulted in a savings of about 14.4 Mtoe and reduced CO_2 emissions by 46.4 Mt.

Of interest when considering differences among the various renewable energy resources is a 'contribution efficiency' that renewable resources can make to power supply, i.e. the ratio of the energy generated to the installed (or operating) capacity, which is 6.4 GWh/MW_e for geothermal [2005], compared to hydro 3.63 GWh/MW_e [2004], solid biomass 5.56 GWh/MW_e [2004], solar PV 0.074 GWh/MW_e [2004] and wind 1.9 GWh/MW_e [2005] (IEA 2006).

Table ES1. Worldwide geothermal power installed capacity and electricity generation at the beginning of 2005 (from Bertani, 2005).

Country	Installed Capacity [MW]	Annual Energy Produced [GWh/y]	% of National Capacity	% of National Energy
Australia*	***.2***	***.5***	***Negligible***	***Negligible***
Austria	1	3.2	Negligible	Negligible
China- Tibet	28	95.7	30	30
Costa Rica	163	1,145	8.4	15
El Salvador	151	967	14	24
Ethiopia	7	n/a	1	n/a
France Guadeloupe Island	15	102	9	9
Germany*	***.2***	***1.5***	***Negligible***	***Negligible***
Guatemala	33	212	1.7	3
Iceland*	***202***	***1,406***	***13.7***	***16.6***
Indonesia	797	6,085	2.2	6.7
Italy*	***790***	***5,340***	***1.0***	***1.9***
Japan*	***535***	***3,467***	***0.2***	***0.3***
Kenya	127	1,088	11.2	19.2
Mexico*	***953***	***6,282***	***2.2***	***3.1***
New Zealand*	***435***	***2,774***	***5.5***	***7.1***
Nicaragua	77	270.7	11.2	9.8
Papua New Guinea Lihir Island	6	17	10.9	n/a
Philippines	1,931	9,419	12.7	19.1
Portugal San Miguel Island	16	90	25	n/a
Russia	79	85	Negligible	Negligible
Thailand	.3	1.8	Negligible	Negligible
Turkey	20	105	Negligible	Negligible
USA*	***2,534***	***17,840***	***0.3***	***0.5***
Total	**8,902**	**56,798**	**8.4****	**9.2****

* *GIA Member Countries*; ** average values excluding negligible contributions.

As of May 2005, 72 countries were utilizing geothermal energy for direct use applications, including: space, greenhouse and aquaculture pond heating; agricultural drying; industrial uses; bathing and swimming; cooling; and snow melting. The total installed capacity was about 28,270 MW_t, and the thermal energy usage 273,372 TJ/y or 75,940 GWh/y (Lund *et. al*, 2005) (Table ES3). In 2005, over 50% of direct use installed capacity was contributed by geothermal heat pumps. Direct use installed capacity has nearly doubled every 5 years since 1995 and energy use has increased by a factor of almost 2.5 since 1995. The 2005 use is equivalent to an annual savings of about 25.4 Mtoe in fuel oil and 81.3 Mt in CO_2 emissions (*ibid.*).

Table ES2. Installed geothermal capacity (1975-2005) and electricity generation (1995-2005) (data from Bertani, 2005).

Year	1975	1980	1985	1990	1995	2000	2005
Geothermal Installed Generating Capacity (MW_e)	1,300	3,887	4,764	5,832	6,798	7,974	8,902
Increase Over Previous Five-Year Period MW_e (Percent)	-	2,587 (99)	877 (22.6)	1,068 (22.42)	966 (16.6)	1,176 (17.3)	928 (11.6)
Electricity Generation GWh/y	-	-	-	-	37,744	49,261	56,831
Increase Over Previous Five-Year Period GWh/y (Percent)	-	-	-	-	-	11,517 (30.5)	7,570 (15.4)

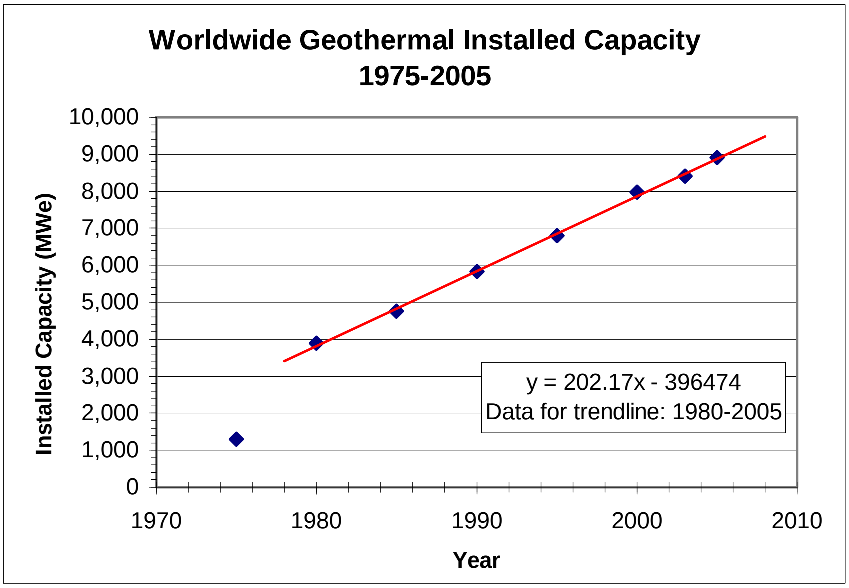


Figure ES1. Worldwide geothermal installed capacity for the period 1975-2005.

THE IEA-GIA- ITS MISSION AND OBJECTIVES

The IEA-GIA provides a versatile framework for extensive international cooperation in geothermal R&D, with its overall mission being: *to advance and support the use of geothermal energy on a worldwide scale by overcoming barriers to its development.* National geothermal programmes are brought together with the aim of building specific expertise and generating synergies by establishing direct cooperative links among geothermal experts in the participating countries. GIA activities are directed principally towards the coordination of the ongoing national activities of the participating countries. New activities are also initiated and implemented when needs are established.

Table ES3. Worldwide direct use categories and their development 1995-2005 (from Lund *et al.*, 2005).

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

The GIA's official scope of activities include: *to conduct international collaborative efforts to compile and exchange improved information* on worldwide geothermal energy research and development concerning existing and potential technologies and practices; *to develop improved technologies* for geothermal energy utilization; and *to improve the understanding of the environmental benefits* of geothermal energy and methods to avoid or ameliorate its environmental drawbacks. Objectives are specifically focused to: expand R&D collaboration, increase the number of participants, increase outreach to non-Member countries with large geothermal energy potential; evaluate market stimulation mechanisms, improve dissemination of information about geothermal energy and use the IEA's reputation to help leverage limited R&D funding.

The project activities, or tasks, are defined and organized in 'Annexes'. Participants must take part in at least one Annex. See Table 1.2 in Chapter 1 (refer to the complete GIA 2005 GIA Annual Report available at: www.iea-gia.org) for the involvement of the participants in the Annexes.

During the current term of the GIA, the Annexes have operated under the task-sharing mode of financing (participants allocate specified resources and personnel to conduct their portion of the work at their own expense), as was the case for the first term. The actual amount of work conducted under the auspices of the GIA has not been quantified, though it is estimated that most countries have an involvement amounting to one to several man-year(s).

The GIA Secretariat was established in March 2003 to provide the ExCo with administrative and other assistance. It is funded through cost-sharing, whereby all Members contribute to a Common Fund according to the number of 'shares' they have been allocated.

2005 was the GIA's next-to-last year of operation in its second 5-year term, which ends on 31 March 2007. The major successes of GIA's activities during this term to date are very encouraging, and the GIA is now considering applying to continue for a third term.

COLLABORATIVE ACTIVITIES

The Annexes

In 2005, the participants in the IEA-GIA worked on five broad research tasks, specified in the following Annexes:

- Annexes I- Environmental Impacts of Geothermal Energy Development.
- Annex III- Enhanced Geothermal Systems.
- Annex IV- Deep Geothermal Resources.
- Annex VII- Advanced Geothermal Drilling Techniques.
- Annex VIII Direct Use of Geothermal Energy.

Annexes I, III and IV were part of the original GIA and have continued programmes into the current term, as has Annex VII, which was started in 2001. In addition, Annexes I, III and VII were extended by the ExCo in September 2005 for a further 4 years, to 2009. Annex VIII held its first working meeting in September 2005, and its first term of operation continues to 2007. Four additional Annexes (II, V, VI, IX) were previously drafted; with two (II and IX) subsequently closed. The possibility of initiating Annex V- Sustainability of Geothermal Energy Utilization continues to be discussed, and Annex VI- Geothermal Power Generation Cycles is still under consideration. See Table 1.1 (refer to the complete GIA 2005 GIA Annual Report available at: www.iea-gia.org) for Annex status details.

A brief description of some of the activities and major highlights for of the Annexes active in 2005 is presented below. Details are available in the Annex Reports included in Chapters 2-6.

The World Geothermal Congress 2005

The World Geothermal Congress is a major international conference that is held every 5 years to demonstrate the successes of geothermal research and development, and to discuss and disseminate information on the major R&D advances that have occurred during the period. The GIA was a very active participant in the WGC 2005, held in Antalya, Turkey, on 24-29 April 2005. The results of GIA Annex work were presented in over 40 papers and posters. In addition, the GIA sponsored an especially successful exhibition booth, in which 10 large posters were displayed and two audio-visual presentations operated. Many hundreds of IEA and GIA brochures and documents were distributed from the booth and discussions of the GIA's work were held with a multitude of booth visitors.

Environmental Issues and Geothermal Energy Use

The environmental effects of energy use are of worldwide concern. Though geothermal is usually regarded as benign, there are environmental issues associated with its utilization that must be addressed. Annex I- Environmental Impacts of Geothermal Energy Development identifies the possible environmental effects and works to devise and adopt countermeasures to avoid or minimize their impacts.

Enhanced geothermal systems (EGS) are currently seen as one of the major options for accessing geothermal resources over larger areas and extending existing geothermal developments. Felt induced seismic events, generated in association with the development and operation of EGS reservoirs, have recently been identified as a potential issue. Annex I convened two international workshops on 'Geothermal Induced Seismicity' in 2005 to advance the understanding of these events, and help design strategies and robust hazard assessment methods to address them.

Geothermal fluids normally contain small quantities of CO_2; consequently, it is naturally emitted from thermal areas. Annex I is investigating the development of methods for monitoring such emissions in order to quantify the long-term effects of CO_2 emission from geothermal developments.

The results of some of the Annex I studies conducted in New Zealand, the Philippines and Turkey were published a second Special Issue of *Geothermics* journal (Hunt, 2005) devoted to environmental issues pertaining to geothermal development.

Artificial Stimulation of Geothermal Resources

Huge volumes of high temperature, water-poor, rock are widespread in the world. In order to access and use the vast amounts of geothermal energy contained in them, Annex III- Enhanced Geothermal Systems (EGS) is investigating the development of new and improved technologies for artificially stimulating these resources to enable commercial heat extraction for electricity and co-generation. These techniques can also be applied to increase energy production at existing geothermal developments.

The successful development of EGS is currently one of the major challenges facing the geothermal community. Several different investigations have been conducted in the pursuit of this energy source for more than 30 years. Annex III has now collected much of the information obtained during these investigations and produced a Project Management Decision Assistant (PMDA) handbook. The PMDA, which is now available, is a classifier that defines the data needed for and helps guide the developer through, each phase of an EGS power development, and it includes an overview of former and current EGS projects, a bibliography and a list of suppliers.

In 2005, EGS projects involving Annex III were being pursued in Australia, Germany, France, Switzerland and the USA. We now appear to be on the verge of success at Soultz-sous-Forêts (Alsace, France) where a joint international EC effort, involving Annex III, is being conducted. Three wells have been drilled to 5,000 m, and circulation and tracer tests conducted during 2005 show the first two wells have good connection, though the third well requires further stimulation. The construction of the first stage pilot plant is expected in 2006. Successful circulation tests have also been obtained at the Cooper Basin (Australia) EGS project, which will shortly be seeking commitment for construction of a demonstration power plant.

Deep Geothermal Resources Extend Resource Base

Temperatures of geothermal resources increase with depth, so being able to access their deeper realms can potentially extend an existing development’s production life, generate more electricity more efficiently, and even allow development of the generally lower temperature geothermal resources available over much larger regions of the world. However, there is a large variety of challenges associated with development of deep resources, which range from problems with locating and modelling them, technical difficulties in drilling to such depths, problems with producing from low-permeability zones, and complications arising from the chemical nature of the fluids accessed.

To commercially develop deep geothermal resources, Annex IV- Deep Geothermal Resources was designed to tackle these issues. However, due to the growing overlap of Annex IV activities with those in Annexes III and VII over the past few years, Annex IV efforts have slowed considerably. Consequently, Annex IV may be redesigned when its current term of operation ends in 2006.

Nevertheless, Annex IV’s studies in 2005 have succeeded in showing that it is possible to extract hot (> 100 ºC) fluids from sedimentary basin formations at depths greater than 4 km at Groß Schönebeck and Horstberg (near Hannover); and work is continuing on the development of such resources.

Reducing Geothermal Drilling Costs

The drilling of geothermal wells is an essential and expensive part of geothermal exploration, development and utilization. Reducing well drilling and completion costs, which can account for more than half the capital cost of a geothermal power project, can have very major benefits, and

Annex VII- Advanced Geothermal Drilling Technology is working to identify and promote the ways and means to do so. An important step towards helping reduce costs is in progress with Annex VII having completed a draft outline for a 'best practices' geothermal drilling handbook in 2005. Annex VII has also successfully conducted collaborative activities such as the 'Life Cycle Considerations for Geothermal Wells' workshop held in New Zealand and the Soultz EGS project presentation and discussion event conducted in the USA.

Using Geothermal Heat

Geothermal energy can be used directly as heat for a multitude of applications such as: building and district heating; industrial process heating; greenhouse heating; and temperature control for fish farming, bathing and swimming; and snow melting. In fact, the earth's very shallowest depths (< 100 m depth) can be utilized for home and building heating by employing geothermal heat pumps- practically anywhere on earth. As mentioned above, the growth in geothermal direct use has been outstanding, almost doubling every 5 years since 1995, and the scope for its continued growth is vast.

Though many direct use applications are well developed and economically viable, there remain challenges resulting from implementation difficulties and unfavourable economics. Annex VIII-Direct Use of Geothermal Resources was initiated to address all aspects of the direct use technology, with emphasis on improving implementation, reducing costs and enhancing use. The 'kick-off' meeting for this Annex was held in association with the 14^{th} ExCo Meeting held in Zürich, Switzerland, in September 2005. Efforts were begun with the introduction of physical and chemical data for the thermal manifestations of the participating countries; and specific projects pertaining to their evaluation and comparison were assigned.

NATIONAL ACTIVITIES

The national geothermal programmes of the countries participating in the GIA provide the foundation for the cooperative IEA geothermal activities. These programmes are directed toward the exploration, development and utilization of geothermal resources. A synopsis of the country activities is included in Chapter 7, with a comprehensive description of the current status of geothermal activities for each of the participating countries and the EC provided in Chapters 8-18.

During 2005, Contracting Parties from ten countries and the European Commission (EC) participated in the IEA-GIA. The member countries were: Australia, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Switzerland and the United States, with the Republic of Korea becoming the tenth Contracting Party in September 2005.

Contributions to Power Generation and Direct Use

In 2005, the 8 IEA-GIA Member Countries that have geothermal generation contributed 5,211 $MW_{e,}$ or about 59%, of the global geothermal installed capacity and 34,523 GWh/y, or about 61% of the generation (Table ES4). The United States was the major producer, generating well over the combined production of Mexico and Italy, who each generated over 5 GWh/y. The percent of national generation provided by geothermal in the 6 IEA-GIA Member Countries with non-negligible generation ranged from 0.4% for Japan, to 17% for Iceland, with an average of 4.8%. Note that the differences between the data presented here and that in Bertani (2005) may be ascribed to the different time periods they represent.

All 10 IEA-GIA member countries contributed to direct use applications, with a total installed capacity well in excess of 4,092 MW_t, or > 15% of the worldwide installed capacity. The thermal energy used was greater than 69,015 TJ/y (25,806 GWh/y), or about 25% of the worldwide total (Tables ES4 and 7.2 [refer to the complete GIA 2005 GIA Annual Report available at: www.iea-gia.org]). Though the smallest population GIA Member Country, Iceland was well in the lead, using about 26,000 TJ/y. As a non-high enthalpy geothermal country, Switzerland also had an extremely good showing, with an installed capacity of about 609 MW_t and use of 4,773 TJ/y.

PLANS FOR 2006

The GIA foresees a very busy 2006-year ahead of it. Research activities will proceed with strength, with Annex I- Environmental Impacts of Geothermal Development, Annex III- Enhanced Geothermal Systems and Annex VII- Advanced Geothermal Drilling having had their terms extended for another four years; and Annex VIII- Direct Use of Geothermal Energy beginning its initial work with comprehensive national data collection and review.

Table ES4. Total geothermal installed capacity and electricity generation in GIA Member Countries in 2005.

Country	Electrical Installed Capacity [MW]	Annual Energy Generated [GWh/y]	% of National Capacity	% of National Energy	Installed Thermal Power (MW_t)	Annual Energy Used (TJ/y)
GIA Member Countries	5,211	34,523	3.8*	4.8*	> 4,092	> 69,015
Worldwide Total**	8,902	56,798	8.4	9.2	28,269	273,372
GIA % of Worldwide Total	59	61	-	-	> 15	> 25

* Average % of 8 GIA Member Countries with non-negligible generation.
** Worldwide totals from Table ES1 (Bertani, 2005).

An emphasis will continue on improving and enhancing the visibility of the GIA's activities and achievements and on promoting geothermal energy as a clean and economic global energy resource. Participation at IEA seminars and other international renewable energy and geothermal conferences is already planned.

The GIA aims to pursue its efforts to grow membership, especially from the geothermal industry sector, where it is expected that new and different perspectives and ideas can be contributed.

In March 2007, the GIA's second 5-year term ends, and the Executive Committee is considering applying for a third term of operation. The associated activities, including the production of the End-of-Term Report and the development of a new Strategic Plan, will definitely make 2006 a very busy year.

REFERENCES

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

Hunt, T.M. (ed.) (2005) Six Annex I Environmental Papers. *Geothermics*, vol. 34, No. 2, April 2005.

IEA (2006) IEA Renewables Information 2006. Paris, France, 238 p.

Lund, J.W., Freeston, D.H. and Boyd, T.L. (2005) Direct application of geothermal energy: 2005 worldwide review. *Geothermics*, vol. 34, 690-727.