Zwischenbericht August 2004

# Projekt
# Arbeiten für das IEA Geothermal Implementing Agreement (GIA) 2004



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| Autor und Koautoren | Prof. Dr. L. Rybach |
| beauftragte Institution | Geowatt AG |
| Adresse | Dohlenweg 28 |
| Telefon, E-Mail, | 01 242 14 54 – rybach@geowatt.ch |
| Internetadresse | http://www.geowatt.ch |
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## ZUSAMMENFASSUNG

Im Berichtszeitraum 01.01. – 31.07.2004 fand das 11th Meeting des GIA Executive Committe (ExCo) in Paris statt (18./19.03.2004). Dabei wurde der Swiss Country Report 2003 präsentiert. Die weiteren, vielfältigen Arbeiten des Berichterstatters als GIA ExCo Vice Chairman sind im Zwischenbericht aufgeführt, wie auch Vorschläge zu einer verstärkten Beteiligung der Schweiz am GIA.

Der Zwischenbericht enthält auch zwei ausführliche und aufschlussreiche Dokumente, welche Direktinformation aus Ländern, die in der Geothermie führend sind, enthalten.

# Bericht über die Tätigkeiten von L. Rybach als Vice Chairman, IEA Geothermal Implementing Agreement (GIA) Executive Committee (ExCo)

**In der Zeit von 1.1. – 31.7.2004**

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## Arbeiten im ExCo

Das 11. Meeting des IEA GIA ExCo fand am 18. und 19. März 2004 in Paris statt. Die notwendigen Vorbereitungsarbeiten (u.a. Mitwirkung an den Arbeiten für die zu behandelnden Geschäfte) begannen schon im Januar 2004.

Dem Unterzeichneten obliegen im ExCo die Arbeiten für neue *GIA Participating Countries*. Anlässlich der ExCo Sitzung wurde der Stand der Bestrebungen präsentiert, für die GIA weitere Teilnehmer (insbesondere China, Frankreich, Türkei) zu gewinnen.

Ebenfalls am 11. ExCo Meeting wurde vom Unterzeichneten der *Swiss Country Report 2003* von L. Rybach und H. Gorhan präsentiert. Der Bericht ist im *GIA Annual Report 2003* enthalten (BEILAGE 1).

## Weitere Arbeiten

- Der umfangreiche und aufschlussreiche GIA Jahresbericht 2003 wurde nach diversen Vorläuferversionen, an denen der Unterzeichnete massgebend beteiligt war, im Juni 2004 abgeschlossen (BEILAGE 1).

- Bei der Redaktion des ausführlichen und aufschlussreichen Protokollentwurfs der 11. ExCo-Sitzung (BEILAGE 2) wurde ebenfalls mitgearbeitet. Dieser wurde im Juli 2004 fertiggestellt und wird an der nächsten ExCo Sitzung offiziell genehmigt.

- Bereits laufen die Vorbereitungsarbeiten für die 12. ExCo Sitzung. Diese wird in am 14./15. Oktober 2004 in Pisa/I stattfinden. Die Vorarbeiten zu den zu behandelnden Geschäften sind angelaufen. Besonders zu erwähnen ist die Vorbereitung der Beiträge zur IEA-Publikationen *Highlights 2003 –2004,* wozu die Schweiz das Project Management Decision Assistant (Produkt des Annex III/Subtask C) beiträgt.

- Einen weiteren Schwerpunkt bildet die Teilnahme des GIA am *World Geothermal Congress 2005* (25.-29.4.2005, Antalya/TR). Neben diversen Vorträgen wird die GIA auch einen Austellungsstand betreiben.

### Laufende Administration

Der Unterzeichnete wirkt als GIA ExCo Officer an allen Vernehmlassungen und Entscheidungen mit. Die weiteren Officers: Dr. David Nieva/Mexico (ExCo Chairman), Dr. Allan Jelacic/USA (ExCo Vice Chairman), Dr. Mike Mongillo (New Zealand (ExCo Secretary). Die Arbeiten werden weitgehend per e-mail abgewickelt. Im Durchschnitt erfolgen etwa drei e-mail Wechsel pro Tag (!). Diese Arbeiten nehmen entsprechend viel Zeit in Anspruch.

### Ausblick

Gegenwärtig wird im Rahmen von GIA Annex III (EGS, Enhanced Geothermal Systems) ein neuer Subtask E eingerichtet (*Field Studies of EGS Reservoir Performance*), worin insbesondere die Erschaffung und das Verhalten von EGS-Reservoiren, auch im Hinblick auf Nachhaltigkeit behandelt wird. Die Teilnahme der Schweiz, angesichts des nun voranschreitenden Deep Heat Mining-Projektes, ist mit Sicherheit vorteilhaft. Ferner eröffnet sich nun die Gelegenheit, am neuen Annex VIII (*Direct Use of Geothermal Energy*) teilzunehmen.

## Schlussbemerkung

Durch die Teilnahme der Schweiz am GIA (und insbesondere durch die verantwortungsvolle Rolle des Unterzeichneten im ExCo) wird ein regelmässiger Erfahrungsaustausch mit Ländern, die in der Geothermie führend sind, überhaupt erst ermöglicht. Hier sind insbesondere die Informationen bezüglich den neuesten Tätigkeiten des USA im Bereich von EGS (*Engineered Geothermal Systems*) für das schweizerische Deep Heat Mining Projekt (DHM) zu erwähnen. Anderseits kann das spezifische know-how der Schweiz im internationalen Rahmen Anerkennung erfahren. Es sind weiterhin interessante und wertvolle Informationen und Kontakte zu erwarten, z.B. zum ZIP-Programm/Deutschland mit zahlreichen DHM-artigen Vorhaben.

BEILAGE 1: GIA Annual Report 2003

BEILAGE 2: Minutes of the 11th GIA Executive Committee Meeting

Zürich, 10. August 2004

(Prof. Dr. L. Rybach)

INTERNATIONAL ENERGY AGENCY

# IEA Geothermal Annual Report 2003

**International Energy Agency (IEA)**
**Executive Committee for the**
**Implementing Agreement for**
**Cooperation in**
**Geothermal Research and Technology**

**June 2004**

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**Website for further information on the IEA GIA:** http://www.gns.cri.nz/GIA/index.html

**Cover Photograph:** The Nesjavellir Geothermal Plant, Iceland (Emil Thor and International Geothermal Association).

## MESSAGE FROM THE CHAIR

The year 2003 was one of continued change for the Geothermal Implementing Agreement, as its Executive Committee (ExCo) adjusted to a new *modus operandi*, and the focus and levels of funding for geothermal research changed in several of the participating countries.

From 1997 through 2001, the GIA relied on the generosity of previous ExCo Chairmen, Prof. Ladislaus Rybach and Dr. John Garnish, to carry out the heavy load of administrative matters, with no more aid than limited cooperation from some of their colleagues. In 2002 the GIA made the decision to create a common fund specifically to engage the services of a geothermal professional to act as Secretary to the ExCo, and thus to relieve most of the administrative burden from the ExCo Chair. The loss of two important participants, the United Kingdom and Greece, who chose to withdraw from the GIA because the establishment of a common fund proved incompatible with the internal regulations of their institutions, was an important consequence of this decision. In spite of these sensible losses, the level and quality of activity that the ExCo has been able to attain, which results, in good measure, from the support provided by the ExCo Secretariat, leaves no doubt that the decision was correct. Thanks are in order for the Institute of Geological & Nuclear Sciences Limited (New Zealand), and in particular for Dr. Michael Mongillo, who has been an extremely efficient Secretary to the ExCo.

The adjustment of research needs and levels of funding led to an ongoing revision of some of the older tasks and Annexes, which will most likely lead to the merging of some of them. The GIA is determined not to abandon any important research front. As expected, Iceland became a Contracting party in 2000 and proved to be a blessing for the GIA, with this country taking the leadership of the proposed Annex VIII on Direct Use of Geothermal Energy, which was formally approved and became active in September 2003.
Changes in the GIA run deeper than those related to the operation of the ExCo, and those imposed by factors mentioned above. The proposed Annex IX on Market Acceleration for Geothermal Energy, although not yet adopted, nevertheless led to deliberations that forced the ExCo to reconsider the role of the GIA in the advancement of geothermal energy utilization throughout the world. Although these deliberations led to a reinforcement of its initial objective, namely to become a positive influence in the planning of geothermal research in the participating countries, they also signaled the necessity of the GIA joining forces with the IEA Renewable Energy Unit (REU) and Renewable Energy Working Party (REWP) in working towards the abatement of institutional barriers to development, and increasing investors' and public awareness of the benefits of geothermal energy. Given the nature of most of the GIA members, it is nearly impossible to create a common fund for anything other than research-related activities. However, we have managed to reach an agreement with the REU and the REWP, through which the GIA will support their activities by providing reliable technical and economic information on geothermal energy, by participating actively in promotional forums and expositions, and by helping to channel international funds to develop geothermal resources in countries not yet utilizing this source of energy.

Despite the recent loss of members, the GIA carries the representation (with some important exceptions) of the leading geothermal-based electric power generating countries in the world. It also benefits from the participation of countries which are most advanced in the direct use of their geothermal resources. The GIA also enjoys the participation of supporters of some of the most important exploratory research for EGS (Enhanced Geothermal Systems), notably the Soultz-sous-Forêts project in Alsace, France, and the Cooper Basin project in Australia. With these combined forces, I am confident that the GIA will play a very important role in geothermal development in the coming years.

Dr. David Nieva, Chairman, IEA-GIA, 2003

## INTRODUCTION

The IEA's involvement in geothermal energy began in 1978, with the launching of the "Man-Made Geothermal Energy Systems" Project (MAGES) Implementing Agreement (IA) in the IEA Energy Technology Collaboration Programme (ETCP). One year later, the "Geothermal Equipment Testing" IA began. However, upon the completion of these two 3-year long studies, there was a hiatus in geothermal activities until the IEA Secretariat in Paris initiated an effort to revive them in 1995.

In May 1995, an *ad-hoc* meeting was convened in Florence, Italy, in conjunction with the World Geothermal Congress'95, where representatives of 14 countries expressed general interest in international collaboration under the IEA ETCP umbrella. An IEA Geothermal Expert Panel was formed specifically to prepare the IA Annexes. The legal text and three technical Annexes of the IEA Implementing Agreement for a Cooperative Programme on Geothermal Research and Technology, or Geothermal Implementing Agreement (GIA), were formulated in two subsequent meetings in Paris (November 1995, April 1996) with significant assistance from the IEA Secretariat. The GIA officially went into effect on 7 March 1997, with an initial operating period of five years. In late 2001, the Agreement was extended for a second 5-year term, to 31 March 2007, with the approval of the Renewable Energy Working Party (REWP) and the IEA Committee on Energy Research and Technology (CERT).

The GIA provides an important and flexible framework for broad international cooperation in geothermal R & D, which seeks especially to overcome barriers to the development of geothermal energy utilization. Important national programmes are brought together with a focus on assembling specific know-how and generating synergies by establishing direct cooperative links among geothermal experts in the participating countries (Table ES1).

GIA activities are directed primarily toward the coordination of the ongoing national activities of the participating countries, and encompass a range of geothermal topics, from "traditional" uses such as power generation and direct use of heat, to new technologies pertinent to enhanced geothermal systems (EGS) and deep resources. New activities are also initiated and implemented when needs are established.

## THE OBJECTIVES AND NEW STRATEGIC PLAN

The GIA's first Strategic Plan, produced at its formation in 1997, identified the organization's goal as: *to encourage and support the worldwide use of geothermal energy*. To attain this goal, objectives were specified that included conducting 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.

Though these efforts kept the GIA on track for its initial years, it was later recognized that the basic environment in which the GIA operated had changed since 1997, and continues to do so. Consequently, a new Strategic Plan was designed to guide the organization through the 2002-2007 term (accepted in 2003). It reflects the actions underway, and those being considered, by the GIA in response to market, management and government policy dynamics, as well as technological advances. It specifies the mission for the second term as being: *to advance and support the use of geothermal energy on a worldwide scale by overcoming barriers to its development*. To do so, the original objectives were augmented with additional ones specifically focused on increasing worldwide use of geothermal energy as follows: 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 leverage limited R&D funding through association with the IEA.

## NATIONAL PROGRAMMES

The foundation for the IEA geothermal cooperation activities is the national geothermal programmes of the participating countries. These programmes are directed toward the exploration, development and utilization of geothermal resources. Summaries of the current situation and progress in geothermal activities for each of the participating countries and the EC are provided in Chapters 8-18.

During 2003, Contracting Parties from 10 countries and the European Commission (EC) participated in the IEA-GIA. The member countries were: Australia, Germany, Greece, Iceland, Italy, Japan, Mexico, New Zealand, Switzerland and the United States. In addition, China, France, Turkey and the Philippines were actively encouraged to join, with the Philippines already participating on an informal basis in Annex IV. The GIA is also investigating extending participation in the programme to Russia and Sweden.

## COLLABORATIVE ACTIVITIES

Participants in the 2003 IEA GIA worked on four research tasks, specified in Annexes I- Environmental Impacts of Geothermal Energy Development, III- Enhanced Geothermal Systems, IV- Deep Geothermal Resources and VII- Advanced Geothermal Drilling Techniques. Three of these annexes (I, III and IV) were part of the original GIA and are continuing into the second term, as is the fourth (VII), which was started in 2001. In addition, a fifth annex, Annex VIII- Direct Use of Geothermal Energy, was initiated in September 2003, with the remainder of its year's efforts directed to setting up the programme. Three additional tasks have been identified as new areas for cooperative research, and the relevant annexes have been drafted (see Table 1.1 for Annex status details).

The involvement of the participants in the Annexes is shown in Table 1.2. It should be noted that participants take part only in those Annexes that are relevant to their current national research and development programmes. The tasks in each Annex are divided into Subtasks, and not all participants are active in all Subtasks of those Annexes in which they participate.

The first term of the GIA (7 March 1997-6 March 2002) operated under the task-sharing mode of financing. It is anticipated that the second term will operate similarly, with the possible exception of Annex VIII (Direct Use), which may also include cost-sharing Subtasks.

The actual amount of work conducted under the auspices of the GIA has not been quantified, though it can be assumed that the involvement of the individual countries is somewhere on the order of one to several man-year(s).

A review of the geothermal situation and progress made by each Contracting Party is provided in Chapter 7, with details reported in individual Country Reports in Chapters 8-18. The title, brief description, status and list of highlights for each of the Annexes are provided here, with more complete details available in the Annex Reports included in Chapters 2-6. More information about the GIA's activities may be obtained by contacting the Operating Agent for the Annex of interest listed in the Annex Reports or the GIA Secretary (iea-giasec@gns.cri.nz).

## ANNEX SUMMARIES

Summaries of the GIA Annexes, including those in draft form and one now closed, are presented here. Detailed discussions of objectives, results and work planned for 2004 are provided for the five active Annexes as Annex Reports in Chapters 2-6.

### ANNEX I - Environmental Impacts of Geothermal Energy Development

In order to expand the use of geothermal energy, possible environmental effects need to be clearly identified and methods devised and adopted to avoid or minimize their impacts. The main activities of this Annex directed toward these issues are divided into three subtasks: to investigate the impacts of development on natural features; to study the problems associated with discharge and reinjection of geothermal fluids; and to examine methods of impact mitigation and produce an environmental manual (see Chapter 2).

The work on this Annex began in 1997 and was extended by the ExCo in 2001 to continue through 2005.

**Highlights of 2003 Annex I Activities**

Improved techniques were developed for the monitoring of heat flux and $CO_2$ in areas of steaming ground. Subsidence modelling was improved, providing a more reliable basis for future prediction and possible mitigation, remediation and avoidance strategies. A better understanding of processes for reducing hydrogen sulphide and mercury emissions, and removing arsenic from wastewater, was also achieved.

Many of the Annex results have been discussed at, and disseminated through, participation at conferences in Iceland and New Zealand. In addition, 10 scientific papers describing these results have been published.

The Operating Agent for this Annex is the Institute of Geological and Nuclear Sciences, Limited (IGNS), New Zealand. Chris Bromley (IGNS, Wairakei) is the Task Leader.

**ANNEX II - Shallow Geothermal Resources**

Though this Annex reached the draft stage, the ExCo made the decision in October 2000 to close it. Its major topic, which was associated with the application of geothermal heat pumps, is now included in new Annex VIII- Direct Use of Geothermal Energy, which became active in September 2003.

**ANNEX III - Enhanced Geothermal Systems (EGS)**

The objective of this Annex is to investigate new and improved technologies that can be used to artificially stimulate a geothermal resource to allow commercial heat extraction (see Chapter 3 for details). The work in this Annex is divided into three subtasks: to review the use of conventional and new geothermal technology to enhanced geothermal system technology; to collect information necessary for decision making, design and the realization of a commercial EGS energy producing plant; and to review and evaluate geochemical and modelling techniques for determining reservoir characteristics. A fourth subtask to evaluate the economics of hot dry rock systems was successfully completed in 2001, with an economic model posted on the Internet in 1999 (http://web.mit.edu/hjherzog/www/) and its usefulness demonstrated in the evaluation and planning of a project in Australia in 2001 (see IEA Geothermal Annual Report 2002, Chapter 3).

Work on this Annex started in 1997 and was extended by the ExCo in 2001 for another 4 years to 2005.

**Highlights of 2003 Annex III Activities**

A new down-hole motor was successfully tested for drilling a highly deviated well at the Geysers Geothermal Field. The use of shear-wave splitting as a fracture characterization tool was developed and will be applied in conjunction with the future Coso massive hydraulic fracture test. Research into the modelling of injection into depleted steam reservoirs continues. Development of new methods for interpreting tracer tests to estimate fluid flow paths and velocities and temperature flow in fractured geothermal reservoirs continued with the goal of producing a simple set of tools for test interpretation in single- and two-phase, fractured geothermal reservoirs. It was decided that the presentation format of the Project Management Decisional Assistant (PMDA) for EGS projects will be a hardcopy (i.e. loose-leaf ring binder system) classifier and work has begun on the design and production of the first version. Drilling, acoustic emission, hydraulic fracturing and modelling/simulation data were compiled for the “Overall Compilation and Review of Hijiori HDR Experiments” as part of the EGS reservoir evaluation project. Very good progress continued on both the European EGS Project Soultz, with successful hydraulic stimulation and the start of second production well drilling; and the Australian Cooper Basin project, with the successful completion of its first well and very positive hydraulic stimulation results.

Many of the results from Annex III were presented at international workshops and conferences in the USA and Mexico. Twelve scientific papers describing the results were also published.

The Operating Agent is the New Energy & Industrial Technology Development Organization (NEDO), Japan. I. Matsunaga (AIST, Tsukuba) is Task Leader.

**ANNEX IV - Deep Geothermal Resources**

This Annex addresses issues necessary for the commercial development of deep geothermal resources at depths greater than about 3,000 m. The activities have been divided into three subtasks: research on exploration technologies and reservoir engineering for deep, hot reservoirs; investigation into drilling and logging techniques; and exchange of information and establishment of a database on fluid chemistry, material properties and corrosion issues, together with field-testing (Chapter 4).

The work of this Annex is closely related to that in Annex III (EGS) because enhanced geothermal systems studies are being pursued in several regions where the desired high temperatures are reached at much greater depths (> 4,000 m) than in the "normal" high-temperature geothermal fields. Consequently, some of the projects are "cross-over" projects, with activities being pursued in both Annexes. This overlap of project work within the two Annexes is currently being sorted out.

Work on this Annex began in 1997 and was extended in 2001 by the ExCo for another 5 years to 2006.

**Highlights of 2003 Annex IV Work**

The first deep geothermal well to be drilled in Australia, in the Cooper Basin, was successfully completed to a depth of over 4,300 m, where fractures and joints were encountered and temperatures in excess of 250 °C reached. As part of the European Soultz project, a third well was successfully drilled and very successful hydraulic tests performed that created two separate reservoirs at temperatures of 165 °C and 200 °C. As part of the German deep geothermal project at Bad Urach, the first well was drilled to about 4,200 m, with subsequent stimulation tests creating a deep reservoir at 3,300-4,200 m depth where temperatures of about 170 °C were attained. Conceptual models of Mexican geothermal fields with deep reservoirs were updated and a new computer code for the rigorous simulation of heat and mass transport in high temperature reservoirs, including effects of high non-condensable gas, was developed and successfully tested.

Several of the Annex participants presented results at a geothermal conference in Iceland and several reports and six scientific papers were published.

Project Management Organization Jülich, Germany, is the Operating Agent. Andrea Ballouk was Task Leader until September 2003, when Dieter Rathjen replaced her. Both leaders are from Project Management Organization Jülich, Germany.

**ANNEX V - Sustainability of Geothermal Energy Utilization**

The objective of this Annex is to study the important aspects of energy production from geothermal resources with the view of determining the long-term economic sustainability of such production.

There was no significant activity towards the development of this Annex during 2003.

**ANNEX 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 has been prepared, though no further consideration was given to it in 2003. The ExCo agreed that it would be implemented as soon as two or more participants agreed to join.

**ANNEX VII - Advanced Geothermal Drilling Techniques**

This Annex pursues advanced geothermal drilling research and investigates all aspects of well construction with the aim of reducing the costs associated with this essential and expensive part of geothermal exploration, development and utilization. The investigation is divided into three subtasks: the compilation of geothermal well drilling cost and performance information that is maintained on a database; production of a geothermal drilling best practices handbook; and monitoring and exchange of information on drilling technology development and new applications (Chapter 5).

This study began in 2001 and will continue through 2005.

**Highlights of 2003 Annex Activities**

The working group for this Annex held two meetings that discussed subtask objectives and specific activities performed in 2003, with excellent participation by members. The format for the presentation of well cost/performance data was defined and first group of well-cost data sets placed into the database. Agreement was reached on the outline for the high-temperature part of *Geothermal Drilling Best Practices Handbook*. Preliminary discussions for collaborative testing at Cerro Prieto, Mexico, were held.

The Operating Agent is Sandia National Laboratories, USA. The Task Leader was John Finger (Sandia, Albuquerque, USA) until November 2003, when Ed R. Hoover, also of Sandia, took over.

**ANNEX VIII - Direct Use of Geothermal Energy**

Geothermal energy can be used directly as heat for many applications such as building and district heating, industrial process heating, commercial uses such as greenhouse heating and temperature control of water for fish farming, bathing and swimming, and many others. Many applications are well developed and economically viable, while implementation problems and unfavourable economics challenge others. The Direct Use Annex will address all aspects of the technology with emphasis on improving implementation, reducing costs and enhancing use.

This study will continue through 2007.

**Highlight for 2003**

The Direct Use of Geothermal Energy Annex is the most recent annex to be included in the GIA. It officially commenced on 19 September 2003, when the agreement entered into force. Work in the Annex is expected to begin in late 2004.

The Operating Agent is The Federation of Icelandic Energy and Waterworks, Reykjavik, Iceland, and the Task Leader is Einar Gunnlaugsson.

**ANNEX IX - Geothermal Market Acceleration**

Though geothermal electricity production and direct heat use are well developed and economically viable in many parts of the world, there are large untapped resources in many countries. The ExCo has been exploring ways to hasten geothermal energy development, or market acceleration, in these countries for the last few years, and decided that a more pro-active approach was needed and might include: 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, a market acceleration Annex was drafted.

The draft Annex was discussed at length at both the March and September ExCo meetings in 2003, with concerns raised over “who” should implement the Annex and the requirement for a common fund to finance it. The decision was made at the September 2003 ExCo Meeting to re-write the Annex to include only those activities that the GIA was able to provide. Work on developing the Annex continues.

## EXECUTIVE COMMITTEE ACTIVITIES

**Officers**

Dr David Nieva (Mexico) served as Chairman for 2003. Dr Ladislaus Rybach (Switzerland) and Dr Allan Jelacic (USA) served as Vice-Chairs for Policy and Administration, respectively, in 2003.

**Membership**

There were two changes in the ExCo composition in 2003, both for Germany. Dieter Rathjen and Norbert Stump replaced Andrea Ballouk and Hubert Hoewener as the Member and Alternate Member, respectively.

The list of ExCo Members and Alternates for 2003 is provided in Appendix B.

**Meetings**

The ExCo held two Meetings in 2003 to discuss and review ongoing tasks and plan future activities.

The 9th ExCo Meeting was held on 13-14 March 2003, in Paris, France, and was hosted by the International Energy Agency (IEA) Headquarters. There were 17 attendees, including nine ExCo members and two

Alternate Members, three ExCo Observers (Annex members) and two IEA staff members, plus the interim Secretary. The ExCo approved unanimously the election of David Nieva as Chairman and Allan Jelacic and Ladislaus Rybach as Vice-Chairmen. The Institute of Geological and Nuclear Sciences Limited bid to operate the GIA Secretariat with Mike Mongillo as ExCo Secretary was confirmed unanimously. Reports were presented on the progress made in each of the Annexes and the name of Annex III was changed from 'Hot Dry Rock' to 'Enhanced Geothermal Systems' in recognition of its broader task coverage. The ExCo agreed to cancel further consideration of proposed Annex VI- Power Generation. A revised draft of Annex V- Sustainability of Geothermal Energy Utilization was presented, as was Iceland's draft of Annex VIII- Direct Use of Geothermal Energy. There was further discussion on Annex IX- Market Acceleration and it was noted that the IEA might initiate a programme on international energy technology cooperation that could supplant this Annex. The decision was made to change the format of the IEA Geothermal Annual Report to make it more comprehensive by including a section on National Activities of the participants. The Common Fund had been established at NREL (USA) at the end of 2002, and Member countries were invoiced for 2003 dues.

The 10th ExCo Meeting was organized and hosted by Orkustofnun (National Energy Authority), Reykjavik, Iceland, on 18-19 September 2003. There were 15 attendees, including eight ExCo Members and two Alternates, four ExCo observers and the GIA Secretary. A review of the new Secretariat work plan was presented and based upon the operational costs reported and the good health of the financial balance, the decision was made by majority vote to reduce the Common Fund "share cost". The Secretary reported that the revised IEA Geothermal Annual Report 2000 was completed and submitted to the IEA as agreed and a paper: *The IEA Geothermal Implementing Agreement - Its Goals, Status, Achievements and Prospects*, had been written and published, and presentations of it made at two conferences (Mexico and Budapest). Revisions of the Strategic Plan for 2002-2007were discussed, with agreement that the final version would be distributed to the ExCo Members for acceptance by the end of the year. Annex work and Country Reports were presented and reviewed. A revised draft of Annex V-Sustainability was presented and discussions led to the decision that the Members investigate the possibilities for obtaining contributions for a common fund for certain tasks. It was decided that Annex V be suspended until further information was obtained. Again, Annex IX- Market Acceleration was discussed with concerns over who should implement it and the requirement for a common fund to finance it. It was decided to change the activities to include only those that the GIA could provide. New Annex VIII-Direct Use of Geothermal Energy was officially started with three participants joining. Issues relating to increasing GIA membership were discussed and it was reported that all of the countries contacted were interested; though cost matters remained a stumbling block. The UK's withdrawal due to their Contracting Party's inability to meet their Common Fund contribution obligation was discussed and encouraged the decision to reduce the share-cost as mentioned above. Following the meeting, our Icelandic hosts conducted field trips to several geothermal direct use and electricity generating facilities and geothermal areas.

**Conference Participation**

The ExCo has recognized the importance of promoting the GIA and its activities in order to encourage geothermal energy use as well as increase membership in the organization. As a part of these efforts, a paper describing the GIA was written: *The IEA Geothermal Implementing Agreement- its status, highlights and future prospects* and presented at the GRC Annual Meeting Conference in Morelia, Mexico and at the IEA Budapest Forum meeting. The paper was also published in the GRC 2003 Transactions proceedings.

## COSTS OF THE AGREEMENT

It became clear in 2001that the decision to increase the scope of activities of the GIA would require greater resources than could be provided by a voluntary ExCo Secretary. In order to carry out the planned new tasks, including: production of GIA documents, papers and brochure(s), creation and maintenance of a new GIA archive and website, maintain timely communication among the Members, *etc*. it was necessary to establish a dedicated Secretariat, which became operational in March 2003. The expenses for running the GIA Secretariat, including the Secretary's salary and travel, and other common costs of the ExCo, are met from a Secretariat Common Fund. This Fund is administered by the Custodian, presently the National Renewable Energy Laboratory (NREL) (USA), who also provides regular accounting reports to the ExCo.

To support the Common Fund, the IEA has provided general guidance on a fair apportionment of monetary contributions in the form of shares assigned to different Member States of the OECD. Based on current membership, the apportionment for the GIA is shown in Table ES1.

**Table ES1** Common fund share apportionment among the GIA Members as of May 2003.

| | | | |
|---|---|---|---|
| Australia | 2 | Japan | 4 |
| European Commission | 4 | Mexico | 1 |
| Germany | 4 | New Zealand | 1 |
| Iceland | 1 | Switzerland | 2 |
| Italy | 2 | United States | 4 |
| ***Total = 25 shares*** | | | |

The ExCo has set the present cost per Common Fund share at US$ 2,500/year. With the addition of new members, or the withdrawal of current ones, the total number of shares may increase or decrease, affecting each member's contribution. Contributions are made annually on a calendar year basis. The number of shares assigned to new members who are non-Members of OECD will be determined by the ExCo acting in unanimity.

## PLANS FOR 2004 GIA

The GIA will continue to strive to improve and enhance the visibility of its work and results, and to encourage the use of geothermal energy worldwide. We recognize the importance of explaining geothermal energy, and the local and worldwide contributions it can, and is making, especially to non-experts, particularly decision makers. The GIA's 2002-2007 Strategic Plan provides a guide for collaborative technology development, deployment, information dissemination, and market acceleration that will help achieve these goals.

As stated in 2002, the second term of the GIA (2002-2007) faces some uncertainties. The first term (1997-2002) has shown that governmental funding of geothermal R&D can be unstable and unpredictable, and there are signs of this continuing. Besides the year-to-year changes, there are contrasting tendencies and trends: whereas in some countries the funding has decreased continuously, other countries are speeding up their geothermal efforts. These somewhat unclear perspectives call for a strong dedication and efforts in the second term of GIA activities.

# CHAPTER 1

## The Implementing Agreement

### 1.1 Activities of IEA Geothermal Research and Technology Programme

Geothermal research and technology cooperation under the auspices of the IEA began in its present form in March 1997, with the signing of the Implementing Agreement for a Cooperative Programme on Geothermal Research and Technology (IEA GIA). This programme revived the IEA geothermal research collaboration that had lapsed with the completion of two earlier Implementing Agreements: the "Man-Made Geothermal Energy Systems" (MAGES) Project (1978-1980) and the Geothermal Equipment Testing Project (1979-1981).

In late 2001, near the conclusion of its first 5-year term of operation, the GIA recognized that though the organization's efforts had been quite successful, the basic environment in which the it worked had altered (and continues to evolve) as the result of changes in market, management and government dynamics, and technological advances. Consequently, with the extension of the GIA for a second term, to 2007, the GIA modified its mission for the new Strategic Plan: *to advance and support the use of geothermal energy on a worldwide scale by overcoming barriers to its development.*

The original objectives of the IEA Geothermal Research and Technology (R&T) Programme still remain the major guides for the organization and are 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 ameliorate its environmental drawbacks.

However, in light of the modified mission, additional objectives have been added to augment them, and include:

- **Expand R&D collaboration:** Geothermal energy technology development is progressing and new areas of collaboration are required. Table 1.1 contains a summary of current collaborative efforts under the GIA. The Executive Committee (ExCo) will consider and implement annexes where additional collaboration could be useful.

- **Increase the number of participants:** There are a large number of countries with significant geothermal resources that are not yet Members of the GIA. Many of them could make important contributions to the GIA and assist with expanding worldwide geothermal development. The GIA is actively seeking membership and extends an open invitation to interested parties to contact the ExCo or Secretariat for information about joining the organization.

- **Increase outreach to non-Member countries with large geothermal energy potential:** The electricity markets in many countries were opened to competition in the 1990s. As energy markets deregulate, they are driven more by market forces and less by government programmes and intervention. Environmental impacts of energy development have become increasingly important. New regions are opening up as international energy markets expand. Although research is still needed on advanced geothermal technology, the GIA will embrace this opportunity and explore ways to accelerate development of the world's geothermal resources.

- **Evaluate market stimulation mechanisms:** In the ExCo's efforts to expand geothermal heat and power markets in both OECD and non-OECD countries, research actions are clearly important and indeed essential, but they are not in themselves sufficient to open up markets. Market stimulation is also needed to create an expanded market for geothermal energy.

- **Improve dissemination of information about geothermal energy:** The ExCo has recognized its role in promoting the use of geothermal energy, but more emphasis is needed on the open distribution of high quality and attractive information products. The GIA is actively pursuing this issue, and as a part of its effort, is currently developing its website, annual reports and a brochure in order to provide information in a more understandable and appealing manner.

- **Leverage limited R&D funding:** The R&D budgets of many of the participants have been declining, and the need for cost-shared collaboration is increasing. An affiliation with the IEA brings added value to activities rather than funding. The IEA's reputation of technical competence and broad unbiased excellence can be leveraged to obtain support from industry and other multilateral organizations and financial institutions.

**Table 1.1** Annex title, Operating Agent and status of GIA Annexes (as of December 2003).

| **Annex No.** | **Title**<br>**Operating Agent (OA)** | **Status** |
|---|---|---|
| **I** | Environmental Impacts of Geothermal Development<br>OA: Institute of Geological and Nuclear Sciences Limited (IGNS), New Zealand | Active, Continuing through 2005 |
| **II** | Shallow Geothermal Resources | Closed |
| **III** | Enhanced Geothermal Systems<br>OA: New Energy & Industrial Technology Development Organization (NEDO), Japan | Active, Continuing through 2005 |
| **IV** | Deep Geothermal Resources<br>OA: Forschungszentrum Jülich, Germany | Active, Continuing through 2006 |
| **V** | Sustainability of Geothermal energy Utilization | Draft |
| **VI** | Geothermal Power Generation Cycles | Draft |
| **VII** | Advanced Geothermal Drilling Techniques<br>OA: Sandia National Laboratories, United States | Active, Continuing through 2005 |
| **VIII** | Direct Use of Geothermal Energy<br>OA: The Federation of Icelandic Energy and Waterworks, Iceland | Active, Continuing through 2007 |
| **IX** | Geothermal Market Acceleration | Draft |

Control of the Geothermal R&T programme is vested in the Executive Committee (ExCo), which comprises one member and one alternate from each of the Contracting Parties. There is typically one Contracting Party for each country, which is usually a government department or agency. The ExCo meets in regular session twice each year to exchange information, discuss progress in each of the tasks and in each of the participating countries, and plan future activities. Decisions are made by majority vote, unless otherwise specified in the IA. As a consequence of the ExCo's decision, in 2002, to increase the scope of the GIA's activities, a dedicated Secretariat was established in March 2003 and is funded by a Common Fund.

The GIA's programme is implemented through the conduct of collaborative projects called tasks, which are described in detail in annexes to the Implementing Agreement (IA) (Chapters 2-6). The Tasks are first approved by the ExCo, and then appended as annexes to the IA. These tasks, referred to by their annex number, are managed by an Operating Agent organization within one of the Member countries. It is estimated that the level of effort spent by each country on GIA activities is on the order of one to several man-years. Up to the end of 2003, all of the GIA annex activities have operated under the "task-sharing" mode of funding. This may change in the near future as a result of an increased scope of activities through the addition of Annex VIII- Direct Use of Geothermal Energy.

The GIA research 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 will be made more widely available on a new GIA website to be operational by mid-2004.

In 2003, 10 countries and one international organization formally participated in this programme (Table 1.2).

**Table 1.2** Country participation in and funding sources for the current Annexes (as of December 2003).

| Participating Country | Annex I (Environment) | Annex III (Enhanced Geothermal Systems) | Annex IV (Deep Resources) | Annex VII (Advanced Drilling) | Annex VIII (Direct Use) |
|---|---|---|---|---|---|
| Australia | | P | P | | |
| EC | | P | | P | |
| Germany | | P | P | | |
| Greece | P | | | | |
| Iceland | P, I | | | P | P |
| Italy | I | I | I | | I |
| Japan | P | P | P | P | P |
| Mexico | P | | P | P | |
| New Zealand | P, I | | P, I | I | P |
| Switzerland | | P | | | |
| USA | P | P | P | P | P |

P = Publicly-funded research institute or university; I = Industry

## 1.2 Future Research Needs for Geothermal Energy Development

Worldwide geothermal installed capacity increased from 6,833 to 7,974 $MW_e$ between 1995 and 2000 (Huttrer, 2000); and it is believed that there is potential for a 45% increase between 2000 and 2010. The new growth is expected mainly from existing suitable resources, particularly in the developing countries of Latin America, Southeast Asia and Africa where the demand for electricity is growing rapidly. In addition, the worldwide installed capacity for geothermal direct heat use increased from about 8,664 $MW_t$ in 1995 to 16,209 $MW_t$ in 2000 (Lund and Freeston, 2000). Direct heat use is also expected to continue growing into the future, especially with the installation of geothermal heat pumps. Very good opportunities for such use exist in Central and Eastern Europe where resources occur near to demand areas. The total worldwide geothermal resource potential suitable for future development is estimated to be approximately 5,000 EJ/a [1 EJ = $10^{18}$ J] (WEA, 2000), with economic exploitation providing about 150 EJ/a for electricity generation and 350 EJ/a for direct uses (Bertani, 2003).

According to the IEA World Energy Outlook 2002 "Reference Scenario" (for OECD countries), forecasts show that geothermal electricity production could grow at 4% per annum during the period 2000-2010, with non-hydro renewable electricity production increasing from 2% in 2000 to about 4% in 2010. The "Alternative Policy Scenario" indicates that if all OECD countries' policies being considered to promote renewables are carried out, non-hydro renewables could provide about 6% of the total generated electricity in 2010.

The IEA GIA can play a significant role in helping attain the abovementioned ambitious targets.

### 1.3 References

Bertani, R. (2003) What is geothermal potential? IGA News, No. 53, July-September 2003, 1-3.

Huttrer, G.W. (2000) The status of world geothermal power generation 1995-2000. Proc. World Geothermal Congress 2000, Kyushu-Tohoku, May 28-June 10, 2000, 23-37.

Lund, J.W. and Freeston, D.H. (2000) World-Wide direct use of geothermal energy 2000. Proc. World Geothermal Congress 2000, Kyushu-Tohoku, May 28-June 10, 2000, 1-21.

WEA 2000. World Energy Assessment: energy and the challenge of sustainability. Ed. J. Goldemberg, United Nations Development Programme, UNDECOSOC, WEC, 2000.

# CHAPTER 2

## Annex I - Environmental Impacts of Geothermal Energy Development

### 2.1 Introduction

Environmental effects of energy use are a worldwide concern. Geothermal is generally regarded as a benign energy source. There are, however, some environmental problems associated with its utilization. To further the use of geothermal energy, possible environmental effects need to be clearly identified, and countermeasures devised and adopted to avoid or minimize their impact. Task 1 of the GIA was set up to address these issues, and is formulated in Annex I.

The goals of Task I are: to encourage the sustainable development of geothermal energy resources in an economic and environmentally responsible manner; to quantify any adverse or beneficial impacts that geothermal energy development may have on the environment, and to identify ways of avoiding, remedying or mitigating such adverse effects. The term "development" here is used in a broad sense to encompass not only energy production but also use for social and economic purposes such as tourism. These activities have been a part of the GIA since its inception in 1997, and in 2001the Annex was extended to 2005.

The specific objectives of Annex I are:

- To study the effects that existing geothermal developments have had on the environment and determine their cause.
- To identify the most likely and serious adverse effects that geothermal developments can have on the environment.
- To identify the development technologies that have proven to be environmentally sound.
- To publish the results of the studies in international journals and present the results at international forums.

To improve communications between individuals and organizations in different countries, and between different professional groups involved in geothermal development by involvement in collective presentation of the results in international forums.

During 2003, five countries were participating in Annex I: Iceland, Japan, Mexico, New Zealand, and United States of America. The participation of other geothermal countries that may join the IEA GIA in future (particularly Turkey, China, Philippines and Russia) was actively encouraged.

The Operating Agent for Annex I is the Institute of Geological & Nuclear Sciences Limited (IGNS), a Crown Research Institute owned by the New Zealand Government. The Task Leader is Chris Bromley.

### 2.2 Subtasks of Annex I

There are three Subtasks in this annex.

#### 2.2.1 Subtask A- Impacts on Natural Features (Subtask Leader: Chris Bromley, Institute of Geological & Nuclear Sciences Limited, Wairakei, New Zealand)

This Subtask focuses on documenting known impacts of geothermal developments on natural geothermal features such as geysers, hot springs and silica terraces. The aim of this subtask is to provide a sound historical and international basis on which to devise methods to avoid or mitigate the impacts of development on these geothermal features, which often have significant cultural and economic value.

Projects that examine the effects of geothermal developments on natural geothermal features are being conducted in Iceland, Japan, New Zealand and United States of America.

#### 2.2.2 Subtask B- Discharge and Reinjection Problems (Subtask Leader: Trevor Hunt, Institute of Geological & Nuclear Sciences Limited, Wairakei, New Zealand)

Work in this Subtask is focused on identifying and determining methods of overcoming the impacts of geothermal developments on other aspects of the environment. This includes the effects of gas emissions from geothermal power plants, effects of toxic chemicals in waste fluid that is discharged both into the ground and into rivers, effects of ground subsidence, and induced earthquakes.

Projects have been organized which examine the problems associated with disposal of waste geothermal fluids from existing geothermal developments in Iceland, Turkey and New Zealand. The effects of $CO_2$, Hg and $H_2S$ gas emissions in Italy, New Zealand, Iceland, the USA and Mexico are being investigated. The effects, causes and possible remedies for subsidence are being researched in New Zealand and Iceland.

### 2.2.3 Subtask C- Methods of Impact Mitigation and Environmental Manual

(Subtask Leader: Chris Bromley, Institute of Geological & Nuclear Sciences Limited, Wairakei, New Zealand)

The objective of this Subtask is to contribute to the future of geothermal energy development by developing an effective, standard environmental analysis process. Field management strategies that result in improved environmental outcomes will be identified and promoted based on operational experience. Successful mitigation schemes that provide developers and regulators with options for compensating unavoidable effects are also being identified, documented and promoted.

New Zealand, Mexico and the USA are the participants in this Subtask.

**Figure 2.1** Mokai , Tirohanga Rd steaming craters, an example of increased steam-heated activity occurring in March 2000 near the Mokai reinjection area, which has resulted in enhanced habitat for thermal vegetation (particularly mosses).

## 2.3 Work Performed in 2003

### 2.3.1 General

Some of the results of the ongoing environmental work conducted in Annex I were published and presented at international conferences in 2003 (see Output section below).

Comments on the planned general work tasks for 2003 follow:

- Further material was collected about the aims of the Annex and results obtained for the public website, but it requires processing.
- Six draft papers have been collected for a second Special Issue of *Geothermics* journal and are currently under review. Further attempts were made to encourage other authors to submit suitable papers.

- Organization of a Session on Environmental Aspects of Geothermal Development at the WGC 2005 geothermal conference, and planning of an Environmental Short Course for international participants at the Geothermal Institute, Auckland University are still under investigation.

- Papers were produced for the New Zealand Geothermal Workshop and International Geothermal Congress Reykjavik 2003, Iceland as part of the support for collaborative publications on topical geothermal environmental issues at leading international.

- Discussions with geothermal industry representatives (both developers and regulators) about longer-term R&D needs have identified new research requirements, particularly in the areas of monitoring $CO_2$ and convective heat flux from naturally steaming ground, classification of the vulnerability of thermal features to reservoir pressure changes, testing of mitigation and remediation methods, and development of bioremediation methods to remove arsenic from waste water discharges.

## 2.4 Highlights of Annex I Programme Work for 2003

The highlights for Annex I for 2003 include:

- Attendance and participation of environmental task participants in the International Geothermal Congress Reykjavik 2003 (IGC 2003) conference held in Iceland in September. This facilitated discussions on recent research results and future plans.

- Development of improved $CO_2$ and heat flux monitoring techniques in areas of steaming ground.

- Improvements in subsidence modelling, which will provide a more reliable basis for future predictions, and possible mitigation, remediation or avoidance strategies.

- Advances in understanding of the processes involved in reducing hydrogen sulphide and mercury emissions, and removing arsenic from wastewater.

## 2.5 Work Planned for 2004

The plan of general work to be conducted by the Annex in 2004 includes:

- Continue website development to inform the general public about the aims of the Annex and results obtained.

- Continue processing papers for a Special Issue of *Geothermics*.

- Provide support for collaborative publications on topical geothermal environmental issues at leading international workshops in New Zealand (NZGW), Philippines (PNOC-EDC), United States (GRC, Stanford), Japan (JGA) and Turkey (WGC 2005).

- Provide support and contacts for collaboration between geochemical researchers in Italy, Iceland, USA and New Zealand to study means of more reliably monitoring natural $CO_2$ emissions from thermal areas, in order to quantify the net long-term effects of geothermal development on global warming through $CO_2$ emissions.

- Encourage collaboration between researchers investigating the potential for thermophyllic bacteria to reduce toxic chemical contaminants from geothermal wastewaters by bio-remediation.

A list of specific ongoing projects by country follows:

### 2.5.1 Iceland

- Interpretation of TIR imagery over geothermal areas (Arnason, Kristmannsdottir, *University of Iceland*).

- Changes to natural thermal features as a result of development (Armannsson, Torfason, Kristmannsdottir).

- Environmental effects of surface water disposal in Iceland (Thorhallson, Kristmannsdottir).

- Production-induced ground subsidence and gravity changes in Iceland (Eysteinsson, Kristmannsdottir).

#### 2.5.2 Japan

- Environmental effects of acidic fumarole gases on rainwater chemistry (Itoi, *Kyushu University*)
- Chemical changes in hot spring waters (Oue, *Beppu*)

#### 2.5.3 Mexico

- Chemical and isotopic monitoring of atmospheric sulphur associated with $H_2S$ emissions from geothermal systems in the Mexican Volcanic Belt (Verma *et al.*, *IIE*)

#### 2.5.4 New Zealand

- Documentation of renewed hydrothermal activity in Rotorua from bore closures (Scott, *IGNS*)
- Numerical modelling of production-induced changes to hot springs and subsidence (Hunt, Bromley, *IGNS*)
- Natural and induced variations to geothermal features (Bromley, *IGNS*)
- Quantification of heat and $CO_2$ flux changes from steaming ground (Bromley, Hochstein, Mroczek and Werner, *IGNS*)
- Impacts of developments on thermophyllic vegetation (Sylvester, *Waikato University*)
- Biodiversity and biomineralization associated with thermophyllic bacteria in waste water from geothermal power plants (Mountain, *IGNS*)

#### 2.5.5 Turkey

- Environmental changes at Kizildere field (Simsek *et al.*)
- Removal of boron from Kizildere waters (Badruk *et al.*)

#### 2.5.6 USA

- Abatement of $H_2S$ emissions from power plants (various)
- Injection of $CO_2$ into underground aquifers (various)

### 2.6 Recent Outputs

#### *2.6.1 Proceedings of International Geothermal Conference (IGC 2003), September 2003, Reykjavik, Iceland:*

Andresdottir, A., Sigurdsson, O., Gunnarsson, T. (2003) Regulatory framework and preparation of geothermal power plants in Iceland- practical experience and obstacles.

Armannson, H. (2003) $CO_2$ emission from geothermal power plants.

Axelsson, G, Stefansson, V. (2003) Sustainable management of geothermal resources.

Bromley, C. J. (2003) Practical methods of minimizing or mitigating environmental effects from integrated geothermal developments, examples from New Zealand.

Gallup, D. (2003) Simultaneous hydrogen sulphide abatement and production of acid for scale control and well stimulation.

Lawless, J., Okada, W., Terzaghi, S., White, P., Gilbert, C. (2003) Two-dimensional subsidence modelling at Wairakei-Tauhara, New Zealand.

Wetang'ula, G., Snorrason, S. (2003) Ecological risk assessment of Nesjavellir co-generation plant wastewater disposal on Lake Thingvallavatn, SW-Iceland.

#### *2.6.2 Proceedings of the 25th New Zealand Geothermal Workshop, November 2003, Auckland, New Zealand:*

Brockelsby, M. (2003) Issues facing Waikato Regional Council in managing geothermal resources.

Bromley, C. J., Currie, S. (2003) Analysis of subsidence at Crown Rd Taupo, a consequence of declining groundwater.

White, S., Allis, R., Moore, J., Chidsey, T., Morgan, C., Gwynn, W., Adams, M. (2003) Injection of $CO_2$ into an unconfined aquifer located beneath the Colorado Plateau, Central Utah.

**Author:** Chris Bromley, IGNS, Wairakei, New Zealand

**Contact:** Chris Bromley: c.bromley@gns.cri.nz

# CHAPTER 3

# Annex III – Enhanced Geothermal Systems

## 3.1 Introduction

Enhanced Geothermal Systems (EGS) energy technologies have been conceived to extract the natural heat contained in high temperature, water-poor rocks in the earth's crust. Heat is extracted from rock formations that are either too dry or too impermeable to transmit available water at useful rates. Necessary permeability can be created by hydraulic fracturing or stimulation, which involves the high-pressure injection of a fluid into the reservoir to crack and enlarge pre-existing openings. The objective of the Enhanced Geothermal Systems Task is to address new and improved technologies, which can be used to artificially stimulate a geothermal resource to enable commercial heat extraction.

The countries and organization participating in Annex III are: Australia, Germany, Japan, Switzerland, USA and the EC.

The Operating Agent for Annex III is the New Energy and Industrial Technology Development Organization (NEDO), Japan. The Task Leader is Isao Matsunaga, AIST, Japan.

## 3.2 Annex III Subtasks

The work undertaken in Annex III is divided among three Subtasks. Note that Subtask A, involving the evaluation of the economics of EGS systems, was successfully completed in 2001, with an economic model posted on the Internet.

### 3.2.1 Subtask B- Application of Conventional Geothermal Technology to Enhanced Geothermal Systems (EGS)

(Subtask Leader: Joel Renner, Idaho National Engineering and Environmental Laboratory, USA)

Subtask B is aimed at reviewing new and future developments such as horizontal drilling, fracture mapping, and pumping in conventional geothermal energy, and their applications to EGS technology.

### 3.2.2 Subtask C- Data Acquisition and Processing

(Subtask Leader: Thomas Mégel, Geowatt AG, Switzerland)

This Subtask involves the collection of information necessary for the realization of a commercial EGS energy producing plant at each stage of reservoir characterization, design and development and of construction and operation. The relevant results and parameter values will be successively collated into a spreadsheet-like synoptic envelope, ready for use in the decision and design processing or, where necessary, to await further refinement and completion.

During the past 30 plus years EGS research projects in different countries have led to specific scientific, technical and organizational knowledge, which points the way towards the industrial construction of EGS power plants. It is of paramount importance, at this period of transition from research and development to commercial exploitation, for new project teams to have access to a synthesis of all the basic knowledge and experience acquired to ensure the successful and frictionless project start.

It was decided to attempt the assembly of a tool to give an overview of what has been achieved and how, without including all technical detail. Compiling an easily understandable management decisional tool for new EGS project teams, with no compromises in accuracy and clearness is a huge task. Nevertheless, it is an integrated part of every development process in the field of enhanced technologies. Thus the development of a tool in the form of a collection of relevant information has been foreseen. We refer to it as a Management Decisional Tool for EGS projects.

Its aim will be to provide an information framework for the project planning and construction of the first generation of commercial EGS plants. The tool, that is to say the resulting information collection, will be assembled to create what we have named a Project Management Decision Assistant (PMDA).

The concept includes documenting the availability of special tools and services and assembling an overview of data, data analyses and experiences (in the way of lists of reports and publications with their abstracts) gained at the major EGS projects worldwide since the early 1970's.

Four activity domains have been envisaged from the start:

- Because of the long gestation time of the EGS technology it was believed useful to document the experiences of the various R & D projects, both past and present, in the field.
- Create a list of literature references with abstracts wherever possible.
- Produce an index of potential suppliers, service operators and consultants with relevant experience would be produced.
- An overview of data requirements during planning and construction of a commercial EGS plant would be given using the idea of a Generic Project as a vehicle for presentation. This is based on a project plan. However its presentation does not show activities as such, but only the data requirements for completing project milestones.

### 3.2.3 Subtask D- Reservoir Evaluation

(Subtask Leader: Tsutomu Yamaguchi, AIST, Japan)

The overall objective of Subtask D is to compile and make clear what kind of methods, techniques, and tools are effective for reservoir evaluation; and then establish the evaluation method that can be applied to develop a new EGS site. An Internet questionnaire was developed and used in 2002 to obtain this information. Unfortunately, the answers, especially from countries other than Japan, were not sufficient to complete this task. Thus, in Subtask D, efforts will be focused on compiling Japanese data from the Hijiori and Ogachi fields.

## 3.3 Work Performed in 2003

### 3.3.1 Subtask B- Application of Conventional Geothermal Technology to EGS

The US DOE has sponsored several activities using hydrothermal technology for EGS. In addition, several projects initiated in response to research needs of the hydrothermal community are being implemented in geothermal fields with ongoing EGS projects. The work performed in 2003 included:

- A new down-hole motor, developed with DOE funding, was tested for horizontal drilling at The Geysers geothermal field. A report on the test has not been released but reportedly the tool worked well in drilling a highly deviated hole using misted water as the drilling fluid.
- DOE researchers and Caithness Energy continued planning for a hydraulic stimulation in the Coso geothermal field to enhance productivity. See Elkibbi and Rial (2003a), Rose *et al*. (2003) and Sheridan *et al*. (2003).
- The current phase of work by Rial and co-workers on the use of shear-wave splitting as a fracture characterization tool has been completed. The results should be published in 2004. This work is being applied in the Coso massive hydraulic fracture test. See Elkibbi and Rial (2003b).
- DOE researchers continue to analyze the effect of injection into The Geysers steam reservoir. They continued modelling a portion of the field that will see a marked increase in injection during 2004. Researchers also conducted laboratory tests of water injection into Geysers type systems. See Bloomfield *et al*. (2003), Moore *et al*. (2003), and Reyes and Horne (2003).
- New methods for interpreting tracer tests are being developed, to estimate fluid flow paths, sweep efficiency, and fluid and temperature velocities in fractured geothermal media. This work extends the techniques currently available for test analysis in hydrothermal and oil and gas reservoirs. These analysis methods will largely follow those previously developed at Idaho National Engineering and Environmental Laboratory and will result in a simple set of tools for test interpretation in single- or two-phase, fractured geothermal reservoirs. See Shook (2003).

### 3.3.2 Subtask C- Data Acquisition and Processing

The main effort during 2003 has focused on developing the presentation format of the Project Management Decisional Assistant (PMDA). For an EGS-PMDA the following four characteristics have been defined:

- It should indicate which data are needed at each stage of the planning, construction and operation and how they may be acquired.
- It should, as far as possible, be based on all the practical and theoretical experience gained to date worldwide.
- It must be easy to understand and to use by project teams new to EGS.
- Certain parts of it should be readily adaptable to any particular project.

In addition, it must be easily adaptable to enable the integration of so far unknown new information form different EGS project sites.

It has been decided that a suitably structured hardcopy classifier containing the output of Subtask C will offer the best base for fulfilling the needs mentioned above. It will take the form of a loose-leaf ring binder. Work on the design and the production of a first version of the distributable loose-leaf classifier has begun.

### 3.3.3 Subtask D- Reservoir Evaluation

From December 2002, AIST began to work on a two-year contract with NEDO to compile all of the main data acquired at the Hijiori test site. This contract is called "Overall Compilation and Review of Hijiori HDR Experiments".

In the first Fiscal Year ending March 2003, data consisting of drilling, acoustic emission, hydraulic fracturing and modelling/simulation were compiled. During the second Fiscal Year, which started April 2003, the working group chaired by Prof. Niitsuma of Tohoku University discussed overall design, reservoir creation, circulation-heat extraction and monitoring methods based on the Hijiori experiment. This work will be finished by March 2004. The Subtask D output will include the summary of this compilation with the reservoir evaluation.

### 3.3.4 Related EGS Activities of Participants

#### 3.3.4.1 Australian EGS Activities

Geodynamics Limited commenced drilling the Habanero-1 well in February 2003. The well is Australia's first geothermal well, and is the start of the EGS (now termed 'hot fractured rock' by Australia) "Proof of Concept" project in high temperature granites beneath the Cooper basin in northern South Australia. Since the work in this project involves depths much greater than 3,000 m, it is considered a "cross-over" project, with applications in both Annex III- EGS and Annex IV- Deep Geothermal Resources.

Habanero-1 was completed at a depth of 4,421m on 18 September. The bottom hole temperatures are at least 250 °C.

Drilling was extremely difficult because of the unexpected discovery of high overpressures (5,200 psi or 36 MPa) in the granite joint network. These overpressures were high enough to cause natural hydraulic stimulation over geological time, and as a result favourably oriented sub-horizontal joints are already permeable. These conditions are most likely to persist over an area of about 1000 $km^2$.

Hydraulic stimulation of the well took place during November and December 2003. In all, 20,000 $m^3$ of water were pumped into the well at pressures up to 9500 psi (65.5 MPa). An acoustic monitoring network mapped over 11,700 seismic events from 6 November until 22 December, with almost all locations mainly located below 4,000m depth (Figure 3.1).

The volume of the reservoir as defined by the microseismic volume, far exceeded all expectations, and is about 3,000 m by 1000 m by 350 m thick, forming a flat pancake shape ideal for heat extraction with multiple well systems. The immense size, as compared to other EGS projects, is attributed to the overpressures in the granite.

The drilling of a second production well (Habanero-2) and circulation test are planned for 2004.

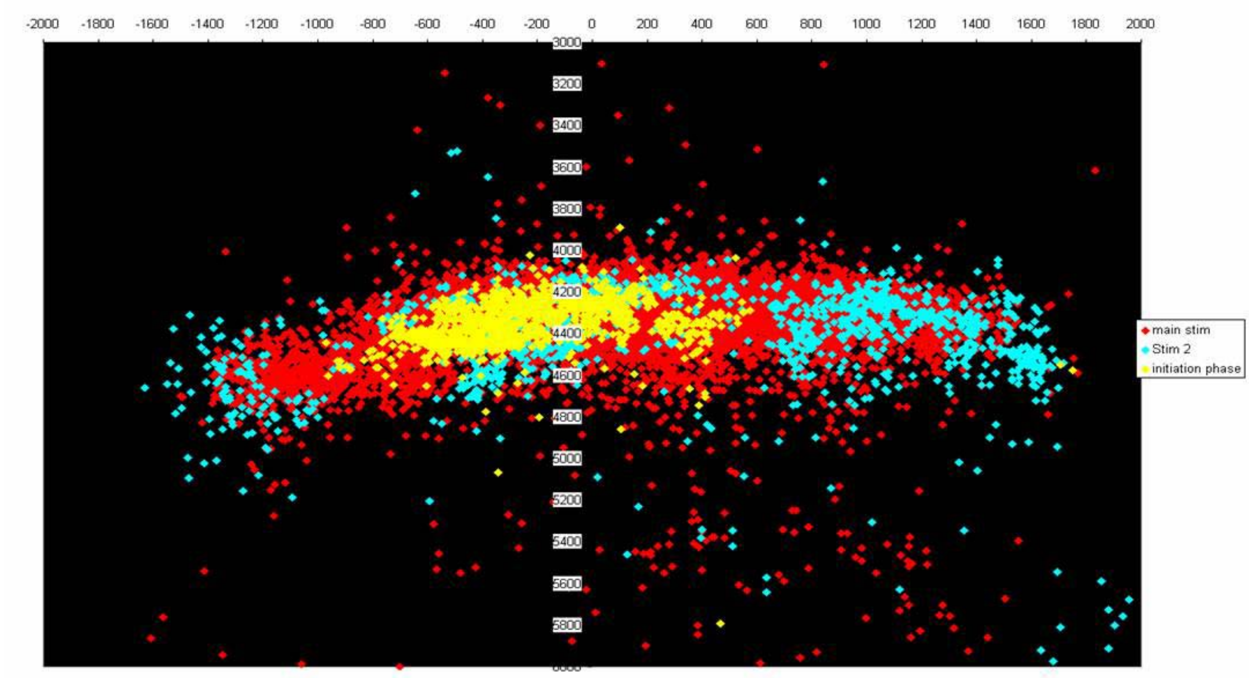


**Figure 3.1** N-S cross-section of seismic mapping of stimulated zone in Habanero-1, Cooper Basin, Australia (scales in metres). Data provided by the Japanese Team for Seismic Monitoring (JTSM) from Tohoku University, CRIEPI and Japex.

### 3.3.4.2 Germany

A number of EGS-related research projects were financed from funds of the ZIP-Programme (Future Investment Programme) of the BMU (Ministry of Environment) and the BMWA (Ministry of Economy, Technology and Labour). This programme, coordinated by the funding agency PTJ (Jülich) and financed with a total budget of about 20 M € (Euros) for the period 2001-2003, stimulated interest in geothermal energy in Germany and will probably be succeeded by a similar programme in the coming years. The following EGS related projects were funded:

- **GeneSys-Project**

The GEOCENTRE Hanover is investigating the feasibility of the EGS concept for recovering heat from tight sediments in a project called "GeneSys" (Generated Geothermal Energy Systems). The focus of the project is the direct use of geothermal energy. The basic concept is to link a borehole to permeable faults or fracture zones by massive water-fracture tests. The GEOCENTRE Hanover plans to produce about 2 $MW_t$ power from a single well system for heating its own and some adjacent buildings. During the initial project period (1 October 2002–30 September 2003) this single well concept is being tested in an abandoned gas well in the Northern German Basin.

In summer 2003, the bottom part of the 5,000 m deep well was cemented up to a depth of 4,120 m in order to seal the Permian gas reservoir. Two fractures were initiated in Triassic sandstone layers at 3,900 and 3,800 m depth. The latter was extended by injecting a total volume of more than 20,000 $m^3$ of fresh water at flow rates up to 50 l/s. This fracture, though not kept open by proppants, showed a remarkably high hydraulic conductivity after depletion of the fluid pressure. This demonstrates that, similar to earlier experiences in granite, a self-propping mechanism is also effective in sandstone fractures. Similarly the fracture showed an extraordinary high storage capacitance over a wide pressure range. This makes it possible to operate the system in a "huff-puff mode", i.e. injecting cold fluid and producing hot fluid in cyclic operations. The thermal performance of this operation will be investigated in early 2004.

- **Bad Urach Geothermal Project**

The municipality of Bad Urach, located at one of the highest temperature anomalies in Southern Germany, started an EGS research project in 2002. The objective of this project is to study the feasibility of the EGS concept in the large area of the Middle and Southern German Crystalline Region. It is envisaged to install a two-well EGS system at about 4,000 m depth at a rock temperature of about 170 °C.

The first of the two wells was stimulated by water-fracture tests in 2002 resulting in a northwest-southeast striking fracture system extending over an area of about 1 $km^2$. Planning of the second well was completed in 2003 with the trajectory of the well based on the spatial distribution of seismicity induced during these tests. Drilling started at the end of 2003 and will be finished in early summer 2004.

- **Resources for Geothermal Power Production in Germany**

In January 2003 the Office of Technology Assessment at the German Parliament (TAB) in Berlin published a study on the potential for geothermal power production in Germany. The study showed that even in a country like Germany, lacking high enthalpy resources at shallow depths, a huge resource for geothermal power production exists at great depth. For the three types of resources considered in this study (hot water aquifers, major faults, and crystalline rock) a total electric energy of about $10^{21}$ J was estimated in the depth range between 3,000 m and 7,000 m. By far the biggest resource is the enormous mass of crystalline rocks underlaying about one half of the area of Germany. The smallest but probably the easiest accessible resources are the hot water aquifers of the Upper Rhine Valley and of the Southern German Molasse Basin. The study also covers the state of the art of the exploitation and conversion techniques, the economics of geothermal power production and the implementation of geothermal power in the German energy market.

### 3.3.4.3 European EGS Project Soultz

This project is coordinated by an industrial consortium (EEIG Heat Mining) and is the most advanced EGS project worldwide. Seven German partners are contributing to the project in the fields of hydraulic-fracturing, hydraulic testing, geothermal measurements and modelling, geology and tectonics, stress measurements and high temperature metal packer development.

The aim of the project is to establish the worlds largest and most efficient EGS system at a depth of about 5,000 m. The system will consist of one central injection borehole and two symmetrical deviated production boreholes, each separated by about 500 m from the injection borehole. A total flow rate of 80 l/s is envisaged, equivalent to a total thermal power of 50 $MW_t$ and an electrical power of 6 MW (Figure 3.2).

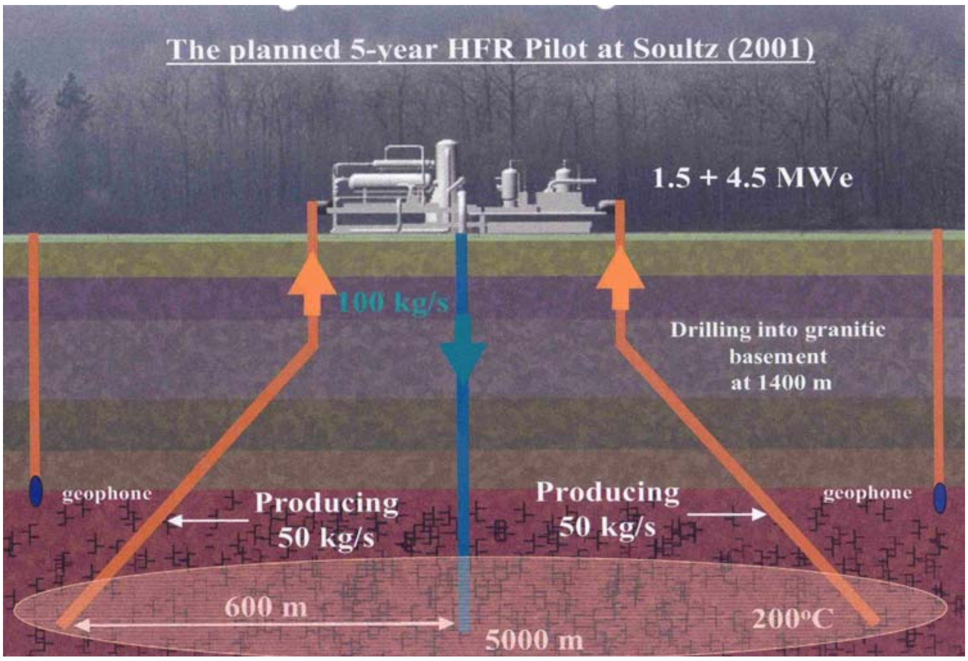


**Figure 3.2** Schematic diagram of the Soultz EGS pilot plant.

After the successful completion of the second borehole (injection borehole GPK-3) in 2002, the hydraulic inter-connection of the two existing boreholes was investigated in 2003 by performing a number of hydraulic tests. These tests indicate that the new borehole, which was directionally drilled into the zone of induced seismicity recorded during the stimulation of the first borehole, is hydraulically linked to the fracture system created in the first borehole. With a separation of about 600 m between the two wells this represents by far the biggest artificially created link in an EGS system achieved so far. A production test in the new well however showed that the quality of the hydraulic link was not sufficient. In order to improve the inter-connection, a massive water-fracture test was performed in the new well. The intense seismicity accompanying this test showed that also in this borehole a large fracture system was created, overlapping the one of the first borehole. Nevertheless, the inter-connection between both wells was not significantly improved so that further measures are required.

## 3.4 Work Planned for 2004

### 3.4.1 Subtask B- Application of Conventional Geothermal Technology to EGS

Proposed activities for the 2004-year include:

- DOE researchers will perform a large-scale stimulation test at the Coso geothermal field in southern California.
- A team funded by DOE and the US Navy will complete development of a state-of-the-art high-temperature acoustic-televiewer for geothermal applications.
- Work will continue on developing methods for analyzing tracer tests in fracture media.

Large-scale injection will begin in the northwest portion of The Geysers vapour-dominated field in northern California. The experiment will examine the feasibility of "huff-puff" operation in a reservoir of limited permeability. The DOE will expand its studies of injection in depleted fields to include additional seismic monitoring and chemical monitoring.

### 3.4.2 Subtask C- Data Acquisition and Processing

The activities proposed for 2004 are listed below:

Review of the current EGS-PMDA by all the project partners from the 2003 contract.

- Assembling of the list of recipients of the EGS-PMDA.
- Production of the specified number of EGS-PMDA classifiers.
- Dissemination of the EGS-PMDA classifiers.
- Assembling of the feed-back from the recipients of the EGS-PMDA classifier.
- Analysis and discussion of the recipients' feedback, compilation of the inputs and updating the EGS-PMDA classifier.

Effort will be invested in consolidating the state of development of the project and involving other cooperating countries in a planned programme of improvement.

### 3.4.3 Subtask D- Reservoir Evaluation

The 2004 efforts in Subtask D will be to:

Continue the work to compile and organize the answers of the Internet questionnaire.

Translate the summary of the report "Overall Compilation and Review of Hijiori HDR Experiments" under a NEDO contract.

Distribute the results of questionnaire and summary using a CD-ROM at the end of the task.

## 3.5 Outputs

Bloomfield, K. K., Goyal, K., and Hulen, J. (2003) Injection studies into the high-temperature reservoir in the northwest Geysers. *Geothermal Resources Council Transactions*, 27, 383-386.

Elkibbi, M., and Rial, J. A. (2003a) Shear-Wave splitting: an efficient tool to detect 3D fracture patterns at the Geysers, CA. *Proceedings Twenty-*

*Eighth Workshop on Geothermal Reservoir Engineering*, Stanford University, Stanford, California, January 27-29, 2003, SGP-TR-173, 143-149.

Elkibbi, Y. M., Rial, J. A. (2003b) Modeling of 3D crack attributes and crack densities in geothermal reservoirs. *Proceedings Twenty-Eighth Workshop on Geothermal Reservoir Engineering,* Stanford University, Stanford, California, January 27-29, 2003, SGP-TR-173, 321-326.

Koshelev, B. and Ghassemi, A. (2003) Hydraulic fracture propagation near a natural discontinuity. *Proceedings Twenty-Eighth Workshop on Geothermal Reservoir Engineering*, Stanford University, Stanford, California, January 27-29, 2003, SGP-TR-173, 150-157.

Li, K., Horne, R. N. (2003) Direct measurement of in-situ water saturation in the Geysers rock. *Proceedings Twenty-Eighth Workshop on Geothermal Reservoir Engineering*, Stanford University, Stanford, California, January 27-29, 2003, SGP-TR-173, 252-258.

Moore, J. R., Glaser, S. D., Morrison, H. F. (2003) Large-scale physical modeling of water injection into geothermal reservoirs and correlation to self potential measurements. *Proceedings Twenty-Eighth Workshop on Geothermal Reservoir Engineering*, Stanford University, Stanford, California, January 27-29, 2003, SGP-TR-173, 166-174.

Reyes, J. L., Horne, R. N. (2003) Inferred water saturation in the Geysers based on well performance data. *Proceedings Twenty-Eighth Workshop on Geothermal Reservoir Engineering*, Stanford University, Stanford, California, January 27-29, 2003, SGP-TR-173, 21-30.

Rose, P., Barton, C., Mulloch, J., Moore, J. N., Kovac, K., Sheridan, J., Spielman, P., Berard, B. (2003) The Coso EGS Project – recent developments. *Geothermal Resources Council Transactions*, v. 27, 879-883.

Sheridan, J., Kovac, K., Rose, P. E., Barton, C., McCulloch, J., Berard, B., Moore, J. N., Petty, S., Spielman, P. (2003) In-situ stress, fracture and fluid flow analysis-east flank of the Coso geothermal field. *Proceedings Twenty-Eighth Workshop on Geothermal Reservoir Engineering,* Stanford University, Stanford, California, January 27-29, 2003, SGP-TR-173, 34-39.

Shook, G. M. (2003) A simple, fast method of estimating fractured reservoir geometry from tracer tests. *Geothermal Resources Council Transactions*, 27, 407-411.

Tenma, N., Yamaguchi, T., Kikuchi, T., Tezuka, K., Zyvoloski, G. (2003) Estimation of the characteristics of the multi-reservoir system at the Hijiori HDR Test Site during the long-term circulation test, Term 1 using FEHM code. *Shgen-toSozai*, 119, 625-634.

Yanagisawa, N., Matsunaga, I., Sugita, H., Tao, H. (2003) Reservoir monitoring by tracer test of a 2002 dual circulation test at the Hijiori HDR site, Yamagata, Japan. *Geothermal Resources Council Transactions*, 27, 785-790.

### 3.6 Websites Related to EGS Studies

Australia: http://www.geodynamics.com.au

Bad Urach project, Germany: http://www.geotermie.de/badurach2.html

Coso stimulation project: http://egs.egi.utah.edu

Deep Heat Mining, Switzerland: http://www.dhm.ch

DOE technical projects: http://www.eere.energy.gov/geothermal/

GeneSys-Project, Germany: http://www.bgr.de/

Hijiori project, Japan: http://www.nedo.go.jp/chinetsu/hdr/hijiorinow.htm/

Germany’s Resources: http://www.tab.fzk.de/

Soultz European EGS Project: http://www.soultz.net/

**Author:** Isao Matsunaga, AIST, Tsukuba, Japan

**Contact:** Isao Matsunaga: matsunaga-isao@aist.go.jp

# CHAPTER 4

# Annex IV - Deep Geothermal Resources

## 4.1 Introduction

The Deep Geothermal Resources Task was started in 1997 as a four-year international collaborative program under the IEA Geothermal Implementing Agreement (GIA). In 2001, the GIA Executive Committee approved the continuation of this Annex to 2006.

The objective of the "Deep Geothermal Resources" Task is to address the issues necessary for the commercial development of deep geothermal resources at depths of about 3,000 m and deeper.

The participants in Annex IV during 2003 were: the Australian National University, Australia; the US Department of Energy (DOE), USA; Enel Green Power SpA, Italy; Forschungszentrum Jülich GmbH, Germany; Institute Geological & Nuclear Sciences Limited, New Zealand; Instituto de Investigaciones Electricas, Mexico; and the Philippines (Non-Member).

The Australian, EC Soultz and German projects included in this Annex also involve the "creation" of geothermal reservoirs at depths much greater than 3,000 m, i.e. the application of EGS to create deep geothermal resources. Consequently, their work spans both Annex III-EGS and Annex IV- Deep Geothermal Resources. See Chapter 3 for additional details regarding these projects.

The Operating Agent for Annex IV is Forschungszentrum Jülich GmbH, Germany. The Task Leader for 2003 was Andrea Ballouk, who was replaced by Dieter Rathjen for 2004.

## 4.2 Subtasks of Annex IV

The investigations in this Task are divided into three subtasks.

### 4.2.1 Subtask A- Exploration Technology and Reservoir Engineering

(Subtask Leader: to be appointed)

The objective of Subtask A is to carry out collaborative research on exploration technology, including geothermal modelling; geophysical, geological and geochemical exploration; and on reservoir engineering, including reservoir characterization and reservoir modelling.

Four countries, New Zealand, Mexico, Italy and Japan, participated in Subtask A during 2003.

### 4.2.2 Subtask B- Drilling and Logging Technology (Subtask Leader: to be appointed)

The objective of Subtask B is to carry out collaborative research on drilling and logging technologies, including the reviews of drilling and logging reports of deep geothermal wells; and exchange of information on improvements in drilling and logging tools.

There are 13 organizations in the Subtask B network from Australia (1), Italy (2), Japan (4), Mexico (1), USA (4) and Philippines (1).

### 4.2.4 Subtask C-Reservoir Evaluation

(Subtask Leader: to be appointed)

Subtask C seeks to exchange experience on materials and chemistries among the group. Published and unpublished information is gathered on past, present and planned experiences, and tests and research on materials in deep and aggressive geothermal systems. The information is then summarized in a database.

## 4.3 Work Performed in 2003

### 4.3.1 Australia

Australia is currently involved in a pioneering EGS project in the Cooper Basin. The EGS venture of Geodynamics Limited in the Cooper Basin is working on a venture in an attempt to enable the production of electricity at lower costs than other mainstream renewable energy resources using deep, high temperature rock.

Habanero-1, the first deep geothermal well drilled in Australia, and the deepest ever drilled on onshore Australia, was completed in September 2003, at a cost of A$ 5.4 M. The geothermal resource is one of the hottest in the Cooper Basin, with temperatures in excess of 250 °C at a true depth of 4,320 m confirmed. Hydraulic stimulation tests in November and December 2003 established the presence of a horizontal reservoir with an estimated area of 0.7 km$^2$.

### 4.3.2 Germany

The deep geothermal projects conducted by and participated in by Germany in 2003 included:

- **Bad Urach**

The first well was drilled for development, verification and demonstration of location independent EGS concepts for the production of electricity and heat with an EGS pilot plant. Stimulation tests were conducted, with production rate increased, and a heat exchanger created at depths between 3,300 and 4,200 m, and a temperature of 170°C (Figure 4.1). The total project cost was 6.7 M €, with 6.5 M € provided by the Federal Environment Ministry (FEM).

- **EC Soultz-sous-Forêts (Alsace, France)**

Germany continued its participation in 2003, with France, Italy, Switzerland and the EC, on the European Soultz-sous-Forêt project to develop a scientific geothermal pilot plant as the first phase. The third borehole was drilled in 2003 (Figure 4.2). Hydraulic stimulation tests were very successful, creating two separate heat exchangers in two horizons. There is no connection between the two exchangers, and temperatures are 165°C and 200°C.

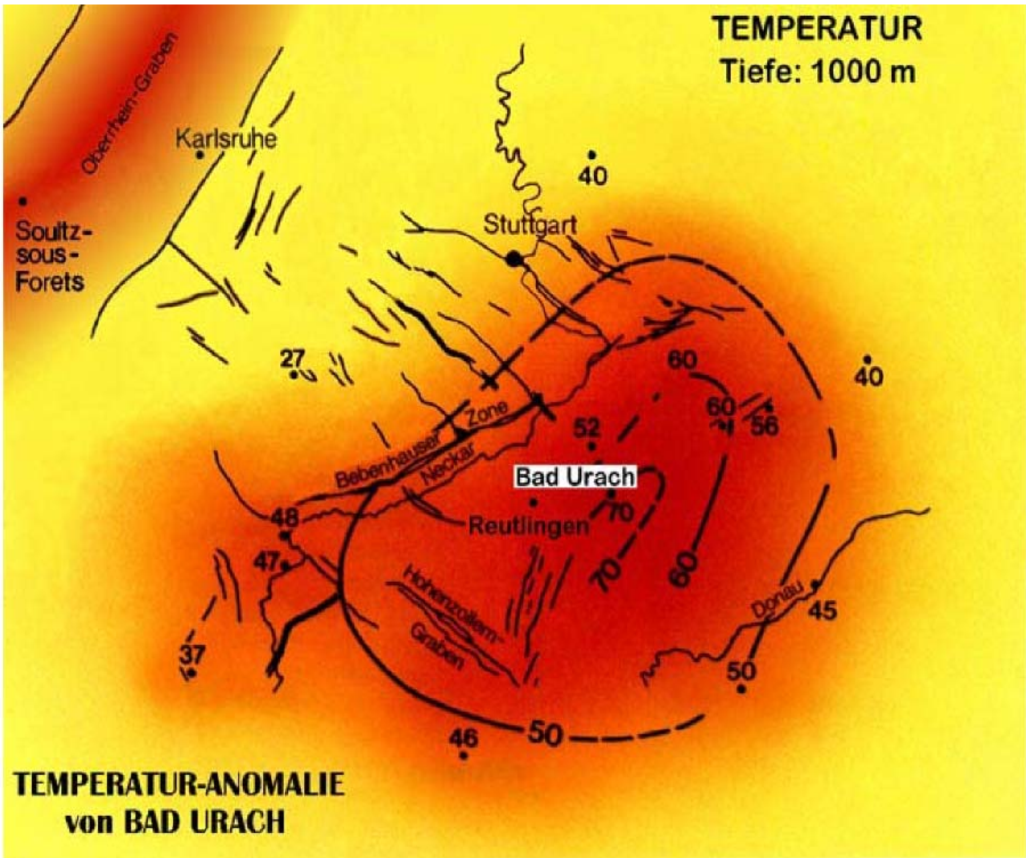


**Figure 4.1** Temperature anomaly in the Bad Urach area.

**Table 4.1** Number of wells and depths drilled during the period 1999-2003.

| Year | Number of wells with depth 3000-4000 m | Number of wells with depth > 4000 m |
|---|---|---|
| 1999 | 2 | 1 |
| 2000 | 1 | 2 |
| 2001 | 3 | 1 |
| 2002* | 1 | 1 |
| 2003* | 1 | 1 |
| **Total** | 8 | 6 |

* In the year 2002, Enel also drilled the well GPK-3 at Soultz-sous-Forêts (France) for the "European EGS, or Soultz, project". The depth of this well is 5,092 m.


**Figure 4.2** Drill rig at Soultz-sous-Forêt project, Alsace, France.

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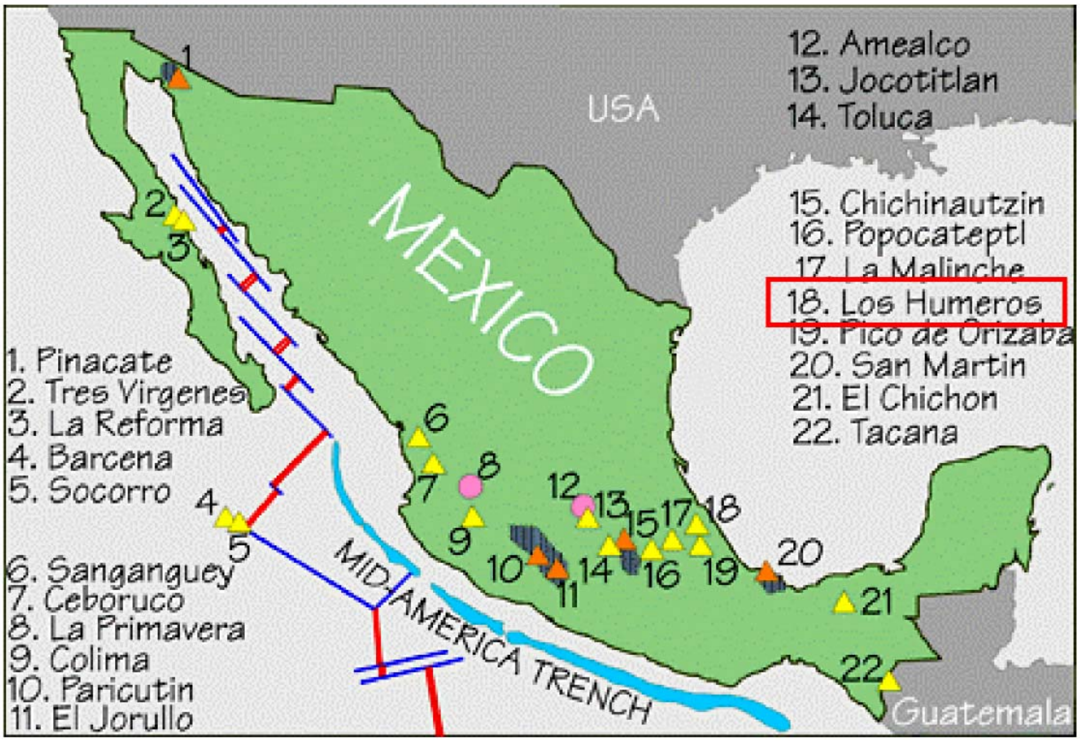
This project is funded by the EC, agencies in France and Germany, and by industry. The total cost of the project to date is about 30 M €, with Germany having provided 9.1 M € (8.4 M €from FEM, previously FELM).

### 4.3.3 Italy

The deep drilling activities in Italy for the development of deeper resources during the past 5 years is outlined in Table 4.1.

### 4.3.4 Mexico

The Instituto de Investigaciones Eléctricas (IIE) worked on conceptual models of Mexican geothermal fields with deep reservoirs, rigorous simulation of heat and mass transport in high-temperature reservoirs and especially the simulation of the effect of high non-condensable gas concentrations (Figure 4.3).




© http://volcano.und.nodak.edu/vwdocs/volc_tour/mex/mex.html

**Figure 4.3** Locations of Mexican geothermal fields.

The conceptual models of the Mexican geothermal fields with deep reservoirs were updated:

- Analysis of data from 42 wells of the Los Humeros geothermal field.
- Estimation of temperature and pressure profiles for the unperturbed reservoir fluids.
- Development of 1-D and 2-D models.

The rigorous simulation of heat and mass transport in high temperature reservoirs and especially the simulation of the effect of high non-condensable gas concentrations was done with a newly developed FORTRAN code based on the equation of state (EOS) for the system $H_2O$-$CO_2$-$CH_4$. The code delivers following possibilities:

- Mathematical modelling of two-phase, two-component flow (pressure and composition of the gas phase).
- Calculation of phase equilibria and/or molar volumes of $H_2O$ and binary mixtures (pressure and temperature).
- Calculation of phase equilibria for ternary mixtures (pressure, temperature, mole fraction of water in gas phase).
- The accuracy of EOS was extensively tested by comparison with experimental data in the range of 50-1000 °C and 0-1000 bar.

## 4.4 Work Planned for 2004

The Soultz project is ongoing and will be continuing with phase II during the 2004-2006 period with government aid from the EC, France and Germany. The German government funds approximately 6.2 M € for the German project partners.

At Bad Urach, a second borehole is planned and will be drilled to a planned depth of 4,500 m.

## 4.5 Outputs

Participants in the Annex attended and presented papers at the International Geothermal Congress Reykjavik 2003, Reykjavik, Iceland.

### 4.5.1 Australia

Reports and Announcements (Quarterly Reports) about the project and situation regarding geothermal well Habanero-1 have been written and presented.

### 4.5.2 Germany

Fachkongress Geothermischer Strom 12-13.11.2003 in Neustadt-Glewe (in German)

Kreuter, H., Harthill, N. (2003) Geothermal Power Generation in the Upper Rhine Valley-The Project Offenbach/Pfalz. *Proceedings of International Geothermal Congress 2003, Reykjavik, September 2003.*

Harthill, N. (2003) A New Interpretation of the Rhine Graben Geothermal Region. *Siena*, 24-27 September 2003.

Baria, R., Baumgärtner, J., Gerard, A. (2003) European Hot Dry Rock Programme 2001-2004 *2nd Year Report for the EC*; October 2003.

### 4.5.3 Mexico

Arellano, V.M., García, A., Barragán, R.M., Izquierdo, G., Aragón, A. and Nieva, D. (2003) An updated conceptual model of the Los Humeros geothermal reservoir (Mexico) (2003) *J.Volcanol. Geothermal Research*, 124, 67-88

David Nieva and Rosa María Barragán (2003) HCO-Ternary: A Fortran code for calculation P-V-T-X properties and liquid vapor equilibria of fluids in the system $H_2O$-$CO_2$-$CH_4$ *Computers & Geosciences*, 29, 469-485.

## 4.6 Websites Related to Annex IV Work

**Australia**

Geodyanmics: http://www.geodynamics.com.au

Geodyanmics: www.geodynamics.com.au/IRM/content/05 investor/05.5.html

**Italy**

Italian National Agency for New Technologies, Energy and the Environment: www.enea.it/com/ingl/default.html

**Mexico**

Instituto de Investigaciones Electricas: www.iie.org.mx

**New Zealand**

Institute of Geological and Nuclear Sciences Limited: www.gns.cri.nz

**Germany**

Bad Urach project: http://www.geotermie.de/bad_urach.htm

International Conference for Renewable Energies, 104 June 2004, Bonn, Germany: www.Renewables2004.de

Federal ministry for the Environment, Nature Conservation and Nuclear Safety: www.bmu.bund.de

Forschungszentrum Jülich, Project Management: www.fz-juelich.de/ptj/

EU-Project in Soultz-sous-Forêt: www.Soultz.net

**Authors:** Andrea Ballouk and Dieter Rathjen; Forschungszentrum Jülich, Jülich, Germany

**Contact:** Dieter Rathjen: d.rathjen@fz-juelich.de

# CHAPTER 5

## Annex VII - Advanced Geothermal Drilling Techniques

### 5.1 Introduction

Drilling is an essential and expensive part of geothermal exploration, development, and application. 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. Annex VII has been developed to pursue advanced geothermal drilling research that will address all aspects of geothermal well construction.

The participants in this Annex during the 2003 period were Japan, Mexico, Iceland, the European Commission, New Zealand and the United States.

Sandia National Laboratories (USA) is the Operating Agent for Annex VII. John T. Finger (Sandia Labs) was the Task Leader until 30 November 2003, when Eddie R. Hoover (Manager, Geothermal Research Department, Sandia National Laboratories) replaced him.

### 5.2 Subtasks

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

**5.2.1 Subtask A- Compile Geothermal Well Drilling Cost and Performance Information** (Subtask Leader: Satoshi Kubo, The New Energy and Industrial Technology Development Organization (NEDO), Japan.)

This activity is a compilation of actual drilling cost and performance results associated with the development, construction and operation of geothermal wells. This information will be maintained in a single database, so that all participants can use it to identify key drilling operations that might be improved by new technology or by different drilling practices. 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.

**5.2.2 Subtask B- Geothermal Drilling Best Practices Handbook** (Co-Subtask Leaders: High Temperature Drilling: Hector Gutierrez, Comisión Federal de Electridad (CFE), Mexico; Low Temperature Drilling: Sverrir Thorhallsson, Orkustofnun (OS), Iceland)

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.

**5.2.3 Subtask C- Advanced Drilling Collaboration** (Subtask Leader: John Finger (to 30 November 2003); Ed Hoover (started 1 December 2003), Sandia National Laboratories (SNL), USA)

The participants will monitor and exchange information on drilling 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.

### 5.3 Work Performed in 2003

The Annex VII working group met twice in 2003; on 12 March 2003 at IEA Headquarters in Paris, France, and on 18 September 2003 in Reykjavik, Iceland.

All Subtasks were discussed at each of these meetings, with extensive input from participants. Although Subtask objectives are fairly clear and, in some cases, specific work assignments have been defined, a serious shortcoming in the work process is the funding mechanism under which the Annex operates. Because the Annex is structured in a task-sharing mode rather than cost-sharing, the Annex VII Charter states, "Each Contracting Party shall bear the costs it incurs in carrying out Program activities . . . unless provision is made for such costs to be reimbursed from common funds." No such provision has been made, so this means that labour-intensive activities such as data collection for Subtask A and writing/editing for Subtask B have very little support. This situation has been reported in some detail to the Executive Committee, and progress by the working group is somewhat dependent on the resolution. Work accomplished in 2003 is summarized by Subtask below.

### 5.3.1 Subtask A- Compile Geothermal Well Drilling Cost and Performance Information

Collection of cost and performance data from varied geothermal reservoirs will allow researchers to identify common problems, assess those problems' costs, and focus development efforts on high-payoff projects. Actual construction of a database, however, faces three major questions: how much data will be available from operators and governmental agencies; in what format should the data be presented; and how will the database be evaluated to achieve the objectives?

The working group agreed on a format for presentation of cost data, but the principal limitation on data availability, particularly cost data, is the reluctance of operators to relax confidentiality requirements on their records. For example, Sandia has cost records for dozens of geothermal wells, but those records were obtained only under condition that they would not be released elsewhere. As a consequence of this difficulty, a parallel effort at collecting performance data in the format of time-depth curves is also underway. Cost data is in hand for three Japanese wells, three Mexican wells, and one US well, with data for three more Mexican wells available soon. Time depth curves for 18 Icelandic and one US well have been collected to date. A sample of the annotated time-depth curves is shown in Figure 5.1. A sample of the cost-data spreadsheet, for a Japanese well, is shown in Table 5.1

### 5.3.2 Subtask B- Geothermal Drilling Best Practices Handbook

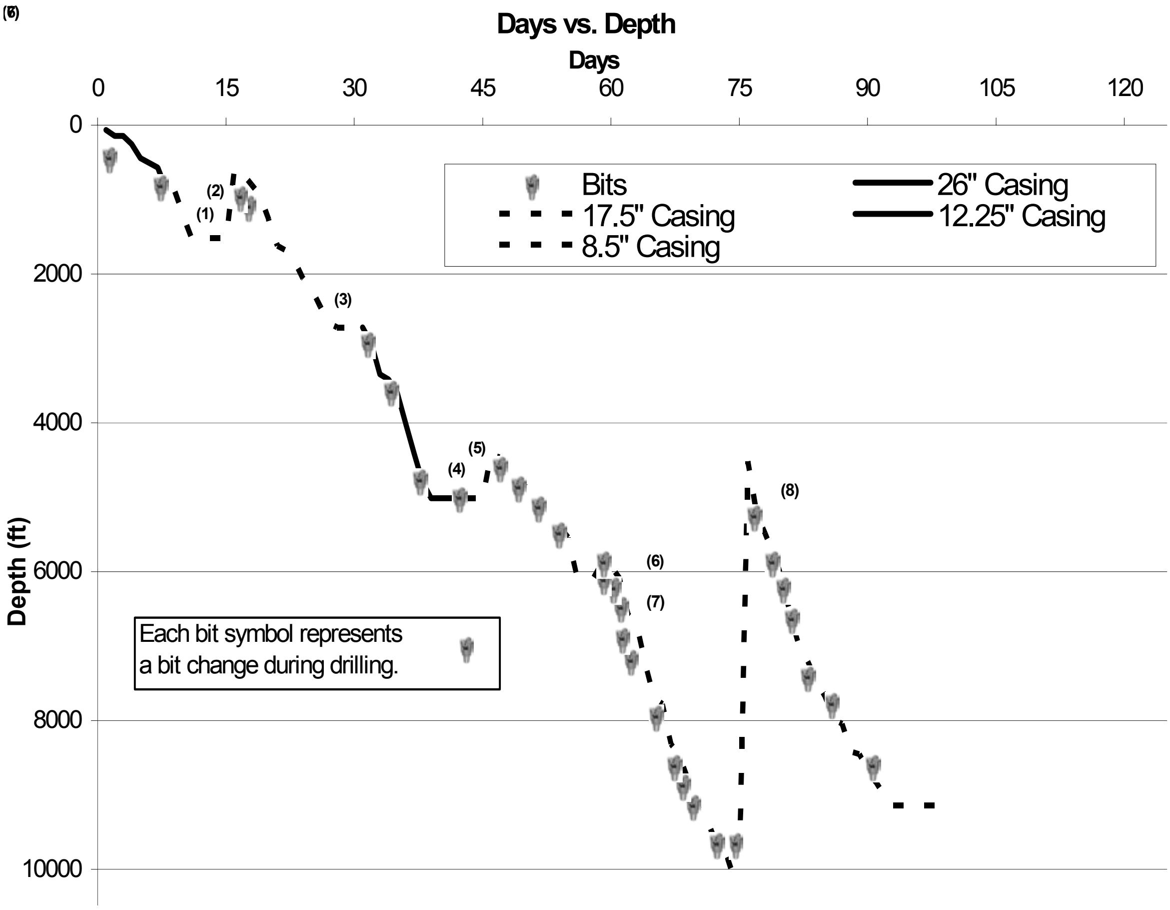
The working group has agreed on an outline for the Handbook, but there has been little feedback on its contents, so it was proposed to the ExCo that the Handbook outline be posted on the GIA web site for comments. Briefing to the ExCo also included the working group's estimate that approximately 0.5 man-year would be required to assemble and edit the Handbook, and that it might be difficult to expend that level of effort without additional support from the GIA common fund.

Many existing literature sources may be available for inclusion in the Handbook. Examples are Geothermal Resource Council (GRC) papers, Society of Petroleum Engineers (SPE) papers, publications from Sandia National Laboratories or other US DOE sources, the New Zealand Code of Practice for Deep Geothermal Wells, Proceedings of the New Zealand Geothermal Workshops and GRC papers. Although there are copyright issues with using some of this material, preliminary investigation indicates that a large volume of literature will be usable. While the working group awaits decisions by the ExCo, participants will continue to update the outline with references to existing literature on a time-available basis.

### 5.3.3 Subtask C- Advanced Drilling Collaboration

The working group discussed the following possible collaborative projects:

- There is still an opportunity to propose experiments or tests in support of advanced drilling technology in the Iceland Deep Drilling Project (IDDP). This opportunity has been widely publicized, but no person or company has yet expressed an interest, at least through Annex VII, in testing tools or technology in this extremely rigorous environment.




**FLAT TIME LOG**

1. 1520'- Stuck pipe/twist off at 822', 123 non-productive fishing hours.
2. 591'- Pull out to shallower depth to drill around fish.
3. 2716'- Run and cement casing, treat wellhead, 88 hours.
4. 5014'- Run and cement 12.25" casing, ream and test well, 143 hours.
5. 4424'- Clean out cement, prepare BHA with mud motor and 3 degree kick-back sub for directional drilling.
6. 8646'- Twist off at 5515', retrieve part of fish, 155 non-productive hours.
7. 6038'- Set cement plug at 6218 ft, try to kick around fish to side track well,
8. 4519'- Pull out of hole to drill second leg.

**Figure 5.1** A sample of the well drilling annotated time-depth curves.

- A request for drilling data to aid in calibration of a drilling simulation code was previously distributed to the working group. This data would be very useful in possibly bringing to the industry a wellbore simulator that can estimate wellbore temperatures, even with the occurrence of lost circulation. Iceland has agreed to provide data for this activity.

- Various items of advanced Japanese technology were described in a brochure, and a list of contact information for people associated with those projects was compiled; both of these were distributed to the working group. NEDO has received expressions of interest in some of these technologies, but no use outside Japan has yet occurred.

- Representatives of Sandia Labs and CFE have held preliminary discussions of running prototype polycrystalline diamond compact (PDC) bits and/or prototype lost circulation treatments in wells at Cerro Prieto.

## 5.4 Highlights of Annex Programme Work for 2003

One highlight of the Annex VII working group has been the excellent participation by the members..

**Table 5.1** Example of sample cost data sheet.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **General Information** | | | Site A | | | Site B | | | Site C | |
| Total days for rig up | | | 20.5 | | | 23 | | | 23 | |
| Total days for site construction | | | 75 | | | No data | | | 29 | |
| Total days for site survey | | | No data | | | No data | | | No data | |
| Total man-days for rig up | | | 348 | | | 392 | | | N-3000 | |
| Site size (m x m) | | | | | | | | | | |
| Draw works type | | | NM-2000 | | | 80UE | | | N-3000 | |
| Number of active mud tank and capacity | | | 3 tanks; 60KL | | | 3 tanks; 60KL | | | 3 tanks; 60KL | |
| Number of storage mud tank and capacity | | | 1 tank; 20KL | | | 2 tank; 40KL | | | 2 tank; 40KL | |
| Mud pump type and number | | | 8P-80 x 1, JD200 x 1 | | | 9P-100 x 2 | | | 9P-100 x 2 | |
| Cementing pump type and number | | | SKD4 (HT400) x 1 | | | SKD4 (HT400) x 1 | | | SKD4 (HT400) x 1 | |
| Number of cement storage tank and capacity | | | 4 tanks ; (96.9m3) | | | 5 tanks ; (121.1m3) | | | 5 tanks ; (121.1m3) | |
| | | | | | | | | | | |
| Exchange rate (Local unit to US$) | | | 108 (\/US$) | (July, 10, 2000) | | 108 (\/US$) | (June, 01, 2000) | | 113 (\/US$) | (Dec., 23, 2000) |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | Site A | | | Site B | | | Site C | |
| **ITEMS** | Sub-Items | Specification | volume | Actual cost (US$) | Specification | volume | Actual cost (US$) | Specification | volume | Actual cost (US$) |
| **Tangibles** | | | | | | | | | | |
| Surface pipe | | 20", STPG, Sch40, | 55m | 11,000 | | | | | | |
| Others | | | | | | | | | | |
| | | | | | | | | | | |
| **Intangibles** | | | | | | | | | | |
| Permit | | | | | | | | | | |
| Survey | | | | | | | | | | |
| Site construction | | | | 376,000 | | | 0 | | | 44,500 |
| Pre-drilling (Set conductor) | | | | 111,500 | | | 0 | | | 0 |
| Company Stuff transport | | | | | | | | | | |
| | | | | | | | | | | |
| Rig mobilization (Contractor) | Total | | | **137,000** | | | **280,500** | | | **289,500** |
| | Trucking | 11ton | 56 Trucks | 18,000 | 10ton | 27 Trucks | 20,000 | 11ton | 72 Trucks | 45,000 |
| | Trucking | 15ton Trailer | 10 Trailers | 7,000 | 23ton Trailer | 18 Trailers | 20,000 | 25ton Trailer | 13 Trailers | 18,000 |
| | Trucking | 20ton Trailer | 10 Trailers | 9,500 | 30ton Trailer | 5 Trailers | 7,000 | | | |
| | Cranes for trucking | 25ton Rafter | 5 days-Crane | 3,500 | 25ton Rafter | 5 days-Crane | 3,000 | 35ton | 4 days-Crane | 4,500 |
| | Cranes for trucking | 45ton Rafter | 3 days-Crane | 4,000 | 45ton Rafter | 2 days-Crane | 2,500 | 45ton | 5 days-Crane | 7,000 |
| | | | | | | | | Labor for Trucking | all | 4,000 |
| | Cranes | 25ton Rafter | 10 days-Crane | 6,500 | 25ton Rafter | 12 days-Crane | 7,000 | 35ton | 10 days-Crane | 11,500 |
| | Cranes | 45ton Rafter | 5 days-Crane | 7,000 | 45ton Rafter | 1 days-Crane | 1,500 | 45ton Rafter | 18 days-Crane | 25,500 |
| | | | | | 100ton Crane | 7 days-Crane | 28,500 | | | |
| | | | | | Rental, Lease | | 10,000 | | | |
| | | | | | Rig Rental | | 85,000 | Rig Rental | | 71,000 |
| | Labor | | 380 man x days | 63,500 | | 392 man x days | 62,500 | | 345 man x days | 68,000 |
| | Labor transport | | | | | 54 cars | 1,500 | | 23 days | 9,000 |
| | Accommodation | | 280 man-days | 18,000 | | 410 man-days | 32,000 | | 326.6 man-days | 26,000 |
| | | | | | | | | | | |
| Consumption | | | | 15,500 | | | 23,000 | | | 0 |
| Others | | | | 0 | | | 1,000 | | | 25,500 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| **Pre-Drilling Cost Total** | | | | **651,000** | | | **304,500** | | | **359,500** |

The accomplishments considered highlights for 2003 are the following:

- First group of well-cost data sets entered into the cost and performance database
- Working group reached consensus on an outline for the high-temperature portion of the *Best Practices Handbook*. It is planned that the outline will be posted on the GIA web site.
- CFE and Sandia personnel held preliminary discussions of collaborative testing at Cerro Prieto.

## 5.5 Work Planned for 2004

### 5.5.1 Subtask A

Sandia Labs will contact US operators for the possibility of releasing time-depth data. John Finger has also contacted Enel for possible information on Italian wells. Chris Bromley will investigate availability of data from New Zealand. Hector Gutierrez will provide data for 3 more Mexican wells.

### 5.5.2 Subtask B

Chris Bromley will attempt to clarify the copyright situation with respect to the NZ Code of Practice; and any other members of the working group should suggest sources of additional literature. John Finger reported to the Executive Committee that additional support is needed for this Subtask, and also proposed posting the Handbook outline on the GIA web site. While we await decisions by the ExCo, the working group will continue to update the outline with references to existing literature on a time-available basis.

### 5.5.3 Subtask C

Sandia National Laboratories will act as clearing-house for any proposals on collaborative testing that participating countries wish to make, and will attempt to facilitate any possible collaborative partnerships.

## 5.6 Outputs

A paper: *Annex 7: The IEA's Role in Advanced Geothermal Drilling* by Finger and Hoover was presented at the Geothermal Resources Council Annual Meeting in Morelia, Mexico, in October 2003.

## 5.7 Websites Related to Annex VII Work

None yet, although the Annex VII working group has requested that an outline for the *Best Practices Drilling Handbook* be posted on the GIA website.

**Author:** John Finger, Sandia National Laboratories, Albuquerque, USA; but future correspondence should be addressed to: E. R. Hoover, Sandia National Laboratories, Albuquerque, USA.

**Contact:** Eddie Hoover: erhoove@sandia.gov

# CHAPTER 6

# Annex VIII – Direct Use of Geothermal Energy

## 6.1 Introduction

The Direct Use of Geothermal Energy Annex is the most recent to be included in the GIA. It officially commenced on 19 September 2003, when the agreement entered into force. Work in the Annex is expected to begin in late 2004, and continue to 2007.

Geothermal energy can be used directly as heat for many applications such as building and district heating, industrial process heating, commercial uses such as greenhouse heating and temperature control of water for fish farming, bathing and swimming, and many other purposes. Many applications are well developed and are economically viable, while others are challenged by implementation difficulties and unfavourable economics. The Direct Use Annex will address all aspects of the technology with emphasis on improving implementation, reducing costs and enhancing use.

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 have agreed to participate in this Annex are: The Federation of Icelandic Energy and Waterworks (Iceland), The United States Department of Energy (DOE, USA), The New Energy and Industrial Technology Development Organization (NEDO, Japan), Italy and New Zealand.

The Operating Agent is The Federation of Icelandic Energy and Waterworks, Reykjavik, Iceland, and the Task Leader is Einar Gunnlaugsson.

## 6.2 Subtasks

The objectives of this Annex will be achieved through work in four subtasks. The Subtask Leaders remain to be appointed.

### 6.2.1 Subtask A- Resource Characterization

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

### 6.2.2 Subtask B- Cost and Performance Database

This Subtask 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.

### 6.2.3 Subtask C- Barrier and Opportunity Identification

Based on subtasks A and B, this Subtask 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.

### 6.2.4 Subtask D- Equipment Performance Validation

The work in this Subtask will 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. The testing can be at multiple sites or can be round robin.

## 6.3 The Proposed Timeline

**2003-2004:** Refine the subtasks in a complete work plan, conduct an organizing workshop, form a steering committee of interested participants. Adopt final subtasks and work plan, obtain agreement from participants and gain approval from the Executive Committee.

**2004-2005:** Complete compilation of the database for resource characterization and the baseline database for cost and performance of current applications in participant countries.

Organize a special session for presentations of results at the World Geothermal Congress, with reports to the Executive committee.

Define the opportunities for improvement and initiate research to provide the bases for accomplishing the opportunities.

**2006-2007**: Conduct an annual workshop of participants in association with an important international geothermal meeting. Participants continue research in their respective countries per the work plan. Report results to the Executive Committee.

## 6.4 Funding

The collaborative direct use technology research to be carried out under this Annex will involve both cost-sharing and task-sharing. A common fund will be established to cover the special duties of the Operating Agent, including the cost of publishing the reports and summary assessments and the cost of maintaining and distributing the cost database. The costs associated with collecting the information in the database shall be borne by the respective participants. In addition, each participant shall bear all costs it incurs in carrying out the Annex activities, including reporting and travel expenses.

The level of effort to perform the work specified in this Annex is estimated to be no more than one-person year per year for each participant.

## 6.5 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. Further, enhanced cooperation between the countries and increased exchange of technical and scientific information within the field of direct use of geothermal energy.

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.

**Authors:** Allan Jelacic (US Department of Energy, Washington, DC, USA), Hrefna Kristmannsdóttir (University of Akureyri, Akureyri, Iceland) and Sveinbjörn Björnsson (National Energy Authority, Reykjavik, Iceland).

**Contact:** Hrefna Kristmannsdóttir: hk@unak.is

# CHAPTER 7

# Synopsis of National Activities

## 7.1 Introduction

In late 2002, the ExCo decided to produce a more comprehensive and informative annual report, aimed at a wider audience, and beginning with the IEA Geothermal Annual Report 2002. One of the outcomes was the inclusion of a new National Activities section, which describes the current geothermal situation in the participating countries, including: national policy; current status of geothermal energy use (both for electricity generation and direct use); market development, stimulation and constraints; economics; research activities; education and international cooperation.

Though there was a limited amount of time available for producing the 2002 national reports, several countries were successful in providing them. Regrettably, there were a few who were not. The IEA Geothermal Annual Report 2003, however, is complete and includes contributions from all of the participating countries and the European Commission. This chapter, which is based on the national activities reports presented in Chapters 8-18, provides a brief overview of the geothermal state of affairs in the Member Countries and EC. The status of geothermal installed capacity, electricity generated and direct use is provided in Table 7.1 for the Member Countries.

## 7.2 The Context

Geothermal energy is used for the production of electricity and for direct heat applications such as district heating, agricultural drying, industrial processes, green house and aquaculture pond heating, bathing and swimming and snow melting. In 2000, electricity was being generated from geothermal sources in 21 countries, with a total installed capacity of 7,974 $MW_e$ (Huttrer, 2000). At the end of 1999, the installed thermal power was estimated to be about 16,209 $MW_t$, with 55 countries reporting the use of 162,000 TJ/yr (Lund and Freeston, 2000). It is believed that there is potential for a 45% growth in geothermal electricity generation by 2010 and that 5% of the global electricity could be supplied by 2020. The installed thermal power doubled between 1995 and 2000, and its growth is expected to continue.

The use of geothermal energy provides many benefits: low emissions of pollutants such as particulates and greenhouse gases, especially $CO_2$; less dependence on imported fuels, hence reduced problems caused by their price fluctuations; increased security and more diversity in supply; independence from weather oscillations on hydro generation; and more employment and opportunity for industry and the local population through equipment supply and plant construction and servicing.

To achieve these benefits, barriers to geothermal development must be overcome. This requires: the improvement of technologies for the use of geothermal energy; an improvement in the understanding of the environmental benefits and how to avoid or minimize the drawbacks; the ability to better characterize geothermal resources; and the distribution of information about geothermal energy and its benefits to governments, industry, the utilities and financial communities and the general public. Success in these endeavours will help to make geothermal development more cost-effective, aid in the penetration of the marketplace and increase the use of geothermal energy.

## 7.3 Review and Highlights of National Activities

### 7.3.1 Australia

At present, electricity is being generated by one 120 $kW_{e\,(net)}$ binary power station operating in western Queensland, and it produced about 1 GWh in 2003. There is a small amount of direct use in the country, mainly for space heating and bathing.

However, Australia's fledgling geothermal industry is growing, with significant interest in the Geodynamics Limited EGS "proof of concept" project resulting from the completion of Australia's first deep geothermal well to 4,421m, where a temperature of 250 °C was confirmed. Hydraulic stimulation created a reservoir approximately 300 m thick, over an area of about 3 k $m^2$.

**Table 7.1** Installed capacity, power generated and direct use for Member Countries in 2003 unless otherwise noted.

| Country* | Installed Capacity ($MW_e$) | Power Generated (GWh) | Direct Use Energy Utilized (GWh) |
|---|---|---|---|
| Australia | 0.120 | 1 | na# |
| Germany | 0.25 | 1.4† | 400 |
| Greece | 0 | 0 | 135 |
| Iceland | 200 | 1,433 | 6,609 |
| Italy | 862 | 5,036 | 975 |
| Japan** | 535.25 | 3,467 | 1,430‡ |
| Mexico | 953 | 6,283 | - |
| New Zealand | 431 | 2,643 | 1,950§ |
| Switzerland | 0 | 0 | 1,123 |
| United States | 2,200 | > 13,357 | 6,040 |

† Estimated annual production, as power plant has not yet operated for a complete year.
‡ This total is for 2001and excludes bathing use, which is widespread.
* Note that the European Community is not listed since it is not a country and generates none of its own energy.
** Data for 2002.
# Not available.
§ Data for the end of 1999.

The Government has provided A$ 5 M through its START R&D programme and further significant amounts, A$ 15 M in 2003, were raised through shareholders. A second well is to be drilled in 2004.

Though Australia does not have a geothermal policy nor strategy *per se*, geothermal energy is included in the *Renewable Energy (Electricity) Act 2000,* which addresses greenhouse gas emission. A National Mandatory Renewable Energy Target (MRET) of 9,500 GWh/year of new renewable electricity by the year 2010 has been set, though it is currently under review.

### 7.3.2 European Community

The European Commission currently supports a major European EGS project at Soultz-sous-Forêts, France. This project involves France, Germany, Italy and Switzerland, in addition to groups from inside and outside Europe, including Japan and the USA. Most of the funding is provided equally by EC, France and Germany.

The aim of this project is to create an EGS at about 5,000 m depth, using a central injection well and two symmetrically located production wells to generate 6 $MW_e$ of electricity. In 2003, two 5,000 m deep wells were linked as a result of successful hydraulic stimulation, with a total volume of about 3 $km^3$ of rock stimulated. A successful circulation test then produced wellhead fluid temperatures of 155 ºC, with final production temperatures of about 180 ºC expected. Drilling of the second production well began in September 2003.

In December 2003, the EC signed a contract for the last phase of the project, the construction of the pilot plant, to be built during 2004-2007.

### 7.3.3 Germany

The lack of natural high temperature geothermal reservoirs in Germany makes the production of electricity via geothermal energy generally uneconomic owing to the current competitive generation prices. However, a highlight in Germany's geothermal programme occurred in November 2003, when the first geothermal power plant was inaugurated at Neustadt-Glewe, where a 250 $kW_e$ plant will produce an estimated 1,400 MW/year as part of a combined heat and power production (CHP) development.

Direct use of geothermal energy in Germany at the end of 1999, on the other hand, amounted to an installed capacity of about 400 $MW_t$. Approximately 55 $MW_t$ were generated at 27 major central installations and 342 $MW_t$ contributed by heat pumps used across Germany for space heating. Direct heat is mainly used for thermal spas, space heating/cooling and greenhouse heating.

Germany is presently working on two deep EGS projects, the first its participation in the European Soultz-sous-Forêts programme; the other, at Bad Urach, where an EGS pilot plant demonstration venture is proceeding. At the latter, the first well has been drilled and hydraulic stimulation has created a reservoir between 3,300 m and 4,200 m with temperatures of about 170 °C. Drilling of a second well is planned.

In addition, work at four sites located in northern Germany, is being conducted on developing methods for utilizing shallower hot water/steam resources, in sedimentary structures having normal temperature gradients (30 °C/km). Techniques for dealing with high salinity fluids and new stimulation methods using water gel proppants are being investigated.

On 1 April 2000, the Law on Energy Supply (LES) became effective as a part of Germany's attempt to promote renewable energy use. It guarantees a minimum payment to companies that provide electricity from renewable resources, with geothermal getting 7.16-8.95 €-cents/kWh. This approach provides long-term planning and control protection. In addition, Germany signed the Kyoto Protocol in 2003, which will further encourage geothermal development as a part their aim to increase electricity production through the use of renewables to 20% by 2010.

### 7.3.4 Greece

A major highlight for Greece's geothermal programme in 2003 was the completion of the MILOS Geothermal ORC-ME Desalination plant. It provides a sustainable alternative to importing water from the mainland at an estimated cost of US$ 1.8/$m^3$ compared with the earlier cost of US$ 356 /$m^3$.

Direct use is the major application of geothermal energy in Greece, with about 135 GWh utilized, predominately for spas, and greenhouse and soil heating. The main electricity development constraints are the high capitol cost and the competition from natural gas.

A new geothermal law went into effect in August 2003, which recognizes geothermal energy as both a renewable energy source and a mineral ore. As an ore, exploration and exploitation rights for geothermal energy with temperatures > 25 °C belong to the State, who can allocate geothermal concessions after public completion. Concessions allocated prior to this new law remain in force.

The geothermal concession tenant pays a "rent" to the Greek State for the geothermal energy use, amounting to 5% or 10% of the equivalent value of natural gas. No concessions are required for use of geothermal heat pumps using shallow formations with water at temperatures < 25 °C. Neither new geothermal programmes nor changes in on-going ones are permitted until "explanatory decrees" that explain the operation and application of the law are issued.

### 7.3.5 Iceland

The renewables hydro and geothermal provide about 70% of the primary energy supply in Iceland, with geothermal providing > 50%. Approximately 99.9% of Iceland's electricity is generated by hydro and geothermal. In 2003, geothermal produced 1,433 GWh, or 17% of Iceland's electricity, with an installed capacity of 200 $MW_e$.

In Iceland, geothermal is mainly employed in direct use, with about 6,609 GWh utilized in 2003. Principally used for space heating, geothermal supplies about 87% of the total. Direct use of geothermal energy is also employed for heating swimming pools (approximately 130, or 90% of all pools), snow melting (sidewalks, parking spaces, streets), greenhouses (air and soil heating), fish farming (~ 50 farms, mainly salmon) and industrial uses (production of diatomite for filters, drying seaweed, salt, liquid $CO_2$, wood and fish drying, *etc*.).

New legislation is liberalizing the energy market and the production and sale of electricity now operates on a competitive basis. Similar legislation for direct use is being prepared.

Through national policy, the use of fossil fuels for space heating has been almost completely eliminated, and they will be replaced for vehicle and ship use by synthetic fuels as soon as the latter can be economically produced using hydro and geothermal. The government provides grants to encourage installation of new and expansion of existing geothermal heating schemes.

The United Nations University Geothermal Training Programme celebrated its 25$^{th}$ Anniversary this year (Fridleifsson, 2004). During its quarter century of operation, 300 scientists and engineers from 39 countries have completed the 6-month graduate-level course, and 80 shorter training. An MSc programme in geothermal science and engineering was begun in 2000.

### 7.3.6 Italy

Geothermal energy In Italy is mainly used to produce electricity, and at the end of 2003 the installed capacity was 862 $MW_e$. Net generation exceeded 5 billion kWh for the first time, providing 1.7% of Italy's domestic generation and 24% of Tuscany's. Geothermal resources are also used in direct applications, with about 975 GWh utilized in 2003 for providing heat to spas, space and district heating, fish farming, greenhouses and industrial processes; and saved about 213 ktoe (thousand tons of oil equivalent). In addition, $CO_2$ for the food industry was being produced from a deep "dead" well. A new proprietary $H_2S$ and Hg emission abatement technology (AMIS) was also commissioned at a second plant in April 2003.

The low oil price and cost of environmental protection make Green Certificates necessary for geothermal to be competitive with fossil fuel electricity generation. Typical geothermal generation costs range from 5-8.5 €-cents/kWh.

The 1999 "Bersani Decree" set a limit on the generation and import of electricity by any one operator at 50% of the domestic consumption, starting 1 January 2003. In addition, from 2002, all electricity operators had to generate, or purchase, at least 2% (> 3.5 billion kWh) from "new renewable plants", thus providing encouragement to the renewables market and giving rise to the "Green Certificate" market. Each Green Certificate proves 100 MWh of electricity is being generated by renewables and for 2003 was worth 8.2 €-cent/kWh. The value of renewable generated electricity is the sum of the base price plus that of the Green certificate.

As a signatory to the Kyoto Protocol, Italy has been charged with reducing greenhouse gas emission by 6.5% of 1990 level within the 2008-2012 commitment period (note the EU's total reduction is 8%). Subsequently, a 2002 economic planning decree stipulated that the Italian electricity industry must reduce their $CO_2$ emission by 26 million tons/year, or 50% of Italy's required total. One consequence has been the setting of a target of 500-1,200 $MW_e$ increase in installed capacity from renewable power plants, resulting in a $CO_2$ reduction of 1.5-3.1 million tons/year. The geothermal target is to generate 5.3 billion kWh/year by 2008.

Italian research activities focused on the development of geophysical models that will improve on the ability to discover resources, hence reduce risk. New methods for interpreting seismic reflection data have been quite successful in locating fractured zones at depths > 3,000 m.

A highlight was that Italy's only geothermal exploration and development for electricity company, Enel Green Power, received the 2002 Global Energy Award for best renewable energy operator.

### 7.3.7 Japan

Japan's total geothermal output capacity has remained almost constant for the past few years and the only new developments expected are small binary units. In 2002, geothermal resources generated about 0.3% of the total electricity generated, or 3,467 GWh of a total of 1,097 TWh. This is equivalent to saving 5.74 million barrels (0.85 million tonnes) of fuel oil per year. Total direct use of geothermal water in 2001 was about 1,430 GWh (5,139 TJ), excluding bathing, equivalent to saving 0.83 million barrels (0.12 million tonnes) of fuel oil/year.

The government has taken a leading role in the development of geothermal resources by providing assistance in the form of compensation for interest on bank credits for well drilling (requires large investment at early stage), ground facilities and, beginning in 2002, for binary power generation facilities. In addition, NEDO has a programme, started in 1980, which helps support geothermal development by funding surveys in prospective areas where investigations are of high risk; and NEF assists with the business of developing new energy sources.

In 2002, the Japanese government legislated a Renewable Portfolio Standard system that became effective in 2003. It requires electricity utilities to procure a certain percentage of electricity from renewable resources. However, geothermal energy is not included among the "new energies" that enjoy protection under the Promotion of the Use of New Energy" law (solar, wind and biomass are); and, at present, the government foresees a zero growth in geothermal energy development.

Geothermal research in Japan during 2003 dealt mainly with the comprehensive evaluation of EGS power generation (AIST) and international cooperation investigations, one into the use of acidic geothermal fluids (NEDO).

In 2002, Japan initiated a doctoral geothermal programme at Kyushu University, following the closure in 2001 of the International Group Training Course on Geothermal Energy that operated for over 30 years and trained almost 400 specialists.

### 7.3.8 Mexico

Geothermal energy is mainly used for the generation of electricity in Mexico. In 2003, the installed capacity was 953 $MW_e$, including 100 $MW_e$ commissioned in 2003 at Los Azufres. 6,283 GWh were generated, amounting to over 3% of the total electricity production. Assuming the typical mix of fuel oil, natural gas and coal in electricity generation, geothermal electricity generation saved 35.6, 15.7 and 8.8 PJ, respectively. There is a small amount of direct use, 164 $MW_t$, mainly for balneology.

In Mexico, geothermal energy is considered a conventional energy source, thus it competes on an equal basis with fossil fuels, hydro and nuclear. Consequently, it faces the economic challenge provided by fossil fuel generation technologies, particularly combined-cycle. The increase in the average electricity price has accelerated in recent years and amounted to 14% from 2001 to 2002.

Most research is focused on the development and exploitation of geothermal resources for power generation, mainly aimed at improving knowledge of fields and predicting their behaviour during exploitation.

A geothermal training programme is offered at The University of the State of Baja California, however, most engineers and geologists are provided on-the-job training.

### 7.3.9 New Zealand

In New Zealand, geothermal energy plays a significant role in both electric power production and direct use. The geothermal installed capacity for the March 2002 year was 431 $MW_e$, or about 5% of New Zealand's total; with 2,643 GWh produced, contributing about 7% of the country's total generation. In 1999, the direct use installed capacity amounted to over 300 $MW_t$, with about 1,950 GWh (7,000 TJ) utilized in applications that included pulp and paper production (210 $MW_t$), timber drying, prawn breeding, glasshouse heating and tourism.

The development of renewables is being strongly encouraged by several government policies that aim to increase energy efficiency by 20%, reduce $CO_2$ emissions by reducing dependence on fossil fuels, and ensure maximum development of renewable resources. In addition, Government has indicated it would like to develop its geothermal assets further.

Greater emphasis is being placed on geothermal development as a result of the drop in natural gas reserves, increasing gas and coal prices and the reliability problems with hydro generation caused by the El Nino weather patterns. It is anticipated that geothermal power generation will at least double in the next 10 years; even more by 2020, to meet increasing demand without use of coal and thereby compromising Kyoto Protocol commitments.

The cost of electricity in New Zealand continues to rise, with government predictions showing the wholesale price likely to be 5-6 US cents/kWh for the next 10 years. The capital costs for geothermal development in New Zealand are about US$ 3,200/kW and US$ 3,000/kW for 25 $MW_e$ and 50 $MW_e$ developments, respectively.

New Zealand government funded research continues at relatively low levels and is concentrated in four areas: deep high-temperature resources, use of low-enthalpy resources, better use of waste geothermal fluids and environmental effects. The use of deep MT for geothermal exploration and development is being emphasized.

The demise of the Geothermal Institute course in 2002 as a result of the withdrawal of government funding ended a 24-year period of international post-graduate education that trained over 670 people. However, geothermal engineering and science MSc and PhD programmes continue at Auckland University.

### 7.3.10 Switzerland

At present, there is no electricity generation from geothermal energy in Switzerland, though an EGS project is underway in Basle and investigations are proceeding at Geneva for the first exploration well. However, there is significant direct use, mainly for heating and at spas, with a total installed capacity of about 553 $MW_t$ and an estimated 1,123 GWh energy produced. This is equivalent to savings of about 115,000 toe and a reduction in $CO_2$ emission of 360,00 tonnes.

Switzerland has seen a rapid growth in the use of geothermal heat pumps, and as a consequence of the very hot 2003 summer, it is expected that the option for combining space cooling with space heating will grow significantly. At present, the most serious competitor for geothermal space heating is natural gas, though, geothermal heating/cooling utilizing geothermal heat pumps can compete with conventional oil-fired systems.

The SwissEnergy 10-year programme, initiated in 2001, supports and promotes the use of indigenous renewable energy. It's objectives include a 10% reduction in consumption of fossil fuels and concomitant $CO_2$ emissions between 2000 and 2010, a less than 5% growth in demand, no reduction in hydro power contribution and an increase in other renewable energy forms of 0.5 TWh or 1%, and 3 TWh or 3% for heating. Its basic strategy is to use voluntary measures as far as possible, though other control measures such as $CO_2$ tax and incentives are available if necessary.

Significant effort is going into geothermal education and information dissemination within Switzerland, including regular university lectures, special post-graduate courses and workshops. In addition, education was also provided on the international level with presentation of short courses in Iceland.

Geothermal research in Switzerland includes involvement in the EC EGS project at Soultz.

### 7.3.11 United States of America

The installed geothermal power capacity in the USA is 2,800 $MW_e$, with about 2,200 $MW_e$ currently operating. In 2002, geothermal generated over 13,357 GWh, or approximately 0.5% of the total US electricity production. Use of geothermal for generating electricity in the US reduces the emission of $CO_2$ by 16 million tons, $S0_2$ by 20,000 tons and $NO_x$ by 41,000 tons compared to state-of-the-art coal-fired power plants.

The installed thermal capacity for direct heat use in 1999 was about 4,000 $MW_t$, with 21,700 TJ or 6,040 GWh annual energy use. Heat pumps are the largest application (59% of energy use), followed by aquaculture (14%), bathing/swimming pools (11%), space heating (7%), greenhouse heating (6%) and industrial processes (2%). It is estimated that, in 2003, total direct use, including geothermal heat pumps, provided an equivalent savings of 12.9 million barrels (1.93 million tonnes) of fuel oil.

Several successes may be highlighted in the 2003 US geothermal programme, including: new power purchase agreements in Nevada, recommendation for approval of a 185 $MW_e$ plant at Salton Sea, and the joint winning by the National Laboratory and National Renewable

Energy Laboratory team of the 2003 Federal Laboratory Consortium Award for Excellence in Technology Transfer for development of a polyphenylenesulfide (PPS) protective coating particularly suited for use in carbon-steel heat exchanger tubes used in geothermal power plants. Two DOE Geothermal Program research projects won R&D 100 Awards in 2003: one for development of the Low Emissions Atmospheric Meter Separator (LEAMS) used for safely containing and cleaning atmospheric-vented steam of polluting solids, liquids and noxious gases; the second for development of an acoustic telemetry system that uses well-drilling tubing as a data transmission medium for conducting measurement-while-drilling data to the surface with the advantages of a 10-fold improvement in data rates and no blocking of the fluid flow path. Operation of a wastewater reinjection project at the Geysers geothermal field began in December 2003, disposing of 11 million gallons/day (with capacity to expand to 26 million gallons/day) of treated wastewater from Santa Rosa and surrounding cities (California), which could allow an 85 $MW_e$ increase in electricity generation.

The mission of the US DOE Geothermal Technology Program is to work with US industry and others to establish geothermal energy as an economically competitive contributor to the US energy supply, with the goal to decrease the levelized price of geothermal generated electricity to 3-5 US cents/kWh (2003 dollar) by 2010. In addition, as part of the US DOE goal of improving energy security and attaining a zero-emission future independent of imported energy, it is working on renewable energy technologies, such as geothermal, and with the private sector in developing domestic renewable resources. The relatively low cost of natural gas and coal generated electricity and competitive markets are the primary constraints to geothermal development. However, the mounting influences of Federal incentives, the requirement that a percentage of power be produced from renewable resources, discovery of new geothermal resources, improvements in technology, and increases natural gas price and electricity demand, will encourage growth in geothermal energy development.

For the better geothermal resources, the average cost of geothermal electricity at present is about 5 US cents/kWh, 30% of its 1980 cost. To continue this trend in reduced costs, more high quality resources must be discovered, reconnaissance tools must be improved so they can more quickly characterize larger areas and drilling costs must continue to drop.

The US DOE works in partnership with US industry, national laboratories and universities to conduct geothermal research in: exploration, to develop and test innovative techniques for exploration that will allow improved well siting, hence reduce well drilling costs; EGS technology development, to improve understanding of geothermal system operation and sustain productivity; geothermal drilling, to make it cheaper and more reliable; geothermal power plant operation, to reduce the high capital and O&M costs; resource assessment, to locate and evaluate new resources; and to improve communication and outreach in the western US to identify and remove barriers to geothermal development.

Geothermal education is supported by the DOE at the graduate level, through a university research programme, and for teachers and students nationwide through the Geothermal Education Office (GEO). The Geothermal Resources Council and the Geo-Heat Center at the Oregon Institute of Technology also provide additional education services; and several universities have geothermal research centres.

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**Author:** Mike Mongillo, IEA GIA Secretary, Institute of Geological and Nuclear Sciences Limited, Wairakei, New Zealand.

**Contact:** Mike Mongillo; iea-giasec@gns.cri.nz; mongillom@reap.org.nz

# CHAPTER 8

# Australia

## 8.1 Introduction

Australia's fledgling geothermal industry continues to grow. Undoubtedly the highlight was the completion, by Geodynamics Limited, of the first Australian deep geothermal well, Habanero-1, drilled to a depth of 4,421m into hot fractured granite beneath the Cooper Basin in northern South Australia. The temperature at the bottom is 250 °C. In November and December 2003, a hydraulic fracture test was conducted in which a total of 20,000 cubic metres of water were pumped at high pressure into the well below 4,000 m. Microseismic mapping of the stimulated rock volume showed that a sub-horizontal reservoir had been created approximately 3,000 m by 1,000 m with a thickness of more than 300 m, making it one of the largest hot fractured rock reservoirs. The size of the reservoir can be partly attributed to the unexpected overpressures of 36 MPa encountered in the fractured granite reservoir. These high overpressures had already stimulated sub-horizontal fractures over geologic time. The company raised a further A$15 million in the year to fund its geothermal program, and a second well will be drilled within 1 km of the first in 2004.

## 8.2 National Policy

### 8.2.1 Strategy

Geothermal energy is included in the National Mandatory Renewable Energy Target (MRET) of 9,500 GW of new renewable electricity by the year 2010.

### 8.2.2 Progress Towards National Targets

The MRET target has not changed since the previous year, but is currently under review.

## 8.3 Current Status of Geothermal Energy Use

### 8.3.1 Electricity Generation

Geothermal energy is presently produced at one small binary power station at Birdsville, in western Queensland. The fluid is 98 °C and derives from the Great Artesian Basin. The gross capacity of the plant is 150 kW, with a net output of 120 kW. The total electricity generated in 2003 was approximately 1 GWh.

Though there were no new developments in 2003, there was one deep geothermal well drilled as part of the Cooper Basin EGS project that is edging closer to success. A "proof of concept" circulation test between two deep geothermal wells is likely in 2004.

### 8.3.2 Direct Use

Geothermal energy is used for space heating and bathing, notably at Portland in Victoria and Moree in NSW. However, the total installed thermal capacity and energy used are unknown. There were no new developments during 2003.

## 8.4 Market Development and Stimulation

### 8.4.1 Support Initiatives and Market Stimulation Incentives

Australian Government funding through its research and development scheme known as START is supporting Geodynamics Limited with A$ 5 M towards its deep geothermal well program beneath the Cooper Basin.

### 8.4.2 Development Cost Trends

The one geothermal well drilled in 2003 by Geodynamics was more expensive than originally budgeted. The higher costs were the result of difficult drilling conditions in fractured granite where high overpressures were discovered in the fracture network.

## 8.5 Development Constraints

Interest in geothermal energy development is growing in Australia, as the success of the first deep well becomes better known.

## 8.6 Economics

Funding for geothermal has continued to increase from the general public (A$ 15 M). Several resource companies are also showing interest in taking up geothermal exploration.

Electricity costs remain low, though uncertainty in the future of Government opinion on dealing with greenhouse gas emissions has meant that there is currently little incentive for new developments of large fossil fuel-based electricity. There are currently more wind projects coming on stream than any other generation type.

## 8.7 Research Activities

The geothermal research focus in Australia is on EGS, with funding from both Government (A$ 5 M provided in 2002 and mostly spent in 2003) and industry (Geodynamics raised a further A$15 M with new share placements, and offers to existing shareholders).

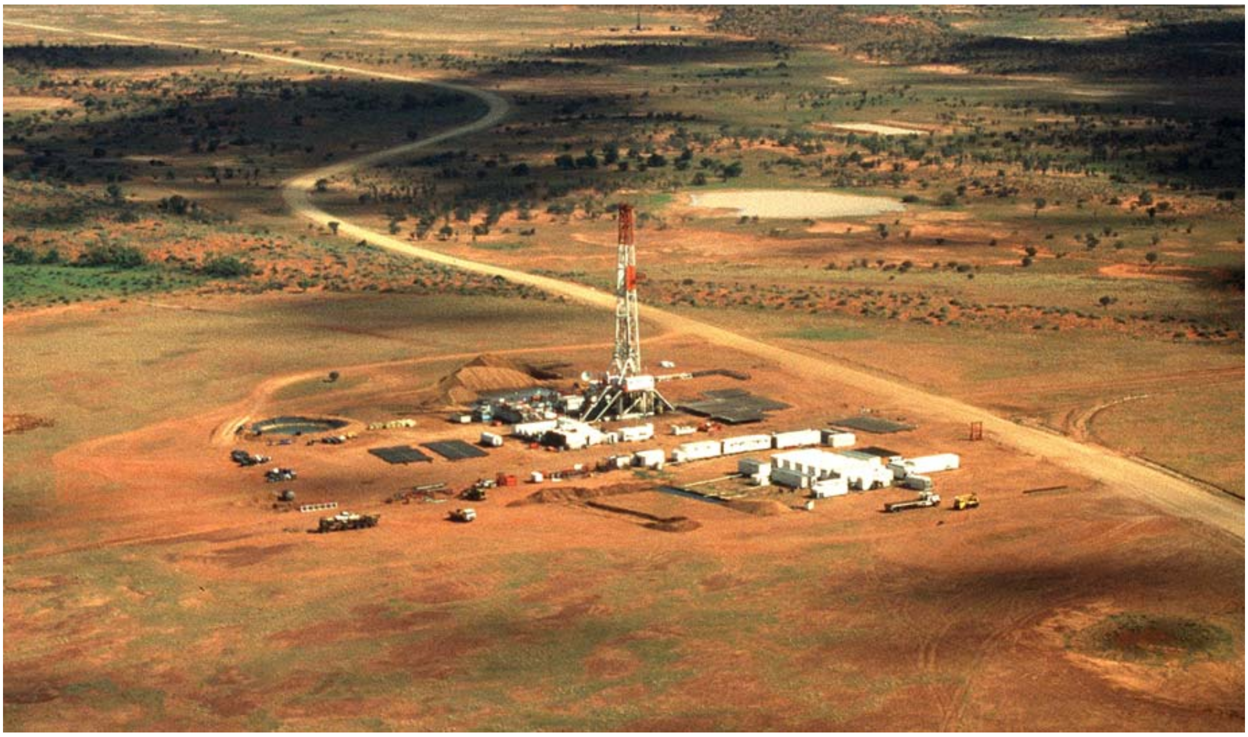


**Figure 8.1** Rig drilling Habanero-1 at the Cooper Basin site.

### 8.7.1 EGS Activities

Geodynamics Limited commenced drilling the Habanero-1 well (Habanero is the name of the world's hottest chilli) in February 2003. The well is Australia's first geothermal well, and is the start of the EGS "proof of concept" project in high temperature granites beneath the Cooper basin in northern South Australia.

Habanero-1 was completed at a depth of 4,421 m on 18 September. The 7-inch casing was set at 4,135 m, leaving a 6-inch open hole section of 286 m for the development of the first underground heat exchanger. Bottom hole temperatures are at least 250 °C.

Drilling was made extremely difficult because of the unexpected discovery of high overpressures (5,200psi or 36 MPa) in the granite joint network. These overpressures were high enough to cause natural hydraulic stimulation over geological time, and as a result favourably oriented joints are already permeable. A predicted overthrust stress regime has been confirmed, and the favourably orient joints are sub-horizontal. These conditions are most likely to persist over an area of about 1,000 km$^2$.

Hydraulic stimulation of the well took place over November and December 2003. In total, 20,000 m$^3$ of water was pumped into the well at pressures up to 9,500 psi (65.5 MPa). An acoustic monitoring network, using seven wells up to 5 km from Habanero-1, mapped over 11,700 events from 6 November to 22 December. The accuracy of location was better than 30 m in 3 dimensions, with almost all locations mainly located below 4,000 m depth.

The volume of the reservoir as defined by the microseismic data, is approximately 3,000 m by 1,000 m by 350 m thick, forming a flat pancake shape ideal for heat extraction with multiple well systems. The immense size, as compared to other HDR projects, is attributed to the overpressures in the granite.

The drilling of a second production well (Habanero-2) and circulation test are planned for 2004.

## 8.8 Geothermal Education

There are no formal geothermal programs yet in Australian schools and universities.

## 8.9 International Cooperative Activities

Australia is a member of the IEA Geothermal Implementing Agreement. In addition, Geodynamics Limited and the Australian National University have formal agreements with Japanese researchers in geothermal energy.

**Author:** Doone Wyborn, Geodynamics Limited, Milton, Queensland, Australia.

**Contact:** Doone Wyborn;
dwyborn@geodynamics.com.au

# CHAPTER 9

## European Community

### 9.1 EGS Activities in the European Union 2003

The European Commission supports a major European EGS project at Soultz-sous-Forêts, France, involving France, Germany, Italy and Switzerland, as well as teams from other countries inside and outside Europe, including Japan and USA. The project is coordinated by an industrial consortium (EEIG Heat Mining). The bulk of the funding is provided more or less equally by EC, France and Germany.

The aim of the project is to establish the world's largest and most efficient EGS at a depth of about 5,000 m. The system will consist of one central injection borehole and two symmetrically deviated production boreholes, each separated by about 500 m from the injection hole at depth. A total flow rate of 80 l/s is envisaged, equivalent to a total thermal power of 50 $MW_t$ and an electric power of 6 $MW_e$ (Figure 9.1).

By the beginning of 2003, there were two 5,000 m deep test wells at the site in Soultz. The well GPK-3, the centre future injection well, had just been finished in November 2002. The first production well, GPK-2, had already been stimulated in 2000, thus laying the foundation of the new deep underground exchanger.

In the summer of 2003, the injection well GPK-3 was successfully stimulated, linking it to the stimulated rock volume around the production well GPK-2. Over a period of 11 days, 34,000 $m^3$ of water were injected into GPK-3 using injection rates of up to 90 l/s. Some 90,000 micro-seismic events were recorded during this experiment. All together, a total of about 3 $km^3$ of rock mass was stimulated in both stimulations (2000 & 2003), creating the biggest manmade underground heat exchanger to date.

Following this stimulation experiment, a successful 12-day long circulation test was performed between the wells GPK-2 and GPK-3, at a flow rate of about 15 l/s and using only the buoyancy effect. At the wellhead of GPK-2 a temperature of 155 ºC was achieved after 12 days. The final production temperature is expected to be more than 180 ºC when the flow rate will be increased to about 40 l/s using a submersible pump.

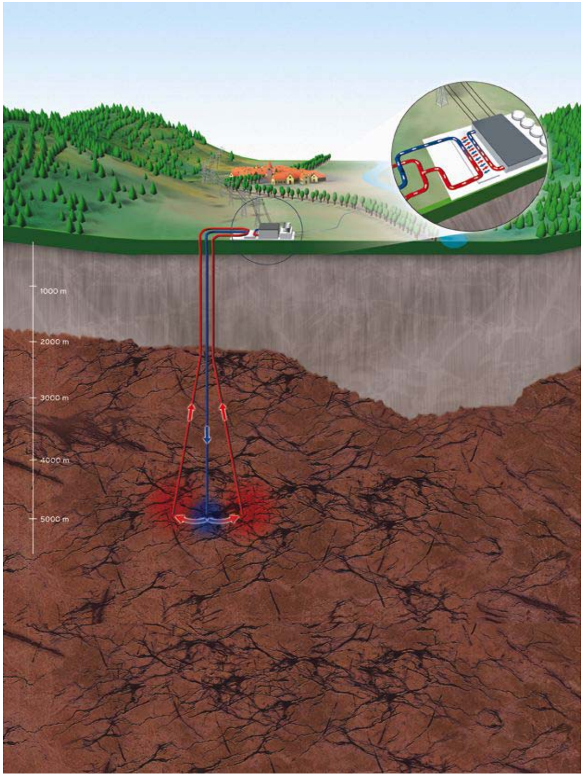



**Figure 9.1** Soultz pilot plant schematic.

Drilling of the second production well, GPK-4, was started in September 2003. The well is drilled vertically from the same platform to approximately 2,100 m depth and then deviated south/southeast.

GPK-4 will be the longest directional well drilled in the crystalline basement in Soultz so far. In early 2004 the construction of the underground part of the scientific pilot plant will be finalized with the stimulation of GPK-4, linking all three wells.

The contract for the last phase of this research project (construction of the pilot plant, 2004-2007) was signed by the EC in December 2003.

### 9.2 Website for Further Information

Soultz project: www.soultz.net

**Author:** Jeroen Schuppers, European Community, Brussels, Belgium.

**Contact:** Jeroen Schuppers; Jeroen.Schuppers@cec.eu.int

# CHAPTER 10

# Germany

## 10.1 Introduction

At present, the lack of natural high temperature geothermal reservoirs makes the production of electricity via geothermal generally uneconomic due to the current competitive prices. However, a highlight in Germany's geothermal programme occurred in November 2003, when the first geothermal power plant was inaugurated at Neustadt-Glewe, where a 250 $kW_e$ plant will produce an estimated 1,400 MW/year as part of a combined heat and power production (CHP) development (Bussmann, 2004). Deep EGS is also being investigated, though the technology is still in the development phase.

At the end of 1999, direct use of geothermal amounted to an installed capacity of about 400 $MW_t$ , of which approximately 55 $MW_t$ was generated at 27 major central installations (Schellschmidt, et al., 2000). The remaining 342 $MW_t$ were contributed by heat pumps and used across Germany for space heating. Direct heat is mainly used for thermal spas, space heating/cooling and greenhouse heating.

## 10.2 National Strategy

The Law on Energy Supply (Energie-Einspeise-Gesetz [EEG]) that became effective on 1 April 2000 is one attempt of the German government to promote the use of renewable energies. Operating companies, which supply electricity from renewable resources to the public net, receive a guaranteed minimum payment.

In that way with renewable resources energy operating companies have a long-term security as regards planning and control. The cost-effectiveness and competitiveness of alternative energy production plants will therefore increase.

The minimum payment is shown in Table 10.1.

**Table 10.1** Minimum payment for renewables.

| | | |
|---|---|---|
| Electricity by wind | 6.1 – 9.0 | €-cents/kWh |
| Electricity by photovoltaic | 48.1 | €-cents/kWh |
| Electricity by water | 6.65 – 7.67 | €-cents/kWh |
| Electricity by biomass | 8.6 – 10.1 | €-cents/kWh |
| Electricity by geothermal | 7.16 – 8.95 | €-cents/kWh |

Explanation: €-cents means Euro-cent

The development of renewable energy resources has been further encouraged with the German Government's signing of signed the Kyoto Protocol in 2003. The Government aims to increase electricity production through the use of renewables to 20% by 2010.

Development of geothermal resources in Germany presently faces constraints resulting from the high risks and costs of drilling, the high saline composition of the fluids discovered to date, and the low costs of oil, gas and coal as alternatives for heating and generating electricity.

In the past the Federal Economy Ministry and Federal Environment Ministry were both responsible for funding of renewable energies in the R&D-Program and the Future Investment Program (FIP).

At present the Federal Environment Ministry alone is responsible for funding of renewable energies. The R&D-Program still exits and the decision if the FIP will be continued in the sense that additional money given will come at end of 2003.

## 10.3 Research Projects

The projects mentioned below are those whose costs exceed 1 M €. Funded projects are those that receive aid from the Federal Environment Ministry (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit) (FEM) or the Federal Economy and Labour Ministry (Bundesministerium für Wirtschaft und Arbeit) (FELM). Total costs refer to costs consisting of both government aid plus own resources.

Though the German energy research program is not entirely compatible with the GIA Annexes, several of the projects being conducted are, including the EGS research, which is the task of both the Bad Urach (D) and the European Soultz-sous-Forêts (F) projects. One can classify these projects in the Annex IV- Deep Geothermal Systems.

In addition, there is a larger group of projects that deal with the shallower hot water and steam resources. These projects are located in Bremerhaven, Groß Schönebeck, Hannover and Neustadt-Glewe, and occur in the north of Germany where you do not find the positive temperature anomalies present in the upper Rhine-Graben (e.g. Bad Urach, Soultz). The temperatures are moderate with a "normal" temperature gradient of 3 °K per 100 m. The aim of the projects in the north of Germany is to make the sedimentary structures accessible for geothermal energy.

All geothermal energy activities are reported below (Table 10.4).

### 10.3.1 Bad Urach

The task of this project is development, verification and demonstration of location independent EGS concepts for the production of electricity and heat from hot deep rocks considering geological, hydraulic, technical and economic parameters of methods and plants (data set for a EGS pilot plant).

Hydraulic stimulations in the first borehole were a success. The production rate increased from 30 l/sec to 50 l/sec. It is assumed that an artificial heat exchanger was created. Seismic clouds were evaluated with a special processing method, which showed that the heat exchanger is placed between 3,300 m and 4,200 m depth. The temperature is approximately 170°C.

A second borehole (4,500 m depth) is planned and will be drilled soon.

The total cost for this project is 6.7 M €; with 6.5 M € funded by FEM.

### 10.3.2 Bremerhaven

The goal of this project was to provide geothermal energy for the new Alfred-Wegener-Institute building in Bremerhaven. A plant for field-tests was to be constructed with a deep geothermal heat probe working with direct evaporation of a cooling medium for heat and electricity production.

A mathematical model was developed. Using modelling and simulation, the working method of the geothermal heat probe was to be examined. The simulation showed that the method is feasible. In the meantime, it was not possible to get an investor for funding of the borehole (drilling was not financed by FELM). The project was therefore discontinued and funding in the amount of 1.2 M € was reclaimed.

The total cost for this project was 3.3 M €, 1.6 M € funding from FELM (minus 1.2 M €).

### 10.3.3 Bruchsal

The objective was to investigate the use of high salinity, high temperature deep geothermal water at the Bruchsal geothermal field for heat and electricity production.

Two wells were drilled earlier (1980). After getting new government aid it was then possible to do the circulation tests. Due to the high salinity and extreme temperature and pressure changes during the circulation tests the heating pipeline (fibreglass pipe) broke up. It is planned to fund a new heating pipeline to get the project running again. Steel will be used for the new pipeline. It will receive an inner wall scaling made of the natural aragonite or calcite precipitation. The scaling will be applied under controlled (temperature, pressure, inhibition of oxygen entry) conditions. Under constant conditions, even during the test phases, and later in operation, the scaling should prohibit corrosion.

The total cost for this project amounts to 3.1 M €, with 1.6 M € funding from FEM (before FELM).

### 10.3.4 Groß Schönebeck

The aim is to prepare hot water rock storage in the sedimentary north German Basin for the use of geothermal heat. This task is done by a network of 6 "stand alone" projects.

The focus of this project lies on new stimulation techniques for sediments. An old oil and gas exploration well was used. Experiments were done in sandstone and vulcanite layers. Stimulation tests were made which included the insertion of water gel props. Fracture growth was observed by seismic events. The flow rate increased but did not reach the milestone of 75 $m^3$/h.

The total project costs amounted to 5.5 M €, with 5.3 M €funding provided by FELM and FEM.

### 10.3.5 Hannover

The task was to study the one-probe-two-layer-method. Two institutions are working on this project.

The aim is the examination of the method for extraction of geothermal heat from sedimentary rocks in the north German basin.

During hydraulic tests temperature and pressure logs will be run as well as seismic detection. The results are interpreted using analytical and numerical models to get information on the thermal capacity and the physical and economic life of the one-probe-two-layer-system. The project is in the start up phase.

The total costs are 2,0 M €, with 2.0 M €funded by FEM (before FELM), hence the project is totally funded, and no "own resources" required.

### 10.3.6 Neustadt-Glewe

This study involves the evaluation of operational parameters for the geothermal heat plant at Neustadt-Glewe for the production of both heat and electricity generation using turbines working on ORC basis. The work is spread over two projects.

The Neustadt-Glewe geothermal plant has been successfully providing heat to industry, commercial customers and about 2,000 private homes since 1995. However, it became very important as the first geothermal power plant producing electricity in Germany when a 250 $kW_e$ organic rankine cycle plant was commissioned in November 2003. Initially, about 1,400 $MW_e$ is expected to be produced each year.

Total costs are 1.3 M €, with 0.6 M €funding from FELM and FEM.

### 10.3.7 Soultz-sous-Forêts (Alsace, France)

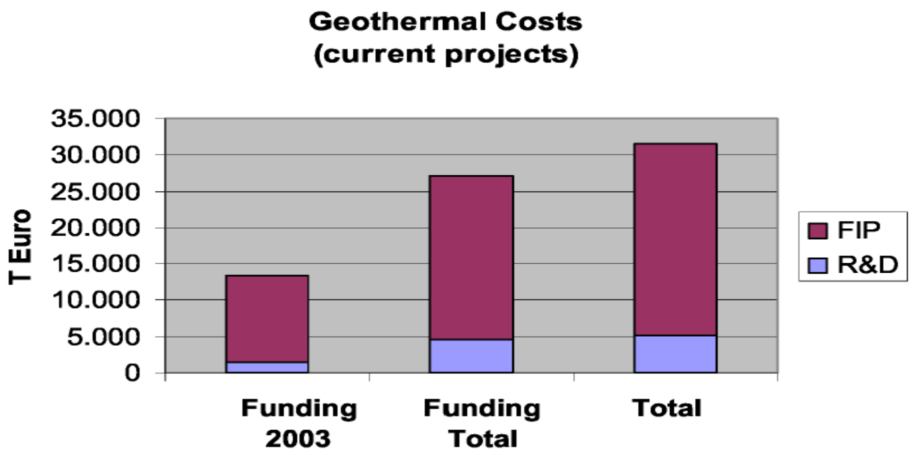
The task is the installation of a scientific geothermal pilot plant (first phase). The project is a European project on EGS. It is funded by the funding agencies of the EC, France and Germany and in a smaller part by the industry. The working plan on the German side is distributed to 5 partners (federal agency, university and companies).

In the first phase, 3 boreholes (GPK-1, 2, 3) are drilled, with two up to 5,000 m deep. Stimulation tests were done with very much success. It was possible to generate two heat exchangers at two horizons. The upper reservoir is located at 3,000 m to 3,600 m depth, and delivers temperatures of 165 °C. The lower reservoir at depths of 5,000 m and deeper has temperatures of 200 °C. The new reservoir at 5,000 m shows closer boundaries compared to the upper reservoir. No leak-off to the upper reservoir has been detected. At the moment the last planned borehole (GPK-4) is being drilled without problems.

The total costs for this project for Germany alone are 9.1 M €, with 8.4 M €funding from FEM (before FELM). The total cost of the investigation for all parties amounts to 30 M €.

### 10.3.8 Funding

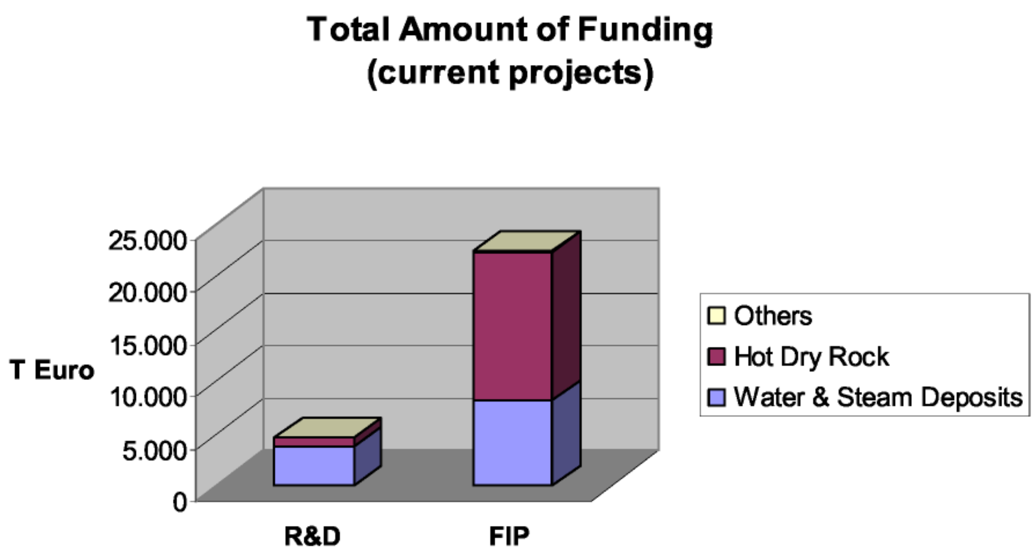
The funding available for geothermal projects in Germany is presented in Figures 10.1 and 10.2 and Tables 10.2 and 10.3.




| | Funding 2003 [T €] | Funding Total [T €] | Geothermal Costs (total) [T €] |
|---|---|---|---|
| **R&D*** | 1,516 | 4,590 | 5,157 |
| **F I P**** | 11,865 | 22,479 | 26,304 |
| **Total** | **13,382** | **27,069** | **31,460** |

* R&D = Research & Development Program
** F I P = Future Investment Program

**Figure 10.1 and Table 10.2** Geothermal costs for current projects.




| | R & D [T €] | F I P [T €] |
|---|---|---|
| **Water & Steam Deposits** | 3,775 | 8,182 |
| **Hot Dry Rock** | 815 | 14,150 |
| **Others** | 0 | 148 |
| **Total** | **4,590** | **22,479** |

**Figure 10.2 and Table 10.3** Total funding for geothermal projects.

**Table 10.4** Overview of the Actual Projects.

| Location | Operator | Wells | Depth [m] | Temperature [°C] | Volume Flow [$m^3$/h] or Power [W] |
|---|---|---|---|---|---|
| Bad Urach | Stadtwerke Bad Urach (swbu) | 1<br>1 | 4,450<br>u.c. | 170 | 1 $MW_e$ |
| Bremerhaven | Stadtwerke Bremerhaven (swb) | 1 | 5,450 | 162 | 500 $kW_t$<br>n.r. |
| Bruchsal | Energie- und Wasserversorgung Bruchsal | 1<br>1 | 1,932<br>2,542 | 135 | 50 $m^3$/h |
| Groß Schönebeck | GeoForschungsZentrum Potsdam | 1<br>1 | 4,300<br>u.c. | 140 | 25 $m^3$/h<br>MS 75 $m^3$/h |
| Hannover | Bundesanstalt für Geowissenschaften und Rohstoffe & Institut für Geowissenschaftliche Gemeinschaftsaufgaben | 1 | 4,000 u.c. | 120 | MS 50 $m^3$/h |
| Neustadt-Glewe | LanGeo / ErdwärmeKraft Neustadt-Glewe | 1<br>1 | 2,455<br>2,335 | 98 | 40-100 $m^3$/h<br>6.75 $MW_t$ |
| Soultz-sous-Forêts (F) | Bundesanstalt für Geowissenschaften und Rohstoffe & international Partner | 1<br>1<br>1<br>1 | 3,590<br>5,000<br>5,000<br>5,000 u.c. | 165<br>202 | 360 $m^3$/h<br>10 $MW_t$ (test) |

u.c. = under construction
n.r. = not realized
MS = Milestone
test = in the first test phase 2 wells, both approximately 3,590 m, deliver 10 $MW_t$

## 10.4 Prospective Work Planned for 2004

The Soultz project is ongoing with phase II. It is planned to cover a period of 3 years (2004–2006) with government aid from the EC, France and Germany. The German government funds approximately 6.2 M € for the German project partners.

The content of the renewable energy program stays as it is, but the amount of funding will be reduced. For geothermal energy one can assume that 5 M € per year will be allocated.

The International Conference for Renewable Energies will be held in Bonn, Germany, on 1-4 June2004.

For project Bad Urach, the second borehole is planned and will be drilled soon (depth 4,500 m).

## 10.5 Geothermal Education

Geothermal education is provided at several universities in Germany, including Uni Bochum, RWTH Aachen, TU Berlin

## 10.6 References

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**Authors:** Andrea Ballouk and Dieter Rathjen (direct correspondence to this author), Forschungszentrum Jülich (Project Management Organization), Jülich, Germany

**Contact:** Dieter Rathjen : dieter.rathjen@fz-juelich.de

# CHAPTER 11

# Greece

## 11.1 Introduction

There were not many changes in the geothermal scene in Greece during 2003. This was mainly due to the fact that the geothermal community in Greece was anticipating the issuing of a new geothermal law that was voted in during June 2003. It was published in the official journal of the Government at the end of August 2003 (Law 3175/03 - Official Journal Issue 207 A / 29/8/03).

Since no explanatory decrees were issued relating to the explanation and the application of this new law No. 3175/03, no new projects nor extension of old ones was permitted. Thus the information presented in the IEA Geothermal Annual Report 2002 is still generally valid for 2003.

At present geothermal resources are not used for electricity generation in Greece. However, there is direct use of geothermal, with an installed capacity of about 70 $MW_t$, producing an estimated 135 GWh. Direct heat applications include: heat pumps, space heating, greenhouse and soil heating, aquaculture, bathing (spas) and desalination.

However, a highlight for 2003 was the completion of construction of the MILOS Geothermal ORC-ME Desalination plant, which received support from the EC.

## 11.2 National Policy

### 11.2.1 Highlights of the New Legislation on Geothermal Energy in Greece

Geothermal energy is recognized by the Greek State as both a renewable energy source and a mineral ore. As a mineral ore, the exploration and exploitation rights of geothermal energy with temperatures exceeding 25 ºC belong to the State. The State, after following a public competition procedure, allocates “geothermal concessions” to interested parties, who need not own the land above the geothermal field, but will gain the right to expropriate it if necessary.

Responsibility for geothermal concessions lies with the Ministry of Development for temperatures higher than 90 ºC and with the Regional Authorities for temperatures between 25 ºC and 90 ºC. Exploration concessions are allocated for a period of 5 years with a 2 years extension option, and exploitation concessions are allocated for a period of 25 years with a 5 years extension option. Any geothermal concessions allocated before the enforcement of this law, remain in force.

The geothermal concession tenant pays a “rent” to the Greek State for the geothermal energy use, equal to 5% or 10% of the equivalent value of natural gas.

The Ministry of Development allocates “Power production permits” for geothermal energy, after a public competition and evaluation of tenders by the Regulatory Authority for Energy. A contract for geothermal energy sales is signed between the owner of the geothermal concession rights and the power production permit owner. Heat sales through a district-heating network are now allowed by the geothermal concession owner. A “heat sales permit” is necessary and issued by the Ministry of Development after consulting the Regulatory Authority for Energy. A public competition procedure may be followed according to the Ministry of Development’s judgement.

The Ministry of Development has the right to declare a particular geothermal concession as predominant upon other mineral ore concessions, to settle any disputes between geothermal and hot spring users, and to confine a particular geothermal concession.

No State concessions are necessary for heating and cooling with geothermal heat pumps using shallow or surface formations and waters cooler than 25 ºC. However, a permit must be issued by local Prefecture.

**Authors:** Costas Karytsas and Dimitrios Mendrinos, CRES, Pikermi-Attiki, Greece.

**Contact:** Costas Karytsas; kkari@cres.gr

# CHAPTER 12

# Iceland

## 12.1 Introduction

Geothermal energy provides over half of the primary energy supply in Iceland. The principal use of geothermal energy is for space heating, and about 87% of all energy used for house heating comes from geothermal resources. Of the total electricity generation, about 17% comes from geothermal energy.

## 12.2 National Policy

The share of renewables, geothermal energy and hydropower, is about 70% of the primary energy supply of the country. Through national policy, fossil fuels have been practically eliminated for space heating and replaced by geothermal energy and electricity. Imported fossil fuels are still used for vehicles on land and fishing boats on sea. A national policy has been set to replace these fuels by synthetic fuels as soon as they can be produced at competitive prices with the aid of renewable energy resources, hydro and geothermal.

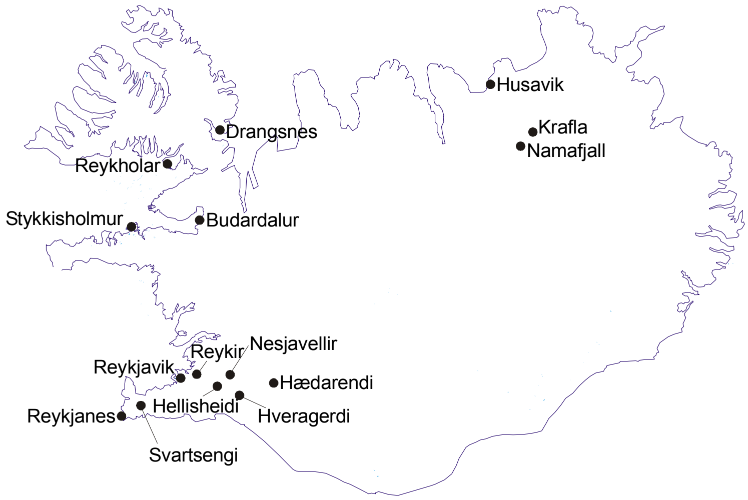



**Figure 12.1** Location of geothermal utilization sites mentioned in the paper.

## 12.3 Current Status of Geothermal Energy Use

### 12.3.1 Electricity Generation

The electricity demand has increased considerably in Iceland in the last years due to a large expansion in the energy intensive industry. This has been met partly by increased geothermally produced electricity. Of the total electricity generation of 8,411 GWh in 2002, 1,433 GWh or 17% came from geothermal energy, 82.9% from hydro and 0.1% from fuels. Figure 12.2 shows the geothermal generation of electricity in Iceland in the period 1970-2002. The total installed capacity of geothermal power plants is now 200 $MW_e$.

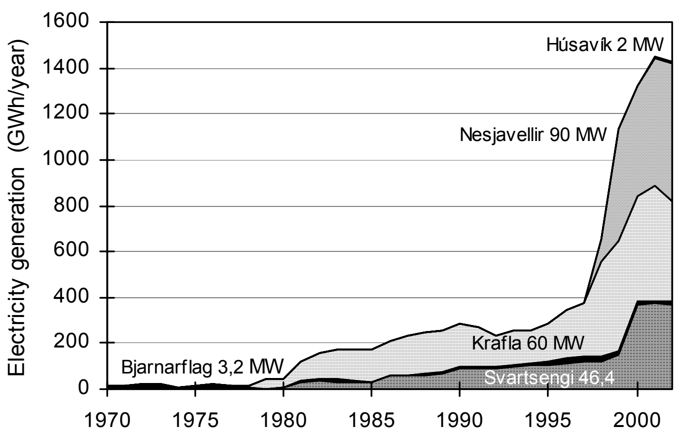



**Figure 12.2** Geothermal generation of electricity in Iceland 1970-2002.

The first geothermal power plant with 3 $MW_e$ started operation in 1969 in Namafjall in North-

Iceland. It has been in operation since, except for three years in 1985-1987 when the plant was closed mainly due to volcanic activity in the area. The reservoir temperature is about 280 °C. Steam is separated from the water at 9.5 bar absolute to provide a steam flow rate of 12.5 kg/s to a single flash turbine.

The Krafla power plant in North-Iceland has been in operation since 1977. For the first 20 years it was generating 30 $MW_e$ in a double flash condensing turbine. Volcanic activity in the area caused inadequate steam supply in the beginning so expansion to the originally planned capacity was delayed. The capacity was increased to 60 $MW_e$ in 1997 by installing a second turbine. The reservoir temperature ranges from 210 to 350 °C. Steam is separated from the water in two stages, at 7.7 and 2.2 bar absolute, to provide 120 kg/s high pressure steam and 30 kg/s of low pressure steam. As a result of exploration drilling activity in the area the last years, a further increase of 40 $MW_e$ is under preparation. Also consideration will be given to building a new plant in the area in the future.

The Svartsengi co-generating power plant has been producing both hot water and electricity since it started operation in 1977. It is located on the Reykjanes peninsula, 40 km from Reykjavik, and serves about 16,000 people. The geothermal reservoir fluid is a brine at 240 °C with high salinity. The geothermal heat is transferred to freshwater in several heat exchangers. In 1999 an expansion of the plant was completed by installing a new 30 $MW_e$ turbine. The total installed capacity is now 200 MWt for hot water production and 46 $MW_e$ for electricity generation. Of that, 8.4 $MW_e$ come from binary units using low-pressure waste steam.

The effluent brine from Svartsengi is disposed of into a surface pond called the Blue Lagoon. It has been used for a long time by people suffering from psoriasis and other forms of eczema, who seek therapeutic effects from the silica rich brine. Also it is very popular among tourists, especially after the opening of new facilities a few years ago.

At Nesjavellir high-temperature field, Reykjavik Energy is operating a co-generating plant. The plant started operation in 1990 with production of hot water for the Reykjavik area 27 km away. Freshwater is heated by geothermal steam and water in heat exchangers. At the end of 1988 the power plant started electricity generation of 60 $MW_e$ in two 30 $MW_e$ turbines. The working pressure of the turbines is 12 bar (190 °C). In the year 2001, the third 30 $MW_e$ turbine was installed bringing the total installed capacity to 90 $MW_e$. Further expansion of the plant to 120 $MW_e$ is under consideration.

At Husavik, located in the northern part of Iceland, the generation of electricity began in the year 2000 by installing a binary plant of Kalina type. Geothermal water of 120 °C is used to generate 2 $MW_e$ of electricity and hereby cooling the geothermal fluid down to 80 °C. The electricity generated is enough to provide more than half of the electrical demand of the town. The 80 °C water from the power plant is then used for district heating of the town.

### 12.3.2 Direct Use

An overview of the direct uses of geothermal energy in Iceland and how the uses are divided on the different utilization sectors is given in Table 12.1 and Figure 12.3.

**Table 12.1** Direct use of geothermal energy in Iceland 2001.

| **Utilization Sector** | **Annual Energy Consumption** | | |
|---|---|---|---|
| | TJ/year | GWh/year | % |
| Space heating | 17,223 | 4,784 | 72.4 |
| Swimming pools | 1,200 | 333 | 5.0 |
| Snow melting | 1,150 | 320 | 4.8 |
| Industrial uses | 1,600 | 444 | 6.7 |
| Greenhouses | 940 | 261 | 4.0 |
| Fish farming | 1,680 | 467 | 7.1 |
| **Total** | **23,793** | **6,609** | **100.0** |

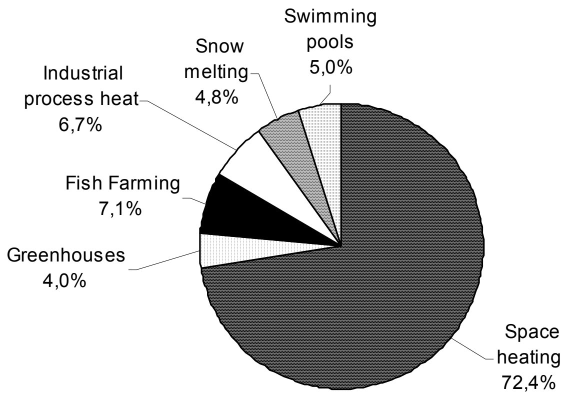



**Figure 12.3** Direct uses of geothermal energy in Iceland in 2001.

### 12.3.2.1 Space Heating

The main use of geothermal energy in Iceland is for space heating (Figure 12.4). It had its beginning early in the 20th century and in 1970 about 43% of the population was served by geothermal district heating systems. After the oil crisis in the 1970s, high priority was given to replacing imported oil with the indigenous energy sources hydro and geothermal. Today about 87% of the space heating is by geothermal energy, the rest is by electricity (11.5%) and oil (1.5%).

District heating in Reykjavik began in 1930 when water from a hot spring area in the city was piped 3 km to a primary school. Soon after, the national hospital, a swimming pool and some 60 private houses were connected. In 1943 geothermal water from a large geothermal field located about 17 km from the city, the Reykir area, was piped to Reykjavik. Reykjavik Energy now utilizes four low-temperature areas within, and in the vicinity of, Reykjavik as well as the high-temperature field at Nesjavellir, about 27 km away. The water from the low-temperature fields is used directly for heating and as hot tap water. However, due to its high content of gases and minerals, the water and steam from Nesjavellir is used to heat fresh water. Today Reykjavik Energy serves about 177,000 people, or practically the whole population of Reykjavik and four neighbouring communities, as well as two towns in a separate system in West-Iceland.

Besides Reykjavik, there are district heating systems in about 30 towns and villages in Iceland, most of them municipally owned. Geothermal heating is now used in all areas in Iceland where geothermal resources have been located. Recent developments in this field include district heating in Stykkisholmur, Drangsnes and Budardalur with a total number of about 1,700 inhabitants.

Heating of dwelling houses by electricity and oil is subsidized by the government in order to keep comparable heating costs all over the country. To encourage installation of new geothermal heating schemes and expansion of older ones, the government gives grants to this type of installation. The amount granted is the equivalent sum of expected subsidies over the next five years to the houses involved, as it would have been in case of continuing electrical heating.

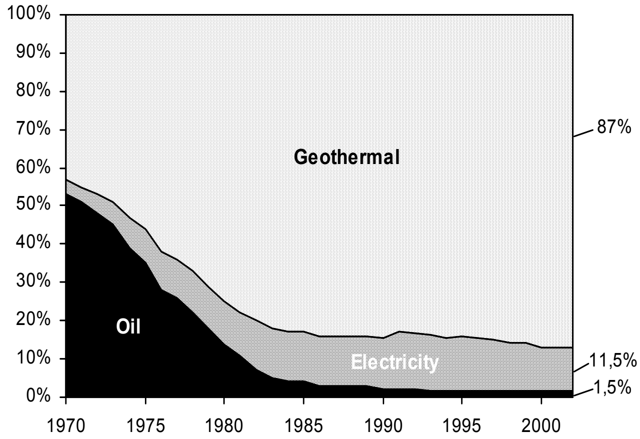



**Figure 12.4** Space heating by sources 1970-2002.

### 12.3.2.2 Other Direct Uses

A brief description of geothermal utilization sectors other than space heating follows.

- **Swimming Pools**

From the time of settlement of Iceland some 1,100 years ago until early in the 20th century the use of geothermal energy was limited to bathing, cooking and laundering. Today, some of these uses are still significant and heating of swimming pools is one of the most important utilization sectors in the country. There are about 100 public swimming pools and about 30 pools in schools and other institutions heated by geothermal energy with a combined surface area of 28,000 $m^2$. This comprises about 90% of all swimming pools in Iceland. Most of the public swimming pools are open-air pools in constant use throughout the year.

Swimming is very popular in Iceland and the pools both serve for recreational use and for swimming instruction. In the greater Reykjavik area there are about ten public outdoor pools and five indoor ones. The largest of these is the Laugardalslaug, having a surface area of 1,500 $m^2$ and five hot tubs in which the water temperature ranges from 35 to 42 °C. The Blue Lagoon at Svartsengi and the Health Facility in Hveragerdi, comprising geothermal clay baths and water treatments, are also very popular.

The number of visitors in swimming pools has increased in the last years, reaching 4.7 million visits last year, which is equivalent to 16 visits per inhabitant. A new swimming pool of average size uses a similar amount of geothermal water as 80-100 private houses.

- **Snow Melting**

The use of geothermal energy for snow melting has been widespread for a long time. It has become increasingly common to use return water from the houses at about 35 °C for de-icing of sidewalks and parking spaces. Most systems have the possibility to mix the spent water with hot water (80 °C) in periods when the load is high. Under an extensive rehabilitation of streets in downtown Reykjavik a few years ago, a snow melting system was installed under pavements and streets covering about 40,000 $m^2$. Many streets in a new construction area in the eastern part of Reykjavik are having snow-melting systems installed.

The total area covered by snow melting systems in Iceland is estimated to be about 740,000 $m^2$, of which about 460,000 $m^2$ are in Reykjavik. The total geothermal energy used for snow melting is estimated to be 320 GWh per year. Of that, about 55% come from spent water from the houses and the rest from 80 °C hot water.

- **Industrial Uses**

The use of geothermal energy for industrial uses began on a large scale in 1967 with the establishment of Kisilidjan, a diatomic plant at Myvatn near the Namafjall high temperature geothermal field. It is still the largest industrial user of geothermal energy in the country. The raw material is diatomaceous earth from the bottom of the lake Myvatn. The annual production is about 27,000 tonnes per year of diatomite filter aids for export. The annual steam consumption is about 270 thousand tonnes at 10 bar absolute for drying.

A seaweed processing plant at Reykholar uses geothermal water for drying. The annual production of seaweed and kelp is 2,000 to 4,000 tonnes and the processing plant is using 28 l/s of 107 °C hot water.

On the Reykjanes peninsula a salt plant was in operation for more than 20 years, but it was closed down in 1994. From geothermal brine and seawater the plant produced salt for the domestic fishing industry as well as low-sodium health salt for export. Part of the plant was restarted in 1999 on a small scale.

At Hædarendi in Southern Iceland, a plant for the commercial production of liquid carbon dioxide has been in operation since 1986. The plant uses 6 l/s of geothermal water at 160 °C with high gas content. The annual production is about 2,000 tonnes of $CO_2$, which is used in greenhouses, soft drink production and other food industries.

Geothermal energy has also been used for other industrial purposes such as drying of hardwood at Husavik which started in 1986, drying of fish at several locations, retreading of car tires in Hveragerdi and production of cements blocks at Myvatn.

- **Greenhouses**

Geothermal heating of greenhouses started in Iceland in 1924, but prior to that naturally warm soil had been used to grow potatoes and other vegetables. The total area under glass is about 195,000 $m^2$. Of this area about 55% is used for growing vegetables (tomatoes, cucumbers, paprika *etc.*) and 45% for growing flowers for the domestic market (roses, potted plants *etc.*). In addition it is estimated that about 105,000 $m^2$ are used for soil heating. It has the main benefit of early thawing of the soil and the vegetables can be brought to market sooner.

The majority of the greenhouses are in the southern part of Iceland. Most of them are glass covered with heating installations made of unfinned steel pipes hung on the walls and over the plants. Undertable, or floor heating, is also common.

Artificial lighting has increased considerably in the last years, doubling the crop yield and allowing year-round production, but with increasing expenses in electricity. Enrichment of $CO_2$ gas in greenhouses during the winter has increased in the past years.

- **Fish Farming**

At present there are about 50 fish farms in operation in Iceland. The total production has been slowly increasing in the past years and is now about 4,000 tonnes per year. Salmon is the main species with about 70% of the production, but arctic char and trout are also raised. Geothermal water, commonly 20-50 °C, is used to heat fresh water in heat exchangers from 5 to about 12 °C. It is mainly used in the hatchery state of the fish production. A great expansion is expected in this sector with a considerable increase in utilization of geothermal energy.

## 12.4 Market Development and Stimulation

New legislation leads to liberalization of the energy market. Production and sale of electrical energy are now on a competitive basis. A similar legislation for direct use of geothermal energy is in preparation. Energy companies that have been owned by communities and the state are merging and expanding their markets.

## 12.5 Development Constraints

Environmental concern and opposition to the development of both hydro and geothermal resources is growing. A Master Plan for the Utilisation of Hydro and Geothermal Resources for the generation of electricity is under preparation. The Plan shall evaluate economic advantages and environmental impact of proposed power development from hydro and geothermal resources and categorize the proposed projects according to their feasibility. The results of the first phase of this study were issued in late 2003, comparing 19 hydro projects and 24 geothermal projects.

## 12.6 Economics

Recent developments of geothermal resources have demonstrated that geothermal power plants can compete with hydro power plants in the country in providing electricity for the industry of aluminium smelters.

## 12.7 Research Activities

During the past five years the Ministry of Industry has been running a programme to encourage geothermal exploration for domestic heating in areas where geothermal resources have not been identified, so-called “cold areas”. A total amount of 150 million ISK (US$ 1.9 M) have been granted for this purpose and used mainly for drilling 50-100 m deep thermal gradient exploration wells. This method has proven to be a successful exploration technique in Iceland.

Reykjavik Energy has in the last years been drilling several exploration wells on Hellisheidi, where they plan to build a new power plant for both electricity and hot water production. Also at Nesjavellir new wells have been drilled as a preparation for expansion of the existing power plant.

At Reykjanes, the Sudurnes Regional Heating Company has been carrying out exploration drilling in connection with plans to utilise this high-temperature field for power production. There they plan to build a power plant of 40 $MW_e$ in the first stage. The company has also been involved in drilling activity at Trölladyngja, which is another high-temperature field on the Reykjanes peninsula.

A consortium of Icelandic energy companies is preparing the drilling of a 4-5 km deep drillhole into one of the high-temperature hydrothermal systems to reach 400-600 °C hot supercritical hydrous fluid at a rifted plate margin on a mid-ocean ridge. The main purpose of the project is to find out if it is economically feasible to extract energy and chemicals out of hydrothermal systems at supercritical conditions. A feasibility report was completed

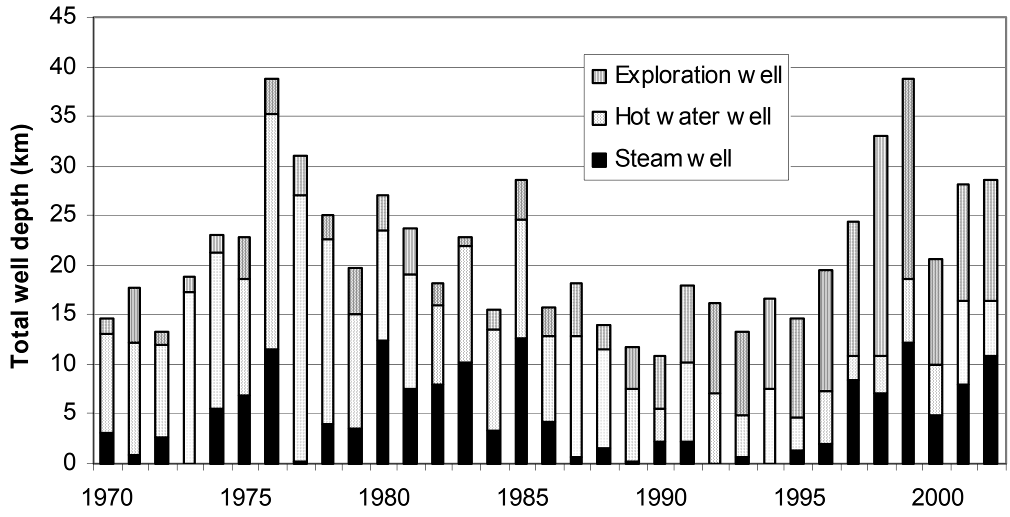



**Figure 12.5** Total depth of geothermal wells drilled annually in Iceland 1970-2002.

in May 2003 and continuance of the project will depend on the financing available.

Figure 12.5 gives an overview of the geothermal drilling activity in Iceland since 1970.

## 12.8 Geothermal Education

Iceland has operated a Geothermal Training Programme under the auspices of the United Nations University since 1978. This programme offers six months graduate education and training in 8 different disciplines of geothermal science and engineering to applicants from developing countries. About 18-20 candidates are selected annually from the group of applicants by personal interviews. A continuation of this programme towards a master's degree at the University of Iceland is now possible.

## 12.9 International Cooperative Activities

Iceland is a member of the International Geothermal Association. The Secretariat of that organisation will be located at Samorka in Reykjavik, Iceland for the next 5 years, from September 2004.

**Authors:** Arni Ragnarsson and Sveinbjorn Bjornsson, Orkustofnun (National Energy Authority of Iceland), Reykjavik, Iceland.

**Contact:** Helga Tulinius: htul@os.is

# CHAPTER 13

# Italy

## 13.1 Introduction

This chapter outlines the development of the geothermal activities in Italy in the year 2003.

Geothermal resources in Italy are mainly used to produce electricity. The first industrial power plant dates back to 1913; since then, geothermal installed capacity has increased, reaching 862 $MW_e$ at the end of the year 2003.

In 2003 geothermal net generation exceeded 5 billion kWh for the first time. Though this represents only 1.9% of the total domestic generation, it meets about 24% of the electricity demand in Tuscany, the Italian region where almost all the plants are located.

In addition to the electricity generation, geothermal fluids are used as heat source, mainly for spas, space and district heating and greenhouses. Thermal energy supplied in 2002 was about 213 ktoe (thousands tons of oil equivalent).

At present, Enel Green Power carries out all the activities related to the exploration, development and exploitation of geothermal resources in Italy for electricity generation. The company is fully owned by ENEL Group and was established in October 1999 with the name of Erga; the name was changed in Enel Green Power in January 2002. The mission of Enel Green Power is to develop electricity generation from renewable energy sources (geothermal, small-hydro, wind, solar and biomass) both in Italy and abroad, in order to achieve the reduction of $CO_2$ emission, according to Kyoto Protocol.

Enel Green Power received the 2002 Global Energy Award as best operator in the renewable energy field for creating value from know-how, resources and assets; for its attention to operation; for its leadership in geothermal energy; for its fast development in wind power; for rehabilitating mini- hydro plants; and more.

## 13.2 National Policy

According to the European Directive 96/82/EC aiming at the creation in the EU of a single market for electricity, on 19 February 1999, the Italian government issued a decree, known as "Bersani Decree", which established the basic rules for the electric power industry. According to the decree, as from 1 January 2003, no individual operator is allowed to generate or import more than 50% of the domestic overall consumption of electricity. In order to comply with this requirement, ENEL has been obliged to sell 15,000 MW of its generating capacity to domestic and foreign operators. To this aim, three Generation Companies (GENCOs) were created and put up for sale on a competitive bidding basis. The process was completed in the year 2002.

In addition, as from the year 2002, all operators (importers and producers of electricity from non-renewable sources) must generate or buy a fixed share of electricity from "new renewable plants". The share was initially set at 2% of the total energy produced or imported in the year, exceeding 100 GWh. Cogeneration, plant auxiliary consumption and exports are excluded from this requirement.

Applied to the Italian market, the 2% share corresponds at present to about 3.5 billion kWh, an amount large enough to spur the market effectively, considering that "new renewable plants" means plants beginning their production or re-powered (in this case only the additional capacity is taken into account) after 22 April 1999. A recent decree, issued on 31 January 2004, increased this share starting from the year 2005 (see paragraph 4).

The conceived mechanism provides a great deal of flexibility: operators are allowed to meet their obligations by generating directly or by purchasing some or all of the "green" energy required or merely emission rights (called "green certificates").

In the year 2002, Italy signed the Kyoto Protocol to the United Nations Framework Conference on Climate Change, together with all the other countries of the European Union (EU). According to the Protocol, EU must reduce total greenhouse gases emission by 8%, in comparison with 1990 level, within the commitment period (from 2008 to 2012). Inside the EU, each country has a different obligation; for Italy, the reduction has been fixed at 6.5%.

According to the decree of the Interdepartmental Committee for Economic Planning (CIPE) of 19 December 2002 (Revision of the Guidelines for the strategy and national measures for greenhouse gases emission reduction), the electricity industry must reduce $CO_2$ emission of 26 million tons per year by the commitment period. This figure represents more than 50% of the total reduction required.

One of the selected measures to pursue this target, is a 500-1,200 $MW_e$ increase in the installed capacity of renewable based power plants, with a reduction of $CO_2$ emission in the range 1.5-3.1 million tons per year.

As regards ENEL Group, by far the major national utility, in May 2002, Mr. Paolo Scaroni was appointed CEO of ENEL Group, largely owned by the Ministry of Treasury (at present, about 60% of the shares). The new Company strategy is focused on the core business (instead of the previous diversification in the field of telecommunications, public lighting and water supply) for increasing ENEL Group activities in the energy market (electricity and gas), especially abroad. One of the most important targets is to reduce the cost of the electricity generated, increasing coal and natural gas use (the latter in combined cycle plants) and reducing fuel oil consumption. Another important target is the development of renewable energy sources (geothermal, small-hydro, wind, solar and biomass) both in Italy and abroad.

The development program for the geothermal generation forecasts new wells drilling, construction of new power plants, revamping of old plants and installation of abatement systems of hydrogen sulphide and mercury emission, based on a proprietary process (AMIS). The target is a yearly generation of 5.3 billion kWh by 2008 and a substantial environmental improvement of the generation park, with a total investment of about 276 million € for the period 2004-2008.

## 13.3 Current Status of Geothermal Energy Use

### 13.3.1 Electricity Generation

As of 31 December 2003, 221 production wells were in operation, feeding many steam line networks for a total length of about 165 km. In addition, 38 reinjection wells were in operation to reinject the condensed steam in the reservoir.

The power plants in operation were 37, with a total installed capacity of 862 $MW_e$ and a maximum electrical capacity of 609 $MW_e$.

In the year 2003, 5.036 billion kWh have been delivered to the electric grid. This figure represents 1.6 % of the domestic electricity demand.

In the year 2003, drilling activities consisted of:

- Drilling and commercial operation of three new production wells, with depth ranging from 2,300 m to 3,800 m (drilling of one well started in the year 2002).
- Start of the drilling of four new deep wells (one at Soultz, France, in the framework of HDR Project), which will be completed in 2004.
- Work over of four wells (3 wells recovered a significant steam production).
- Deepening of one well (1,200 depth increase).

As a result, additional steam availability was 330 t/h, corresponding to an increase in the generating capacity of about 50 $MW_e$.

Other 2003 activities included:

Following the successful results obtained from operating the first hydrogen sulphide and mercury emission abatement plant based on AMIS proprietary technology on a 20 $MW_e$ unit, a second plant was commissioned in April 2003 to clean the emission from two other units (1x40 $MW_e$ and 1x20 $MW_e$).

The development program for 2004 forecasts:

- Drilling of five new production wells.

- Completion of drilling and commercial operation of the four production wells, whose drilling started in 2003.

- Work over of one production well.

- Start-up of a drilling project focused on enlarging the well-exploited productive horizons and areas. Eleven wells will be drilled by 2006.

- Start-up of projects concerning the revamping of a 40 $MW_e$ plant and the installation of a 15 $MW_e$ unit de-commissioned some years ago. Commissioning of both units is forecast for 2005.

- Retrofitting of two power plants (1x60 $MW_e$ and 1x20 $MW_e$) with hydrogen sulphide and mercury abatement plants, based on AMIS technology (Figure 13.1).

- Start-up of the design of fourteen AMIS plants, to be commissioned in the period 2005-2006, for a substantial environmental improvement of the generation park (two plants on new units and the others for retrofitting twelve existing units).

### 13.3.2 Direct Use

In addition to the electricity generation, geothermal fluids are also used in Italy as thermal sources. In 2002 the total heat supply was about 213 ktoe.

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

Enel Green Power is the most important domestic operator in the field of direct use, supplying about 30 ktoe of geothermal heat: 47% for both greenhouses and district heating, 4% for industrial processes and the balance for fish farming and bathing.

**Figure 13.1** Power plant Bagnore 3 built in 1999 and retro-fitted with the AMIS system.

In addition, Enel Green Power is selling nearly pure $CO_2$ (35,700 t/y), produced from a deep dead well and mainly used, after purification, in the food industry.

### 13.3.3 Energy Saving

The use of the geothermal fluids for electricity generation and direct use allows saving of about 1.4 Mtoe (million tons of oil equivalent), avoiding, at the same time, emission to the atmosphere of about 4 million tons of $CO_2$.

It should be noted that the exploitation of steam-dominated fields reduces the amount of $CO_2$ naturally emitted from the soils in the geothermal areas, so that total $CO_2$ emission (natural plus power plant emission) remains unchanged.

$CO_2$ emission has not been included by APAT (the National Agency for the protection of the environment and the territory) in the GHG inventory.

## 13.4 Market Development and Stimulation

Since 1 January 2003, in Italy, Bersani decree requires producers or importers of electricity from non-renewable sources to deliver to the grid a share of electricity generated from renewable sources. This provision gave rise to the "Green Certificate" market.

The Green Certificate proves that a certain amount of energy is produced by renewable (each certificate refers to 100 MWh of electricity). It does not matter what the source of renewable energy is, but it is necessary that this energy will be produced by new plants or by plants re-powered, rebuilt or re-activated, which begin operation after 2 April 1999. Green certificates apply for the first eight years of plant operation.

For the first year (2002), a share of 2% was established. According to Decree n° 387/2003, issued on 31 January 2004, which enforces in Italy the European Directive 2001/77/EC on the promotion of the electricity from renewable sources in the internal market, this share is increased to 2.35% in 2005. In addition, an annual increase of 0.35% is established for the two following years (2.7% in 2006 and 3.05% in 2007). The Decree also states that the Minister of Industry will fix the shares for the years 2008-2010 by 31 December 2004 and the shares for the years 2011-2013 by 31 December 2007.

Green Certificates will be exchanged between producers and importers in an open market. In order to carry out this exchange, the Electric Market Authority will promote the negotiation of the certificates.

As a consequence, the value of the kWh generated from renewables is the sum of the base price of the energy and of the market value of the Green Certificates (the latter is limited to the first eight years of plant operation). For the year 2003, the value of the Green Certificates was 8.2 €-cent/kWh.

Producers and importers can also comply with the decree by importing electricity generated from renewable energy plants of foreign countries adopting similar policies for renewable energy promotion.

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

- Incentive to the end users of 10.33 €/$MW_t$ on a permanent basis plus 15.49 €/ $MW_t$ to be confirmed every fiscal year.
- Incentive to the developers for new supplies or for the increase of the existing ones is 20.66 €/ $MW_t$.

## 13.5 Development Constraints

As a consequence of low oil price and the cost of environmental protection, geothermal generation needs Green Certificates in order to be competitive with fossil fuel generation. Therefore, geothermal development is limited, on the one hand, by the amount of electricity that could benefit from Green Certificates and, on the other, from the competition with other renewables. This competition favours the renewable sources with the lower generation cost.

Environmental issues could also limit geothermal development in areas characterised by natural beauty, tourism-based economy, vicinity to spas or major ground waters, *etc*. The bad smell of hydrogen sulphide, build-up of boron and mercury on soils and rivers, depletion of groundwater or spas and landscape degradation are the most common arguments for the local opposition to the geothermal development.

## 13.6 Economics

Capital cost of the geothermal plants largely depends (50% or more) from the total cost of the production wells feeding the power plant. The latter varies from field to field, as a consequence of the stratigraphy, well depth, well productivity, fluid enthalpy, non-condensable gas content, *etc*. Capital cost must also take into account the costs of field development (feasibility studies, surface exploration, drilling of exploration wells, *etc*.), which require a large investment at an early stage. Typical capital costs range from 2.5 to 3.5 million € /$MW_e$ installed.

Generation costs largely depend on the capital costs (about 80%); O&M costs are the balance. Typical costs range from 5 to 8.5 €-cent/kWh.

## 13.7 Research Activities

Research activities are mainly focused on the implementation of geophysical models able to improve the ability to discover geothermal resources, reducing mining risk. Advanced methodologies for understanding the results of seismic prospecting based on reflection have been applied with good results in order to locate the fractured zones inside the geothermal reservoirs at depths higher than 3,000 m.

Research is totally funded by ENEL.

## 13.8 International Cooperative Activities

ENEL (by means of the fully owned Enel Green Power) is a partner of La Geo (former Geotermica Salvadorena or Gesal), the El Salvador geothermal company, which currently operates 56 $MW_e$ in Berlìn and 62 $MW_e$ in Ahuachapàn.

Enel Green Power received 8.5 % of La Geo's shares in exchange for drilling six wells and for evaluating the geothermal resources in Southeast Berlìn and in the area of the Ahuachapan. field. If the resources will support a capacity increase, Enel GreenPower will build new power plants in exchange of an increase in its share in La Geo.

In 2003 two wells were drilled and two other wells will be drilled in 2004.

**Author:** Aldo Baldacci, Enel Green Power SpA- Enel Group, Pisa, Italy.

**Contact:** Aldo Baldacci; aldo.baldacci@enel.it

# CHAPTER 14

# Japan

## 14.1 Introduction

Japan's first geothermal electricity generation of 1.12kW took place in Beppu, Oita Prefecture, Kyushu, in 1925. The practical use of geothermal energy commenced in 1966, with the introduction of the first full scale geothermal power plant, the Matsukawa Geothermal Power Plant of 9.5 $MW_e$ (23.5 $MW_e$ at present), Iwate Prefecture, in the Tohoku District of northern Honshu.

Japan, as a volcanic country, has favourable conditions for geothermal development. However, the construction of geothermal power plants has been restricted due to factors such as the restrictions on the use of National Parks and low and stable oil prices. Therefore, as shown by Figure 14.2, at the end of the 1980s only nine plants were operating, with a total capacity of about 215 $MW_e$.

The risks involved in initial investment also hinder geothermal development. Thus, the government has been promoting research and development of exploration techniques in several areas of geothermal activities. As a result, geothermal development in several areas in the Tohoku and Kyushu Districts reached the construction stage in the early 1990s.

The operational status of Japan's geothermal power plants as of 31 March 2003 is indicated in Table 14.1. No geothermal generation plants were begun in fiscal year 2003 (April 2003-March 2004). The total authorized output of the geothermal power generation in Japan is 535.25 $MW_e$. Geothermal direct use in Japan is shown in Table 14.2, as a database developed by the New Energy Foundation (NEF). It must be noted that data for bathing and geothermal heat pumps are not included in this table by their policy. The total installed capacity of geothermal heat pump systems in Japan is probably less than 3,000 kW.

**Table 14.1** Geothermal power plants in operation as of 31 March 2003.

| 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. | Donan Geothermal Energy Co., Ltd. | 50.0 | 184,794 | Nov. 1982 |
| Sumikawa | Tohoku Electric Power Co., Inc. | Mitsubishi Materials Corporation | 50.0 | 353,498 | Mar. 1995 |
| Onuma | Mitsubishi Materials Corporation | same as on the left | 9.5 | 59,378 | June 1974 |
| Matsukawa | Japan Metals & Chemicals Co., Ltd. | same as on the left | 23.5 | 171,651 | Oct. 1966 |
| Kakkonda 1 | Tohoku Electric Power Co., Inc. | Japan Metals & Chemicals Co., Ltd. | 50.0 | 230,414 | May 1978 |
| Kakkonda 2 | Tohoku Electric Power Co., Inc. | Tohoku Geothermal Energy Co., Ltd. | 30.0 | 242,310 | Mar. 1996 |
| Uenotai | Tohoku Electric Power Co., Inc. | Akita Geothermal Energy Co., Ltd. | 28.8 | 205,679 | Mar. 1994 |
| Onikobe | Electric Power Development Co. | same as on the left | 12.5 | 80,643 | Mar. 1975 |
| Yanaizu - Nishiyama | Tohoku Electric Power Co., Inc. | Okuaizu Geothermal Ltd. Co., | 65.0 | 399,661 | May 1995 |
| Hachijojima | Tokyo Electric Power Company | same as on the left | 3.3 | 14,964 | Mar. 1999 |
| Suginoi | Suginoi Hotel | same as on the left | 3.0 | 9,383 | Mar. 1981 |
| Kuju | Kuju Kankou Hotel | same as on the left | 2.0 | 5,368 | Dec. 2000 |
| Takigami | Kyushu Electric Power Co., Inc., | Idemitsu Oita Geothermal Co., Ltd. | 25.0 | 215,165 | Nov. 1996 |
| Otake | Kyushu Electric Power Co., Inc. | same as on the left | 12.5 | 93,234 | Aug. 1967 |
| Hatchobaru 1 | Kyushu Electric Power Co., Inc. | same as on the left | 55.0 | 333,697 | June 1977 |
| Hatchobaru 2 | Kyushu Electric Power Co., Inc. | same as on the left | 55.0 | 450,987 | June 1990 |
| Takenoyu | Hirose Trading Co., Ltd. | same as on the left | 0.05 | 0 | Oct. 1991 |
| Ogiri | Kyushu Electric Power Co., Inc. | Nittetsu Kagoshima Geothermal Co., Ltd. | 30.0 | 262,369 | Mar. 1996 |
| Kirishima Kokusai Hotel | Daiwabo Kanko Co., Ltd. | same as on the left | 0.1 | 611 | Feb. 1984 |
| Yamagawa | Kyushu Electric Power Co., Inc. | Japex Geothermal Kyushu Co., Ltd. | 30.0 | 153,504 | Mar. 1995 |
| **Total** | | | **535.25** | **3,467,310** | |

Note : 1. "Annual Energy Production" covers energy production for one year from April 1, 2002 to March 31, 2003.

## 14.2 National Policy

### 14.2.1 Strategy

In June 2002, the Japanese government concluded a law to introduce the Renewable Portfolio Standard (RPS) system. Under this law, each electric utility business must procure a certain percentage of its electricity sales by target energy categories. Target energy categories are wind, photovoltaic, geothermal (target unit is binary system), hydroelectric (target unit size under 1 $MW_e$) and biomass. Electricity businesses can trade the excess or deficiency of renewable energies versus the target, in the form of securities. The system was implemented by Financial Year (FY) 2003. The government will determine the target and the procedures for the security dealing as an administration ministerial ordinance.

### 14.2.2 Legislation and Regulation

There is no separate "geothermal legislation" that defines geothermal resources and governs their use and development in Japan.

## 14.3 Current Status of Geothermal Energy Use

### 14.3.1 Electricity Generation

#### 14.3.1.1 Installed Capacity

The total installed generation capacity of geothermal energy at the end of March 2003 was 535.25 $MW_e$, including industry-owed power plants (Figure 14.1 and Table 14.1). The total installed generation capacity for the country at the end March 2003 was 266,129 $MW_e$, of which thermal power accounted for 65.0%, hydroelectric power 17.5%, nuclear power 17.2%, and geothermal 0.2% (Figure 14.3).

#### 14.3.1.2 Total Electricity Generation

The total electricity generation for geothermal energy of FY 2002 was 3,467GWh. (Figure 14.2 and Table 14.1).

**Table 14.2** Direct Use of Geothermal Energy in Japan as of March 2002.

| | Utilization Capacity (MWt) | Annual Mean Utilization (TJ/y) |
|---|---|---|
| Greenhouse heating | 41.49 | 404.11 |
| Aquaculture | 16.91 | 212.34 |
| Stockbreeding (Space heating) | 0.14 | 1.48 |
| Agriculture (Paddy warming, Washing crops) | 2.12 | 30.07 |
| Industry | 1.52 | 40.86 |
| Food processing | 0.16 | 3.60 |
| Accommodation (Space heating, Hot water) | 49.43 | 715.16 |
| Tourism (Cooking, Pool) | 13.79 | 125.15 |
| Housing (Space heating, Hot water) | 27.50 | 564.33 |
| Medical treatment (Space heating, Hot water) | 10.59 | 128.05 |
| Welfare (Space heating, Hot water, Pool) | 17.25 | 250.22 |
| Public service (Space heating, Hot water) | 39.53 | 672.64 |
| Snow melting | 133.26 | 448.60 |
| Other (Hot water supply) | 55.70 | 1,542.11 |
| **Total** | **409.38** | **5,138.71** |

Source : Results of the survey conducted by Geothermal Energy Development Center, New Energy Foundation Geothermal Energy Vol.27, No.4

* : It must be noted that data of "Accommodation" this table includes only swimming pool and not bathing.

* : It must be noted that geothermal heat pump data is not including of this table.

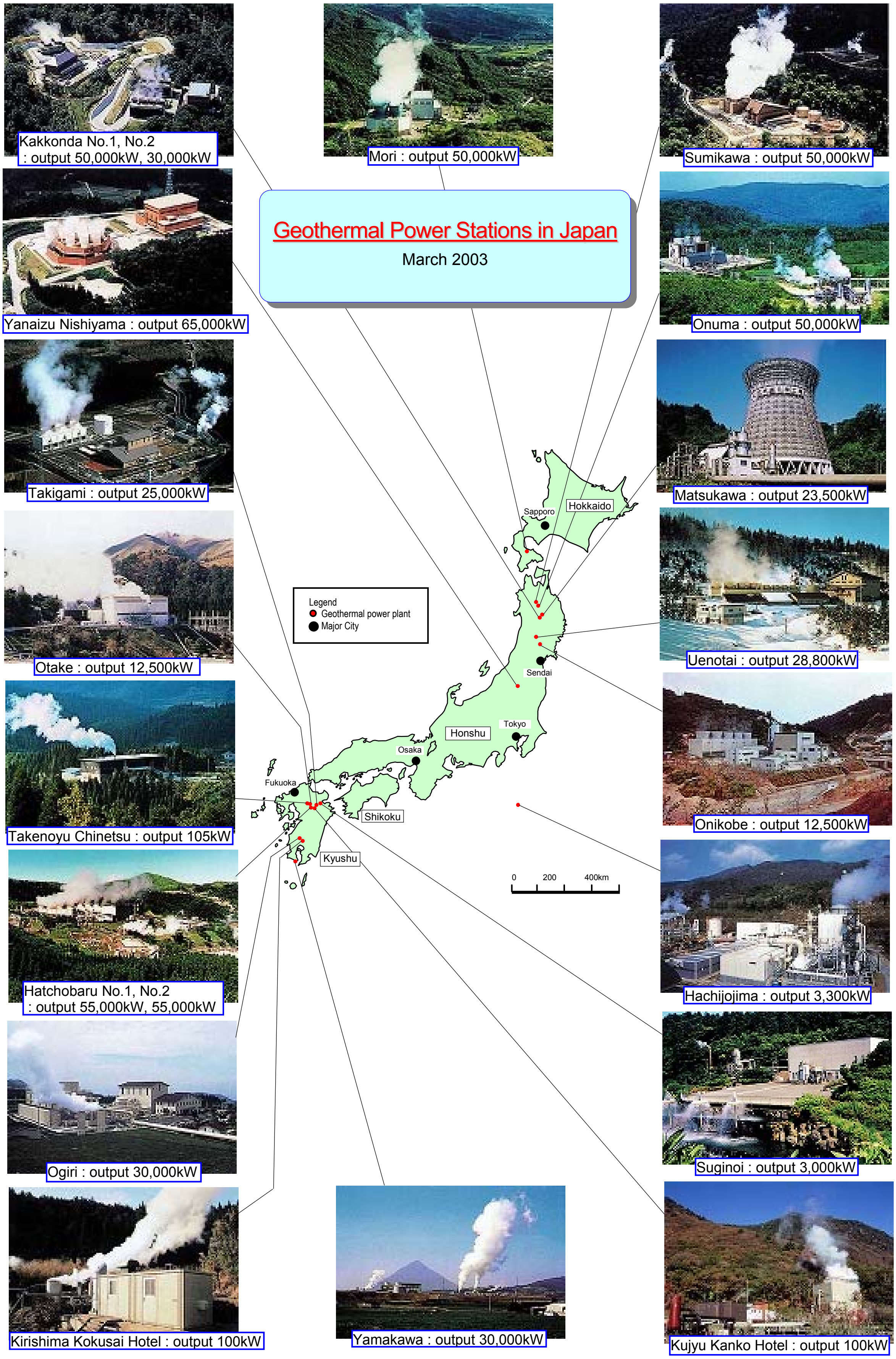



**Figure 14.1** Geothermal power stations in Japan as at March 2003.

#### 14.3.1.3 New Developments During 2003

At the end of November, a trial run of the first binary unit for geothermal energy generation was begun by Kyushu Electric Power Co. Inc. at Hatchobaru. The unit is manufactured by Ormat and its generation capacity is 2 $MW_e$. At present, promising geothermal areas to be developed in the future are very few.

#### 14.3.1.4 Rates and Trends in Development

The output capacity for geothermal energy has remained almost constant in the past few years, and there is no plan to develop new power plants in the near future, without some small binary generation unit.

#### 14.3.1.5 Number of Wells Drilled for Power Plants

Production wells were drilled at: Onuma, 1 well; Onikobe, 1 well; Yanaizu-Nishiyama, 1well; Hatchobaru, 1well and Ogiri, 1 well.

Reinjection wells were drilled at: Hatchobaru, 1well and Otake, 1well.

Survey wells were drilled at: Kirishimaeboshi-dake field, 2 wells and Appi field, 1 well.

#### 14.3.1.6 Contribution to National Demand

The total electricity generation in Japan for FY 2002 was 1,097 TWh (Figure 14.3), with geothermal providing about 0.3%.

### 14.3.2 Direct Use

Direct use of geothermal water in Japan amounts to 5,139 TJ per year (exclude bathing, data compiled in March 2001), with heat pump utilization almost zero (Table 14.2).

### 14.3.3 Energy Saving

The total geothermal electricity produced in Japan is equivalent to saving 5.74 million barrels (0.85 million tonnes) of fuel oil per year (generating electricity with a 0.35 efficiency factor). The total direct use and geothermal heat pump energy use in Japan is equivalent to savings of 0.83 million barrels (0.12 million tonnes) of fuel oil per year.

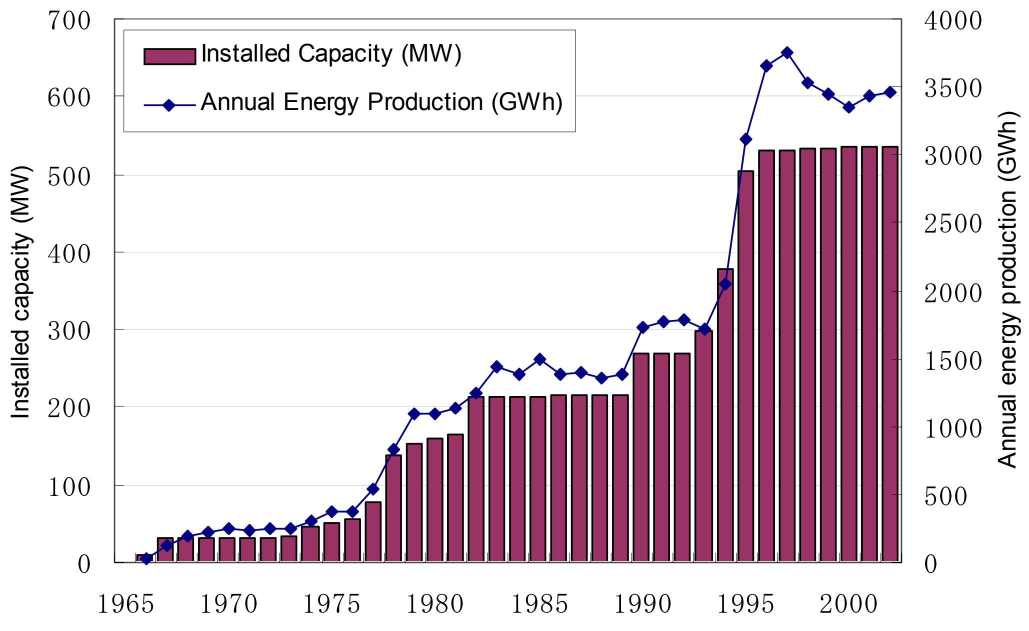


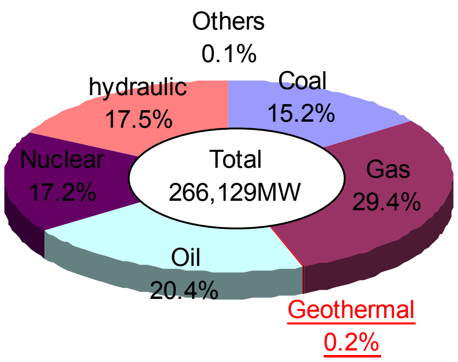

**Figure 14.2** Installed capacity and Annual energy production of the geothermal power plant in Japan (The fiscal year in Japan is from 1st of April to 31th of March.)

## 14.4 Market Development and Stimulation

### 14.4.1 Support Initiatives and Market Stimulation Incentives

#### 14.4.1.1 NEDO

The New Energy and Industrial Technology Development Organization (NEDO) initiates "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 was started in 1980. The survey programme is composed of Surveys A, B and C, varying the scale and the content depending upon the regional potential and existing data. Surveys have been completed in 54 areas as at the end of 2003. Since 1999, NEDO has been carrying 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 those preliminary results. Therefore, geothermal reservoir evaluation using large-bore production wells for long-term production tests is included.. For this purpose, a total of 2 areas was to be surveyed in FY 2003. These were Appi and Kirishimaeboshi-dake as Program C (Figure 14.4, Figure 14.5).



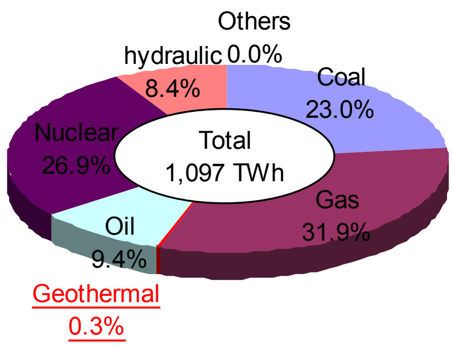




**Figure 14.3** Condition of Power-generation in Japan at FY2002

#### 14.4.1.2 Subsidy System

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 on the ground, with a subsidy ratio of 20%. These systems started in 1983.

Beginning in 2002, binary facilities in geothermal power generation systems are rewarded with a subsidy ratio of 30%.

Actual subsidy record for FY 2003:

- Exploration well: nothing.
- Production well: Onuma 1 well, Onikobe 1 well, Yanaizu-Nishiyama 1well, Hatchobaru 1well, Ogiri 1 well.
- Reinjection well: Hatchobaru 1well, Otake 1 well.
- Facilities (including new pipe laying, *etc.*): Kakkonda, Yanaizu-Nishiyama, Ogiri.
- Binary Facilities: Hatchobaru 1unit.

### 14.4.2 Organizations for Promoting the Development of Geothermal Energy

#### 14.4.2.1 NEDO

NEDO was established in 1980. This organization is devoted to the promotion of technological development, aiming in particular at reducing the Japanese economy's dependence on oil. Furthermore, as part of its activities, it grants subsidies for the development of geothermal resources.
To support geothermal development, NEDO conducts Geothermal Development Promotion Surveys C and provides a compensation system for geothermal developers.

#### 14.4.2.2 New Energy Foundation (NEF)

Established in 1980, this foundation handles business related to the development of new energy sources. It is active in such fields as surveying, research, feasibility testing, and the distribution of information concerning the development and utilization of small and medium sized hydraulic, geothermal and other local energy sources.

#### 14.4.2.3 Geothermal Research Society of Japan (GRSJ)

GRSJ was established in 1978 to promote research and development in scientific and technical fields related to the exploration, development, and multipurpose utilization (including power generation) of geothermal energy. This society holds its general meeting in autumn of each year, welcoming participation by numerous foreign specialists. The association consists of approximately 90 corporate and 667 individual members. The society also is also open to foreign members. In December 2001, the Technical Division of Underground Thermal Utilization came under GRSJ with a strong collaboration with GeoHPAJ.

#### 14.4.2.4 Geo-Heat Promotion Association of Japan (GeoHPAJ)

GeoHPAJ was established in April 2001. Its base were the members of former Geothermal Heat Pump Association, which was formed in 2000 by interested people from universities and private companies. Currently GeoHPAJ consists of 76 company members (including geo-technical consultants; electric power companies; drilling, construction and civil engineering companies; heat-pump manufactures; facility owners; *etc*.) and several individual members from research institutes and universities. Four working groups: public information, planning, drilling technology and regulation and strategy, perform activities on a voluntary basis. Besides regular information exchange, services for the members and public information are emphasized.

#### 14.4.2.5 Heat Pump & Thermal Storage Technology Center of Japan (HPTCJ)

HPTCJ is an affiliate of METI. It was begun as a study group for the utilization of geothermal heat pumps in July 2002 for information exchange and technical improvement. HPTCJ is the Japanese agency for International Energy Agency (IEA) tasks on heat pump systems and thermal storage (Annex 17 and Annex 14).

#### 14.4.2.6 Geothermal Journals and Booklet

The following two journals play a leading role among Japanese journals in the field of geothermal science and technology:

- ***Chinetsu Energy*** (***Geothermal Energy***) **-** New Energy Foundation
- ***Nihon Chinetsu Gakkaishi*** **-** Journal of Geothermal Research Society of Japan

The Thermal and Nuclear Power Engineering Society publishes the booklet: *Trends of Geothermal Power Generation in Japan* (*Wagakuni no chinetsu hatsuden no doko*) written in Japanese, which gives detailed information on geothermal energy in Japan and the world.

### 14.5 Development Constraints

To date, geothermal energy in Japan has been developed as a substitute for oil energy since the oil crisis. No adequate study has been done to evaluate the potential of geothermal energy as a renewable energy consistent with the earth's environment. Internationally, geothermal energy is recognized and categorized as a new and/or renewable energy together with solar, wind, hydro and biomass energy. However, in Japan, only solar and wind are classified as "new energies" that enjoy protection under the law concerning Promotion of the Use of New Energy enacted in 1997. Geothermal is not included. Moreover, in 2001, biomass was added to the list of renewable energies to be promoted by the New and Renewable Energy Subcommittee of the Advisory Committee for Natural Resources and Energy, but geothermal was not. According to the Energy Supply and Demand Outlook presented by the Japanese Government, future growth in geothermal energy is assumed to be zero. Consistent with this perspective, in 2001, the Ministry of Economy, Trade and Industry (METI) decided to cut the entire budget for geothermal energy research and development. This decision was purely political.

## 14.6 Research Activities

Research and Development activities are conducted under the leadership of NEDO and National Institute of Advanced Industrial Science and Technology (AIST).

In April 2001, the Geological survey of Japan (GSJ), the Agency of Industrial Science and Technology (AIST) and the National Institute for Resources and Environment (NIRE) were consolidated into AIST as a single organization. In 2003, the only investigation being pursued was a comprehensive evaluation for the development project of Hot Dry Rock Power Generation System.

NEDO is conducting some international cooperative projects, one of which is a "study of methods for utilizing acidic geothermal fluids". In this study, which operates from December 2002 to March 2004, a neutralization method is being investigated. The use of acidic geothermal fluids is usually avoided because it causes corrosion problems. In Costa Rica, acidic fluids have been used after neutralization for power generation since 2000, but scaling problems were occurring in the production wells and surface equipment.

**Figure 14.4** Production test for exploration well in Appi (North side of Honshu) geothermal field, research activities under Survey Program C conducted by NEDO, started from FY2000 to FY2003. Flowing rate : Steam 50t/h, water 0t/h (August 2003)

**Figure 14.5** Drilling for exploration well in Shiramizugoe (South side of Kyushu) geothermal field, research activities under Survey Program C started FY1999 to FY2002. (April 2002)

The optimal conditions for neutralization will be determined from the results of this study, based on data collected for scaling rates, corrosion rates and other monitoring results under certain conditions.

## 14.7 Geothermal Education

Japan has made a great contribution to extend technical assistance in the field of geothermal energy to developing countries through the group-training course at Kyushu University and the geothermal projects in developing countries provided by the Japan International Cooperation Agency. An International Group Training Course on Geothermal Energy was started in the Earth Resources Engineering Department of Kyushu University for development of alternative energy resources at the request from United Nations (UNESCO) and JICA (OTCA) in 1970. From 1970 to 2001 when the course ended, a total of 393 specialists from 37 countries have participated to the group training courses on geothermal energy and environmental sciences held in Kyushu University.

A new geothermal course was initiated at Kyushu University on October 2002 following the end of the JICA course. It is a doctoral programme in the Graduate School of Engineering entitled: "International Special Course on Environmental Systems Engineering" (http://www.c-shop.net/kyushu/). Twenty students are admitted per year into the Graduate school of Engineering, ten of which are awarded with a MEXT (Ministry of Education, Culture, Sports, Science and Technology) Scholarship. Participants in this new course study under five advanced departments of Kyushu University 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, the language used for all education and other activities is English.

## 14.8 International Cooperative Activities

The Japan International Cooperation Agency (JICA) has been in charge of the geothermal development activities for developing counties since 1973. From 2001 to 2005, one of the development projects being conducted is at the Yangbajain field located in Tibet, China.

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**Author:** Kubo Satoshi, Chief Officer and Yumi Kiyota, Renewable Energy / Energy Conservation Promotion Department, New Energy and Industrial Technology Development Organization (NEDO), Tokyo, Japan.

**Contact:** Kenji Haruguchi: haruguchiknj@nedo.go.jp

# CHAPTER 15

# Mexico

## 15.1 Introduction

Geothermal energy is, by far, the most important non-conventional renewable energy source utilized in Mexico. Although there is some tradition for direct uses of geothermal energy, mainly related to balneology, the most important use is for electricity generation.

Geothermal development for electricity generation started in Mexico in 1959, with the commissioning of the first commercial plant in the Pathé field (central Mexico). By December 2003 the geothermal-based installed capacity for electricity generation reached 953 $MW_e$, placing Mexico in third place worldwide. This installed capacity includes 100 $MW_e$ commissioned in 2003 at the Los Azufres field.

In addition to the usual specialized meetings with high geothermal content, such as the annual meetings of the Unión Geofísica Mexicana and the Asociación Geotérmica Mexicana, in 2003 the Comisión Federal de Electricidad (CFE), Mexico's national utility company, hosted the Annual Meeting of the Geothermal Resources Council (GRC) in the city of Morelia. This was the first time the GRC held its annual event outside of the United States of America.

## 15.2 National Policy

About 86% of the installed capacity for electricity generation belongs to the two government-owned utilities, namely the Comisión Federal de Electricidad (CFE) and Luz y Fuerza del Centro (LyFC). 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 under the same bases as fossil fuel, conventional hydro and nuclear technologies. With the commissioning of four 25 $MW_e$ plants in Los Azufres, CFE reached its target of 953 $MW_e$ of geothermal installed capacity for 2003. Although there are no formally scheduled geothermal projects for the next few years, CFE continues to study the possibility of increasing its installed capacity in the three main fields under exploitation (Cerro Prieto, Los Azufres and Los Humeros), in a partially developed field (Cerritos Colorados; La Primavera) and undeveloped areas with geothermal potential (see below).

## 15.3 Current Status of Geothermal Energy Use

### 15.3.1 Electricity Generation

The installed capacity of 953 $MW_e$ is distributed among the four producing geothermal fields as follows: Cerro Prieto (720 $MW_e$), Los Azufres (188 $MW_e$), Los Humeros (35 $MW_e$) and Las Tres Vírgenes (10 $MW_e$). The total electricity generated with geothermal steam during 2003 was 6,283 GWh.

New developments during 2003 include the commissioning of four additional 25 $MW_e$ units in the Los Azufres field 2003.

During the year 2003, CFE drilled a total of 13 new geothermal wells, 5 in the Cerro Prieto field and 8 in the Los Azufres field. Generation from geothermal sources represented 3.07% of total electricity production (base on information to September 2003), and the geothermal contribution to electricity generation is more than 1.5 times higher than its contribution to the installed capacity, reflecting the very high capacity factor.

### 15.3.2 Direct Use

The installed thermal power amounted to an estimated 164 $MW_t$, used for balneology in 160 sites distributed in 19 states.

### 15.3.3 Energy Savings

The electricity generated from geothermal steam in 2003 amounts to the avoided consumption of 35.6, 15.7 and 8.8 PJ of primary energy from fuel oil, natural gas and coal, respectively, considering the typical mix of fossil fuels utilized in Mexico.

## 15.4 Market Development and Stimulation

### 15.4.1 Support Initiatives and Market Stimulation Incentives

At present there are no incentives for geothermal development in Mexico. The Comisión Federal de Electricidad , the larger of two national utilities, increased its installed capacity for power generation with geothermal sources from 853 to 953 $MW_e$ in the year 2003, and this is the only substantial increase expected throughout 2006, although studies for possible new developments and expansions in developed fields are underway (see below).

## 15.5 Development Constraints

As mentioned above, power generation with geothermal energy is considered conventional in Mexico, and thus it is set to compete under 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 against modern fossil fuel generation technologies, particularly combined-cycle generation. At least in one case, namely that of the La Primavera geothermal field, which is a fully proven resource, development has come to a full stop because of concerns from the local (State) government about possible environmental impacts.

## 15.6 Economics

### 15.6.1 Trends in Geothermal Investment Foreseen

As mentioned above, although the target for geothermal development in the present federal administration has been met, studies are underway in CFE for future developments on the order of 50 $MW_e$ in Los Humeros, 50 $MW_e$ in Los Azufres, 100 $MW_e$ in Cerro Prieto and 50 $MW_e$ in Cerritos Colorados (La Primavera), as well as the development of new fields in Acoculco, San Pedro, La Soledad and Tacaná.

### 15.6.2 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 and 14% from 2001 to 2002), reflecting the trend in fossil fuel prices and also the reduction of subsidies for certain consumer sectors.

## 15.7 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 the exploration of new areas with geothermal potential. The federal government funds practically all geothermal research.

## 15.8 Geothermal Education

The University of the State of Baja California (UABC) offers a Geothermal Training Program (10-month program) which, in addition to the program offered by Iceland and the one previously offered by New Zealand, has been utilized by CFE to train some of their young engineers. 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.

## 15.9 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 Geothermal Implementing Agreement.

In 2003, 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.

**Authors:** J. L. Quijano León, *Comisión Federal de Electricidad* and D. Nieva, *Instituto de Investigaciones Eléctricas*, Mexico

**Contact:** David Nieva: dnieva@iie.org.mx

# CHAPTER 16

# New Zealand

## 16.1 Introduction

Geothermal energy continues to play a significant role in both electric power production and direct uses in New Zealand. The NZ government signed the Kyoto Protocol in 2003 and this policy will encourage further development of geothermal.

The drop in natural gas reserves, combined with increases in gas and coal prices and problems with the reliability of hydro resources due to El Nino weather patterns places great emphasis on the development of geothermal resources.

## 16.2 New Zealand National Policy

### 16.2.1 Strategy

Energy supply planning for New Zealand anticipates that geothermal power will at least double over the next 10 years to replace depleting gas supplies. Even more geothermal production will be needed by 2020 to meet increasing demand without resorting to coal, and thereby compromising New Zealand's commitment to the Kyoto Protocol of reducing greenhouse gas emissions. Research objectives are expected to help achieve this goal.

The government has a number of policies in place designed to encourage more development of renewable energy resources, including geothermal. These initiatives include:

- **The National Energy Efficiency and Conservation Strategy (NEECS)**

This strategy aims to improve energy efficiency by 20%, and increase use of renewables, including geothermal, which has been identified as one of the priority sectors.

- **The National Climate Change Policy Package (CCPP)**

This is designed to reduce $CO_2$ emissions by reducing dependence on fossil fuels and placing more emphasis on renewable sources.

- **Sustainable Development Programme of Action for Energy**

One of the outcomes of this programme is to ensure that renewable sources of energy are developed and maximised.

- **Resource Management (Energy and Climate Change) Amendment Bill**

This bill seeks to align national energy objectives (such as those described above) with local government plans. If passed, the bill will require decision makers to have regard to efficient energy use, climate change, and consider the benefits of renewable sources of energy.

- **Development of Geothermal Assets Owned by the Crown**

The Crown has indicated that it would like to develop its geothermal assets further.

- **Energy Outlook to 2025**

This document, published by the Ministry of Economic Development, projects that use of geothermal energy for electricity generation will increase to 600 $MW_e$ by 2025.

### 16.2.2 Progress Towards National Targets

With at least three power companies currently actively exploring and developing geothermal fields there was some progress towards achieving national targets in 2003.

## 16.3 Current Status of Geothermal Energy Use

### 16.3.1 Electricity Generation

The total installed geothermal generating capacity for the 2002 March year was 431$MW_e$, with the total electricity generated amounting to 2,643,888 MWh.

Geothermal drilling during 2003 was conducted by Century Drilling (Wairakei) and Parker Brothers of New Plymouth. Several work-overs of existing wells were carried out. Four new wells in the producing fields of Rotokawa and Mokai were drilled during 2003 with more planned for 2004.

Magneto-telluric surveys were carried out at the Putauaki Project, adjacent to the developed Kawerau field during 2003 to guide the planned 2004 drilling.

The geothermal installed capacity amounted to about 5% of New Zealand's total, with geothermal contributing about 7% of the total generation.

### 16.3.2 Direct Use

At the Kawerau geothermal field, production of geothermal steam to the local pulp and paper mill has continued at a level of 210 $MW_t$. In addition, surplus steam and hot water have been used to generate electricity. The electrical equivalent of the total geothermal energy output is about 40 $MW_e$. Deep pressure drawdown over the life of the field has been very small and local Maori land owners are intending to expand field development to the east of the existing borefield.

Direct use of heat from reinjection pipelines at Ohaaki geothermal field is presently being used for drying timber at the old lucerne drying facility.

At Wairakei, the Prawn Farm continues to use heat from reinjection pipelines to maintain temperatures in prawn breeding ponds. In addition, a new tourist facility has been established by diverting waste hot water from the drains into the historic *Te Kiri o Hinekai* thermal stream; and by using separated water from the reinjection line to create artificial silica terraces and a geyser.
At Mokai, some of the surplus direct heat is used in glasshouses for horticulture.

In addition, geothermal is used for bathing purposes at many thermal pool establishments.

## 16.4 Market Development and Stimulation

The costs associated with well drilling are a significant portion of total geothermal development costs. In New Zealand, the average cost of a typical geothermal well, drilled to a depth about 2 km, is about NZ$ 3 M.

The capital costs for geothermal development in New Zealand amount to about US$ 3,200/kW for a 25 $MW_e$ development and about US$ 3,000/kW for a 50 $MW_e$ development. Operation and maintenance costs are about US$ 93/kW/year (station + steamfield).

## 16.5 Development Constraints

Environmental regulations are relatively strict but manageable. However, the Resource Management Act has limited the scale of geothermal development, in part due to the costs associated with the long regulatory process.

## 16.6 Economics

### 16.6.1 Trends in Geothermal Investment

There has been a very definite increase in geothermal investment in both developed and undeveloped fields.

### 16.6.2 Trends in the Cost of Energy

The cost of energy continues to rise. The Ministry of Economic Development predicts that the wholesale price of electricity is likely to be in the range of 6.5 NZ cents/kWh (5 US cents/kWh) to 8 NZ cents/kWh (US 6 cents/kWh) for the next 10 years.

## 16.7 Research Activities

New Zealand's geothermal research budget was about $NZ 2,000,000 (US$ 1,400,000) in 2003. This NZ Government funded research has been focussed into four target areas: deep high-temperature resources, use of low-enthalpy resources, better use of waste geothermal fluids and environmental effects. Special emphasis has been placed on the application of deep MT to exploration/development of geothermal fields. There has also been potential interest in deep geothermal development.

## 16.8 Geothermal Education

Due to the withdrawal of New Zealand Government funding for the Geothermal Institute in 2002, there were no students enrolled in the diploma course. However, several graduate students were supervised in the MSc and PhD programmes in engineering and geology at the University of Auckland.

Other geothermal educational events included the 25th annual NZ Geothermal Workshop, which was successfully held at Auckland University in November 2003, attracting the usual large number of local and overseas participants; and The New Zealand Geothermal Association's 7th Annual Seminar held in Taupo in June 2003.

## 16.9 International Cooperative Activities

New Zealand has collaborative research relationships and links with many international agencies including: USGS (USA), KIGAM (South Korea), GSJ (Japan), AEA (Switzerland), University of Utah, Energy and Geoscience Institute (USA), University of Alberta (Canada) and Tohoku University (Japan).

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**Authors:** Colin Harvey and Chris Bromley, Institute of Geological and Nuclear Sciences Limited, New Zealand.

**Contact:** Chris Bromley: c.bromley@gns.cri.nz

# CHAPTER 17

## Switzerland

### 17.1 Introduction

The 2002 Swiss Country Report, available in the IEA Geothermal Annual Report 2002 (http://www.gns.cri.nz/GIA/index.html), was based on an extensive compilation of facts and trends on one hand and on a thorough statistical survey on the other. Since that survey, conducted in 2002, no recent statistical data collection, evaluation and compilation have been carried out. Therefore the key figures and numbers for 2003 have been estimated by extrapolation and are presented below. For 2004 a new statistical survey is foreseen and its results will certainly be reported in due time.

In addition, several new items that are now part of the GIA Country Report format and were not included in the 2002 Swiss Report will be presented (e.g. Legislation and Regulations).

### 17.2 National Policy

The SwissEnergy program, mainly devoted to a more efficient use of energy, with specific tasks such as energy saving, reduction of $CO_2$ emissions and a definitive increase in the contribution of renewable energies and its goals and measures, was described in the 2002 Country Report.

#### 17.2.1 Strategy

A discussion of the strategy for energy development was provided in the 2002 Country Report. Further information can be found in Vuataz *et al*. (2003).

#### 17.2.2 Legislation and Regulations

Being a country of federal structure, there is legislation in Switzerland on the state (Confederation) and the county (Canton) level. According to federal law the ground property extends to depths of direct practical interest (a few storeys); below that depth everything belongs to the government. No Mining Law exists on the federal level.

Geothermal energy utilization is not well defined in federal and cantonal legislation. Legal experts like Gottesmann (1985) make a distinction between geothermal heat (an energy source, given by the physical conditions of the subsurface) and geothermal energy, which is used and distributed at the surface. Thus, geothermal heat could be subsumed in public law and geothermal energy, through its use, in private law. So far, federal law does not cover geothermal energy; existing federal legislation regulating electricity, atomic power and pipelines is not applicable.

On the other hand, in cases where the use of geothermal energy involves water as the heat carrier, water management legislation comes into play. Since shallow and deep groundwater belongs to the cantons, they regulate the tapping and use of geothermal fluids. In this sense, the use of geothermal energy needs a permit and concession. In this, existing and well-established cantonal Water Laws are being applied.

A special situation exists with ground-source heat pumps involving borehole heat exchangers (BHE). Although such systems operate in closed circuit, their construction and operation fall under environmental legislation: it is feared that the BHEs could establish hydraulic connections between otherwise separated aquifers and/or could have negative effects on groundwater quality. In fact, both the federal Environment Protection Law (*Umweltschutzgesetz USG*) and the Water Protection Law (*Gewässerschutzgesetz GSchG*) are applicable. This leads to permitting: a) no permits can be obtained within groundwater protection zones or in areas with potential groundwater occurrences; b) in special areas like border zones of the above category, karstic areas and environs of thermal and mineral springs, the permits are given on the basis of detailed investigations; c) for all other areas the permits can be obtained. Based on this practice, several cantons have published maps of BHE exclusion zones. As an example, such a map can be seen for the canton St.Gall (SG) on www.geoportal.ch. The list of permitting cantonal authorities can be found on www.fws.ch. The applications must name the applicant, the geologic advisor, the location, the BHE and heat pump technicalities, as well as the foreseen safety and control measures. The open-mindedness of cantonal authorities allowed rapid BHE development in Switzerland (see below and in Rybach and Kohl, 2003).

For geothermal installations with thermal power > 5 MW, an environmental impact report must be submitted, according to the Federal Order on Environmental Impact Assessment (19 October 1988). Application and approval are carried through cantonal legislation.

So far no tax must be paid for geothermal energy utilization in Switzerland. Recently, however, the administration of canton Berne considered the introduction of geothermal taxation: a fee of 3 Swiss francs (equivalent of US$ 2) per year per $MW_t$ capacity was foreseen for thermal water production from deep drillholes; and 0.5 – 2 Swiss francs per BHE meter and year (!). Fortunately, thanks to the protests of national and international organisations (including a letter of GRC President John Lund in February 2002) the legislative body (cantonal Parliament) did not follow the suggestion of the administration.

### 17.2.3 Progress Towards National Targets

The progress in reaching both the overall goals of the SwissEnergy Program as well as of the Geothermal Program was satisfactory in 2003.

## 17.3 Current Status of Geothermal Energy Use

### 17.3.1 Electricity Generation

So far there is no electricity generation from geothermal sources in Switzerland. However, there is a substantial project underway (DHM: Deep Heat Mining) with the aim to establish EGS-type co-generation plants based on the EGS principle (at sites in Basle and Geneva, within the next 10 years). At the Basel site a recently drilled 2.7 km deep exploration well was equipped in 2003 with seismic instrumentation to record natural and artificial seismicity. At the Geneva site detailed investigations are being conducted to site the first exploratory drilling. The DHM project is co-funded by federal and local governments, with private funding also provided.

### 17.3.2 Direct Use

As mentioned above, there is no new statistical material to cover the years 2002 and 2003. Therefore it has been assumed that from the various utilization technologies only the geothermal heat pumps exhibited further growth since 2001. Their installed capacity and heat production figures have been estimated by extrapolation, whereas the other categories were left unchanged. Tables 17.1 and 17.2 show the results.

The most common technology for direct use applies borehole heat exchanger (BHE)-heat pump coupled systems. Their share is by far the highest among the other categories (see Tables 17.1 and 17.2). Figure 17.1 shows a typical construction location during BHE emplacement. After the workplace cleanup, nothing can be seen. This can create a “visibility problem” for the utilization of the ubiquitous shallow geothermal resource since there is nothing to show visitors!

#### 17.3.2.1 Installed Thermal Power

Table 17.1 shows the estimated installed capacity of the various utilization technologies. Although it has been assumed that the category geostructures (mostly energy piles) did not expand in 2003, their increasing use is evident, with the prominent example being the Midfield Terminal C at Zurich International Airport “Unique” which was in service since summer 2003. The new terminal is heated and cooled by an energy piles/heat pump system. Switzerland still occupies a prominent rank in geothermal heat pump applications (Lund *et al.* 2003).

#### 17.3.2.2 Thermal Energy Used

The amount of energy produced by the different categories has also been estimated, following the same procedure (Table 17.2).

The average load factor, due to the climatic conditions is around 20%, and corresponds to a running time of 1,800 hours/year. A low capacity factor is not necessarily disadvantageous; in well insolated buildings the heat pump runtimes can be kept low.

**Figure 17.1** Construction site where a BHE-type geothermal heat pump system is being installed at Bevaix/NE, Switzerland.

### 17.3.2.3 Category Use

The various direct use categories are listed in Tables 17.1 and 17.2. No significant new categories have emerged in 2003.

### 17.3.2.4 New Developments During 2003

As in many parts of Europe, the 2003 summer was extremely hot. Sudden, increasing demand is now emerging for combined heating and cooling. For this, geothermal heat pumps are well suited. Often "free cooling" circulating the heat carrier in the BHEs without running the heat pump is sufficient to create a comfortable indoor environment. It can be expected that in coming years the geothermal option for space cooling will penetrate the market significantly.

### 17.3.2.5 Rates and Trends in Development

Since no new statistical data are available for 2002 and 2003 it can only be assumed that the development trends and rates reported in the 2002 Swiss Country Report are approximately the same for 2003.

### 17.3.2.6 Number of Wells Drilled

To our knowledge no wells with depths exceeding 500 m have been drilled for geothermal purposes in Switzerland in 2003. However it is certain that several thousand drillholes have been deepened for BHE installations. The total drilling length must exceed 500 km (!).

### 17.3.3 Energy and $CO_2$ Emission Savings

It is estimated that the 1,123 GWh heat produced from geothermal sources in Switzerland in 2003 corresponded to a saving of about 115,000 toe, and avoided the emission of 360,000 tonnes of $CO_2$.

## 17.4 Market Development and Stimulation

The rapid development of geothermal heat pumps in Switzerland is striking. The various reasons, trends and costs are presented and discussed in detail in Rybach and Kohl (2003).

## 17.5 Development Constraints

The most serious competitor for geothermal space heating systems in Switzerland is natural gas. In addition to strong marketing there is also a financial advantage for gas-based systems over geothermal- whereas geothermal solutions need two pipes (for delivery and

**Table 17.1**. Installed capacity for direct use in Switzerland at the end of 2003 (estimated numbers, see text).

| **Energy Source/Use** | **Capacity ($MW_t$)** | **Percent of Total (%)** |
|---|---|---|
| GHP with borehole heat exchangers (including shallow horizontal coils) | 430 | 77.8 |
| GHP with groundwater | 70 | 12.6 |
| Thermal springs/boreholes (balneology) | 37 | 6.7 |
| Deep aquifers | 6 | 1.1 |
| Tunnel waters | 5 | 0.9 |
| Deep borehole heat exchangers | 0.2 | 0.0 |
| Geostructures (“energy piles”) | 5 | 0.9 |
| **Total** | **553** | **100.0** |

**Table 17.2** The heat production in 2003 from the various sources.

| **Energy Source/Use** | **Heat Produced in 2003 (GWh)** | **Percent of Total (%)** |
|---|---|---|
| GHP with borehole heat exchangers (incl. shallow horizontal coils) | 635 | 56.5 |
| GHP with groundwater | 105 | 9.4 |
| Thermal springs/boreholes (balneology) | 322 | 28.7 |
| Deep aquifers | 37 | 3.3 |
| Tunnel waters | 14 | 1.2 |
| Deep borehole heat exchangers | 1 | 0.1 |
| Geostructures | 9 | 0.8 |
| **Total** | **1123** | **100.0** |

return), gas only requires one pipe since the return pipe is the atmosphere.

## 17.6 Economics

Geothermal space heating and cooling, when based on geothermal heat pumps, can compete with conventional oil-fired systems, thanks to their lower running cost. A detailed comparison was presented in the 2002 Country Report; the situation has not changed since then. Demand for energy contracting and subsidies by local utilities is increasing.

## 17.7 Research Activities

Whereas university research is rather stagnant or even decreasing there is increasing activity in SM enterprises in this field. Applied research, funded by the Federal Government, is being implemented more and more by specific teams. The Swiss Geothermal Association (SVG) is acting as a Competence Center for research funded by the Federal Office of Energy (BFE). Increasing private involvement, especially for the DHM project, must also be noted. Important research activities are embedded in international frameworks (see below).

The research projects supported by the BFE produce intermediate and final reports. These can be downloaded or ordered at:

http://www.energieforschung.ch/ENET/ENETHome.nsf/pgHomeEN?OpenPage

## 17.8 Geothermal Education

Significant efforts are undertaken for education and information dissemination. The SVG has a mandate from BFE for information and education. F.-D. Vuataz (CHYN Neuchâtel) is responsible for information. Several leaflets have been produced and a geothermal exhibition for the French part of Switzerland has been organized in 2003. T. Kohl (ETH Zurich) is responsible for education. Besides regular university lectures various special courses and workshops were organized for postgraduate training in 2003. Further details can be found in Vuataz *et al*. (2003).

Education is also provided at the international level. In September 2003, L. Rybach presented two lectures at the *International Short Course on Sustainable Use and Operating Policy for Geothermal Resources*, UN University Geothermal Training Program in Reykjavik, Iceland:

- *Sustainable use of geothermal resources: renewability aspects*
- *Regulatory framework for geothermal development in Europe– with special reference to France, Germany, Hungary, Romania and Switzerland*

## 17.9 International Cooperative Activities

As a part of its international cooperative activities, Switzerland participates in the IEA GIA, with funding from the Swiss Federal Office of Energy. It is especially involved in Annex III- Enhanced Geothermal Systems and acts as the Subtask C Leader. There is also strong interest in joining the recently implemented Annex VIII- Direct Use of Geothermal Energy.

Switzerland also participates in the EC Project Soultz, with funding provided by the Swiss Federal Office of Education and Science.

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Vuataz, F.-D., Gorhan, H.L., Geissmann, M. (2003) Promotion of geothermal energy in Switzerland – a recent programme for a long-term task. *Geothermics* 32, 789-797.

## 17.11 Websites for Further Information

Further information can be found about:

The Swiss Geothermal Programme and Swiss Geothermal Association at: http://www.geothermal-energy.ch

The Deep Heat Mining project: http://www.dhm.ch/dhm.html

**Authors:** L. Rybach, Institute of Geophysics, ETH Hoenggerberg, CH-8093 Zurich, Switzerland and GEOWATT AG, Dohlenweg 28, CH-8050 Zurich, Switzerland; and H. Gorhan, Manager of Swiss Geothermal Program, Neudörfli 10, CH-5600 Lenzburg, Switzerland.

**Contact:** L. Rybach: rybach@geowatt.ch

# CHAPTER 18

# United States of America

## 18.1 Introduction

Commercial development of geothermal energy in the United States started in 1960 with the first commercial-scale power plant, a 10 $MW_e$ unit owned by Pacific Gas & Electric, which began operations at The Geysers in northern California.

The United States Federal geothermal program began in 1971 with activities at the Atomic Energy Commission and the National Science Foundation. Formal authority and commitment to geothermal energy were signalled by passage of the Geothermal Energy Research, Development and Demonstration Act in 1974. Federal geothermal research activities were consolidated in the Energy Research and Development Administration in 1975, which was subsumed under the United States Department of Energy in 1976.

Significant incentives to commercial development in the United States were:

- **1978-Public Utility Regulatory Policies Act (PURPA)**

PURPA mandated the purchase of electricity from qualifying facilities (QFs) meeting certain technical standards regarding energy source and efficiency. PURPA also exempted QFs from both state and Federal regulation under the Federal Power Act and the Public Utility Holding Company Act.

- **1980s-California Standard Offer Contracts**

California's Standard Offer Contract system for PURPA QFs provided a relatively firm and stable power market, allowing the financing of capital-intensive projects such as geothermal energy facilities. Geothermal installed capacity expanded from about 500 $MW_e$ of electric power, largely at The Geysers steam field in northern California, before PURPA, to over 2600 $MW_e$ today.

This report describes the status of geothermal energy development in the United States and the role of Department of Energy (DOE) Geothermal Technology Program in that development. The United States Geological Survey (USGS) retains its historical role of responsibility for the assessment of the country's geothermal resources. Broad authority for the current energy programs in the United States stems from the Energy Policy Act of 1992.

The US geothermal power industry underwent a boom in the 1970s and 1980s, followed by consolidation in the 1990s. Since 1990, only minimal new domestic development has occurred, and the industry has focused on international markets. Domestic geothermal energy production is currently a US$ 1 billion/year industry that accounts for about 4% of all renewable electricity production (including hydropower), and about 0.5% of total US electricity production. Installed nameplate geothermal electricity-generating capacity in the US has grown from about 500 $MW_e$ in 1973 to over 2,600 $MW_e$ today. Geothermal electric generation is currently limited to high-quality sites in California, Nevada, Hawaii, and Utah. Other states with significant potential include Alaska, Arizona, Colorado, Idaho, New Mexico, Oregon, and Washington.

Direct use geothermal systems have been installed throughout the United States. The number of applications will continue to grow as the price of natural gas increases and gas supplies become limited. The geothermal heat pump industry is well established in the United States with more than 500,000 units installed. The direct heat installed capacity in the United States is about 600 $MW_t$.

### 18.1.1 Highlights for 2003

The events and activities in this report that have been selected for highlighting are:

#### 18.1.1.1 Power Purchases Under State Energy Laws

- **Nevada**

The Public Utilities Commission (PUC) unanimously approved Nevada's first six contracts under a renewable energy law on 6 March 2003. The contracts would provide enough electricity in 2005 and 2006 for Nevada Power to comply with the non-solar portion of the state's Renewable Energy Portfolio Standard.

#### 18.1.1.2 New Power Plants

- **Salton Sea Geothermal Power Plant**

In November 2003, the siting committee of the California Energy Commission recommended that the full commission approve the construction of a 185 $MW_e$ power plant. CE Obsidian Energy, LLC plans to begin power production at the plant in 2005. The proposed project would be located on an 80-acre site, currently in agricultural production, southeast of the Salton Sea in Imperial County California.

- **Medicine Lake-Telephone Flat Geothermal Power Plant**

In May, the Interior Department issued an operating license for a 48 $MW_e$ geothermal plant at Telephone Flat near Medicine Lake.

- **Raft River Geothermal Plant**

Developer US Geothermal, Inc. has procured a bridge loan on commercial terms to facilitate the start of well inspection work at the Raft River Project in Idaho. A detailed technical report on the project was completed by GeothermEx Inc., which estimates a production potential of 14 to 17 net $MW_e$ from the 5 existing production steam wells. GeothermEx further estimates that the known reservoir has the potential to produce up to 90 net $MW_e$. US Geothermal looks to start construction in 2004 and begin power production late that year or early in 2005.

## 18.2 National Policy

The energy security goal of the new DOE Strategic Plan (2003) is to improve energy security by developing technologies that foster a diverse supply of reliable, affordable, and environmentally sound energy. The Department of Energy has a long-term vision of a zero-emission future in which the nation does not rely on imported energy. One of DOE's strategies for achieving this goal is to work on renewable energy technologies such as geothermal energy and to work with the private sector in developing domestic renewable resources.

The National Energy Policy (NEP) report contains recommendations to diversify the national energy supply, moving towards clean and affordable energy resources and to modernize the electricity infrastructure. Specifically, the program supports the NEP goal of increasing energy supplies. The NEP report also recommends reducing barriers to accessing and leasing Federal lands for geothermal development.

Almost 50% of the nation's production geothermal energy is on Federal land. The US Bureau of Land Management administers 29 power plants in California, Nevada and Utah. These power plants have a total capacity of 1,250 $MW_e$ and supply the needs of 1.2 million homes. See the following website for more information: www.blm.gov/energy/geothermal.htm.

Proposed energy legislation, which did not pass in 2003, included two significant provisions designed to stimulate investment and create new jobs in the US geothermal industry. The first provision would expand the Production Tax Credit (PTC) to include new geothermal power facilities. As proposed, new geothermal facilities placed in service by 1 January 2007 would receive a tax credit of 1.8 US cents/kWh during their first five years of operation. The second provision would streamline and update the laws governing leasing and permitting on public lands.

### 18.2.1 Strategy

The Goal of the US Geothermal Technology Program is to decrease the levelized price of electricity from hydrothermal systems to 3-5 US cents/kWh (in 2003 dollars) by 2010.

The Program's approach to achieving its goal consists of: 1) improvements to existing technology that support decreased costs and increased electricity production from geothermal resources, 2) development of new advances in technology that broaden and expand the economic resource base, 3) cooperation with industry and other Federal agencies to find and evaluate additional geothermal resources throughout the western United States and 4) communication and outreach.

Since the late 1980s, the Federal Geothermal Technology Program has emphasized research intended to solve technical problems affecting near-term development of high-quality hydrothermal resources. This research was focused on major areas of relevant technology: exploration, drilling, reservoir engineering, and energy conversion (i.e. electricity production). The Program has now taken a more encompassing approach by considering the entire available resource as a target for development. The resource is now treated as a continuum of heat content, saturation, and permeability, rather than several distinct resource types. The Program is emphasizing longer-term, high-payoff research with cost-shared field applications (as opposed to nearer-term, incremental improvements in technology with laboratory-based studies) to promote broader use of geothermal energy.

The mission of the Geothermal Technology Program is to work in partnership with US industry and others to establish geothermal energy as an economically competitive contributor to the US energy supply.

### 18.2.2 Progress Towards National Targets

Over the life of the Federal program, DOE-sponsored R&D has supported the US geothermal industry in reducing the cost of electricity (at locations other than The Geysers) from about 16 US cents/kWh in 1980 to 5 to 8 US cents/kWh today. New geothermal power plants would probably cost about 5 US cents/kWh for optimum hydrothermal resources. The world's largest geothermal power plant, The Geysers, sells power at 3 to 3.5 US cents/kWh. New geothermal generation capacity will soon be competitive in some US markets. As natural gas prices and electricity demand increase, the prospects for geothermal electricity grow. In the near- to mid-term, the presence of Renewable Portfolio Standards (RPS), which require a percentage of power production from renewable sources, together with large-scale power purchases in states with geothermal potential, will be the dominant forces behind geothermal capacity growth.

Some exogenous factors that influence the development of geothermal energy include electricity prices, and competition from natural gas and coal. Average electricity prices from all sources are projected to decline from 7.3 US cents/kWh in 2001 to a low of 6.3 US cents/kWh (2001 dollars) by 2007. After 2008, average real electricity prices are projected to increase by 0.4% per year as a result of rising natural gas prices and a growing need for new generating capacity to meet electricity demand growth. Real electricity prices reach 6.6 US cents/kWh in 2020 and 6.7 US cents/kWh by 2025 as natural gas prices continue to increase. The natural gas share of electricity generation is projected to increase from 17% in 2001 to 29% in 2025. Coal, at a 47% share, remains the primary fuel for electricity generation through 2025. Geothermal is projected to grow slowly because of the relatively low costs of fossil-fired generation and because competitive electricity markets favour less capital-intensive natural gas technologies over coal and baseload renewables in the competition for new capacity. Geothermal capacity, all located in western States, is projected to increase to 5.6 GW.

In this environment, the extent to which the geothermal programme goals can be attained depend on the commitment on the part of US Government and the geothermal industry to making the goals a reality. At the current annual level of funding for the Federal Program, about US$ 25 M, the goal to reduce the levelized cost of hydrothermal systems to 3-5 US cents/kWh would be achievable by 2010. The other goals are long-term, circa the year 2050. In the base case, geothermal power would total about 12,000 $MW_e$ in 2050, with most of the energy coming from hydrothermal systems.

## 18.3 Current Status of Geothermal Electricity Generation

### 18.3.1 Installed Capacity

Net installed geothermal power capacity in the US has grown from about 500 to 2,800 $MW_e$ between 1973 and 2003. However, only about 2,200 $MW_e$ currently operate due to reductions at The Geysers geothermal field in California.

Geothermal electric power plants are located in California, Nevada, Hawaii, and Utah. A number of other western states, including Idaho, Wyoming, Oregon, Arizona, New Mexico, Colorado and Alaska, also have significant geothermal electric potential.

#### 18.3.1.1 California

According to the California Energy Commission, in 2001 the state had 46 geothermal plants with a total installed electrical capacity of 2,561.7 $MW_e$. For most sites, installed capacity is very close to the generating capacity (power output) from the field; The Geysers is an exception, with a current generating capacity of less than 1,000 $MW_e$. Thus, actual generating capacity of California geothermal plants is about 1,800 $MW_e$.

#### 18.3.1.2 Nevada

In 2002, Nevada had 239 $MW_e$ of generating capacity from 14 geothermal power plants at ten different physical locations.

#### 18.3.1.3 Hawaii

Hawaii has one power plant comprised of 10 generating units for a total generating capacity of 25 $MW_e$.

#### 18.3.1.4 Utah

In 2002, Utah geothermal plants had a generating capacity of 37.3 $MW_e$ at two locations.

Using 1700 $MW_e$ for California (assumes 900 $MW_e$ for The Geysers) and the generating capacities reported for Nevada, Hawaii and Utah, the total geothermal generating capacity in 2003 for the United States was about 2,000 $MW_e$. According to the Geothermal Energy Association (GEA), the power plants at The Geysers have a total rated capacity of 1,650 $MW_e$, although the plants are currently achieving an average annual net capacity of only 862 $MW_e$. For additional information check the website of the Geothermal Energy Association, www.geo-energy.org/Existing, which provides complete information on all US geothermal power plants.

### 18.3.2 Total Electricity Generated

In 2002, the US Energy Information Administration (EIA) reported geothermal electricity generation at 13,357,034 thousand kilowatt hours (tkWh). The total for all renewable energy was 347,450,482 tkWh, of which conventional hydropower was 259,532,522 tkWh. Total net electricity generation from all sources was 2,545,917 thousand megawatt hours. Based on these figures, geothermal accounts for 15% of renewable power generation, excluding hydropower, but only 0.5% of total US electricity production in 2002.

### 18.3.3 New Developments During 2003

#### 18.3.3.1 Renewable Power in California

Southern California Edison (SCE) drew on renewable energy resources for 23% of its power in June and 22% of its power in May, thereby achieving the state's 20% renewable energy requirement 14 years early. SCE also released an RFP seeking new contracts for up to 20 years of power from renewable energy sources.

#### 18.3.3.2 Near-Term Opportunities on Public Lands

In April, Rebecca Watson, Assistant Secretary of the Interior for Land and Minerals Management, and David Garman, Assistant Secretary of Energy for Energy Efficiency and Renewable Energy, announced the availability of a new report that identifies opportunities for near-term development of geothermal energy in the West. The report was undertaken in response to a task from the President's National Energy Policy. The report, titled "Opportunities for Near-Term Geothermal Development on Public Lands in the Western United States" was prepared by the Bureau of Land Management (Interior) and the National Renewable Energy Laboratory (DOE). The BLM and NREL used geographic information system (GIS) data to assess geothermal energy potential on BLM lands in the West.

#### 18.3.3.3 Raft River Geothermal Plant

US Geothermal, Inc. has procured a bridge loan on commercial terms to facilitate the start of well inspection work at the Raft River Project in south-eastern Idaho. The work was approved under the US Department of Energy's Geothermal Resource Exploration and Development grant program. A detailed technical report on the project was completed by GeothermEx Inc., which estimates a production potential of 14 to 17 net $MW_e$ from the 5 existing production steam wells. GeothermEx further estimates that the known reservoir has the potential to produce up to 90 net $MW_e$. The Raft River geothermal venture, in Cassia County near the Idaho-Nevada-Utah border, would likely start in the range of 10 $MW_e$ to 15 $MW_e$ capacity, although eventually could produce as much as 90 $MW_e$. US Geothermal looks to start construction in 2004 and begin power production late that year or early 2005. In the late 1970s and early 1980s the US Department of Energy conducted a geothermal power demonstration project at Raft River, drilling five production wells, two injection wells and seven monitoring wells. The plant successfully generated 7 $MW_e$ in 1981-82. In a series of rulings last year, the Idaho Public Utilities Commission (IPUC) adopted more generous rules for qualifying facilities under the Federal Public Utility Regulatory Policies Act (PURPA). The IPUC ultimately allowed 20-year contracts for projects up to 10 $MW_e$. Utilities are required to pay levelized prices (for non-fueled projects with 2005 on-line dates) of about 5.1 US cents/kWh.

### 18.3.3.4 Salton Sea Geothermal Power Plant

CalEnergy plans to increase production by 185 $MW_e$ with construction of Unit 6 at its Salton Sea development in Imperial County, California, which will be the largest geothermal power plant in the world. The company filed a permit application with the California Energy Commission in July 2002 for construction of the new power plant, and executed a US$ 2 billion, 20-year power sales agreement with the Imperial Irrigation District for 85% of its energy output. In November 2003, the siting committee of the California Energy Commission recommended that the commissioners approve the project. On 17 December 2003, the Commission voted to license the project. CE Obsidian Energy, LLC plans to begin power production at the plant in 2005. The proposed project would be located on an 80-acre site currently in agricultural production. The site is adjacent to the Sonny Bono Salton Sea National Wildlife Refuge. Seventeen geothermal production and injection wells, and associated brine pipelines, would be located on eight well pads within an approximate 1.5 miles radius from the project site.

### 18.3.3.5 Redfield Campus, Reno, NV

Nevada will soon have the only college campus in the world completely powered by renewable energy. A new 30-year agreement between Advanced Thermal Systems, Inc. of Reno and the University of Nevada at Reno will bring advanced geothermal technology to provide heat and power for the new Redfield Campus and provide a source of clean, affordable power for northern Nevada. Under the agreement, ATS will build and operate an 11 $MW_e$ Kalina Cycle geothermal power plant adjacent to the new campus. The plant will provide electricity, hot and chilled water. It will also supply hot water to support university research in areas such as hydroponics and aquaculture.

### 18.3.3.6 Nevada Power Purchase Agreements

On 6 March 2003, the Nevada Public Utilities Commission (PUC) unanimously approved the state's first six contracts under a renewable energy law. The contracts would provide enough electricity in 2005 and 2006 for Nevada Power Company to comply with the non-solar portion of the state's Renewable Energy Portfolio Standard. The six contracts include four geothermal plants totalling 107 $MW_e$: 25 $MW_e$ at Desert Peak 2, 13 $MW_e$ at Desert Peak 3 (ORMAT), 25 $MW_e$ at Hot Sulphur Springs (Earth Power Resources), and 44 $MW_e$ at Steamboat IV (Advanced Thermal Systems). All projects are expected to become operational by 2005. Under the contracts, Nevada Power will pay 4.2-5.2 US cents/kWh for electricity over the next 20 years.

### 18.3.3.7 Medicine Lake-Telephone Flat Power Plant

In May, the US Interior Department issued an operating license for a 48 $MW_e$ geothermal plant at Telephone Flat near Medicine Lake in northern California. The lake is a sacred site to

American Indians, and the proposed plant has been the focus of controversy. The developer, Calpine Corp. of San Jose, must realign its proposed power line to address tribal concerns. The Interior and Agriculture departments approved the project in November 2002.

### 18.3.3.8 Research Awards

Brookhaven National Laboratory and National Renewable Energy Laboratory team jointly won the 2003 Federal Laboratory Consortium Award for Excellence in Technology Transfer for their development and transfer of a smart, high-performance coating. The industrial partners in developing the coating material included Bob Curran & Sons of Dickenson, Texas, and Ticona Corporation, of Summit, New Jersey. The polyphenylenesulfide (PPS) protective coating system is particularly suited for use in carbon-steel heat exchanger tubes in geothermal power plants.

Two DOE Geothermal Program research projects won R&D 100 awards for 2003. The Low Emissions Atmospheric Metering Separator (LEAMS) is a family of atmospheric separators used in the development of geothermal power. The primary function of LEAMS is to safely contain and clean the atmospheric-vented steam of polluting solids, liquids, and noxious gasses. This system is designed to be environmentally friendly, intrinsically safe, and relatively easy to transport and assemble. LEAMS has a wide operating range and can be used in drilling, well testing, and geothermal power plant start-up. The LEAMS technology was supported by work done at Sandia National Laboratories and was developed by Two-Phase Engineering and Research, Inc. Drill Cool Systems, Inc accomplished most fabrication. Sandia, in cooperation with Extreme Engineering Ltd. of Calgary, Alberta, led the development of acoustic telemetry, which enhances communication between the driller and the drill bit. Existing measurement-while-drilling communication methods, based on mud-pulse techniques, were revolutionary when introduced in the early 1980s, but today represent a deterrent to the precision drilling needs of the 21st century. Acoustic telemetry technology uses the well-drilling tubing as a data transmission medium for carrying encoded sound waves to the surface. Among the advantages compared to other techniques are a 10-fold improvement in data rates and no blocking of the fluid flow path.

### 18.3.3.9 Santa Rosa Pipeline

Santa Rosa's largest-ever public works project began operations on 3 December 2003; nearly 19 years after a sewage spill sparked a search for alternatives to dumping treated effluent into the Russian River. The US$ 200 M project includes a buried pipeline that runs 40 miles through Sonoma County, California, winding past towns, under rivers and up the steep Mayacamas Mountains before crossing into Lake County. There, the recycled wastewater is injected, helping to recharge The Geysers geothermal steam field. The Santa Rosa pipeline is expected to allow Calpine to generate an additional 85 $MW_e$ of electricity, or enough to power 85,000 homes. The pipeline, which carries about 11 million gallons of treated effluent a day and has the capacity to expand to 26 million gallons, is estimated to be able to dispose of about half of the wastewater created annually by Santa Rosa and its partners, the cities of Cotati, Rohnert Park, Sebastopol and unincorporated parts of the county.

### 18.3.3.10 New Geothermal Resource Maps

The US Department of Energy announced the availability of new, first-of-their-kind geothermal resource maps that show low- to moderate- and high-temperature geothermal energy resource locations in 13 western states. The Idaho National Engineering and Environmental Laboratory (INEEL) produced the maps as part of DOE's GeoPowering the West activity. The maps have also been consolidated into a western United States geothermal resources regional map to provide a broader view of potential for power and direct use applications. Using geographical information system (GIS) technology, the INEEL prepared the maps to show areas with potential for geothermal electricity production and direct use; as well as known geothermal wells and springs, existing geothermal power plants, direct use applications and land ownership. The regional geothermal resource map and the maps for each of the 13 Western states (Alaska, Arizona, California, Colorado, Hawaii, Idaho, Montana, New Mexico, Nevada, Oregon, Utah, Washington and Wyoming) are available on the Internet at: http://geothermal.id.doe.gov/maps-software.

### 18.3.4 Rates and Trends in Development

The potential for geothermal electricity in the United States remains highly uncertain. In the near-term, Renewable Portfolio Standards requirements in Nevada and California are supporting expanded development in known geothermal fields. However, these requirements have not stimulated a marked increase in geothermal leasing. For example, in June, bids were received on potential competitive geothermal leases in only six of 56 tracts offered at auction by the US BLM's Nevada State Office. Leases at Soda Lake, Dixie Valley and Brady were ignored, while one tract at Gerlach and five at Salt Wells drew mostly single bids. The BLM will offer the remaining 49 parcels for non-competitive leasing. The BLM believes that interest in geothermal leases is expected to continue as a result of the state mandates for renewable power purchases by utilities.

In the longer-term, the combination of Renewable Portfolio Standards, Federal incentives, the discovery of new geothermal resources, improvements in technology, and increasing prices and demand for electricity will be strong drivers for geothermal energy development.

### 18.3.5 Number of Wells Drilled

Determining the number of wells drilled for geothermal purposes is not a straightforward process even for electricity generation and almost impossible for direct-use and geothermal heat pumps.

#### 18.3.5.1 California

The California Division of Oil, Gas and Geothermal Resources states that there are about 470 producing steam wells and 230 high-temperature, hot-water wells in 10 high-temperature geothermal fields in California. There are several hundred low-temperature geothermal wells in the state for which the Division has no records. In addition, there are about 160 geothermal injection wells located in about a dozen geothermal fields. The Division regulates all high-temperature geothermal wells on private and state lands. The US Bureau of Land Management regulates all high-temperature geothermal wells on Federal lands, except for wells on military bases, which are regulated by the Department of Defence. The Division maintains a downloadable JAVA application, 'GeoSteam', on its website that allows quick access to well records and technical data that geothermal companies have submitted to the Division since 1967. GeoSteam currently provides basic information on 3,571 geothermal wells. In addition, the Division and the California Geological Survey released *The Geothermal Map of California*, which includes digital layers of geothermal field boundaries, sites of power plants and other commercial geothermal projects, low- and high-temperature wells, and thermal springs. The map includes the locations of 740 high-temperature geothermal wells, which could support the generation of electricity.

#### 18.3.5.2 Nevada

The State of Nevada in its 'Nevada Geothermal Update' provides the following information on geothermal well permitting and drilling in 2003:

- **Desert Peak Power Plant**

ORMAT Nevada Inc. was issued permits for three production wells. All were completed in 2003.

- **Steamboat Geothermal Power Plant**

Yankee Caithness Joint Venture, LLC was issued permits for two wells. The first was a production well, which was completed in 2003. The second was a replacement injection well, also completed in 2003.

- **Hot Sulphur Springs**

Earth Power Resources, Inc. was issued a permit for a geothermal project area to include 8 production wells, 6 injection wells, and 10 observation wells. The project area is at Hot Sulphur Springs, Elko County, Nevada. The purpose of the project is to supply a 25 $MW_e$ power plant for a power purchase contract awarded by Sierra Pacific.

- **Humboldt House**

Presco Energy began their drilling program in the Humboldt House KGRA (Known Geothermal Resource Area) southwest of Winnemucca, Nevada, in May 2003. The five-well program was completed in July. Funded by DOE through the National Renewable Energy Laboratory, the program evaluated the lifetime and potential of the geothermal system.

### 18.3.6 Contribution to National Demand

Total electricity demand is projected to grow by 1.9% per year from 2001 through 2020 and 1.8% per year from 2001 to 2025 (EIA Annual Energy Outlook 2003). Generation from natural gas, coal, nuclear, and renewable fuels is projected to increase through 2025 to meet growing demand for electricity and offset the projected retirement of existing generating capacity, mostly fossil steam capacity, being displaced by more efficient natural-gas-fired combined-cycle capacity brought online in the past few years and still being constructed.
Total renewable generation, including CHP, is projected to increase from 298 billion kWh in 2001 to 495 billion kWh by 2025. Geothermal capacity is projected to increase to 5.6 GW, supplying 37 billion kWh of electricity (0.6% of total generation) in 2025.
Geothermal energy is still a small contributor to the electric power capacity and generation in the United States. In 2002, geothermal power contributed 0.5% of total US electricity production. However, the Department of Energy has developed several scenarios for geothermal development, which could support rapid deployment of geothermal electricity generation after 2025 leading to as much as 98,000 $MW_e$ capacity by 2050. Achievement of this scenario, accelerated hydrothermal plus high EGS, would require significant financial resources beyond that currently envisioned.

## 18.4 Current Status of Direct Use

The survey paper by Lund and Boyd, 'Geothermal Direct-Use in the United States', which covers the period 1995-1999, is the only recent comprehensive study of direct-use in the United States. The statistics used in this status report for direct use (excluding heat pumps) through 1999 are based on Lund and Boyd. The paper is available at http://geoheat.oit.edu/bullet.htm. *Any extrapolations from 1999 to 2003 are clearly indicated and the responsibility of the editors of this status report.* Some examples of direct use of geothermal energy in seven states are given below:

- **California**

46 of California's 58 counties have adequate resources for direct-use geothermal. The City of San Bernardino has developed the largest geothermal direct use project in North America, heating at least three-dozen buildings, including a 15 story high-rise and government facilities. The fluids are distributed through 15 miles of pipelines. The environmentally benign fluids are discharged to surface water channels after heat is extracted. Other areas in the state have tapped geothermal heated water to warm greenhouses during the winter. The Division of Oil, Gas and Geothermal Resources and the California Geological Survey released The Geothermal Map of California, which includes digital layers of geothermal field boundaries, sites of power plants and other commercial geothermal projects, low- and high-temperature wells, and thermal springs. The map includes the 28 counties with low-temperature geothermal projects.

- **New Mexico**

New Mexico has the largest acreage of geothermally heated greenhouses in the nation and has the two largest geothermal greenhouse operations. Direct-use is estimated to save more than US$1.2 M in energy savings annually when compared to natural gas use. Since 1982, New Mexico State University (NMSU) has operated one of the larger geothermal direct use district heating installations in the nation.

- **Idaho**

Boise was the first site in the United States to use geothermal for a direct use. Homes on Warm Springs Avenue began using geothermal fluids for heating in 1892. Boise now has four geothermal district heating systems: Boise Warm Springs Water District System (the original), Boise City System, Veterans Administration Hospital System and State of

Idaho Capitol Mall System. Over 360 buildings are heated by these four geothermal systems.

- **Utah**

Construction has begun on a new geothermal heating system for the Utah State Prison near Bluffdale in southern Salt Lake County using existing wells. The spent geothermal water will exit near the Jordan River where the Utah Department of Transportation is interested in using it to develop wetlands.

- **Alaska**

Lower temperature geothermal resources are used for balneology, space heating, heating greenhouses, and other direct use applications but much more could be done. Chena Hot Springs, just east of Fairbanks, uses geothermal hot springs for a bathhouse and to heat the resort. Bell Island Hot Springs near Ketchikan also uses geothermal hot springs for bathing and heating.

In 2003, the Geo-Heat Center prepared a report 'Geothermal Direct-Use Case Studies, for the US DOE. The direct-use case studies of seven sites provide a cross-section of direct-use geothermal in the western United States: 1) California Correctional Center, Susanville, California, 2) Ouray Hot Springs Pool, Ouray, Colorado, 30). 'Gone Fishing' aquaculture project, Klamath Falls, Oregon, 4) Merle West Medical Center, Klamath Falls, Oregon, 5) Fairmont Hot Springs Resort, Fairmont, Montana, 6) Geothermal District Heating System, Philip, South Dakota, and 7) Milgro-Newcastle Greenhouse, Newcastle, Utah.

### 18.4.1 Installed Thermal Power

The installed thermal capacity is 4,000 $MW_t$ (1999) and the annual energy use is 20,600 billion Btu (21,700 TJ or 6,040 GWh). The largest application is heat pumps (59% of the energy use), followed by aquaculture. During the period 1995-1999, the thermal capacity of direct heat projects increased by 170 $MW_t$, representing an annual energy consumption of 2,649 billion Btu/yr (2,792 TJ/yr).

Geothermal heat pumps increased in capacity by 1,956 $MW_t$, representing an annual energy utilization of 3,950 billion Btu/yr (4,160 TJ/yr).

The growth in direct heat use has been almost 8% compounded annually over the past five years (Lund and Boyd). Growth during 1995 to 2000 could have been higher, but competition from natural gas was a major limiting factor. Interestingly, the volatility of natural gas prices since 2000 and increasing concerns about natural gas supplies, could be major drivers for direct use in the future.

### 18.4.2 Thermal Energy Used

See Sections 18.4.1 and 18.4.3.

### 18.4.3 Category Use

Apart from heat pumps, 35% of the annual energy use for direct use is in the aquaculture industry, 28% is in bathing and swimming (resort and spa pool heating), 18% in space heating (including district heating), 14% in greenhouse heating, and 5% in industrial processing, including agriculture drying and snow melting. If geothermal heat pumps are included, they contribute 59% of the annual energy use and 41% of the direct use.

Results of the first-ever Energy Information Administration (EIA) survey of geothermal heat pump manufacturers showed 155,406 geothermal heat pumps were shipped during the period 1994 through 1996. During that period, 49% of geothermal heat pumps were shipped to the South, followed by 23 percent to the Midwest, and 13 percent to the Northeast. An estimated 36,000 units were installed in 2000 with an estimated total of 450,000 installed as of the year 2000. Using a COP of 3.0, and 1,000 full-load hours per year in the heating mode, the 450,000 units remove approximately 12,250 billion Btu/yr (12,900 TJ/yr) from the ground. The EIA stated that geothermal heat pump shipments increased 4% between 2000 and 2002, but that more of the units were sized for homes. Calculations of the capacity and the energy supplied by geothermal heat pumps are only approximate since it is difficult to determine the number of units installed. Also, most are sized for cooling and may be oversized for the heating load.

The Geothermal Heat Pump Consortium, Inc., www.geoexchange.org/publications/case.htm, provides information on geothermal heat pumps and case studies of residential, commercial, government facility and school applications. The website also provides a listing of initiatives by state. The 'geoexchange' website also provides a site list of 1,566 installations in the US and Canada providing information on the type of installation, name, city, state or province, description and a list of contacts for each site.

### 18.4.4 New Developments During 2003

#### 18.4.4.1 Michigan

The Michigan Technical Education Center/Technical Training Center (M-TEC) will be heated and cooled with geothermal heat pumps. The owner is Lansing Community College (LCC) of Lansing, Michigan. The "M-TEC" is a 52,000 $ft^2$, $ 8.7 million facility specially designed to provide workers/students with a flexible "open-entry, open-exit" training. Along with the credit programs, many vocational classes for Eaton Intermediate School District will be moving to the site. For heating and cooling, the college opted to utilize a geothermal system, which is uncommon for a project of this size. In front of the building, contractors have dug wells up to 285 ft deep to tap into the earth's consistent 55 °F (13 °C) temperatures. A closed loop system will act as a heating and cooling exchanger and provide 65% of the building's heating and cooling capacity. The system is expected to save the school about US$ 150,000 per year in utility costs, allowing the more expensive system to pay for itself in 10 years.

#### 18.4.4.2 New York

PRI, Ithaca's Paleontological Research Institution, has started drilling wells to make geothermal heating and cooling possible. The geothermal heat pump system was designed by a New Hampshire company specialized in geothermal heating and cooling. The system entails wells that will pump 54 °F (12 °C) water into the buildings. There the water will feed a conventional boiler system and be employed to heat or cool the new buildings. The cost of this system, compared to a conventional one of the same capacity, is twice as much and was supported by a New York State grant, but without the grant, it would pay for itself in five to ten years, depending on natural gas prices.

#### 18.4.4.3 Utah

Construction has begun on a new geothermal heating system for the Utah State Prison near Bluffdale in Southern Salt Lake County using existing wells. The prison is working with Johnson Controls (ESCO) and third party financing. The estimated Phase I-project cost of US$ 519,000 will save approximately US$ 69,000 per year on natural gas charges (7.6-year payout). The spent geothermal water will exit near the Jordan River where the Utah Department of Transportation is interested in using it to develop wetlands, which can be applied toward environmental mitigation credits.

### 18.4.5 Rates and Trends in Development

Most of the applications experienced some increase in use over the period 1995-2000. Aquaculture has the largest annual energy growth rate of the direct use categories, increasing by 16.9% compounded per year over the past five years. From 1990, the growth rate for direct use was 6.0% annually and for geothermal heat pumps 8.4% annually for a combined total of 7.4% annually. These historical rates are expected to continue.

### 18.4.6 Number of Wells Drilled

See Section 18.3.5 for a discussion of geothermal wells drilled.

### 18.4.7 Energy Savings

In 1999, the total direct use and geothermal heat pumps energy use in the United States was equivalent to savings of 10.3 million barrels (1.54 million tonnes) of fuel oil per year (generating electricity at 0.35 efficiency factor). Projected to 2003 the savings are 12.9 million barrels, based upon direct use increasing at 6%/year over this 4-year period (approximately 25%).

## 18.5 Market Development and Stimulation

### 18.5.1 Support and Market Stimulation Initiatives

Most activity is at the state level with the most significant market stimulation initiatives being through the RPS and power purchase agreements. The DOE provides support to the industry through cost-shared exploration and to other stakeholders through GeoPowering the West, an education and outreach endeavour.

#### 18.5.1.1 Federal Incentives and Market Stimulation

- **Modified Accelerated Cost Recovery System (MACRS)**

Under the Modified Accelerated Cost Recovery System (MACRS), businesses can recover investments in solar, wind, and geothermal property through depreciation deductions. The MACRS establishes a set of lifetimes, ranging from three to 50 years, for various types of property over which the property may be depreciated. For solar, wind, and geothermal property placed in service after 1986, the current MACRS property class is five years.

- **Solar and Geothermal Business Energy Tax Credit**

The Federal business energy tax credit is a 10% tax credit available to commercial businesses that invest in or purchase energy property in the United States. Energy property is defined as either solar or geothermal energy. Geothermal energy property includes equipment needed to produce, distribute, or use energy derived from a geothermal deposit. For electricity produced by geothermal power, equipment qualifies only up to, but not including, the electrical transmission stage. The tax credit is limited to US$ 25,000 per year, plus 25% of the total tax remaining after the credit is taken.

- **Renewable Energy Systems and Energy Efficiency Improvements Grant Program**

The Renewable Energy Systems and Energy Efficiency Improvements Grant Program provided funding of almost US$ 23 M to agricultural producers or rural small businesses during 2003. Eligible projects included those that derive energy from a wind, solar, biomass, or geothermal sources, or hydrogen derived from biomass or water using wind, solar, or geothermal energy sources.

- **Tribal Energy Grant Program**

DOE's Office of Energy Efficiency and Renewable Energy's (EERE) Tribal Energy Program provides financial and technical assistance to tribes for feasibility studies and shares the cost of implementing sustainable renewable energy installations on tribal lands. This program promotes tribal energy self-sufficiency and fosters employment and economic development on America's tribal lands. DOE has awarded and funded renewable energy projects to American Indian and Alaska Native tribal governments in 1994-1995, 1999, 2000, and 2002-2003. The most recent solicitation, which closed on 30 April 2003, was to: 1) conduct feasibility studies for the development of economically sustainable renewable energy installations on Tribal lands; or 2) implement sustainable renewable energy development projects. Eligible technologies under the solicitation included geothermal electric generation, and geothermal resources for direct heating or cooling applications.

- **GeoPowering the West**

GeoPowering the West (GPW) is a DOE geothermal outreach program, which works with the US industry, power companies, industrial and residential consumers, public interest groups, and Federal, state, and local officials to provide technical and institutional support and limited cost-shared funding for state-level activities. GPW provides information and assistance to states and local communities on how to explore and develop their own geothermal energy resources. GPW goal is to double the number of states generating geothermal electricity to eight by 2006.

#### 18.5.1.2 State Incentives for Electricity Generation

According to DSIRE (Database of State Incentives for Renewable Energy)(September 3, 2003), 14 states now have rules requiring that a certain percentage of the state's electricity come from renewable energy sources – an approach called a Renewable Portfolio Standard. Renewable Portfolio Standards (RPS) have been identified by the EIA as the main drivers for geothermal power additions in states with significant geothermal resources. Of the four states that have geothermal electrical generation plants, California, Nevada, Hawaii, and Utah; only Utah does not currently have an RPS.

- **California**

Legislation enacting California's Renewable Portfolio Standard (RPS) - SB 1078 - was signed by the Governor of California on September 12, 2002. This legislation, which requires retail sellers of electricity to purchase 20% of their electricity from renewable sources by 2017, establishes California as having the most aggressive RPS in the country. Geothermal is included as a renewable source. Under the RPS, retail sellers of electricity are required to increase their procurement of eligible renewable energy resources by at least 1% per year so that 20% of their retail sales are procured from eligible renewable energy resources by 2017. The RPS legislation requires that the Energy Commission and CPUC work collaboratively to implement the RPS and assigns specific roles to each agency.

- **Nevada**

As part of its 1997 restructuring legislation, the Nevada legislature established a renewable energy portfolio standard. Under the standard, the state's two investor-owned utilities, Nevada Power and Sierra Pacific Power, must derive a minimum percentage of the total electricity they sell from renewable energy resources. In 2001, the legislature revised the minimum amounts to increase by 2% every 2 years, starting with a 5% renewable energy requirement in 2003 and achieving a 15% requirement by 2013 and each year thereafter. Not less than 5% of the renewable energy must be generated from solar renewable energy systems. Geothermal energy is a qualifying renewable energy resource. The Public Utilities Commission of Nevada (PUCN) adopted a temporary regulation on 20 November 2002 that allows energy providers to buy and sell renewable energy credits (REC). With the passage of four REC-related bills in the 2003 legislative session, the REC regulations are in the process of being revised. Retail energy providers complying with Nevada's RPS can purchase credits from the owners of the REC. One REC will represent 1 kWh of electricity for geothermal energy.

- **Hawaii**

Act 272 of 2001 established goals for electric utility companies in implementing an RPS by including a minimum percentage of renewable energy resources within an overall resource portfolio. Each electric utility is required to establish the following RPS goals:

- 7% of its net electricity sales by December 31, 2003.
- 8% of its net electricity sales by December 31, 2005.
- 9% of its net electricity sales by December 31, 2010.

Existing renewables, about 7% statewide, can be counted in the total. In addition, an electric utility company and its electric utility affiliates may aggregate their renewable portfolios in order to achieve the renewable portfolio standard (i.e. the Hawaiian Electric Company affiliates -- Hawaiian Electric, Maui Electric, and Hawaii Electric Light Company -- may add together their renewable energy numbers to meet the goal). Renewable energy includes geothermal resources.

### 18.5.2 Development Cost Trends

The cost of geothermal electricity was as much as 16 US cents/kWh during the 1980s and today probably averages about 5 US cents/kWh for the better resources. To sustain this trend in reduced costs, additional geothermal resources of high quality will have to be found. Thus, in exploration technology development, the trend is toward using improved reconnaissance tools, which can be deployed quickly to characterize large geographical areas. Drilling costs will continue to decrease as a result of experience gained with improved technology. In overall development, the trend appears to be toward expanding existing sites with infrastructure in place to lower costs. Cost-shared application and testing of EGS techniques at existing hydrothermal sites will continue. Another trend, which should help to reduce costs, is the effort to improve the performance of air-cooled condensers and other energy conversion equipment.

## 18.6 Development Constraints

### 18.6.1 Cost and Price Constraints

The cost of producing electricity from geothermal resources versus the cost of alternative fuels, coal and natural gas, is the primary constraint on commercial development in the near term. Geothermal costs have declined dramatically over the last two decades reaching parity at some hydrothermal locations. In addition, RPS in California and Nevada will support development at somewhat higher cost levels. However, future cost reductions at less promising sites will become increasingly difficult. The DOE Geothermal Technology Program has adopted a goal for 2010 that reduces the cost of power to competitive levels. In the longer-term, the EIA predicts that the demand for electricity will outstrip supply leading to somewhat higher prices that will favour development of additional geothermal power plants.

### 18.6.2 Undiscovered Geothermal Resources

The US Geological Survey (USGS) has estimated that already-identified geothermal systems hotter than 150 ºC have a potential generating capacity of about 23,000 $MW_e$ and could produce electricity for 30 years. A general map locating these resources is shown in Figure 18.1.

Additionally, undiscovered geothermal systems are estimated at 72,000-127,000 $MW_e$. The highest heat flow areas are in the western United States. Major resource areas that have been partially developed there include the Basin and Range area of Nevada, Utah and parts of Idaho, Oregon and California; The Geysers in northern California; and the Imperial Valley area in southern California.

Some experts believe that the amount of discovered geothermal resources in the United States is sufficient for only an additional 2000-3000 $MW_e$ under current conditions. With aggressive exploration and application of technology for Enhanced Geothermal Systems, the generating capacity could perhaps achieve the amounts indicated by the USGS estimates. The USGS has plans for a new effort to assess

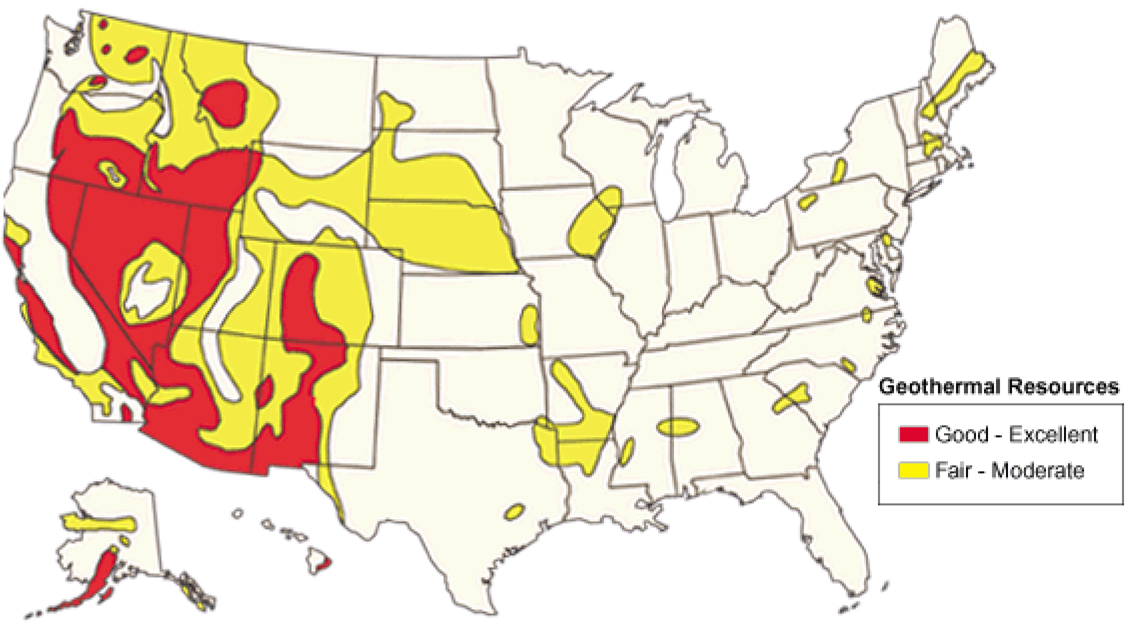


**Figure 18.1** A general map locating identified geothermal resources in the US.

the nature and extent of geothermal systems and to produce an updated estimate of geothermal resources in the Great Basin of the United States.

### 18.6.3 Environmental Concerns

Geothermal resources contribute to energy supplies through both electrical power generation and direct heat uses, and reduce the use of fossil fuels through savings in electricity and natural gas that result from the use of geothermal heat pumps to heat and cool buildings.

#### 18.6.3.1 Air Impacts

Greenhouse gas emissions from geothermal sources are almost zero; ozone-depleting chemicals from both direct and indirect sources are also almost zero; and sulphur oxide emissions are virtually zero because, by design, modern closed-cycle geothermal systems reinject almost everything but the extracted heat. Geothermal plants operating in the US annually displace 16 million tons of carbon dioxide ($CO_2$), 20,000 tons of sulphur dioxide and 41,000 tons of nitrogen oxides that would be emitted into the atmosphere if compared to state-of-the-art coal-fired power plants. The two processes used currently for the generation of electricity are flash steam and binary-cycle. Hydrogen sulphide may be present in the geothermal fluid, but in the case of the binary cycle plant would be injected underground. For flash steam plants, hydrogen sulphide is removed chemically.

#### 18.6.3.2 Land Impacts

Geothermal power plants require relatively little land, taking up only a fraction of that needed by other energy sources and other land uses can coexist with geothermal plants with little interference. No fuel storage facilities are required. Destruction of geyser activity as a result of extracting geothermal fluids for power generation has proven to be an environmental liability. The Beowawe geyser field in central Nevada and the Steamboat Springs geyser field, located several miles south of Reno, Nevada, no longer support geyser activity. Subsidence associated with geothermal fluid extraction is rare, but has occurred over a large area at Heber in the Imperial Valley of California. While many geothermal resources are located in active seismic belts, apparent induced seismicity has been noted in association with reinjection of fluids in geothermal reservoirs. To date, the magnitude of that seismicity has been small.

#### 18.6.3.3 Other Impacts

The best geothermal resources are often found in areas of great natural beauty. Such areas are not only national treasures, but may also be sacred to Native American tribes. As a result, a number of geothermal resources, especially those in and around national parks, have been restricted from future commercial development.

## 18.7 Economics

### 18.7.1 Trends in Geothermal Investment

Because of the site-specific nature of geothermal resources, investment decisions are typically made on a project-by-project basis. The driving factor is the projected economics of the project. The combination of a Production Tax Credit at the Federal level and Renewable Portfolio Standards at the state level would be powerful incentives for the development of geothermal power by improving the economics and providing long-term market stability.

Geothermal projects are capital-intensive in an area where investors prefer the lower capital costs of natural gas power plants. Siting a geothermal facility is also very expensive-requiring millions of dollars in up-front administrative expenses for the plant and for permits and processes required for leasing, rights of way, *etc*. Developers have approached this most recently by developing previously discovered, but largely undeveloped fields. This also minimizes exploration risk and avoids the risks associated with drilling in unexplored areas.

Beyond expanding at current sites, which already are producing geothermal electricity, the investment climate for geothermal is unclear. Probably the greatest need is to have a portfolio of new geothermal resources that have been characterized and which are ready for development. This is the reason for DOE's emphasis on improving exploration technology. Reducing the cost of geothermal drilling is also an important consideration.

### 18.7.2 Trends in the Cost of Energy

See sections 18.2.2, 18.5.2 and 18.6.1 for discussions of cost trends for geothermal and electricity in the United States.

## 18.8 Research Activities

The U. S. Department of Energy's Office of Geothermal Technology Program conducts research, development, and deployment activities in partnership with US industry to establish geothermal energy as an economically competitive contributor to the US energy supply. The goal is to reduce the levelized cost of geothermal energy to 3-5 US cents/kWh by 2010.

### 18.8.1 Program Element: Exploration

The exploration element of the Program develops and tests innovative techniques for exploring for geothermal resources and applies exploration and characterization techniques to reduce the cost of drilling through improved well siting. Only a small portion of the US Geological Survey's estimated geothermal resource base has been developed, and current exploration methods have had limited success in delineating and correctly identifying resources. Improved methods for exploration and well siting will enable development of a much larger portion of the estimated resource base. Exploration technology involves the identification, understanding, and characterization of the geothermal resource, and research involves seismic, remote sensing, electromagnetic, and reservoir modelling methods.

Two strategies are used to achieve program objectives: (1) cost-shared research with industry in areas of greatest current need, and (2) DOE-sponsored studies/efforts to meet longer-term industry needs and apply technologies that are not available to the industry to meet shorter-term needs. The cost-shared research emphasizes attaining near-term objectives and provides a role for industry in setting the research and development agenda.

The current program comprises exploration research at DOE national laboratories and research at several universities. Research projects include development of new techniques for both regional and site-specific exploration.

DOE researchers rely heavily on cooperative work with geothermal developers to gain the data needed to conduct their research and to verify results. The goal of the Exploration program element is to enable the geothermal industry to discover geothermal fields with little or no use of deep drilling. The goal will be reached through three strategic objectives: 1. Develop more selective, remote tools for regional geothermal exploration, 2. Develop site-specific exploration tools that will lead to success rates of 40% when drilling exploration wells and 3. Develop techniques that will enable subsurface permeability to be located early in the development of geothermal fields.

### 18.8.2 Program Element: EGS

The Enhanced Geothermal Systems (EGS) element of the Geothermal Technology Program addresses the need to better understand subsurface conditions and to develop techniques to recover energy from systems lacking sufficient natural fluid flow and permeability for economic development. Current technology only allows the economic recovery of geothermal energy in natural systems with sufficient heat, fluid, and permeability. Geothermal explorers have delineated many systems that are not economically viable. In some of these, drilling has failed to reach zones of natural permeability, and in others there may not be adequate natural permeability to sustain economic production.

The Program has initiated a two-fold strategy for developing EGS technology: 1) conduct a research program that develops an improved understanding of how hydrothermal systems operate and how to sustain their productivity, and 2) perform field experiments of EGS technology with industrial partners who will be the ultimate users of the technology. The field experiments will encompass three phases: 1) enhancing productivity within existing hydrothermal systems, 2) adding production to areas adjacent to but not currently included in existing hydrothermal systems, and 3) developing an engineered system not associated with a known hydrothermal system. Each phase will involve more sophisticated earth science and engineering.

### 18.8.3 Program Element: Drilling

Making geothermal drilling cheaper and more reliable is critical to attaining Program goals, because drilling is involved in almost all aspects of a geothermal development cycle. The Program is developing new capabilities, or modifying existing ones, that will lower drilling costs and reduce financial risk in geothermal environments. The program comprises in-house research, informal cooperative developments through Non-Disclosure Agreements with industry, and close cooperation with industry and academia. These activities encompass five principal research areas: high-temperature electronics, rock reduction (drill bits), diagnostics-while-drilling, wellbore integrity and advanced drilling systems.

The goal is to decrease the cost of drilling by 25% by 2008 compared to the cost in 2000. Providing better techniques for standard practice will sustain the geothermal industry and enable expansion into more challenging resource areas.

Specific Research Objectives Include:

- **High-Temperature Electronics**

Create a commercially viable high-temperature electronics and sensors industry to support geothermal development and production by developing HT batteries and an HT Field Programmable Gate Array (FPGA).

- **Rock Reduction**

Dramatically enhance rock penetration rates and bit life via the development, demonstration, and commercialization of technologies including next-generation drag cutters with improved wear and impact resistance; bit/drillstring vibration modelling, simulation, and active and passive control; drag-bit augmentation with high-performance hydraulics.

- **Diagnostics-While-Drilling**

Demonstrate a robust DWD system using high-temperature electronics, and optimized to improve bit performance, in geothermal wells.

- **Wellbore Integrity**

Develop technologies that allow uninterrupted rock reduction inexpensively, and ensure the structural integrity, durability, and protective properties of well cements/sealants throughout the well life.

- **Advanced Drilling Systems**

Integrate advanced technology components into an effective, efficient drilling system, possibly including design of a purpose-built geothermal drill rig.

### 18.8.4 Program Element: Advanced Heat and Power

Geothermal power plants have unique challenges compared to fossil fuel power plants. The most significant is the relatively low temperature of the geothermal brine. This results in low conversion efficiency and a relatively capital-intensive geothermal plant. In addition, geothermal power plants tend to have high maintenance expenses because the brines are sometimes corrosive. Research that addresses high capital costs and high O&M costs include: advanced power cycles, including working fluid mixtures; improved component performance; improved heat rejection processes; automation and optimization of plant processes; and advancements in both materials and fluid chemistry.

Moderate- to low-temperature resources are more abundant than high-temperature resources, but their power producing capability is lower. Research activities for these plants include: investigating advanced power cycles, including working fluid mixtures; improving component performance; improving and augmenting sensible heat rejection processes; and reducing conversion system O&M costs.

### 18.8.5 Program Element: Resource Assessment

The Program also engages in a cooperative DOE/industry effort to find and evaluate additional geothermal resources throughout the western United States. The objective is to locate new geothermal resources and thereby increase the amount of proven geothermal resources that can be used for power generation in the United States. The technical challenge is to find and verify geothermal resources in previously unexplored areas. This is accomplished through cost-shared activities wherein industry has the responsibility to develop plans for exploration, drilling, and flow testing. The primary approach is through Geothermal Resource Exploration and Definition (GRED).

GRED is a DOE/industry cost-shared effort to find, evaluate, and define additional geothermal resources throughout the western United States. The objective is to locate new geothermal resources and thereby increase the resource base for power generation. A typical project might consist of surface exploration to discover probable geothermal resources and select a site for drilling an exploration slim hole; drilling a slim hole (6 inches or less in diameter); and flow testing to confirm the resource. GRED also serves as a field-testing laboratory for new exploration technology produced by the DOE research program.

### 18.8.6 Program Element: GeoPowering the West

GeoPowering the West (GPW) is the communication and outreach component of the Program. It encompasses state and local public-private partnership efforts across the western United States to significantly increase the use of geothermal energy over the next decade. Outreach efforts are aimed at providing information to relevant decision-makers to help them identify and address non-technical and institutional barriers to geothermal development. The broad goal of GPW is to identify barriers to development and work with stakeholders to eliminate the barriers.

GeoPowering the West cooperates with State and local entities to remove institutional barriers to deployment and provides support for both power generation and direct use development activities. GPW assists in implementing the following objectives within the states: 1) educate stakeholders and increase public awareness, 2) organize state geothermal energy working groups and assist the states in implementing their strategic plans, 3) promote policies that encourage the use and development of geothermal energy, 4) encourage the development of geothermal energy for power generation and direct use applications, and 5) increase technical knowledge and understanding of the state's geothermal resources and their uses.

### 18.8.7 Focus Areas

#### 18.8.7.1 Technical Assessment

Technical assessment ensures that every research activity is linked to the Program's top-level objectives and goals. The program assesses technical progress against known technology, and against estimates of the potential for improvement to those technologies, using well-defined metrics such as cost of energy as the basis for comparison. In prioritizing program activities, program planners select those research areas that yield the maximum improvement for a given level of investment. Research activities of lesser value are terminated or deferred. Annual peer reviews ensure that projects are achieving as expected, and provide a formal mechanism for industry and other stakeholders to provide feedback to the program. The results of the peer review are taken into account in the program planners' prioritization of program activities.

#### 18.8.7.2 Program Documents/Planning

The Program's activities are documented in a Strategic Plan, which describes the program's goals, objectives, and priorities; the Multi-Year Plan provides a description of program activities and schedules, milestones, and performance metrics; and the Annual Operating Plan, which describes program activities for the current fiscal year.

### 18.8.7.3 Program Structure

In organizing the Program to meet the stated goals and objectives, the program is organized along the following key activities and subactivities:

- **Geosciences and Supporting Technologies**
    - Core Research (Geoscience research at national laboratories)
    - University Research (Geoscience research at universities)
    - Enhanced Geothermal Systems (Cost-shared projects with industry)
- **Exploration and Drilling Research**
    - Detection and Mapping (Research on exploration technology)
    - Innovative Drilling Subsystems (Drilling R&D)
- **Energy Systems Research and Testing**
    - Advanced Heat & Power Systems (Energy conversion research)
    - Systems Field Verification (Small-scale systems demonstrations)
    - Industry Support (Systems analysis and other industry needs)
    - GeoPowering the West (Education and outreach)

## 18.8.8 Government Funded

The Federal Government has been supporting geothermal energy development since the 1970s. The focus has evolved from an early emphasis on sites where access to geothermal resources was readily available to the development of advanced systems for using geothermal resources at many more locations. This now requires the development of more sophisticated exploration, characterization, drilling, and energy conversion technologies.

The Geothermal Technology Program is implemented as follows:

- Research by national laboratories directed toward technology development to meet industry needs.
- Cost-shared solicitations to develop and/or prove new technology. These are often high risk projects involving industry partners who are committed to adopting the technology
- University-based research, particularly in the geosciences, to complement work at the national laboratories.

The DOE Geothermal Technology Program funding by fiscal year since 2000 is presented in Table 18.1.

**Table 18.1** DOE Geothermal Technology Program funding.

| US DOE Geothermal Technology Program Funding by Fiscal Year in US$ M | |
|---|---|
| **Year** | **Funding** |
| 2000 | 23.6 |
| 2001 | 26.6 |
| 2002 | 27.3 |
| 2003 | 28.4 |

## 18.8.9 Industry Funded

The United States geothermal industry consists primarily of independent power generation companies, developers, service companies, and equipment manufacturers. Little independent research is conducted by the geothermal industry. However, there is a high degree of interest by a number of companies in applying the results of DOE geothermal research in the exploration and development of geothermal resources. This has led to a number of DOE/industry cost-shared field projects particularly in exploration and resource definition, drilling, heat exchangers, Enhanced Geothermal Systems, and operating and maintenance improvements.

## 18.9 Geothermal Education

The Geothermal Technology Program supports geothermal education at the graduate level through its university research program. The Program also provides partial support to the Geothermal Education Office (GEO), Tiburon, California, a non-profit educational organization serving teachers and students nationwide to increase awareness and understanding of geothermal energy. Additional educational services are provided through the Geothermal Resources Council and the Geo-Heat Center at the Oregon Institute of Technology. A number of universities, including Stanford, Southern Methodist University, and the University of Nevada, Reno, have centres for geothermal research.

### 18.9.1 Geothermal Education Office, Tiburon, California

The purpose of the Geothermal Education Office (GEO) is to promote public understanding of geothermal resources and their importance in providing clean sustainable energy. The GEO produces and distributes educational materials about geothermal energy to schools, energy/environmental educators, libraries, industry, and the public. The GEO collaborates frequently with education and energy organizations with common goals, and, through its website, responds to requests and questions from around the world. The GEO is funded by the US Department of Energy and by geothermal industry participation in joint education and public information projects.

### 18.9.2 Geothermal Resources Council, Davis, California

The Geothermal Resources Council (GRC) is a tax-exempt, non-profit, educational association. The Council was founded in 1970, and with members in more than 20 countries, the Council actively seeks to expand its role as the primary geothermal educational association throughout the world. The goals of the Council are to:

- Encourage the development of geothermal resources worldwide through the collection and timely distribution of data and technological information.
- Encourage and promote research, exploration and development of geothermal energy in ways compatible with the environment.
- Serve as a public forum for the world geothermal community, and provide transfer of objective and unbiased information on the nature of geothermal energy and its development.
- Cooperate and communicate with academic institutions, industry and government agencies on economically and environmentally sound development and utilization of geothermal resources.

The GRC develops educational functions on a variety of topics that are critical to geothermal development. The Council can provide comprehensive, professional meeting services to fulfil industry and agency needs and the GRC convenes special meetings, workshops, conferences, courses, and symposia on the full range of subjects pertaining to geothermal exploration, development and utilization. The Geothermal Resources Council Foundation, created in 1986 by the GRC, has an education fund which provides scholarships, speaker travel expenses and miscellaneous costs associated with educational activities.

### 18.9.3 GeoHeat Center, Oregon Institute of Technology, Klamath Falls, Oregon

The transfer of technological information to consultants, developers, potential users, and the general public is an important element in the development of direct heat utilization of geothermal energy. The Geo-Heat Center's resources are available to the public. Information developed through firsthand experience with hundreds of projects is provided to individuals, organizations or companies involved in geothermal development. The Geo-Heat Center maintains a geothermal library of over 5,000 volumes for lay and technical readers. The library is searchable through the Geothermal Resource Council (GRC) website. Volumes are available for public use on-site. The Geo-Heat Center also provides technical analysis for those actively involved in geothermal development.

### 18.9.4 Stanford Geothermal Program, Stanford University, Stanford, California

The primary objective of the Stanford Geothermal Program is the development of reservoir engineering techniques to allow for the production of the nation's geothermal resources in the most efficient manner possible. The Stanford Geothermal Program has conducted geothermal reservoir engineering research for more than 25 years. During this time, about 150 separate projects have been completed, each producing a technical report for dissemination of the results to the public. The program has undertaken studies in a number of areas, with some of the more notable ones including well test analysis of fractured and multiphase reservoirs, design and interpretation of tracer tests in fractured reservoirs, adsorption in vapour-dominated reservoirs, experimental measurements of fluid flow parameters, and optimization of production and reinjection strategies. As an outgrowth of the research, the Stanford Geothermal Program has produced a large number of graduate engineers who have taken up leadership positions in the geothermal industry, both in the US and worldwide. As of the end of 2001, more than 100 people have graduated from the program, and many of them have worked in the geothermal industry in US companies well as in Japan, Philippines, Turkey, Costa Rica, Mexico, New Zealand and Indonesia.

### 18.9.5 Geothermal Laboratory, Southern Methodist University, Dallas Texas

Students studying the Earth's heat follow the requirements for a Geophysics degree with an emphasis in Geothermal. The individual's interests and research help tailor the courses taken. The Geothermal Laboratory has national/international connections for research purposes. Requests for resource assessment of existing and exploration geothermal sites stimulate many short and long -term projects. Projects are primarily in the United States, but international research is completed as well.

### 18.9.6 Great Basin Center for Geothermal Energy, University of Nevada, Reno

The goal of the Center is to guide Nevada in obtaining 10% of its electrical power from geothermal sources by 2013 and to establish geothermal energy as a sustainable, environmentally sound, economically competitive contributor to the energy supply in the western United States. The Center is producing a web-based, stakeholder geothermal information system for Nevada geothermal data. Fieldwork consists in part of using the highest-tech capabilities available, including the Global Positioning Satellite System (GPS) and other remote sensing instruments to locate "hidden systems," i.e. those that do not have hot springs issuing at the surface. The Center's mission also includes identifying new and emerging technologies for geothermal energy production, storage, transmission and use; fostering new scientific and technological developments; facilitating outreach, training and communication between geothermal energy stakeholders; promoting collaborative geothermal research between academic organizations and industry to accelerate applications; and stimulating public awareness of geothermal energy and the advantage of its use.

## 18.10 International Cooperative Activities

The United States was one of the original Contracting Parties to the International Energy Agency Implementing Agreement for a Co-Operative Programme on Geothermal Energy Research and Technology (Geothermal Agreement) signed on 7 March 1997. The US DOE participates in each of the technical Annexes to the Agreement. The DOE Geothermal Technology Program and its researchers have participated in many international conferences and meetings including the World Geothermal Conference 2000 in Japan and the 2003 Annual Meeting of the Geothermal Resources Council in Mexico. The DOE is also a sponsor of the World Renewable Energy Conference scheduled for September 2004 in Denver, Colorado.

**Authors:** Allan Jelacic, US Department of Energy and Clifton Carwile, National Renewable Energy Laboratory.

**Contact:** Allan Jelacic: Allan.Jelacic@hq.doe.gov

**Members and Observers at an IEA-GIA Executive Committee Meeting, Reykjavik, Iceland.**

# IEA Geothermal Implementing Agreement Executive Committee 2003

| Country / Name | Delegate | Organization / address | e-mail / tel / Fax | Alternate | Address, *etc.* (where different) |
|---|---|---|---|---|---|
| **AUSTRALIA** | **Doone Wyborn** | **Geodynamics Limited**<br>PO Box 2046<br>Milton<br>Queensland 4064<br>Australia | dwyborn@geodynamics.com.au<br>Tel. +61-7-3721-7500<br>Fax +61-7-3721-7599 | Prame Chopra | **Australian National University**<br>Department of Geology<br>Canberra, ACT 0200<br>AUSTRALIA<br>prame.chopra@anu.edu.au |
| **EUROPEAN COMMISSION** | **Jeroen Schuppers** | **European Commission**<br>DG RTD / (MO75 07/11)<br>B-1049 Brussels<br>BELGIUM | Jeroen.schuppers@ cec.eu.int<br>Tel. ++32-2-295-7006<br>Fax ++32-2-299-3694 | William Gillett | **European Commission**<br>DG TREN / D-2 (DM24 03/126)<br>B-1049 Brussels<br>BELGIUM<br>Tel. ++32-2-299-5676<br>Fax ++32-2-296-3765<br>william.gillett@cec.eu.int |
| **GERMANY** | **Andrea Ballouk (to Sept)**<br>**Dieter Rathjen (from Sept)** | **ForschungszentrumJülich GmbH**<br>Project Management Organization<br>D-52425 Jülich<br>GERMANY | d.rathjen@fz-juelich.de<br>Tel. ++49-2461-61-42-33<br>Fax ++49-2461-61-28-40 | Norbert Stump | **ForschungszentrumJülich GmbH**<br>n.stump@fz-juelich.de<br>Tel. ++49-2461-61-31-72<br>Fax ++49-2461-61-28-40 |
| **GREECE** | **Constantine Karytsas** | **CRES**<br>19th Kim Marathanos Ave<br>GR-19009 Pikermi-Attiki<br>GREECE | kkari@cres.gr<br>Tel. ++30-210-660-3375<br>Fax ++30-210-660-3301 | Dimitrios Mendrinos | **CRES**<br>dmendrin@cres.gr<br>Tel. ++30-210-660-3205<br>Fax ++30-210-660-3301 |
| **ICELAND** | **Sveinbjörn Björnsson** | **National Energy Authority**<br>Grensavegi 9<br>IS-108 Reykjavik<br>ICELAND | svb@os.is<br>Tel. ++354-569-6000<br>Fax ++354-568-8896 | Hrefna Kristmannsdóttir | **University of Akureyri**<br>Faculty of Natural Resource Sciences<br>Solborg, Nordurslod, 600<br>Akureyri<br>ICELAND<br>hk@unak.is<br>Tel. ++354-463-0974<br>Fax ++354-463-0998 |
| **ITALY** | **Aldo Baldacci** | **ERGA SpA (Gruppo ENEL)**<br>Via Andrea Pisano 120<br>I-56122 Pisa<br>ITALY | baldacci.aldo@enel.it<br>Tel. ++39-050-535-744<br>Fax ++39-050-535-5940 | Guido Cappetti | **ERGA SpA (Gruppo ENEL)**<br>cappetti.guido@enel.it<br>Tel. ++39-050-535-781<br>Fax ++39-050-533-290 |

## IEA Geothermal Implementing Agreement Executive Committee 2003 (continued)

| Country / Name | Delegate | Organization / address | e-mail / tel / Fax | Alternate | Address, *etc.* (where different) |
|---|---|---|---|---|---|
| **JAPAN** | **Kenji Haruguchi** | **Director, Geothermal Energy Development Department**<br>**NEDO**<br>Sunshine 60, 30F, Higashi-Ikebukuro<br>1-1-3 Toshima-ku, Tokyo 170-6028<br>JAPAN | haruguchiknj@nedo.go.jp<br>Tel. ++81-3-3987-9451<br>Fax ++81-3-3986-8197 | Satoshi Kubo | **NEDO**<br>kubosts@nedo.go.jp<br>Tel. ++81-3-3987-9452<br>Fax ++81-3-3986-8197 |
| **MEXICO** | **David Nieva**<br>*Chairman* | **Manager of Technology Transfer**<br>Instituto de Investigaciones Electricas<br>Av. Reforma N˚113, Col. Palmira<br>62490 Temixco, Mor.<br>MEXICO | dnieva@iie.org.mx<br>Tel. ++52-777-318-3811, ext. 7495<br>Fax ++52-777-318-9542 | Victor Manuel Arellano Gómez | **IIE**<br>vag@iie.org.mx<br>Tel. ++52-777-3-62-38-03<br>Fax ++52-777-3-62-38-04 |
| **NEW ZEALAND** | **Chris Bromley** | **Institute Geological & Nuclear Sciences**<br>Wairakei Research Centre<br>Private Bag 2000<br>Taupo<br>NEW ZEALAND | c.bromley@gns.cri.nz<br>Tel. ++64-7-374-8211<br>Fax ++64-7-374-8199 | Colin Harvey | **IGNS**<br>c.harvey@gns.cri.nz |
| **SWITZERLAND** | **Ladislaus Rybach**<br>*Vice Chairman* | **ETH Zurich**<br>Institute of Geophysics<br>ETH-Hoenggerberg<br>CH-8093 Zurich<br>SWITZERLAND | rybach@ig.erdw.ethz.ch<br>rybach@geowatt.ch<br>Tel. ++41-1-633-2605<br>Fax ++41-1-633-1065 | Harald L. Gorhan | Neudoerfli 10<br>CH-5600 Lenzburg<br>SWITZERLAND<br>harald.gorhan@bluewin.ch<br>Tel. ++41-62-891-8368<br>Fax ++41-62-891-8368 |
| **USA** | **Allan Jelacic**<br>*Vice Chairman* | **Office of Geothermal Technologies**<br>US Department of Energy, EE-2C<br>1000 Independence Ave SW<br>Washington, DC 20585<br>USA | allan.jelacic@hq.doe.gov<br>Tel. ++1-202-586-6054<br>Fax ++1-202-586-8185 | Roy Mink | **US Department of Energy**<br>roy.mink@ee.doe.gov<br>Tel. ++1-202-586-5463<br>Fax ++1-202-586-8185 |
| **STAFF** | **Mike Mongillo**<br>*IEA GIA Secretary* | **IEA-GIA Secretariat**<br>**Institute Geological & Nuclear Sciences**<br>Wairakei Research Centre<br>Private Bag 2000<br>Taupo<br>NEW ZEALAND | IEA-GIASec@gns.cri.nz<br>m.mongillo@gns.cri.nz<br>mongillom@reap.org.nz (home office)<br>Tel. ++64-7-378-9774 (home office)<br>Tel. ++64-7-374-8211<br>Fax ++64-7-374-8199 | - | - |

# *International Energy Agency*
# *Geothermal Implementing Agreement*

# DRAFT

## Minutes
## of the
## 11th Meeting of the Executive Committee (ExCo)

## Paris, France
## 18-19 March 2004

**Prepared**
**by**

**IEA-GIA Secretariat**
**Institute of Geological and Nuclear Sciences Limited**
**Wairakei Research Centre**
**Private Bag 2000**
**Taupo**
**NEW ZEALAND**

*International Energy Agency- Geothermal Implementing Agreement*

**Minutes of the**
**11th Meeting of the Executive Committee (ExCo)**
**Paris, France**
**18-19 March 2004**

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# International Energy Agency- Geothermal Implementing Agreement
# Minutes of the
# 11th Meeting of the Executive Committee (ExCo)

# Paris, France
# 18-19 March 2004

## 1. MINUTES

The 11th meeting of the IEA-GIA Executive Committee (ExCo) was held at the Headquarters of the International Energy Agency (IEA), Paris, France, on 18-19 March 2004.

Chairman David Nieva called the meeting to order at 9:40 AM, 18March 2004. Nieva welcomed the ExCo members, observers and guests.

Eight members and three alternates of the IEA-GIA ExCo were present, satisfying the quorum requirements of a minimum of six members (Appendix 1).

### 1.1 ExCo Members and Alternate Members Present

ExCo members Aldo Baldacci (Italy), Kenji Haruguchi (Japan), Allan Jelacic (Vice-Chairman, USA), David Nieva (Chairman, Mexico), Dieter Rathjen (Germany), Ladsi Rybach (Vice-Chairman, Switzerland), Jeroen Schuppers (European Commission), Helga Tulinius (Iceland) and alternate members Harald Gorhan (Switzerland), Colin Harvey (New Zealand) and Hrefna Kristmannsdóttir (Iceland) attended (see Appendix 1 for signature and business card pages; Appendix 3 for list of ExCo Members and contact information).

### 1.2 Observers Present

Roy Baria (European Geothermal Project, Soultz-sous-Forêt), Manuela Caruso (IEA Deputy Chief Legal Council), Christophe Debouit (NEDO Representative, Paris Office), Kazunori Fukasawa (NEDO Chief Representative in Paris Office), Satoshi Kubo (Annex VII member), Isao Matsunaga (Annex III Leader), Antonio Pflüger (IEA Headquarters), Rick Sellers (IEA), Peter Tulej (IEA Desk Officer) and Marry Harries White (IEA).

Mike Mongillo, IEA-GIA Secretary.

### 1.3 Apologies

Doone Wyborn (Australia) and Chris Bromley (New Zealand).

## 2. AGREED ACTION ITEMS FROM 11th ExCo MEETING

**Action 11/1:** Secretary to contact the authors of the annex and country reports submitted for inclusion in the 2003 GIA annual report to request further information where needed.
**Action 11/2:** Secretary to send ExCo Members the website address so they can access the GIA annual reports.
**Action 11/3:** Secretary to arrange with NREL to send a second invoice notice, in July rather than September, to Members who have not yet paid their Common Fund contribution.
**Action 11/4:** Nieva to re-send (via e-mail) the IEA "suggested" re-wording for the IA changes. (Superseded by Action 11/15.)
**Action 11/5:** Jelacic to contact Jim Koenig to attempt to arrange for the GIA WGC 2005 paper to be presented at a Plenary Session.
**Action 11/6:** Secretary to provide work plan for 2005 at the Pisa meeting (October 2004), and from then on, the next year's work plan at every autumn meeting.
**Action 11/7:** Secretary to provide an up-to-date financial statement to ExCo, taking into account all GNS expense invoices to date.
**Action 11/8:** Harvey to notify Nieva as soon as he hears if he will be attending the Bonn Conference.

**Action 11/9:** Secretary to include statement in 2003 annual report that there is an "overlap" of work in Annexes III and IV and that it is presently being sorted out.
**Action 11/10:** Nieva to ask CFE if they would agree to be the Subtask A Leader for Annex VII.
**Action 11/11:** Participants in Subtask B of Annex VII to provide a list of references covering information for the Handbook to the Subtask Leaders (Hector Gutierrez, CFE (Mexico); Sverrir Thorhallsson, Orkustofnun (Iceland)).
**Action 11/12:** CFE and Iceland to provide information on their "wells of opportunity" for equipment testing.
**Action 11/13:** Secretary to place "THE IEA GEOTHERMAL IMPLEMENTING AGREEMENT-It's Goals, Activities, Benefits, Obligations and Costs" document in a prominent location on the GIA website.
**Action 11/14:** Secretary to include a statement that the first German geothermal power station went on-line at Neustadt-Glewe in November 2003, in the 2003 GIA annual report.
**Action 11/15:** Secretary to distribute to the ExCo the IEA letter with the exact wording changes for the new IEA IA framework. (Supersedes Action 11/4.)
**Action 11/16:** Secretary to send Mary Harries White a list of GIA ExCo Members' e-mail addresses.
**Action 11/17:** All ExCo Members to submit a logo design for the GIA by early-May for a competition.

## 3. STATUS OF AGREED ACTION ITEMS FROM 10th ExCo MEETING, PRIOR TO THIS MEETING

**Action 10/1:** IEA-GIA Secretary to pursue GIA signatory issues with Peter Tulej, IEA Secretariat.
- ***Completed***

**Action 10/2:** Rybach to obtain more confident values from IGA for the future development potential of worldwide geothermal resources.
- ***Completed***

**Action 10/3:** Bromley and Mongillo to discuss with Trevor Hunt and/or Ian Thain (Organizing Committee on WGC 2005) arranging IEA-GIA sessions at WGC 2005.
- ***Completed***

**Action 10/4:** The Secretariat's operating year should be changed to agree with the calendar year, i.e. January to December.
- ***Completed***

**Action 10/5:** Secretary to organize the Archive of GIA documents.
- ***Continuing***

**Action 10/6:** GIA Secretary to notify NREL that the cost per share has been reduced to US$ 2,500/year and that credit towards future payment should be calculated for those who have already paid US$ 3,600.
- ***Completed***

**Action 10/7:** The Secretary is to direct NREL to send invoices in January and September of each year.
- ***Completed***

**Action 10/8:** Haruguchi to discuss whether NEDO wishes to continue as Operating Agent for Annex III with Matsunaga and report decision to Nieva.
- ***Completed***

**Action 10/9:** Task Leaders to submit Annex Reports to IEA-GIA Secretary for inclusion in the 2003 IEA-GIA Annual Report by a date to be specified.
- ***Completed***

**Action 10/10:** All ExCo Members to investigate the possibility of contributing to a Common Fund for certain tasks (e.g. Annex V Sustainable Geothermal Energy Production).
- ***Continuing***

**Action 10/11:** Bromley to investigate NZ government agencies for possible "sustainability" study funding.
- ***Continuing***

**Action 10/12:** Nieva to make changes to Annex IX document to include only those activities that the GIA can provide.
- ***Continuing***

**Action 10/13:** Secretary to notify Peter Tulej (IEA Secretariat) of the results of Motion 10/3.
- ***Completed***

**Action 10/14:** Secretary to send out formal letters of invitation after Rybach is notified of Peter Tulej's response. Rybach will provide contact details to the Secretary.
- ***Completed***

**Action 10/15:** ExCo Members to distribute the Annex and Country Report formats to the Operating Agents.
- ***Completed***

**Action 10/16:** Secretary to place UK's official letter of resignation (e-mail) into the GIA archives.

- ***Completed***

**Action 10/17:** Nieva to notify Greece and Australia of the new share cost (US$ 2,500) and request their action on outstanding payments.

- ***Completed***

**Action 10/18:** Nieva to contact the IEA Secretariat in response to some requests for action included in the IEA Secretariat's Report to the GIA.

- ***Completed***

**Action 10/19:** Participants from European countries and organizations are to consider the possibility of one of them attending the 1 March 2004 IEA meeting.

- ***Completed***

**Action 10/20:** Nieva to circulate the new IEA framework that requires revision of GIA.

- ***Continuing***

**Action 10/21:** Nieva to contact the IEA to determine if the revised GIA, compliant with the new IEA Framework, would have to be re-signed by the Participants.

- ***Completed***

**Action 10/22:** Secretary to revise the Strategic Plan with the help of Allan Jelacic and distribute it for ExCo acceptance before the end of the calendar year.

- ***Completed***

**Action 10/23:** Secretary to contact Peter Tulej (IEA) regarding suitability of 18-19 March 2004 date for the 11th GIA ExCo Meeting in Paris.

- ***Completed***

## 4. CONTINUING ACTION ITEMS FROM 9th ExCo MEETING, PRIOR TO THIS MEETING

**Action 9/8:** Rybach to continue membership discussions with China, France, Russia and Turkey.

- ***Continuing***

**Action 9/11:** Mexico and Italy provide drilling cost data to Finger and Kubo.

- ***Continuing*** on Italy.

**Action 9/13:** Nieva (potential Annex IX task leader) to write draft proposal on marketability of a Latin American prospect.

- ***Continuing*** (see Action 10/12 above).

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## 5. CALL TO ORDER

Chairman Nieva called the meeting to order at 9:40 AM, Thursday 18 March 2004.

Nieva noted in his opening that it was a sad event that Greece was withdrawing from the GIA (Appendix 18). However, he was happy that Australia was fairly confident that they would be able to obtain the funds to make their Common Fund contribution, hence remain a Member.

**Motion 11/1:** Rybach moved that the ExCo endeavour to end the meeting by 3:00 PM tomorrow. Schuppers seconded, and the motion was carried unanimously.

## 6. ADOPTION OF AGENDA OF 11th ExCo MEETING

The draft agenda for the 11th ExCo meeting prepared by the IEA-GIA Secretary was approved with minor revision by the Chairman (Appendix 2).

## 7. APPROVAL OF MINUTES OF 10th ExCo MEETING

The final draft minutes of the 10th ExCo meeting prepared by the IEA-GIA Secretary were adopted.

**Motion 11/2:** Nieva moved that the ExCo accept the Minutes of the 10th ExCo Meeting. Jelacic seconded, and the motion was carried unanimously.

## 8. STATUS AND DISCUSSION OF ACTIONS OF THE 9th and 10th ExCo MEETINGS

The Secretary presented a review of the continuing actions for the 9th and 10th ExCo Meetings.

**Action 10/3:** Discussions with the WGC 2005 Organizing Committee regarding having Special GIA Sessions have ceased. Jelacic asked how GIA work was to be presented at the WGC 2005. Nieva stated that we are still pursuing having a GIA review paper presented at a Plenary Session (see discussion below, p. 6 of these Minutes). Rybach pointed out that the issue was to be discussed under Agenda Item 3d, so we should leave it until then.

**Action 10/5:** The Secretary has created an Archive of important GIA documents, which was up-to-date as of the 11th ExCo Meeting, except for the Minutes of the 1st ExCo Meeting. Schuppers is providing a scanned version of the missing minutes.

**Action 10/9:** All of the Annex reports have been received as of the time of this meeting.

**Action 10/10:** To date, only Iceland has stated that they would be able to contribute to a common fund for certain tasks (e.g. Annex VIII- Direct Use).

**Action 10/11:** Bromley is still investigating possible NZ Government agency "sustainability" study funding, though there is nothing to report yet.

**Action 10/12:** Nieva will be discussing the status of Annex IX later at this meeting under Agenda Item 8.

**Action 10/14:** This action is now complete, with Rybach having received comments from Peter Tulej.

**Action 10/18:** Nieva has completed this action.

**Action 10/19:** This action is completed, with the decision not to send someone to the 1 March 2004 IEA meeting.

**Action 10/20:** Nieva distributed the new IEA IA framework on 18 February 2004, completing this action. It is to be discussed under Agenda Item 3c.

**Action 9/8:** Rybach has continued discussions with prospective member countries. Results to be discussed under Agenda Item 9a.

**Action 9/11:** Drilling cost data was sent from Mexico with action still on Italy to provide some data.

**Action 9/13:** Nieva discussed this item at this meeting under Agenda Item 8b.

## 9. MATTERS ARISING

Rybach noted that the IEA had made several requests for input from the GIA and it was very important to discuss the revised IEA IA framework document (Appendix 4). Discussion was included under Agenda Item 12 Other Business along with Peter Tulej's IEA report.

## 10. OTHER ExCo ISSUES

### 10.1 Status of 2003 Annual Report

The Secretary noted that, in general, contributors had followed the annex and country report formats, though important material was missing in some cases. Nieva requested that contributors be contacted to provide further information where needed.

**Action 11/1:** Secretary to contact the authors of the annex and country reports submitted for inclusion in the 2003 GIA annual report to request further information where needed.

Rybach stated that country reports were a very important part of the GIA annual report. Nieva pointed out that the quality of the annual report was more important than the "promptness" in submitting it to the IEA, and it should be as complete a document as possible for use of the IEA.

Rybach asked how to access the 2002 GIA Annual Report since the "old" address no longer worked. The Secretary noted that since the IEA had created a new homepage, it seemed no longer possible to access the IA annual reports directly. The Secretary will investigate the problem.

**Action 11/2:** Secretary to send ExCo Members the website address so they can access the GIA annual reports.

### 10.2 Action on Non-Paying GIA Members

Nieva informed the meeting that Greece withdrew from the GIA because they were against contributing to the Common Fund (Appendix 18). However, he noted that the Australian ExCo Member (Wyborn) had stated that Australia would probably make their contribution, though it was not clear when. Nieva recommended that the ExCo give them more time to pay.

Rybach asked what if Australia said they would pay from now on, but not for the previous years. Jelacic stated that he believed they should pay for all arrears as bound by their original membership. Nieva replied that he believed that Australia was considering paying the total amount, and that the issue should be decided on at the next ExCo meeting, after he has had time to pursue the matter.

**Motion 11/3:** Nieva moved that the ExCo wait until the next ExCo meeting to make a decision on Australia's position in the GIA. Rybach seconded, and the motion was carried unanimously.

Harvey suggested that the second notification and invoice for the annual Common Fund payment be sent out in July rather than September.

**Action 11/3:** Secretary to arrange with NREL to send a second invoice notice, in July rather than September, to Members who have not yet paid their Common Fund contribution.

### 10.3 Required Amendments to the GIA

Nieva presented the IEA's request that the GIA should be modified. He referred to the e-mail he sent to all Members on 18 February 2004 (Appendix 4), in which he listed the IEA's suggested amendments.

Schuppers stated that the EC was opposed to all four of the IEA's suggested changes. Therefore, it would be impossible for the changes to be accepted since a "unanimous" vote is required by the ExCo for changes in the GIA to be made. The EC must follow internal procedures in order to make the requested changes, which require a formal decision. Consultation has begun but it is not clear how long it will take for the EC to make a decision on the matter. Nieva asked if a decision could be expected by the time of the next ExCo meeting, but Schuppers did not know. Sellers noted that this is an EC problem that is being worked on and that Tulej would be reporting on it later in the meeting.

Nieva said it would not be useful to spend the time discussing the matter further since the EC would not be accepting the modifications at this time. Jelacic requested a brief review of the changes and Nieva presented them (Appendix 4): (1) extend participation so just about any country could be a Member, (2) formally remove the term "Guiding Principles" and replace it with "Framework", (3) that "abstention" would not be counted as a vote and (4) the new Framework gives us more freedom. Since several of the ExCo Members were not familiar with the document, Nieva agreed to re-send it.

**Action 11/4:** Nieva to re-send (via e-mail) the IEA "suggested" re-wording for the IA changes. (Superseded by Action 11/15.)

Sellers stated that Tulej would be distributing and commenting on the document later in the meeting.

### 10.4 Participation in the WGC 2005

Several of the meeting participants, including Baria (Soultz-sous-Forêt), Jelacic (USA), Kristmannsdóttir (Iceland), Matsunaga (Japan), Mongillo (NZ), Nieva (Mexico) and Rybach (Switzerland) noted that papers would be submitted to the WGC 2005.

Rybach noted the great success the GIA had at the WGC 2000, with three full IEA-GIA sessions held. He would like special GIA sessions to be arranged at the WGC 2005. However, Nieva pointed out that Roland Horne (WGC 2005 Organizing Committee) was against this and wanted all sessions organized by "topics", which would probably result in better attendance to the GIA papers than if they were presented at a special small GIA session.

Rybach wanted recognition of the GIA's efforts, and thought the inclusion of "GIA" in the papers' titles would suffice. Jelacic noted that having a GIA paper in the Plenary Session that highlights the GIA's work and achievements would help. Kristmannsdóttir agreed with Jelacic. Nieva noted that there were two options: (1) having "GIA" in the title of papers and (2) having the general GIA paper presented in a Plenary Session. Jelacic will talk to Jim Koenig (IGA) about arranging for the general GIA paper to be presented at the Plenary Session.

**Action 11/5:** Jelacic to contact Jim Koenig to attempt to arrange for the GIA WGC 2005 paper to be presented at a Plenary Session.

Nieva requested that every contributor make reference to the annex and GIA in their paper's title. He also agreed to present the general GIA paper at the Plenary Session.

Rybach suggested having a GIA booth at the WGC 2005. Jelacic agreed with Rybach and suggested using Common Fund money to pay for it. However, Rybach pointed out that the GIA does not have much material to present in such a booth, but Jelacic said that it could be a modest affair and could include annex material.

Harvey noted that this latter discussion raised the issue of the Bonn (Germany) Conference to be held on 1-4 June 2004. Nieva stated that the Common Fund could pay for travel expenses. However, Harvey said that IGNS had been invited to participate and that he could make the GIA presentation at no cost.

Nieva noted that the GIA is afraid of having a booth because there is not enough material to offer. We must face reality- that the GIA and geothermal has generally "come down". We have less to show than 5 years ago, and must somehow make up for the deficit. However, perhaps we should decide that the roll of the GIA is to "positively influence" geothermal research in all participating countries- the GIA could become the "force" that does this. We must make up for the deficit of results. Rybach stated that the GIA must do its best and take advantage of its active Secretariat.

## 11. ELECTION OF CHAIRMAN AND VICE-CHAIRMEN

Jelacic nominated Nieva for Chairman of the GIA. Nieva accepted nomination and the vote was unanimous, with Nieva re-elected as Chair of the GIA.

Nieva nominated Rybach and Jelacic as Vice-Chairmen. They both accepted nomination and again the vote was unanimous, with Rybach and Jelacic re-elected as Vice-Chairmen.

## 12. REVIEW OF SECRETARIAT OPERATION AND WORK PLAN

Mongillo presented the IEA-GIA Secretary's Report (Appendix 5), which included a review of work conducted since the last ExCo Meeting, a draft work plan for the 2004-year (Appendix 1 to the Secretary's report) and a detailed accounting of the Secretary's time and costs for the 2003-year (Appendix 2 to the Secretary's report). An estimate of costs for the operation of the GIA Secretariat by IGNS for the 2004 calendar year was presented by Harvey and is also included as Appendix 3 to the Secretary's report.

Mongillo noted that he placed an emphasis on maintaining regular and timely communications with the ExCo Chairman and Vice-Chairmen, within the GIA and with IEA Headquarters. The Secretary attended the 10th ExCo Meeting in September 2003, in Reykjavik, Iceland and "Minutes of the 10th ExCo Meeting" were completed and distributed. Arrangements were made with the IEA Headquarters for their hosting of the present meeting, and documents prepared and distributed to the ExCo Members for this meeting. The Secretary assisted Jelacic with the final editing of the 2002-2007 GIA Strategic Plan, which was accepted unanimously (with Greece abstaining). A document for prospective GIA members was written: "The IEA Geothermal Implementing Agreement- It's Goals, Activities, Benefits, Obligations and Costs" (Appendix 6) and an abstract for a general GIA paper: "The IEA Geothermal Implementing Agreement - Its Goals, Status, Achievements and Prospects" was written and submitted for the WGC 2005. The 2003 GIA Annual Report was reported to be in draft form, with significant work remaining to complete it.

An archive of important GIA documents was initiated and was reasonably complete, though it will be continually added to as new documents are created. It will be accessible to all ExCo Members through the GIA website. Significant headway was made on the GIA website, a draft of which is available for viewing at: http://www.gns.cri.nz/GIA/index.html .

The Secretary, as a representative of the GIA, participated in the Budapest Forum in October 2003, presenting a PowerPoint talk, "The IEA Geothermal Implementing Agreement- Its Status, Highlights and Future Prospects" (by Mongillo and Nieva) describing the GIA, its activities and strategic plan (posted on the IEA website at: http://library.iea.org/dbtw-wpd/textbase/work/2003/budapest/geother.pdf). Since the GIA website was given priority over the GIA brochure at the last ExCo meeting, no further work was done on the latter since that meeting.

Mongillo reported that 372 hours had been spent on duties performed by the Secretary during the period September 2003-February 2004. The total time and cost for the GIA Secretary's time for the first year of operation, March 2003 to December 2003, were: 594 hours and NZ$ 44,546.25 (~US$ 30,736.91 @ 0.69). Based upon this information and the original IGNS bid, a budget estimate for the 2004 year was produced and submitted to the ExCo by Harvey with the following highlights: (1) the total estimated time and cost for the Secretary's time for the 1 January-31 December 2004 year are: 800 hours and NZ$ 60,000 (~US$ 41,400 @ 0.69); (2) office and consumables, the Secretary's travel expenses, brochure production, website construction and maintenance are: NZ$ 36,000 (~US$ 24,840 @ 0.69). Thus, the total estimated cost for the 2004-year of operation (January –December 2004) is: NZ$ 96,000 (~US$ 66,240 @ 0.69).

Nieva agreed that the Secretariat's first year of operation was an unusual one because of the up-grade in the 2002 annual report and the two presentations (GRC and Budapest) made as part of the GIA's move to maintain a high profile and encourage new membership. Rybach stated he was happy with the active Secretariat and glad to see it operate in its present manner. Jelacic also noted he was happy with the Secretariat's work to date and Schuppers complimented the report.

Harvey asked if it was necessary to continue to approve the NZ Secretariat contract. Nieva stated that IGNS must continue to submit a work plan for ExCo acceptance, however he believed that the NZ Secretariat was chosen for the 5-year period of operation (i.e. 2003-2007) and it would not be practical to change Secretariats every year. Kristmannsdóttir agreed that the NZ Secretariat was for the period covering the extended lifetime of the GIA.

**Motion 11/4:** Nieva moved that unless there are strong reasons for the Secretary to be replaced that the NZ Secretariat should remain for the rest of the GIA's operation. Rybach seconded, and the motion was carried unanimously.

Jelacic stated that since the Secretariat is already well into the work plan for the year, the next year's annual work plan should be submitted at the autumn meeting.

**Motion 11/5:** Jelacic moved that the Secretary's work plan for 2005 be submitted at the autumn 2004 meeting. Baldacci seconded, and the motion was carried unanimously.

**Action 11/6:** The Secretary to provide the 2005 work plan at the Pisa ExCo meeting and from then on for the "next" year at autumn meetings.

**Motion 11/6:** Nieva moved that the Secretary's 2004 work plan be accepted. Harvey seconded, and the motion was carried unanimously.

## 13. FINANCIAL REPORT

The financial report of GIA activities as of 29 February 2004 (Appendix 7) was supplied by NREL and presented to the meeting by the Secretary.

Though the NREL report stated that the total balance of available funds was US$ 117,731.93, Harvey noted that it did not include all of the un-billed and unpaid IGNS invoices and he estimated the total funds available to be in the range US$ 90-95,000 as of March 2004.

Rybach stated that with Greece withdrawing, the total number of shares dropped from 26 to 25, decreasing the GIA Common Fund. Nieva's opinion was that the GIA currently has enough money so the share cost would be able to remain at US$ 2,500 per share per year. Harvey said the Secretariat could distribute a more accurate financial statement taking into account IGNS's outstanding invoices.

**Action 11/7:** The Secretariat to provide an up-to-date financial statement to the ExCo, taking into account all IGNS expenses and invoices.

Harvey inquired whether the GIA required "audited" financial statements, and Nieva answered that it was not necessary at this time.

Rybach noted that Agenda Item 6b regarding Common Fund "shares and share cost" was just included as a standing item and there was nothing to discuss related to it at this meeting. Nieva pointed out that the Common Fund share price might have to be re-adjusted in the future.

The issue of providing support from the Common Fund for a representative of the GIA to attend important meetings was discussed. Nieva stated that travel expenses would be provided, preferably for a person nearest the meeting location (e.g. a GIA representative from Europe to attend the Bonn Conference). Jelacic pointed out that the Chairman is "legally" able to allocate funds from the Common Fund, and then report the action at the next ExCo meeting. However, Nieva wished to obtain the ExCo's "official" permission to be allowed to allocate Common Fund money to attend meetings and present papers, as this is a category of actions that would likely be repeated. Though there were no objections, Nieva requested a motion be made and voted on.

**Motion 11/7:** Nieva moved that the Chairman be given permission to allocate money from the Common Fund to support meeting attendance and paper presentation. Jelacic seconded, and the motion was carried unanimously.

The Bonn (Germany) renewable energy conference was discussed and Harvey volunteered to represent the GIA there at no expense, if his participation through IGNS was confirmed. He expected to know within a few weeks.

**Action 11/8:** Harvey to notify Nieva regarding his attendance at the Bonn conference as soon as possible.

Rybach volunteered to represent the IGA if Harvey was unable to attend.

Rybach also noted that if the GIA wished to have a booth at the WGC 2005, e-mail could be used to obtain ExCo Members' decisions regarding the plans and costs.

## 14. PROGRESS REPORTS AND WORK PLANS OF CONTINUING ANNEXES

### 14.1 Annex I Environmental Impacts of Geothermal Energy Development (presented by Colin Harvey)

Harvey presented this report orally for Bromley who was unable to attend. A written report will be sent to the Secretary later (Appendix 8).

Harvey reported that there was increased geothermal work in New Zealand with subsidence being a major issue. He noted that the New Zealand Resource Management Act imposes strict control on geothermal development and use, and requires several types of monitoring. Because natural gas resources are being depleted there is more interest in geothermal now, including deep resources and enhanced geothermal systems.

Jelacic noted that there are micro-earthquake problems in California, with some concern in the communities around the SE Geysers where substantial reinjection of wastewater is occurring and where there has been a major increase in their number. He has seen some damage "purportedly" caused by these quakes. The public have had meetings with some of the operators of the Geysers (e.g. Calpine and NCEAC) and Calpine is attempting to work with the citizens on the matter. The Santa Rosa pipeline is now in operation, however, the area where this water is being reinjected is nearer the centre of the field and some distance from populated areas, so probably not a problem. These micro-earthquakes could be a problem for EGS development. Lawrence Berkeley Laboratory (LBL) is presently investigating the issue. Jelacic believes this is an issue for the GIA ExCo to investigate in Annex I or Annex III.

Rybach supports Jelacic's suggestion, but commented that the problems appeared site specific, though this could definitely be an issue for EGS. The problems have also occurred at the Soultz (France) and the Coopers Basin (Australia) EGS sites (based on Wyborn's report to this meeting), so it is not an isolated Geysers problem.

Nieva asked if the US DOE had defined a plan to assess the problem, and Jelacic answered that there is no long-term plan, however, they are encouraging LBL work with developers and citizens to provide an opinion and review of induced seismicity. Jelacic also noted that a long-term plan was needed and that if there was a problem with public perception, it could be a serious enough problem to stop EGS.

Rybach noted that at the deep heat mining site, in the Basel earthquake area, a seismic station has been installed to map background seismic activity before EGS begins. It was necessary to obtain more data on this important issue. Baria believes there is a fundamental lack of knowledge and that once the seismicity is understood; it might be possible to design stimulation procedures that alleviate the seismicity.

Nieva said that because of the micro-seismicity problems in California, the increased seismicity associated with reinjection is now being discussed in Mexico. It would be desirable to be able to give an estimate of the "expected" size of induced earthquakes, e.g. "not greater than..."

Kristmannsdóttir stated that there were no earthquakes during a test at the Svartsengi field in Iceland. However, fewer larger earthquakes occurred, hence there was a change in the baseline activity. She thinks it is a good idea to monitor earthquake activity, but it is expensive. Now reinjection is required for disposal of "waste" water in Iceland, and is now conducted at Krafla.

Baria pointed out that geological conditions must be considered and understood.

Nieva noted that "perception" of induced earthquakes by the public could be a problem and work must be done to overcome it. He asked if someone could gather information from sites that have been in operation for a reasonable length of time to help identify the magnitude of the problem. He could obtain data for Cerro Prieto. Baria stated that discussions were being conducted behind scenes and that with Jelacic's help a literature search could be done to lay the foundation for a study. Nieva agreed with the idea of starting a review. Baria believes that field experiments are needed to develop an understanding of the mechanism.

Jelacic stated that the GIA needs to consider establishing a subtask in Annex I to formally highlight the issue. He would be reluctant to play a dominant role, but would be very active in supporting it and even provide funds to a special common fund for such a study. Schuppers believes that the EC would be willing to participate, but needs to become formally involved in Annex I first. Nieva stated that it is only necessary for a statement in the Minutes to be made for a new participant to join an Annex.

There was general agreement that a proposal for a new Annex I Subtask D be produced, with the participation and leadership of EC. Matsunaga noted that Japan had much experience with micro-seismic activity and that he would ask others to join the new Subtask D on induced seismicity when it is formed.

Kristmannsdóttir stated that the work on Iceland's environmental remote sensing project had been slow and there was no report to be presented.

Baldacci reported that work on ENEL's $H_2S$ abatement process was proceeding and will be installed at all plants in Italy.

**14.2 Annex III Enhanced Geothermal Systems (presented by Isao Matsunaga, Task Leader)**

Matsunaga presented the report and work plan for Annex III, which is included as Appendix 9.

The objective and subtasks were reviewed and the participants identified as Australia, EC, Germany, Italy, Japan, Switzerland and USA. Subtask B, which is sponsored by US DOE and operated by the Idaho National Engineering and Environmental Laboratory (USA), conducted several projects including: testing of a new down-hole motor for horizontal drilling, completion of a shear-wave splitting technique for monitoring stress patterns and fractures and plans to use it at a major hydraulic fracture (MHF) test at Coso geothermal field, conduct of laboratory tests to analyze effects of injection into The Geysers reservoir, and examination of tracers for characterizing heat transfer in fractured reservoirs.

Subtask C, led by Geowatt of Switzerland, has been compiling data for a project management decision assistance (PMDA) for EGS and has almost completed development of the loose-leaf ring binder presentation format.

Subtask D, lead by the National Institute for Advanced Industrial Science and Technology (AIST), Japan, has compiled and reviewed a major collection of R&D data for Hijiori test site; including the technical aspects and problems associated with the overall design, site characterization, reservoir creation and circulation-heat extraction.

The work conducted at the Cooper Basin project, Australia, was outlined, noting that the first geothermal well was completed in September 2003 to 4,421 m depth with the bottom hole temperature ≥ 250 º C. Subsequent hydraulic fracture tests stimulated a volume of 3,000 m by 1,000 m by 350 m. Germany was reported working on the European EGS Soultz and Bad Urach projects.

Japan reported that all NEDO funds for EGS R&D will be stopped at the end of March 2004, though NEDO will continue to fund travel and expenses for GIA meetings. Some research will continue with funding from a small in-house budget of AIST and science grants from the Ministry of Education, Culture, Sports, Science and Technology (MEXT). Funding will be requested for the new Annex I Subtask D on induced seismicity in EGS.

During the 2004-year work will be conducted in: Subtask B- the MHF at the Coso field, the high temperature acoustic televiewer will be completed and studies will continue on injection in depleted fields and tracer analysis; Subtask C- distribute the draft PMDA and use the comments to compile inputs and update the classifier; Subtask D- publish, translate and distribution CD-ROM the report of the review of the Hijiori EGS study.

Rybach commented in detail on Subtask C work, noting that after 7 years of work the PMDA is nearing completion. It is now ready for comment on the technical input and legal issues by the Annex III participants. It will provide a guide for making decisions on EGS from the beginning to de-commissioning. All data is on CD-ROM. Jelacic recognized that the PMDA was a substantial tool and major outcome for Annex III, and he thanked the participants for it. Gorhan asked what would be done with the completed results and Nieva answered that they would be made widely available.

Nieva informed the meeting that the report on the Soultz project would be presented tomorrow.

Jelacic pointed out that it was curious that many countries were participating in Annex III, however, there seemed to be very little "joint" work on the tasks, i.e. there was significant "individual" effort being reported, but no "cooperative" work. He identified this situation as of concern. Nieva agreed but was not sure what to do about it, though he added that the work in Annex VII and the discussion of and agreement to produce a proposal for a new Annex I Subtask D showed good cooperation in the GIA. Jelacic hoped that there would be more close participation among the participants in Annex III.

Rybach noted that it was important for participants to know what work others were doing and that the information dissemination is what the GIA does. He stated that cooperation must grow "organically" and it was difficult to formalize and institute it. Perhaps once a major breakthrough occurred at Soultz there would be more cooperation. However, much has been learned through the Annex III work, regardless of the lack of cooperation.

Jelacic presented Peter Rose's report: *Creation of an Enhanced Geothermal System Through Hydraulic and Thermal Stimulation*, which describes the US DOE work at Coso geothermal field (located in eastern California) for Subtask B. Due to the size of this report it is not appended to these Minutes, however it will be accessible through the GIA website at: http://www.gns.cri.nz/GIA/index.html.

The concept of this study is that well stimulation can produce permeability enhancements due to hydraulic, thermal and chemical effects; and the results can be applied to other geologic settings where appropriate tectonic and thermal conditions exist. The study objectives are to design, create and evaluate an EGS within the margins of the Coso field and to demonstrate an increased electrical production of 20 $MW_e$ upon creation of the Coso EGS. The east flank of the Coso reservoir was the chosen location for this investigation because of its high temperatures (often > 300 º C), abundant fracturing and good wells for stimulation testing. A large team of researchers are working on this investigation that includes: well drilling, completion and testing; hydraulic stimulation and monitoring; geomechanical/structural analysis; geochemical modelling; geology; structural modelling and 3-D visualization; fluid-flow modelling, electrical geophysics; and microseismics.

### 14.3 Annex IV Deep Geothermal Resources (presented by Dieter Rathjen, Task Leader)

Rathjen presented the progress report for Annex IV (Appendix 10).

The annex participants were identified as: Australia, Germany, Italy, Mexico, New Zealand, the Philippines and the USA. Rathjen commented that progress reports were only available for Australia, Germany and Italy; and that the USA does not pursue any activity in this annex.

The first deep geothermal well in Australia, Habanero #1, was completed in the Cooper Basin to a depth of about 4.9 km and attaining a bottom hole temperature of 290 ºC, at a cost of A$ 5.4 M. A second well is planned. More details can be found at the Geodynamics Ltd. homepage: http://www.geodynamics.com.au/.

Italy (ENEL) drilled 14 deep (> 3,000 m deep) wells during the 5-year period 1999-2003. Eight wells were drilled with depths in the range: 4,002-5,100 m. Two of these 8 were at Soultz-sous-Forêts (France) as part of the EGS project, with depths of 5,036 m and 5,100 m. The remaining 6 were drilled in Italy for steam production: 4 wells in the Travale area at depths of 4,002-4,379 m and 2 in Larderello with depths of 4,216-4,350 m. One of the 6 Italian wells is not productive and is used for field control, another requires a workover to remove a "salt plug" and the other 4 produce about 130 t/h of steam. The other 6 Italian wells were drilled to depths of 3,380-3,944 m. All of these are productive, with a total steam flow of about 220 t/h.

Germany's current project at Bad Urach, involves the development, verification and demonstration of EGS concepts for heat and electricity production. The first well was drilled, with successful stimulation creating a reservoir between 3,300-4,200 m and a temperature of 170 ºC. Germany was also participating in the EU Soultz project, having contributed 9.1 million euros. Details of the Soultz project were presented by Schuppers and Baria during the second day of the meeting and can be found below.

Nieva responded that a Mexican report had been sent to Rathjen describing a study of the production history of Mexican geothermal fields, especially Los Azufres, from the initial state through the changes induced by production and injection.

Rathjen's report again raised the issue of the "crossover" of work between Annexes III and IV and discussion of this matter followed.

Schuppers pointed out that there was a mix-up of work between Annexes III and IV, and that Soultz results would be reported on tomorrow in the EC "country" report.

Rybach stated that he was happy that Germany had taken over as Leader of Annex IV. However, there were problems in the crossover of work in Annexes III and IV. Apparently, the definition of Annex IV studies was not clear, that it included all resources with fluid, at depths > 3,000 m. EGS is not Annex IV work. Rybach believes that the Gross Schönebeck project is the only German Annex IV project, and he will discuss this tomorrow during the Germany country report.

Nieva believes that Rybach's definition for Annex IV, i.e. resources deeper than 3 km and containing natural fluid, was not quite correct, since it is possible to have enhanced "natural' geothermal systems. He suggested moving some of the work now conducted in Annex IV into other annexes, though it is not clear how best to do this. Rybach did not think it was a good idea to mix the Annex IV work with other annexes.

Schuppers suggested having Annex IV deal with "high temperature" rather than "deep geothermal with fluid". Jelacic pointed out that "deep geothermal" is not correct, that there is not much new in the annex and that it does overlap with other annexes, so the US is working in Annex III. He thought that "high temperature" would be better, though this re-definition would require re-writing, which the Secretary could do.

Baria pointed out that wherever you have reinjection you have EGS!

Nieva suggested the possibility of cancelling Annex IV and moving the existing tasks into Annexes III and V (Sustainability of Geothermal Energy Utilization). After further consideration, he agreed that Schuppers' and Rybach's suggestion might be better- "high temperature with fluid in place" was a clear definition and would keep Annex III separate.

Rybach noted that there was a definition of "> 3,000 m", but what exactly would "high temperature" mean? Nieva pointed out that a "natural" definition of high temperature could be > 300 ºC, because there are particular difficulties with such high temperature fluids: get acid fluids, acute scaling from $SiO_2$ and these temperature problems are not depth problems. Rybach agreed with Nieva, that there is more to consider than depth and temperature; hence perhaps it is not good to continue with Annex IV as it is now defined.

Harvey suggested re-naming Annex IV to "Advanced Research" or "Advanced Technology", which interested Jelacic.

Nieva proposed moving gradually by separating those topics that can be clearly distributed to Annexes III and IV.

Rybach stated that there would be a "mix" of work between Annexes III and IV in the 2003 GIA Annual Report and questioned if it would be left. Nieva suggested including a statement in the 2003 GIA Annual Report that could explain that there is a mixing of work in the annexes that is now being sorted out.

**Action 11/9:** Secretary to include statement in 2003 annual report that there is an "overlap" of work in Annexes III and IV and that it is presently being sorted out.

**14.4 Annex VII Advanced Geothermal Drilling (presented by Allan Jelacic)**

Jelacic stated that there had been a meeting of Annex VII participants the previous day, with the EC, Iceland, Italy (who is considering joining the Annex), Japan, Mexico, New Zealand and the USA present. He informed the meeting that Ed Hoover, the Task Leader, had left Sandia, so there was no longer a Task Leader for the Annex. Minutes of this Annex VII meeting are included as Appendix 11.

The leader of Subtask A (Cost Performance Data), Satoshi Kubo, returned to JAPEX from his position in NEDO, consequently, NEDO is no longer participating and a new subtask leader is needed. Nieva was requested to ask CFE if they would become the subtask leader.

**Action 11/10:** Nieva to ask CFE if they would agree to be the Subtask A Leader for Annex VII.

Jelacic reported that there is a substantial amount of data, but much of it is proprietary, so effort will be concentrated on the "performance" data. A decision was made at the Annex VII meeting held on the previous day to canvas and provide well drilling reports that are in the format that NEDO developed. Harvey volunteered to obtain data from other countries, e.g. Indonesia. The data is to be sent to Jelacic.

Jelacic stated that work on the Subtask B drilling handbook could not be performed as previously outlined because of the major effort required and, therefore, the possible need for an associated common fund. It was decided that the participants would provide a list of references for the information, then decide how to proceed (e.g. publish the reference list).

**Action 11/11:** Participants in Subtask B of Annex VII to provide a list of references covering information for the Handbook to the Subtask Leaders (Hector Gutierrez, CFE (Mexico); Sverrir Thorhallsson, Orkustofnun (Iceland)).

Jelacic noted that an outline for the handbook had been produced.

There have been no firm proposals for the testing of participants' equipment (e.g. US is working on developing drill bits and high-temperature logging tools) received for Subtask C. However, CFE and Iceland are able to provide wells for these studies and were requested to provide information on the wells that would be available

**Action 11/12:** CFE and Iceland to provide information on their "wells of opportunity" for equipment testing.

Jelacic was optimistic about the progress made so far in the Annex.

Rybach stated the hope that a successor to the Task Leader, Ed Hoover, would be found soon and noted that the drilling handbook would be a very good product of the Annex. Jelacic replied that he will do his best to find a Task Leader.

Nieva pointed out that Annex VII is a model annex being jointly planned, etc.

Harvey asked if it was possible to obtain common fund for production of the handbook. Nieva stated that the present GIA Common Fund can only be used for the Secretariat and the GIA as a whole, not for specific annex projects. Jelacic pointed out that **Action 10/10**, which was continuing, was for all participants to check on support for special common funds.

**Action 10/10:** All ExCo Members to investigate the possibility of contributing to a common fund for certain tasks (e.g. Annex V Sustainable Geothermal Energy Production).

- ***Continuing***

### 14.5 Annex VIII Direct Use of Geothermal Energy (presented by Helga Tulinius)

Tulinius stated that work had not yet started in this new annex, but will begin in earnest this autumn.

A letter of invitation to join Annex VIII (Appendix 12) and a draft description of it (Appendix 13) had been prepared and were distributed at the meeting.

Harvey asked if/how John Lund (Geo-Heat Center, USA) would fit into this annex. Jelacic stated that he had discussed this with Lund, but that the US did not have much funding for direct use applications; however, the US is interested and will provide a description of how they will participate.

## 15. STATUS OF PENDING AND PROPOSED ANNEXES

### 15.1 Annex V Sustainable Geothermal Energy Production (presented by Allan Jelacic)

As an aid to these minutes, I include the following paragraph from the Minutes of the 10th ExCo Meeting (see pages 8-9 therein and Appendix 12 of those minutes for the revised draft of this proposed annex):

> *Jelacic provided a revised draft of Annex V Sustainable Geothermal Energy Production (Appendix 12). This sustainability approach was developed by Mike Wright to counteract criticism against geothermal being "renewable". The annex will evaluate the worldwide potential of sustainable geothermal energy production and contribute significantly to resolving the issues of renewability and sustainability of geothermal energy production. It will also help provide a basis for policy decisions regarding development of geothermal resources.*

Jelacic stated that the US could contribute some money to a common fund for this annex. Baldacci noted that Italy might be able to contribute and Tulinius stated that Iceland might also. Harvey said that NZ might be able to participate in activities related to NZ research, but would only be able to contribute "in time", not financially.

The EC, Germany and Switzerland would not be able to contribute financially. However, Rybach stated that Switzerland might be able to provide an "in-kind" contribution.

Rybach also noted that geothermal sustainability is a very important issue and that the GIA is the group that should deal with it.

Haruguchi stated that NEDO cannot participate in any new annexes, but there may be other possibilities for Japan's participation.

Rybach thought that maybe something would be possible on an individual basis.

Nieva said that creating a common fund for Annex V and other new annexes was not yet hopeless.

Kristmannsdóttir pointed out that the GIA was running out of time, therefore decisions would need to be made soon about starting Annex V if any useful work was to be done. Nieva agreed.

### 15.2 Annex IX: Geothermal Energy Market Acceleration (presented by David Nieva)

Nieva did not circulate a proposed draft of this annex because he discovered at the 2003 GRC Annual Meeting in Morelia, Mexico (October 2003), that the GEF offer to provide funding for geothermal development was for East Africa. Consequently, he did not pursue this issue.

However, there is now something new- the Renewable Energy Working Party (REWP) decided to have a market acceleration annex for all renewables. Therefore, the GIA would not require a common fund to participate. At this point, Nieva suggested letting the IEA move with market acceleration; he would raise the issue with Peter Tulej at tomorrow's session of the ExCo meeting.

Rybach noted that market acceleration was not a GIA invention, that a request had come from the IEA to all IAs to implement an annex on market acceleration. Now the IEA will have a specific annex on market acceleration with participation by country. Hence, market acceleration is out of the GIA's hands.

**Motion 11/8:** Nieva moved that today's session of the 11$^{th}$ ExCo meeting adjourn until tomorrow. Rybach seconded, and the motion was carried unanimously.

The first day's session of the 11$^{th}$ ExCo Meeting ended at this point at 4:10 PM.

## *Meeting Recommenced at 9:40 AM on Friday, 19 March 2004.*

### 16. PROSPECTIVE PARTICIPATING COUNTRIES (reported by Ladsi Rybach)

Rybach pointed out that though the GIA decided to invite several countries to become Members, it was not an easy task to get them to join.

The main obstacle was that only governments and higher organizations can participate, therefore bureaucrats such as high government officials must sign the agreement. Rybach has contact only with the lower levels, making this a long process.

Several efforts have been made by the IEA with China, and several meetings held previously to bring them into the IEA. The last contact the GIA had was between Nieva and Rybach and a member of the Chinese Academy of Science. The problem is that China is against all financial contributions, so they are not able to join the GIA. Rybach noted that China will be holding the "Green Summer Olympics" in 2008, and they will be using geothermal heating- so maybe this will encourage China to join.

Rybach has been trying to convince France to join the GIA for over 5 years. He gave a presentation to high French officials 5 years ago and there has been a flow of information to them ever since. Discussions are still in progress. Baria stated that the new Minister is optimistic and he has sent material to him and is now waiting for a response.

Rybach reported that Turkey had significant geothermal direct use, 100's of $MW_t$. In addition, some of the cities struck by a large earthquake a few years ago were planning to install geothermal heating as part of the re-building process. The MTA (the State geological survey) has a geothermal department with a new Head of Department who was becoming familiar with the job; however, they have a small budget therefore it was unlikely that they would be able to contribute to the Common Fund.

Rybach mentioned the GIA document prepared by the Secretary, *THE IEA GEOTHERMAL IMPLEMENTING AGREEMENT- It's Goals, Activities, Benefits, Obligations and Costs* (Appendix 6), which he was sending to prospective members and which he requested be placed on the GIA website.

**Action 11/13:** Secretary to place "THE IEA GEOTHERMAL IMPLEMENTING AGREEMENT-It's Goals, Activities, Benefits, Obligations and Costs" document in a prominent location on the GIA website.

Rybach had sent the Philippines GIA membership information and an invitation to join the GIA, but had only received confirmation that they had received the material, no comment about their intent to join.

Rybach also said that there had been communication with Russia through the IEA where there had been bureaucratic hold-ups.

Nieva asked why it was so difficult for people to convince their governments to join the GIA? Perhaps it was the bureaucrats who made the decision not to join, rather than those with more geothermal knowledge.

Rybach noted that each country is different and that the high-level people in geothermal and in the pertinent ministries need to be identified.

Rybach asked Tulej about Russia and whom he should contact through the IEA. Tulej noted that there is an MOU on energy policy with Russia, but so far Russia only participated in solar. Tulej stated that the IEA has no contacts, though they published a book on Russia. Rybach stated that he had a list of Russian contacts and that there had been a conference on funding geothermal with World Bank funds.

Rybach asked Tulej about China and noted that there was a heat pump meeting there. Tulej replied that there were now new rules of participation with both OECD and non-OECD members and private companies as Sponsors. He said that China was participating in some IEA areas, but that they were not interested in joining the renewables. Tulej hoped that the ExCo would be discussing the changes to the GIA, since the "old" GIA limits GIA participants. He had asked the IEA Legal Council to join the meeting later. Nieva stated his desire to sort out the GIA legal problems soon.

## 17. NATIONAL (COUNTRY) REPORTS

This topic began with the Soultz report at Nieva's request.

### 17.1 Soultz-sous-Forêt (presented by Roy Baria)

Baria presented a review of the current state of European HDR at Soultz.

Funding for the Soultz project for the 2002-2004 period was 26 M euros (€), split about equally among the EC, France and Germany. The current phase of investigation includes drilling, stimulation, technical development, stimulation development and modelling.

Soultz is located in the central west of the Rhine Graben.

Well GPK-1 passed through 1,400 m of sedimentary cover, then granite to a depth of 3,600 m. It was stimulated, producing an "upper" reservoir. GPK-2 was then drilled and when stimulated microseismics data indicated that the stimulated volumes of both wells overlapped. Higher temperatures were desired, so GPK-2 was deepened to 5,000 m and stimulated.

GPK-3 was drilled along a deviated path to the exact location planned, about 600 m from the bottom of GPK-2. The casing was designed to expand/contract by ~ 8 m as a result of heating during production and cooling during reinjection. The bottom hole temperature was about 200 ºC.

Stimulation of GPK-3 caused an earthquake of magnitude 2.6. Consequently, a new stimulation programme was designed to reduce the strength of induced earthquakes, which involved performing a "slow increase-slow decrease" stimulation. This resulted in a magnitude 2.9 earthquake, which was a cause for concern as it was hoped that this procedure would result in smaller magnitude earthquakes.

During circulation tests, the micro-earthquakes were concentrated in the "reservoir" stimulated area, not above it.

Stimulating both GPK-2 and GPK-3 simultaneously resulted in the shearing pressure being reached between the wells very quickly, in < 3 hours.

It is believed that a volume of rock ~ 3 $km^3$ was stimulated.

GPK-4 is being drilled at present, is at a depth of ~ 4,000 m, and looks good for reaching the desired target.

Phase 2004-2007 has a budget of 22 M €.

Jelacic asked about whether the 9-12 month circulation test was long enough? Baria said that 9 months will give an idea of the temperature drawdown, etc. and that there was a need to demonstrate (as soon as possible) to the funding agencies that power could be produced.

Rybach asked Baria what the prerequisites were for a successful EGS? Baria stated that what Soultz demonstrates is the "skeleton" of techniques and that local variations would need to be made for local conditions at new areas. However, depths of 5-6 km were required for successful EGS. He does not believe that micro-earthquake events can be eliminated, but thinks that they can be "controlled".

Schuppers provided copies of three papers describing: the Soultz project, seismic source parameter use in development of EGS systems and microseismic monitoring at Soultz; and two CD-ROMS with Soultz 1998-2001 final publishable report and 2001-2004 1st and 2nd year reports. This information may be made available on the GIA website.

### 17.2 Germany (presented by Dieter Rathjen)

Rathjen provided a brief review of the German geothermal projects and it is included as Appendix 14.

He noted that Germany was involved in five geothermal projects within Germany: Bad Urach, Bruchsal, Groß Schönebeck, Hannover and Neustadt-Glewe. In addition, Germany is also participating in the Soultz project.

He noted that funding for geothermal had decreased from 9 M € in 2002 to 6 M € in 2004, and he thinks it will decrease in the future.

Rybach noted that Germany was now a geothermal electricity producer, with the first German geothermal power station having gone on-line at Neustadt-Glewe in November 2003 using a 250 $kW_e$ generator. Rybach wished this important event to be included in the 2003 GIA annual report.

**Action 11/14:** Secretary to include a statement that the first German geothermal power station went on-line at Neustadt-Glewe in November 2003, in the 2003 GIA annual report.

### 17.3 United States (presented by Allan Jelacic)

Jelacic stated that his report would cover the EGS work that the US DOE is conducting.

The DOE provided funding of US$ 6-7 M for EGS. Since it was decided to give EGS top priority, funding will increase to US$ 10 M next year and continue to increase in coming years. However, the total geothermal budget is flat within the US and probably will not increase in coming years.

The EGS strategy is: (1) to emphasize basic research on how to produce and maintain EGS for economic electricity production and (2) conduct field projects and demonstrations with industrial partners to: (i) create EGS within existing operating fields, (ii) apply EGS at the margins of fields and (iii) create EGS in unexplored geothermal areas.

There are three projects currently in place: (1) with Caithness at Coso in southern California (on US Navy land), (2) with Ormat at Desert Peak in northern Nevada where attempts are being made to expand the field and (3) with Calpine at The Geysers, where an injection well at the Aidlin Plant is being stimulated and where induced seismicity is being studied.

The remainder of Jelacic's presentation dealt with the Coso project, where attempts are being made to induce permeability by opening fractures. Both thermal and chemical effects are being examined. Along the east flank of the Coso reservoir where temperatures are > 300 ºC, candidate wells are available. This is a large team effort which includes geophysics, geochemistry, modelling, stimulation and monitoring, well drilling and testing, microseismics and structural analysis. The objectives are to design, create and evaluate an EGS and to produce an additional 20 MW of electricity.

### 17.4 Australia (presented by Mike Mongillo for Doone Wyborn)

Mongillo presented Wyborn's report on Australian geothermal activities.

Four companies have acquired geothermal exploration tenements in Australia: Geodynamics Limited (Cooper Basin in South Australia and Hunter Valley in New South Wales), Scopenergy Limited (Cooper Basin), Mngi Pty Ltd (Northern Flinders Ranges, South Australia) and Perilya Limited has an application for an area around the Olympic Dam mineral deposit in South Australia). This report concentrated on the Geodynamics effort at Cooper Basin, South Australia.

There is a gravity low in the Cooper Basin area being investigated. Geodynamics Limited drilled the first deep EGS geothermal well in Australia, Habanero 1, which was completed to a depth > 4,400 m in September 2003. The well underwent hydraulic stimulation in November-December 2003, with 20,000 $m^3$ of water injected at pumping pressures up to 65.5 MPa. Approximately 11,700 seismic events were located and ranged in magnitude from 2 to 3.7. These events extended over an area of > 3 $km^2$ and a volume of > 0.7 $km^3$. Existing joints and fractures were found to contain water under pressure, with natural over-pressures greater than 35.5 MPa found. Temperatures > 250 ºC at 4,400 m were found and a horizontal reservoir confirmed. Drilling of a second well, Habanero 2, is scheduled to begin in May 2004, with a circulation test scheduled for the 2nd half of 2004.

Rybach pointed out that Geodynamics had been doing some good work, but noted that the largest EGS reservoir was now at Soultz (3 $km^3$). He asked when the 3.7 magnitude earthquake occurred, but the answer was not in the report.

Jelacic asked where the 2nd well was sited and Matsunaga answered that the exact location had not yet been decided.

Baria stated that 65 MPA was a very high pressure to drive the system.

**17.5 Italy (presented by Aldo Baldacci)**

Baldacci stated that Enel Green Power was in charge of all geothermal electricity generation in Italy.

Effort had been concentrated in three areas in 2003: (1) to make all existing power plants operate at full load, (2) to define an exploration program to find new fields and to check if the exploited fields are larger than previously thought and (3) to overcome local opposition to local development.

A total of 12,000 m had been drilled in 2003 and 50 MW of electricity generation recovered. In 2003, over 5 billion kWh of electricity had been generated for the first time. The plan for the future is to increase generation to 6 billion kWh.

It is also planned to drill 6-7 exploration wells to investigate if existing fields are larger, and if some are possibly connected.

Efforts have been made to improve environmental aspects of geothermal generation. There is local opposition to the bad smell of $H_2S$ produced that ENEL is working to overcome. Baldacci has invented a method for reducing $H_2S$ (a very economic catalytic reduction method) and Hg that removes 90% of the $H_2S$ and 95 % of the Hg.

Rybach asked about the "production" of $CO_2$ versus its natural production. Baldacci stated that studies are in progress and the IGA is examining this issue. The Italians have the concept that if $CO_2$ is produced from power plants, there is a reduction of natural emission of an equal amount, so the total production of $CO_2$ remains unchanged.

Harvey noted that New Zealand is studying the $CO_2$ issue and could work cooperatively with Italy.

Hrefna also noted that Iceland is looking at the $CO_2$ to see if there are any changes before and after production and that these studies should be a part of Annex I.

Harvey also reported that New Zealand has been examining the presence of $CO_2$ as a method of fault location.

**17.6 Iceland (presented by Helga Tulinius)**

Tulinius reported that 58% of Iceland's primary energy supply comes from geothermal and that geothermal use will grow in the future. Iceland has 200 $MW_e$ installed and 200 $MW_e$ more is on the table now. Geothermal plays a very important role in the Icelandic energy policy.

Geothermal energy is more favourable than hydro due to the environmental issues associated with developing more hydro since the best hydro sources have already been used.

One problem with the use of geothermal for electricity production is the “left over’ hot water. Iceland is looking at using more of it for tourist applications.

About 100,000 €/year are now being spent in the use of heat pumps, but their use has not yet become widespread.

Energy intensive industry is very important for Iceland because they have such an abundance of energy.

## 18. OTHER BUSINESS

### 18.1 IEA Deputy Chief Legal Council Presentation (made by Manuela Caruso)

Manuela Caruso, IEA Deputy Chief Legal Council, was invited to speak at the ExCo meeting by Nieva to address the problem of the EC not agreeing with the changes the IEA has proposed for the IAs.

Caruso pointed out that the acceptance of the changes being recommended by the IEA requires “unanimous” agreement within the GIA (and other IAs). Since the EC is now investigating these changes and has not yet made a decision about them, it is not appropriate to vote on them at this time. The difficulty seems to be only related to EC internal procedures.

The IEA voted on the change in Framework in 2003 and it now applies to all new IAs automatically. However, it is not retroactive to existing IAs, so the ExCos must make their own decisions.

Schuppers noted that since the EC is not on the IEA Board i.e. it is not a Member country of the IEA, it has no voting rights, hence did not participate in the new Framework acceptance by the IEA. Consequently, the Framework issue must be decided upon internally by the EC, so he does not have a mandate to vote on the issue at the present ExCo meeting.

Caruso again pointed out that the new Framework cannot be adopted if the GIA vote is not unanimous. She hopes that the EC makes their decision soon and recommends that each country write to the EC stating that their “holding-up” is preventing the smooth operation and work of the GIA.

Jelacic asked if the GIA had to accept the new Framework, to which Caruso answered “no”, the GIA does not have to accept it. However, Caruso noted that the new Framework provides more freedom to operate. Since the “associate Member” category no longer exists, non-Members of the IEA may not be able to join the GIA. Also, in the new Framework, Sponsors have the right to vote, but with the present GIA, Sponsors cannot be a Member of the ExCo therefore cannot vote.

Rybach asked how many IA’s had adopted the new Framework and Caruso stated that a few had, though all IA’s in which the EC is a Member had not yet agreed.

Caruso noted that the only participant who should not be in the GIA, i.e. the EC, is the one who objects.

**Action 11/15:** Secretary to distribute to the ExCo the IEA letter with the exact wording changes for the new IEA IA framework. (Supersedes Action 11/4.)

Schuppers had no idea when the EC would make its decision regarding the new Framework.

Nieva thanked Manuela Caruso for her participation at the meeting.

Caruso said that the GIA could contact her with any questions that she might be able to help with.

## 17. NATIONAL (COUNTRY) REPORTS (continued)

### 17.7 New Zealand (presented by Colin Harvey)

Harvey reported (Appendix 15) that New Zealand had signed the Kyoto Protocol in 2003, and that New Zealand has hydro development problems and a natural gas shortage, thus good conditions for further geothermal development. Geothermal electricity production is expected to double in the next 10 years.

Currently, geothermal energy provides 5% of the installed capacity (~ 430 $MW_e$) and 7% of the national energy production.

Six deep wells were drilled in the past 12 months, with half on existing producing fields. The average cost for drilling a geothermal well to 2 km was ~ NZ$ 3 M.

There was a slight increase in direct use with about 210 $MW_t$ used in the timber industry.

The cost of electricity production in New Zealand is expected to be about 6.5-8 NZ-cents for the next several years.

The Institute of Geological and Nuclear Sciences Limited research budget was ~ NZ$ 1.4 M in 2003, with effort concentrated in four areas: low enthalpy, better use of waste fluids, environmental and deep high temperature resources. There are also some microbiological studies being conducted on geothermal fluids, which are turning out some very interesting results, i.e. a bacterium that uses arsenic as an energy source.

Harvey noted that the Geothermal Institute (Auckland University) would formally close in July of 2004.

Rybach stated that $CO_2$ production should be included as part of the country reports and asked what it was for New Zealand. Harvey answered that work was presently being conducted to determine New Zealand's $CO_2$ production.

### 17.8 Switzerland (presented by Ladsi Rybach)

Rybach stated that the Country Report format developed for the GIA annual report was a step forward. He also noted that it was important to present quantitative values for the geothermal information that were based on fact and that surveys are conducted in Switzerland to obtain them. See the GIA 2003 Annual Report for a published version of this Switzerland country report.

The numbers being presented for Switzerland's geothermal information for 2003 were, however, determined by Rybach and Harald Gorhan using trends, since no detailed surveys had been conducted in the country in 2003. Geothermal surveys would be performed soon to provide accurate values for 2004.

In Switzerland, hydro produces roughly 60% and nuclear 40% of the electricity used. Consequently, there is practically no $CO_2$ produced during electricity production.

Geothermal energy use in Switzerland is not well defined in legislation. There is no tax on geothermal energy use and environmental impact reports are required for use of > 5 $MW_t$.

Two deep heat-mining projects in which EGS are to be used to produce electricity are underway in Basel and Geneva.

There is significant direct use, especially through heat pump utilization, with an average of 1 heat pump per 2 $km^2$. About 550 $MW_t$ are installed as heat pumps, with 78% using borehole heat exchangers.

There were no wells drilled deeper than 500 m, however, a total depth of > 500 km of was drilled for borehole heat exchangers in 2003!

It is estimated that 1,123 GWh were produced from geothermal energy in 2003 and geothermal is also now used for "cooling".

Government support for geothermal energy is decreasing and is expected to be severely cut in 2004.

Switzerland participates in the EU Soultz project and in the IEA-GIA, in Annex III, with the project assistant, and has an interest in Annex VIII.

Gorhan stated that there would be no decrease in geothermal research funding. However, the support for demonstration plants is finished as a purely political decision, because they are seen as a form of subsidization, which is not wanted. There will also be some funding available for information dissemination and education.

### 17.9 Japan (presented by Satoshi Kubo)

A history of the geothermal production and funding was presented.

The first geothermal power station with a capacity of 12 $MW_e$ was commissioned in 1966. At present there is a total of 20 geothermal power plants, with a total installed capacity of 535 $MW_e$.

There were no new geothermal power stations constructed after 1998.

In 1999, "new energy" was defined to include all renewable resources except for geothermal and the geothermal budget was cut very quickly. All NEDO projects were terminated in 2002.

In April 2004 three new geothermal areas are to be surveyed.

Gorhan asked why there was a sudden decrease in research funding? Matsunaga replied because geothermal energy is now established, so NEDO did not wish to support more research. However, research funding can still be obtained from the Ministry for Environment and from some private companies.

### 17.10 Mexico (presented by David Nieva)

Nieva presented a review of the 2003 Mexico country report (see 2003 GIA Annual Report for details).

In Mexico, geothermal is the most important renewable energy source after hydro.

At present, there is 953 $MW_e$ of installed capacity in Mexico making it third in the world after the Philippines and USA. Electricity generation from geothermal sources represented > 3% of the total in 2003. The geothermal contribution to electricity generation is > 1.5 times higher than its contribution to the installed capacity, reflecting the very high capacity factor. About 86% of the installed capacity is owned by two Government utilities: Comisión Federal de Electricidad (CFE) and Luz y Fuerza del Centro (LyFC).

Four geothermal fields contribute to Mexico's geothermal generation, with La Primavera having wells but no power generation due to environmental objections.

In 2003 four x 25 $MW_e$ were commissioned at Los Azufres, and five new wells were drilled at Cerro Prieto and eight at Los Azufres.

Rybach asked if there was much geothermal direct use in Mexico. Nieva said that about 164 $MW_t$ was used for balneology.

## 18. OTHER BUSINESS (continued)

### 18.2 IEA Secretariat Report for 11th GIA ExCo Meeting (presented by Peter Tulej, IEA Secretariat)

Tulej welcomed the ExCo to the IEA Headquarters and introduced Mary Harries White from the IEA Office of Energy Efficiency, Technology and R&D.

Harries White distributed and discussed the IEA/CERT Open Energy Technology Bulletin, which is a service that provides on-line energy news (Appendix 16). It allows the GIA to circulate messages regarding meetings, conferences, etc. and disseminate news. She invited the GIA to make contributions to the Bulletin.

**Action 11/16:** Secretary to send Mary Harries White a list of GIA ExCo Members' e-mail addresses.

Rybach asked if this was purely electronic in form and Harries White confirmed it was.

Rybach pointed out that it gives the GIA a very good opportunity to spread the work about the Agreement. The GIA should make a good appearance when we first use the Bulletin, i.e. do a good job, rather than be hasty.

Jelacic asked about graphics and Harries White replied that for the sake of speed there are no graphics or pictures included. This is to provide "instant" impact upon opening the Bulletin.

Tulej then presented the IEA report to the ExCo meeting describing the developments within the IEA Secretariat and issues related to the GIA (see Appendix 17). He noted that the CERT approved the REWP Strategy and Mandate for 2004-2006 and included a brief outline of major points, including the mission and vision statements. The four objectives were stated: (1) Primary source of information and analysis on renewables, (2) Oversight and support of the renewable Implementing Agreements, (3) Identify and describe policies, financial and other market-related factors and (4) Develop and help implement accelerated market deployment.

Tulej discussed the upcoming International Conference for Renewable Energies to be held in Bonn, Germany, on 1-4 June 2004 (see website: http://www.renewables2004.de/). This event is expected to create further impetus for the global development of renewable energy. Such topics as: financing instruments and market development, formation of enabling political framework conditions, capacity building (education, research, networks, cooperation, etc.) would be covered. He informed the meeting that there would be an IEA side event in which several IA's will participate and reiterated his invitation to the GIA to participate in it (e.g. make a presentation) and the associated technology exhibition.

Antonio Pflüger, Head of the Energy Technology Collaboration Division of the IEA, also spoke. He is preparing a major book based on the Bonn Conference. He noted that geothermal is the third largest renewable and important that it be included in the book. He stated that the IEA would have a large booth at the Bonn Conference and that the Conference would be good for geothermal. The IEA was also producing a new *IA Highlights* book in 2005 and he wanted to include information from the GIA.

Of great interest was Pflüger's comment that the IEA made brochures of 2-16 pages and that the IEA would produce a glossy brochure for the GIA with our design and data, etc. at no cost to the GIA.

Rybach thanked Pflüger and stated that the GIA looked forward to the IEA's support and confirmed that the GIA could provide material to the IEA for distribution at their booth at no cost to the GIA.

Tulej then continued with a review of IEA potential collaborative projects including the R&D Seminar at REWP 47 to be held in the spring of 2005 (see Annex 1 in Appendix 17). The mid- to long-term R&D priorities for renewable energy will be defined in collaboration with the IA's. The GIA was requested to communicate with the IEA Secretariat regarding interest in attending and speaking at the Seminar. The GIA was also asked to consider and comment on the draft programme.

Several actions were placed on the GIA related to providing information and support to IEA projects (See Appendix 17) as follows:

1. GIA requested to communicate to the IEA Secretariat interest in attending and speaking at the R&D Seminar at REWP 47 (spring 2005). The GIA is also asked to consider, comment and make suggestions on the tentative programme and its contents.

2. The GIA is requested to consider providing information for the OPEN Bulletin. It is also possible to have a special issue of the Bulletin on geothermal energy. Contact Tulej.

3. The GIA is requested to consider providing support to the application of geothermal energy for the large-scale production of hydrogen by sharing information and experience with the IEA Secretariat and by verifying reports. The GIA's interest in participating is to be communicated to Tulej.

4. The GIA is requested to consider providing support to the project dealing with assessing the degree to which renewable energy resources are limited by their intermittency, and technical options and regulatory strategies for overcoming them. The GIA's interest in participating is to be communicated to Tulej.

In conclusion, Tulej noted the information support that the IEA can provide to the GIA through its *Highlights of Implementing Agreements* book, the IEA OPEN Energy Technology Bulletin and the IEA website and links.

### 18.3 General Comments and Business

Mongillo presented a list of actions generated at the 11th ExCo Meeting.

Gorhan noted the GIA's need for a logo and Nieva agreed that the GIA could use a poster and logo. After brief discussion it was decided to have a competition for the best GIA logo design.

**Action 11/17:** All ExCo Members to submit a logo design for the GIA by early-May for a competition.

## 19. DATES AND VENUES FOR THE 12th and 13th ExCo MEETINGS

The 12th IEA-GIA ExCo Meeting will be held in Italy on 14-15 October 2004. This decision was accepted unanimously.

Nieva requested that ExCo Members consider holding the 13th ExCo Meeting in conjunction with the WGC 2005, which will be held in Antalya, Turkey on 24-29 April 2005.

## 20. THANKS TO THE IEA SECRETARIAT

GIA Chairman Nieva expressed the IEA-GIA Executive Committee's thanks to the IEA hosts for their hospitality and efforts in hosting this 11th ExCo Meeting. Their assistance with the meeting arrangements was very much appreciated.

## 21. ADJOURNMENT

The 11th GIA ExCo Meeting was adjourned at 2:53 PM on 19 March 2004 with unanimous agreement.

**APPENDIX 1: List of Meeting Participants (Signature Page)**

# 11th Executive Committee Meeting
# Paris, France
# 18-19 March 2004

## Signature Page

### ExCo Members/Alternates

1. Aldo Baldacci ..........
2. Harald Gorhan ..........
3. Kenji Haruguchi ..........
4. Colin Harvey ..........
5. Allan Jelacic ..........
6. Hrefna Kristmannsdottir ..........
7. David Nieva ..........
8. Dieter Rathjen ..........
9. Ladislaus Rybach ..........
10. Jeroen Schuppers ..........
11. Helga Tulinius ..........

### Observers

1. Roy Baria ..........
2. Jörg Baumgärtner ..........
3. Christophe Debouit ..........
4. Kazunori Fukasawa ..........
5. André Gerard ..........
6. Ed Hoover ..........
7. Satoshi Kubo ..........
8. Isao Matsunaga ..........
9. Mike Mongillo (Secretary) ..........

**APPENDIX 1 (cont'd): List of Meeting Participants (Business Card Page)**

EnelGreenPower

Aldo Baldacci
Manager, Environment Quality, Health and Safety

56122 Pisa, Via Andrea Pisano 120
Tel. +39 050 535744 Fax +39 050 533290
Cell. +39 329 2258358
E-mail: baldacci.aldo@enel.it

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EEIG heat-mining

**Roy BARIA**
*Project Coordinator*
*European geothermal project - Soultz-s/s-Forêts*

EEIG "Heat Mining"
Route de Soultz - BP 38
67250 KUTZENHAUSEN
France

Tél. : (33) 3-88-80-53-63
Fax : (33) 3-88-80-53-51
Home : (33) 3-88-96-29-87
E-mail : baria@soultz.net

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**Dr. Harald L. Gorhan, M.Sc.**
***Programmleiter Geothermie Schweiz***

Neudoerfli 10
CH-5600 Lenzburg,
Schweiz

Tel. = Fax: +41(0)62/891 83 68
Mobile: +41(0)76/388 27 33
mailto: harald.gorhan@bluewin.ch
http://www.geothermal-energy.ch

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NEDO
http://www.nedo.go.jp

**KENJI HARUGUCHI**
Director
Energy and Environment Policy Department
**New Energy and Industrial Technology Development Organization ( NEDO )**

MUZA KAWASAKI Central Tower 18F,
1310 Ohmiya-cho, Saiwai-ku, Kawasaki-city,
Kanagawa, 212-8554, JAPAN

TEL : +81-44-520-5183
FAX : +81-44-520-5186
E-Mail: haruguchiknj@nedo.go.jp

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UNIVERSITY OF AKUREYRI

Hrefna Kristmannsdóttir
Professor
Geothermal Research

Faculty of Natural Resource Sciences
Glerargata 36
IS-600 Akureyri
ICELAND

Tel.: +354-463-0974
Fax: +354-463-0998
E-mail: hk@unak.is
Home Tel.: +354-463-1530

---

NEDO
http://www.nedo.go.jp

**Kubo Satoshi**
**Chief Officer**
Energy and Environment Policy Department
New Energy and Industrial Technology
Development Organization

MUZA KAWASAKI 18F, 1310 Ohmiya-cho
Saiwai-ku, Kawasaki, Kanagawa
212-8554, JAPAN

E-Mail: kubosts@nedo.go.jp
TEL : +81-(0)44-520-5183
FAX : +81-(0)44-520-5186

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**National Institute of Advanced Industrial Sciences and Technology**
Deputy Director, Institute for Geo-resources and Environment

**Isao Matsunaga**

AIST Tsukuba west, 16-1 Onogawa, Tsukuba,
Ibaraki 305-8569, JAPAN
Tel: +81-29-861-8201, 8700
Fax:+81-29-861-8708
E-mail:matsunaga-isao@aist.go.jp

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Dr. Dieter Rathjen
*Division ERG*
Project Management Organization Jülich
of BMBF and BMWi

Forschungszentrum Jülich
GmbH

PtJ

52425 Jülich
Phone: +49-2461-614233
Fax: +49-2461-612840

http://www.fz-juelich.de/ptj
e-mail: d.rathjen@fz-juelich.de

**APPENDIX 1 (cont'd): List of Meeting Participants (Business Card Page)**

GEOWATT AG
SWISS GEOTHERMAL EXPERT GROUP
GEOTHERMAL ENERGY
HYDROGEOLOGY
ENGINEERING
NUMERICS
Ladislaus Rybach
Prof. Dr. Ing. ETH / sia
Managing Director
Dohlenweg 28, CH-8050 Zürich
Tel +41 (0)1 242 14 54 Fax +41 (0)1 242 14 58
rybach@geowatt.ch www.geowatt.com

Jeroen SCHUPPERS
New and Renewable Energy Sources
European Commission
Directorate-General for Research
Mail: European Commission - Office: MO75 07/11 - B-1049 Brussels
Address: Rue Montoyer/Montoyerstraat 75, B-1050 Bruxelles/Brussel
Tel.: + 32-2-295.70.06 - Fax: + 32-2-299.36.94 - E-mail: jeroen.schuppers@cec.eu.int

OS ORKUSTOFNUN
National Energy Authority
Energy Resources
Orkustofnun
Grensásvegur 9
IS-108 Reykjavík
ICELAND
Tel.: +(354) 569 6000 / 6007
Home Tel.: +(354) 588 4484
Mobile: +(354) 899 7264
Fax: +(354) 568 8896
E-mail: htul@os.is
http://www.os.is
Helga Tulinius
Project Manager
Energy projects and computing

Institute of
GEOLOGICAL & NUCLEAR SCIENCES
Limited
A Crown Research Institute
M A (Mike) Mongillo
PhD, MSc, BSc (Hons),
DipEnergyTech (Geothermal)
Secretary
Geothermal Implementing Agreement (GIA)
International Energy Agency (IEA)
Wairakei Research Centre
114 Karetoto Road, SH1, Wairakei
Private Bag 2000, Taupo
New Zealand
Telephone: +64-7-374 8211
Facsimile: +64-7-374 8199
Home: +64-7-378 9774
Email: iea-giasec@gns.cri.nz
http://www.gns.cri.nz

**APPENDIX 2: Revised Agenda for 11th ExCo Meeting**

# REVISED AGENDA

## The 11th Executive Committee Meeting of the I.E.A. Geothermal Implementing Agreement

## 18 & 19 March 2004 at IEA Headquarters Paris, France

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**The meeting will start at 9:30 AM on Thursday 18 March**

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1. Opening at 9:30 AM (welcome, apologies, adoption of Agenda)

2. Minutes of the 10th ExCo Meeting (18-19 September 2003, Reykjavik, Iceland)
   a. Approval of minutes
   b. Status of actions
   c. Matters arising

3. Other ExCo Issues
   a. Status of 2003 Annual Report
   b. Action on non-paying GIA Members
   c. Required amendments to the GIA
   d. Participation in WGC 2005

4. Election of Chairman and Vice-chairmen

5. Review of Secretariat Operation and Work Plan
   a. Work conducted since 10th ExCo Meeting
   b. Costs of operation/budget for 2004
   c. Proposed work for remainder of year (routine duties, GIA website, GIA brochure)
   d. IGNS secretariat contract for 2nd year

6. Financial Report (Common Fund)
   a. Status of Common Fund (contributions for 2002 and 2003, un-paid contributions, expenditure, balance, forecast)
   b. Shares and share cost for participants (reminder)
   c. Fund use for attending important meetings

7. Progress Reports and Work Plans of Continuing Annexes
    a. I Environmental Impacts (Chris Bromley)
    b. III Enhanced Geothermal Systems (I. Matsunaga)
    c. IV Deep Geothermal Resources (Dieter Rathjen)
    d. VII Advanced Geothermal Drilling (Ed R. Hoover)
    e. VIII Direct Use of Geothermal Energy (Einar Gunnlaugsson)

8. Status of Pending and Proposed Annexes
    a. V Sustainability (USA, Allan Jelacic)
    b. IX Market Acceleration (draft proposal on marketability of a Latin American prospect (David Nieva)

9. Prospective Participating Countries
    a. Potential membership (China, France, Russia, Turkey, Philippines and Sweden (Ladsi Rybach)

10. National (Country) Reports

11. Dates and Venue of next ExCo Meetings
    a. 12th ExCo Meeting: Thursday and Friday, 14-15 October 2004; Pisa, Italy.
    b. 13th ExCo Meeting: Consider week prior to WGC 2005: 18-22 April 2005, in Turkey.

12. Other Business
    a. IEA report (Peter Tulej, Friday 19 March 2004)
    b. IEA new IA framework (Manuela Caruso, Friday 19 March 2004)
    b. Review of Actions for the 11th ExCo Meeting (Secretary)

## APPENDIX 3: List of IEA-GIA ExCo Members as of March 2004

# IEA Geothermal Implementing Agreement Executive Committee (March 2004)

| Country / Name | Delegate | Organization / address | e-mail / tel / Fax | Alternate | Address, etc. (where different) |
|---|---|---|---|---|---|
| **AUSTRALIA** | **Doone Wyborn** | Geodynamics Limited<br>PO Box 2046<br>Milton<br>Queensland 4064<br>Australia | dwyborn@geodynamics.com.au<br>Tel. +61-7-3721-7500<br>Fax +61-7-3721-7599 | **Prame Chopra** | Australian National University<br>Department of Geology<br>Canberra, ACT 0200<br>AUSTRALIA<br>prame.chopra@anu.edu.au |
| **EUROPEAN COMMISSION** | **Jeroen Schuppers** | European Commission<br>DG RTD / (MO75 07/11)<br>B-1049 Brussels<br>BELGIUM | Jeroen.schuppers@ cec.eu.int<br>Tel. ++32-2-295-7006<br>Fax ++32-2-299-3694 | **William Gillett** | European Commission<br>DG TREN / D-2 (DM24 03/126)<br>B-1049 Brussels<br>BELGIUM<br>Tel. ++32-2-299-5676<br>Fax ++32-2-296-3765<br>william.gillett@cec.eu.int |
| **GERMANY** | **Dieter Rathjen** | ForschungszentrumJülich GmbH<br>Project Management Organization<br>D-52425 Jülich<br>GERMANY | d.rathjen@fz-juelich.de<br>Tel. ++49-2461-61-42-33<br>Fax ++49-2461-61-28-40 | **Norbert Stump** | ForschungszentrumJülich GmbH<br>n.stump@fz-juelich.de<br>Tel. ++49-2461-61-31-72<br>Fax ++49-2461-61-28-40 |
| **ICELAND** | **Helga Tulinius** | Orkustofnun<br>(National Energy Authority)<br>Grensavegi 9<br>IS-108 Reykjavik<br>ICELAND | htul@os.is<br>Tel. ++354-569-6000<br>Fax ++354-568-8896 | **Hrefna Kristmannsdóttir** | University of Akureyri<br>Faculty of Natural Resource Sciences<br>Solborg, Nordurslod, 600 Akureyri<br>ICELAND<br>hk@unak.is<br>Tel. ++354-463-0974<br>Fax ++354-463-0998 |
| **ITALY** | **Aldo Baldacci** | ERGA SpA (Gruppo ENEL)<br>Via Andrea Pisano 120<br>I-56122 Pisa<br>ITALY | baldacci.aldo@enel.it<br>Tel. ++39-050-535-744<br>Fax ++39-050-535-5940 | **Guido Cappetti** | ERGA SpA (Gruppo ENEL)<br>cappetti.guido@enel.it<br>Tel. ++39-050-535-781<br>Fax ++39-050-533-290 |

## IEA Geothermal Implementing Agreement Executive Committee (continued) (March 2004)

| Country / Name | Delegate | Organization / address | e-mail / tel / Fax | Alternate | Address, etc. (where different) |
|---|---|---|---|---|---|
| **JAPAN** | **Kenji Haruguchi** | Director<br>Energy and Environment Policy Department<br>NEDO<br>MUZA KAWASAKI, 18F,<br>1310 Ohmiya-cho<br>Saiwai-ku, Kawasaki, 212-8554<br>JAPAN | haruguchiknj@nedo.go.jp<br>Tel: ++81-44-520-5183<br>Fax:++81-44-520-5186 | **Yumi Kiyota** | NEDO<br>kiyotayum@nedo.go.jp<br>Tel: ++81-44-520-5183<br>Fax:++81-44-520-5186 |
| **MEXICO** | **David Nieva**<br>*Chairman* | Manager of Technology Transfer<br>Instituto de Investigaciones Electricas<br>Av. Reforma N°113, Col. Palmira<br>62490 Temixco, Mor.<br>MEXICO | dnieva@iie.org.mx<br>Tel. ++52-777-318-3811, ext. 7495<br>Fax ++52-777-318-9542 | **Victor Manuel Arellano Gómez** | IIE<br>vag@iie.org.mx<br>Tel. ++52-777-3-62-38-03<br>Fax ++52-777-3-62-38-04 |
| **NEW ZEALAND** | **Chris Bromley** | Institute Geological & Nuclear Sciences<br>Wairakei Research Centre<br>Private Bag 2000<br>Taupo<br>NEW ZEALAND | c.bromley@gns.cri.nz<br>Tel. ++64-7-374-8211<br>Fax ++64-7-374-8199 | **Colin Harvey** | IGNS<br>c.harvey@gns.cri.nz |
| **SWITZERLAND** | **Ladislaus Rybach**<br>*Vice Chairman* | ETH Zurich<br>Institute of Geophysics<br>ETH-Hoenggerberg<br>CH-8093 Zurich<br>SWITZERLAND | rybach@ig.erdw.ethz.ch<br>rybach@geowatt.ch<br>Tel. ++41-1-633-2605<br>Fax ++41-1-633-1065 | **Harald L. Gorhan** | Neudoerfli 10<br>CH-5600 Lenzburg<br>SWITZERLAND<br>harald.gorhan@bluewin.ch<br>Tel. ++41-62-891-8368<br>Fax ++41-62-891-8368 |
| **USA** | **Allan Jelacic**<br>*Vice Chairman* | Office of Geothermal Technologies<br>US Department of Energy, EE-2C<br>1000 Independence Ave SW<br>Washington, DC 20585<br>USA | allan.jelacic@hq.doe.gov<br>Tel. ++1-202-586-6054<br>Fax ++1-202-586-8185 | **Roy Mink** | US Department of Energy<br>roy.mink@ee.doe.gov<br>Tel. ++1-202-586-5463<br>Fax ++1-202-586-8185 |
| **STAFF** | **Mike Mongillo**<br>*IEA-GIA Secretary* | IEA-GIA Secretariat<br>Institute Geological & Nuclear Sciences<br>Wairakei Research Centre<br>Private Bag 2000<br>Taupo<br>NEW ZEALAND | IEA-GIASec@gns.cri.nz<br>m.mongillo@gns.cri.nz<br>mongillom@reap.org.nz (home office)<br>Tel. ++64-7-378-9774 (home office)<br>Tel. ++64-7-374-8211<br>Fax ++64-7-374-8199 | - | - |

**APPENDIX 4: E-mail Sent to ExCo re. Amendments to the GIA**

**E-mail sent to ExCo from David Nieva on 18 February 2004**
**Re. Amendments to the GIA**

Dear Members of the GIA Executive Committee:

As mentioned at our 10th. ExCo Meeting (Item 18.2 of the Draft Minutes) the Legal Counsel of IEA has suggested that we make amendments to our Implementing Agreement, in order to:

a) Make the IA compatible with our current practices,

b) Make the best use of the lower restrictions than the new IEA Framework for International Energy Technology Cooperation establishes, as compared with the original Guiding Principles for Co-operation in the Field of Energy Technology and Development.

Fortunately, there is a provision in our current IA that allows the Executive Committee to make amendments acting by unanimity. That is, we would not be required to have the IA signed again by our countries' authorities.

In view of the above, I ask you to be prepared to define your position on the following recommendations by the Legal Counsel:

i) Modify the current Article 11 of the GIA in order to allow participation of governments from both OECD member and OECD non-member countries, of the European Communities, of international organizations in which the participating governments have a stake, and of any national agency, public organization, private corporation or other entity designated by the participating governments or by the European Communities.
ii) Modify Article 10(c) so as to make reference to the new Framework as opposed to the original Guiding Principles (which have been annulled).
iii) Specify that an abstention does not count as a vote (therefore not blocking a unanimous decision without taking a definite position).
iv) Modify Article 12 so that we could invite as a "Sponsor" an entity of OECD member countries AND OECD non-member countries, and also no to be required to obtain a clearance from the Committee on Energy Research and Technology (CERT) to make such invitation.

The IEA Legal Counsel offers a specific wording for each one of these amendments. However, as mentioned above, they must unanimously be accepted by the ExCo.

The IEA Framework for International Energy Technology Cooperation could be consulted on the IEA's webpage under Technology Agreements.

I look forward to seeing you all in Paris next month.

Best regards,

David Nieva

**APPENDIX 5: IEA-GIA Secretary's Report (including Secretary's 2004 Draft Work Plan)**

# IEA-GIA Secretary's Report

**11th Executive Committee Meeting**
**Paris, France**
**18-19 March 2004**

***Introduction***

This report covers the GIA Secretary's work for the period beginning with the 10th ExCo Meeting held in Reykjavik, Iceland, on 18-19 September 2003 and ending 29 February 2004.

The general duties of the Secretary are specified in the IEA-GIA Implementing Agreement (Article 5). The work plan for this period was based on Article 5, the IGNS bid, action items specified at the 10th ExCo Meeting and specific requests made by the Chairman and Vice-Chairmen. The Secretary's work has proceeded as planned, though a change in priorities caused some projects to be sidelined. A brief review of the work conducted follows.

A work plan for the 2004-year is included as Appendix 1.

A detailed outline of the time and costs associated with the operation of the New Zealand based GIA Secretariat for 2003 is also included with this report (Appendix 2).

A letter from Dr Colin Harvey (New Zealand ExCo Alternate Member, and Manager, Geothermal, Minerals and Groundwater Research, IGNS) that provides an estimate of costs for the operation of the NZ GIA Secretariat by IGNS for the 2004 calendar year is included as Appendix 3.

***General Administrative Work***

The IEA-GIA Secretary has strived to maintain regular and timely communication with the ExCo Chairman, Vice-Chairmen, committee members and IEA Headquarters. Minutes of the 10th ExCo Meeting were written, edited and distributed (50 hours); arrangements were made with the IEA Secretariat for their hosting of the 11th ExCo and Annex VII meetings; and documents for the 11th ExCo Meeting were prepared and distributed.

Smaller projects arising from 10th ExCo Meeting Actions on the Secretariat were also completed, including: investigation into how GIA could participate in the WGC 2005; submission of abstract an to the WGC 2005 for the general GIA paper; working with NREL to change Common Fund share cost and invoicing based upon the new share cost and calendar year operation. Other miscellaneous administrative tasks were also performed.

(September 2003-February 2004: 200 hours)

***Attendance at 10th ExCo Meeting and Budapest Forum***

The Secretary attended the 10th ExCo Meeting (September 2003) and participated at the Budapest Forum (October 2003). A PowerPoint presentation describing the GIA, its activities and Strategic Plan and geared to gaining new membership was presented at the Budapest Forum, and is posted on the IEA website at: http://library.iea.org/dbtw-wpd/textbase/work/2003/budapest/geother.pdf

(September and October 2003: 80 hours)

*GIA Strategic Plan*

The Secretary assisted Allan Jelacic with the editing of the 2002-2007 GIA Strategic Plan and its distribution to ExCo members for ratification. The Plan was accepted unanimously, with Greece abstaining.

(November 2003-January 2004: 20 hours)

*GIA Document Archive*

An archive of important GIA documents was initiated as actioned at the 10th ExCo meeting. It is reasonably complete and will be available through the GIA website via a password protected option. At present the archive includes the Implementing Agreement, Annex descriptions, Annual and End of Term Reports, all but one of the ExCo meeting minutes, the 2002-2007 Strategic Plan, a few GIA produced papers, etc.

(December 2003: 6 hours)

*IEA-GIA 2003 Annual Report*

We are still working towards the production of high quality GIA Annual Reports in the re-designed format that was begun with the IEA-GIA 2002 Annual Report. To this end, a Country Report section was added in 2002 and detailed Country and Annex Report formats were produced by the Secretariat, and distributed both at the 10th ExCo Meeting and again on 6 November 2003. All of the reports have arrived at the Secretariat, most by early February 2004.

The current status of the 2003 Annual Report is that a draft document exists, consisting of ONLY the Annex and Country reports. Several of the reports remain to be edited, then the general information, summary and introductory sections will be written. It is estimated that about 100 hours will be required to complete the report, with about 6 hours already spent.

(January-February 2004: 6 hours)

*GIA Website*

A basic GIA website has been drafted and is available for demonstration at this meeting. Comments and suggestions are welcome from Members. NOTE that this is by no means complete, and significant changes are still anticipated.

A mock-up is available for demonstration purposes for this meeting.

(December 2003-February 2004: 60 hours)

*GIA Brochure*

Since the website was given priority over the brochure at the 10th ExCo meeting, no further work has been done on the GIA Brochure since that meeting. It remains in its initial design stage (about 40% complete) as reported at the Reykjavik Meeting.

(September 2003-February 2004: 0 hours)

**Submitted in March 2004 by:**

Dr Mike Mongillo
IEA-GIA Secretary
Wairakei Research Centre
Institute of Geological and Nuclear Sciences Limited
Private Bag 2000
Taupo 2730
NEW ZEALAND

| | | |
|---|---|---|
| Phone: | Wairakei office: | +64-7-374-8211 extension 875 |
| | Home office: | +64-7-378-9774 |
| Fax: | Wairakei office: | +64-7-374-8199 |
| E-mail: | Wairakei office: | IEA-GIASec@gns.cri.nz |
| | Home office: | mongillom@reap.org.nz |

## APPENDIX 1

## IEA-GIA SECRETARY'S DRAFT WORK PLAN FOR January-December 2004

M.A. Mongillo
March 2004

The following is an outline of the Secretary's work plan for 2004. It is based on the list of secretarial duties as specified in the IEA GIA Implementing Agreement, the IGNS Bid and 10th ExCo Meeting Action items.

1. Prepare and distribute documents (agenda, discussion papers, etc.) for the 11th ExCo Meeting, attend the meeting; take notes, prepare, edit and distribute the minutes.

2. Complete the IEA-GIA 2003 Annual Report and submit to IEA in April 2004.

3. Write the Minutes of the 11th ExCo Meeting.

4. Complete the development of the IEA-GIA website.

5. Assist with writing the WGC 2005 GIA paper. Due date is the end of May 2004.

6. Complete the IEA-GIA Brochure, arrange its production and distribute it.

7. Prepare and distribute documents (agenda, discussion papers, etc.) for the 12th ExCo Meeting, attend the meeting; take notes, prepare, edit and distribute the minutes.

8. Maintain regular and timely communication with the ExCo Chair, Vice-Chairs, Committee Members, Operating Agents and IEA Headquarters.

9. Continue with maintenance of the GIA Secretariat document archive (GIA Archive).

10. In general, conduct work for the GIA ExCo as specified for the Secretary in the Implementing Agreement and as requested by the Chairman and Vice-Chairmen of the ExCo.

## APPENDIX 2

### GIA Secretary's Total Time for 2003 Financial Year
### M.A. Mongillo
### March 2004

**A. 21 March – 20 April 2003**

a. Set-up of GIA Office, General Communication and Administration, and Production of the 2002 Annual Report.
***Monthly Total***: 158 hr @ $ 75/hr: NZ$ 11,850.00

**B. 21 April – 21 May 2003**

a. General Communications and Administration (10.75 hr) and Brochure Design and Writing (27 hr).
***Monthly Total***: 37.75 hr @ $75/hr: NZ$ 2,831.25

**C. 22 May – 23 June 2003**

a. General Communications and Administration, Strategic Plan, etc. (23.85 hr), Brochure Design and Writing (3 hr) and GRC Paper (59.25 hr).
***Monthly Total***: 86.1 hr @ $ 75/hr: NZ$ 6,457.50

**D. 24 June – 20 July 2003**

a. General Communications and Administration, etc.
***Monthly Total***: 32 hr @ $ 75/hr: NZ$ 2,400.00

**E. 23 July – 31 August 2003**

a. General Communications and Administration, Preparation for 10th GIA ExCo Meeting in Iceland and Budapest Forum (25.5 hr) and GRC PowerPoint Presentation (16.5 hr).
***Monthly Total***: 42 hr @ $ 75/hr: NZ$ 3,150.00

**F. Expenses for Attending 10th ExCo Meeting and Budapest Forum**

a. 10th ExCo Meeting in Reykjavik, Iceland.
- Airfare for Iceland: NZ$ 4,400.00
- ExCo Hotel, Meals, etc. Expenses: NZ$ 1,187.92

***Total Secretary's Cost for Attending ExCo Meeting:*** NZ$ 5,587.92

b. Budapest Forum.
- Airfare: NZ$ 1,016.30
- Hotel, Meals, etc. Expenses: NZ$ 789.00

***Total Secretary's Cost for Attending Budapest Forum:*** NZ$ 1,805.30

**G. Time for Secretary to Travel and Attend Meetings**

| | |
|---|---|
| a. 10th ExCo Meeting in Reykjavik, Iceland (50 hr): | NZ$ 3,750.00 |
| b. Budapest Forum (30 hr): | NZ$ 2,250.00 |

**H. 1 September – 14 September 2003**

a. General Communications and Administration, Preparation for 10th ExCo Meeting (19.7 hr), GRC and Budapest PowerPoint (12.2 hr).

***Monthly Total***: 31.9 hr @ $ 75/hr: NZ$ 2,392.50

**I. 17 October – 31 October 2003**

a. General Communications and Administration, and Preparation of Minutes for 10th ExCo Meeting.

***Monthly Total***: 22.3 hr @ $ 75/hr: NZ$ 1,672.50

**J. 1-30 November 2003**

a. General Communication and Administration (17.5 hr), editing Strategic Plan (17.7 hr), Completion of Draft Minutes 10th ExCo Meeting (20.4 hr).

***Monthly Total***: 55.6 hr @ $75/hr: NZ$ 4,170.00

**K. 1-30 December 2003**

a. General Communications and Administration (15.5 hr), editing Strategic Plan (2.25 hr), GIA Archive (5.55 hr), Completion of 10th ExCo Draft Minutes (13.75 hr) and Webpage Design (11.25 hr).

***Monthly Total***: 48.3 hr @ $75/hr: NZ$ 3,622.50

**L. Total Cost for Secretary in 2003 (@ exchange rate of 0.69)**

| | |
|---|---|
| **a. Secretary's Time (594 hours):** | **NZ$ 44,546.25**<br>**US$ 30,736.91** |
| **b. Travel Expenses for 10th ExCo Meeting and Budapest Forum:** | **NZ$ 7,393.22**<br>**US$ 5,101.32** |
| **c. Total Cost:** | **NZ$ 51,939.47**<br>**US$ 35,838.23** |

## APPENDIX 3

**Letter from Colin Harvey to ExCo Officers (8 March 2004)**

**Subject: Re: Secretarial hours and costs.**

As the project manager for the IEA-GIA Secretariat contract I am pleased to present our cost estimate for secretarial services for the 2004 calendar year (1 January– 31 December 2004).

### A. SECRETARIAL TASKS AND TIME ESTIMATE

| | |
|---|---|
| 1. GIA Annual Report 2003 | 100 hours |
| 2. Correspondence & miscellaneous small projects 32 hrs per month x 12 | 380 hours |
| 3. Assist in preparation of papers, etc. (e.g. GIA exhibit, WGC 2005 Paper) | 50 hours |
| 4. GIA Brochure (underway but to be completed) | 40 hours |
| 5. Attendance at 2 ExCo Meetings (Paris and Italy)<br>50 hours/meeting including international travel time | 100 hours |
| 6. Reporting and Minutes of 2 ExCo Meeting at 40 hrs/meeting | 80 hours |
| 7. Website design | 50 hours |
| **Estimate of Secretary's Time for 1 January-31 December 2004** | **800 hours** |

b. Other Costs for related activities and disbursements

| | |
|---|---|
| 1. Office, consumables etc. (based on bid estimate) | NZ$ 6,000 |
| 2. Travel and accommodation for meetings (March 2004 and Oct 2004) | NZ$10,000 |
| 3. Cost of producing the brochure (based on the estimate) | NZ$10,000 |
| 4. Website construction and maintenance for 2004 | NZ$10,000 |
| ***The Total Other Costs for 1 January-31 December 2004 Year*** | ***NZ$ 36,000*** |

### C. TOTAL ESTIMATED COST FOR 2004 CALENDAR YEAR

| | |
|---|---|
| **1. SECRETARY'S TIME: 800 HRS AT NZ$ 75/HR** | **NZ$60,000** |
| **2. OTHER COSTS FOR RELATED ACTIVITIES AND DISBURSEMENTS** | **NZ$36,000** |
| **Total Estimated Cost for Second Year** | **NZ$96,000** |
| **At the current exchange rate of 0.69 this equates to** | **US$ 66,240** |

**D. Comments**

1. The cost estimates in Section A are based on the time that Dr. Mike Mongillo has taken to carry out the secretarial services during the 2003 year.

2. The cost estimates in Section B are based on 2003 costs.

3. The website cost estimate was provided in last year's budget and has been reduced because of preliminary work already carried out.

4. Design and writing of the GIA brochure was begun in 2003 by the Secretary in preparation for its final production and printing in 2004.

**E. PREVIOUS ANNUAL BUDGET**

1. The IEA-GIA Secretariat cost estimate presented in September 2003 totalled NZ$99,000.

2. Since that time the NZ$ has moved positively from 0.58 to 0.69 against the US$.

Dr. Colin Harvey
Manager
Geothermal, Minerals and Groundwater Research
Institute of Geological and Nuclear Sciences
Private Bag 2000, Taupo
New Zealand

| | |
|---|---|
| Phone: | +64-7-374-8211 |
| Fax: | +64-7-374-8199 |
| Cell Phone: | +64-27-289-0250 |
| Email: | c.harvey@gns.cri.nz |
| Website: | http://www.gns.cri.nz/ |

**APPENDIX 6: The IEA Geothermal Implementing Agreement Document**

## THE IEA GEOTHERMAL IMPLEMENTING AGREEMENT
## It's Goals, Activities, Benefits, Obligations and Costs

**March 2004**

### THE IEA GEOTHERMAL IMPLEMENTING AGREEMENT (GIA)

The GIA officially went into effect on 7 March 1997, being designed to operate for an initial period of five years. In late 2001, the GIA's mandate was extended for another 5-year term, to 31 March 2007.

The GIA provides an important framework for wide-ranging international cooperation on geothermal issues. It brings together important national programmes for exploration, development and utilization of geothermal resources, emphasizing the assemblage of specific expertise and increasing effectiveness by establishing direct cooperative links among the geothermal experts in the participating countries. The GIA's present activities are directed primarily toward the coordination of the ongoing national programmes of the participants.

As of March 2004, the European Commission (EC) and nine countries: Australia, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Switzerland and the United States were members. The present involvement of these 10 members in the Annexes is shown in Table 1. Participants take part in those Annexes to which they can contribute, hence are not necessarily active in every one.

### GOALS AND OBJECTIVES OF THE GIA

According to the IEA World Energy Outlook 2002, the total share of non-hydro renewable energy sources used for electricity generation is expected to increase from 2% in 2000 to 4-6% in 2010 in the OECD countries, with the geothermal energy contribution forecasted to grow at a rate of 4%/yr during this 10-year period. The IEA GIA can play a significant role in helping achieve these ambitious growth targets.

In fact, the overall goal of the GIA for its second term, as stated in the GIA 2002-2007 Strategic Plan, is to advance and support the use of geothermal energy on a worldwide scale by pursuing following objectives:

- Expanding R&D collaboration by implementing new annexes where additional collaboration will be useful
- Increasing outreach to non-Member countries with large geothermal energy potential
- Evaluating market stimulation mechanisms to expand the use of geothermal energy
- Improving the dissemination of high quality information about geothermal energy through the production of easily understandable and attractive products
- Leveraging limited R&D funding using the IEA's reputation of technical competence and broad unbiased excellence to obtain support from industry and other multilateral organizations and financial institutions

### ACTIVITIES OF THE GIA

The scope of GIA's activities consist of international collaborative efforts to:

- Compile and exchange information on geothermal energy research and development worldwide 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 environmental impacts

Work is presently being conducted on five diverse tasks that are specified in five annexes to the implementing agreement, with the activities of each divided into subtasks. Each annex has a minimum of two participants and is coordinated by an Operating Agent (appointed by the Member country) through a chosen Task Leader, with Subtasks supervised by Subtask Leaders.

Currently, there are five active annexes:

***(1) Annex I: Environmental Impacts of Geothermal Energy Development:*** The main activities of this Annex are directed at clearly identifying possible environmental effects and devising and adopting methods to avoid or minimize their impact.

***(2) Annex III: Enhanced Geothermal Systems:*** This Annex investigates new and improved technologies that can be used to artificially stimulate a geothermal resource to allow commercial heat extraction.

***(3) Annex IV: Deep Geothermal Resources:*** Issues associated with the commercial development of deep geothermal resources at depths greater than 3,000 m are addressed by this Annex.

***(4) Annex VII: Advanced Geothermal Drilling Techniques:*** This Annex pursues advanced geothermal drilling research and investigates all aspects of well construction with the aim of reducing the costs associated with this essential and expensive part of geothermal exploration, development and utilization.

***(5) Annex VIII: Direct Use of Geothermal Energy:*** This Annex addresses the direct use of geothermal energy and the identification and removal of barriers to use.

A list of the GIA Operating Agents, Task Leaders and participating countries is provided in Table 1 below.

The results from the annex work include: numerous technical papers, databases (on CD–ROM), meetings and conference proceedings, and annual reports. In addition, a new interactive GIA website is being completed that will provide basic GIA information to the public, including access to GIA reports, papers and links to the IEA and participant sites. A password-protected section will provide GIA participants with an information archive; specially collected data, reports and other documents and meeting information.

Funding for all five existing annexes is of the *task-sharing* mode, whereby the participants allocate specified resources and personnel to conduct a portion of the annex work at their own expense. However, *cost-sharing* tasks, in which participants contribute to a common fund that is used for research, equipment purchase, information processing and exchange, *etc*. may be considered in the future.

## BENEFITS OF BEING A GIA MEMBER

The research, government, industry and academic sectors are the main beneficiaries of membership in the GIA, at both technical and policy levels.

Collaboration within the GIA provides researchers with the opportunities for joint R&D cooperation and information exchange on recent R&D developments via meetings, symposia, workshops and networking. Members from industry are able to participate together on R&D projects and to develop databases, models and handbooks. Policy and decision makers are able to gain an international perspective on geothermal issues, opportunities and development. In addition, there are benefits to society that arise from the acceptable development of geothermal resources in an environmentally acceptable manner.

More specifically, membership within the GIA provides the following benefits:

- Increases R&D capabilities beyond that of single a country/group by combining the efforts of several nations
- Provides appropriate focus for R&D, hence avoids duplication and unproductive research
- Provides opportunities for research networking
- Develops skills and knowledge required to meet future technical challenges
- Improves R&D cost effectiveness by sharing research costs and technical resources
- Provides wider and easier access to key information, research results and technological capabilities
- Makes accessible a strong technical base provided by R&D activities in the participating countries
- Provides impartial information and analysis to help guide national policies and programmes
- Provides the opportunity to review current issues, ongoing research and the need for future research
- Provides opportunity to draw upon expertise and efforts of our sponsoring organization, the OECD/IEA
- Knowledge and ability to help avoid or minimize environmental impacts of development
- Helps build a common understanding of the technical basis for various geothermal issues
- Investigates barriers to development
- Helps develop technical standards and methodologies
- Contributes to the development of energy policies
- Opportunities to join in cooperative efforts with the United Nations Environment Programme (UNEP), the Global Environmental Fund (GEF) and other project financing agencies

**STRUCTURE OF GIA AND OBLIGATIONS OF MEMBERS**

Members of the GIA shall participate in one or more tasks described by the Annexes to the implementing agreement. They will coordinate their activities with other task participants in order to avoid duplication and enjoy mutual benefits from existing resources and expertise. They will also cooperate in coordinating the annex work and will endeavour, on the basis of an appropriate sharing of burdens and benefits, to encourage cooperation among other participants with the objective of advancing the state of understanding of all participants.

Member countries shall designate an Operating Agent for each task in the relevant annex. Each annex is binding only upon its Operating Agent and the participants therein, and shall not affect the rights or obligations of other members.

Supervisory control of the GIA is vested in the Executive Committee (ExCo). Decisions made by the ExCo are binding on the members. The ExCo consists of one voting member from each member country. An alternate may serve on the ExCo if the designated member is unable to do so. The ExCo meets twice a year and members and/or their alternates should endeavour to attend. The ExCo manages all administrative activities resulting from or affecting the GIA. During ExCo meetings the members report on national programmes, exchange information and results of work under annexes, and consider ongoing or arising issues.

Members will continue to cover the travel expenses for their representatives to attend meetings and workshops. Travel costs will be minimized by doing business by mail and e-mail whenever possible. To the extent practicable, meetings will be scheduled to coincide with other events to minimize travel costs. Each participant bears all the costs they incur in carrying out its task activities, including reporting and travel expenses. Unless otherwise specified, the cost of publishing annex reports and summary assessments shall be borne by the Operating Agent.

The GIA ExCo has established a Secretariat, now based in New Zealand, and managed by a Secretary who provides secretarial, administrative and other duties as required for the organization (basic duties are defined fully in the Implementing Agreement).

## GIA FINANCIAL STRUCTURE AND COSTS

The expenses for the operation of the GIA Secretariat, including the Secretary's salary, and other common costs of the ExCo are met from a Secretariat Common Fund, administered by the Custodian, presently the National Renewable Energy Laboratory (NREL) (USA).

To support the Common Fund, the IEA has provided general guidance on a fair apportionment of monetary contributions in the form of shares assigned to different Member States of the OECD. Based on current membership, the apportionment for the GIA is:

| | | | |
|---|---|---|---|
| Australia | 2 | Japan | 4 |
| European Commission | 4 | Mexico | 1 |
| Germany | 4 | New Zealand | 1 |
| Greece | 1 | Switzerland | 2 |
| Iceland | 1 | United States | 4 |
| Italy | 2 | | |
| ***Total = 26 shares*** | | | |

The ExCo has set the present cost per Common Fund share at US$ 2,500/year.

With the addition of new members, or the withdrawal of current members, the total number of shares will increase or decrease, affecting each member's contribution. Contributions will be made annually on a calendar year basis. The number of shares assigned to new members who are non-Members of OECD will be determined by the ExCo acting in unanimity. The Custodian will be responsible for administering the Common Fund and providing periodic accounting reports to the ExCo.

Other common funds may be established as required to meet the needs of new annexes. The costs will be shared among the participants of the relevant annex in accordance with the shares established by the IEA and set out in the Table above. The designated Operating Agent will serve as the Custodian of the annex common fund. Arising issues of finance and budgeting will be decided based upon the conditions and requirements of Art.7 of the GIA.

**Table 1.** List of GIA Annex titles, operating agents, task leaders & contact e-mail addresses, participating countries and operating status.

| Annex Number | Title<br>Operating Agent (OA)<br>Task Leader (TL); Contact E-mail<br>Participants | Status |
|---|---|---|
| I | Environmental Impacts of Geothermal Development<br>OA: Institute of Geological and Nuclear Sciences Limited (IGNS), New Zealand<br>TL: Chris Bromley; IGNS, New Zealand; c.bromley@gns.cri.nz<br>Participants: Iceland, Italy, Japan, Mexico, New Zealand, USA | Active,<br>Continuing through 2006 |
| II | Shallow Geothermal Resources | Closed |
| III | Enhanced Geothermal Systems<br>OA: New Energy & Industrial Technology Development Organization (NEDO), Japan<br>TL: I. Matsunaga; AIST, Japan; matsunaga-isao@aist.go.jp<br>Participants: Australia, EC, Germany, Italy, Japan, Switzerland, USA | Active,<br>Continuing through 2006 |
| IV | Deep Geothermal Resources<br>OA: Forschungszentrum Jülich (F-J), Germany<br>TL: Dieter Rahtjen; F-J, Germany; d.rathjen@fz-juelich.de<br>Participants: Australia, Germany, Italy, Japan, Mexico, New Zealand, USA | Active,<br>Continuing through 2006 |
| V | Sustainability of Geothermal Energy Utilization | Draft |
| VI | Geothermal Power Generation cycles | Draft |
| VII | Advanced Geothermal Drilling Techniques<br>OA: Sandia National Laboratories, United States<br>TL: Ed Hoover, Sandia, USA; erhoov@sandia.gov<br>Participants: EC, Iceland, Japan, Mexico, New Zealand, USA | Active,<br>Continuing through 2004 |
| VIII | Direct Use of Geothermal Energy<br>OA: Federation of Icelandic Energy and Waterworks<br>TL: Einar Gunnlaugsson, Reykjavik Energy, Iceland; einar.gunnlaugsson@or.is<br>Participants: Iceland, New Zealand, Switzerland, USA | Active,<br>Began Sept 2003 |
| IX | Geothermal Market Acceleration | Draft |

## FOR FURTHER INFORMATION CONTACT

Dr Mike Mongillo
IEA-GIA Secretary
e-mail: mongillom@reap.org.nz; iea-giasec@gns.cri.nz

## APPENDIX 7: STATEMENT OF GIA COMMON FUND ACTIVITIES (Gerry Nix, NREL)

2002-2004 IEA GEOTHERMAL IMPLEMENTATION ACTIVITIES ACCOUNT 3201 02/29/04

| SPONSOR/ MEMBER COUNTRY | INVOICE AMOUNT | PAID AMOUNT | DATE PAID | PAYMENTS MADE | AMOUNT | DATE PAID | FUNDS PAID AVAIL |
|---|---|---|---|---|---|---|---|
| Beginning Balance | | ($9,022.76) | | | | | |
| 2002 European Commission IEAGEO-01 | $14,400.00 | $14,400.00 | 4/12/02 | George Frye | $333.40 | 6/01/03 | |
| 2003 European Commission IEAGEO-15 | $14,400.00 | 14,400.00 | 3/10/03 | George Frye | $466.76 | 7/01/03 | |
| 2004 European Commission IEAGEO-32 | $1,200.00 | | | George Frye | $533.44 | 7/01/03 | |
| 2002 Germany IEAGEO-02 | 14,400.00 | $14,400.00 | 14/11/02 | George Frye | $1,300.26 | 7/01/03 | |
| 2003 Germany IEAGEO-16 | $14,400.00 | $14,400.00 | 4/11/03 | George Frye | $1,652.35 | 10/04/03 | |
| 2004 Germany IEAGEO-33 | $1,200.00 | $1,200.00 | 20/02/04 | George Frye | $533.44 | 6/05/03 | |
| 2002 Iceland IEAGEO-04 | $3,600.00 | $3,582.00 | 09/30/02 | George Frye | $2,067.08 | 6/05/03 | |
| 2003 Iceland IEAGEO-17 | $3,600.00 | $3,575.00 | 08/11/03 | George Frye | $2,133.76 | 6/05/03 | |
| 2004 Iceland IEAGEO-28 | $300.00 | $275.00 | 02/02/04 | George Frye | $350.07 | 6/06/03 | |
| 2002 Japan IEAGEO-06 | $14,400.00 | $14,400.00 | 12/03/02 | Clifton Carwile | $450.00 | 7/07/03 | |
| 2003 Japan IEAGEO-18 | $14,400.00 | $14,400.00 | 09/08/03 | IGNS | $6,932.40 | 13/09/03 | |
| | | | | IGNS | $12,316.79 | 15/12/03 | |
| | | | | IGNS | $10,719.06 | 5/03/04 | |
| 2004 Japan IEAGEO-34 | $1,200.00 | | | | | | |
| 2002 New Zealand IEAGEO-08 | $3,600.00 | $3,080.00 | 4/10/02 | | | | |
| 2003 New Zealand IEAGEO-20 | $3,600.00 | $2,482.00 | 18/02/04 | | | | |
| 2004 New Zealand IEAGEO-29 | $300.00 | | | | | | |
| 2002 Switzerland IEAGEO-09 | $7,200.00 | $7,200.00 | 11/19/02 | | | | |
| 2003 Switzerland IEAGEO-21 | $7,200.00 | $7,175.00 | 01/21/03 | | | | |
| 2004 Switzerland IEAGEO-35 | $600.00 | | | | | | |
| 2002 Greece IEAGEO-10 | $3,600.00 | | | | | | |
| 2003 Greece IEAGEO-22 | $3,600.00 | | | | | | |
| 2004 Greece IEAGEO-30 | $300.00 | | | | | | |

| SPONSOR/ MEMBER COUNTRY | INVOICE AMOUNT | PAID AMOUNT | DATE PAID | PAYMENTS MADE | AMOUNT | DATE PAID | FUNDS PAID AVAIL |
|---|---|---|---|---|---|---|---|
| 2002 Italy IEAGEO-11 | $7,200.00 | $7,174.50 | 02/24/03 | | | | |
| 2003 Italy IEAGEO-23 | $7,200.00 | $7,200.00 | 10/02/03 | | | | |
| 2004 Italy IEAGEO-36 | $600.00 | | | | | | |
| 2002 Mexico IEAGEO-12 | $3,600.00 | $3,600.00 | 5/11/02 | | | | |
| 2003 Mexico IEAGEO-24 | $3,600.00 | $3,600.00 | 13/11/03 | | | | |
| 2004 Mexico IEAGEO-31 | $300.00 | | | | | | |
| 2002 Australia IEAGEO-13 Revised | $7,200.00 | | | | | | |
| 2003 Australia IEAGEO-25 Revised | $7,200.00 | | | | | | |
| 2004 Australia IEAGEO-37 | $600.00 | | | | | | |
| 2002 United States IEAGEO-00 | $14,400.00 | $14,400.00 | 01/21/02 | | | | |
| 2003 United States IEAGEO-26 | $14,400.00 | $14,400.00 | 01/21/02 | | | | |
| 2004 United States IEAGEO-38 | $1,200.00 | $1,200.00 | | | | | |
| TOTALS | $195,000.00 | $157,520.74 | | | $39,788.81 | | $117,731.93 |

Prepared by: Kerry Walker; (303) 275-4547; e-mail: kerry_walker@nrel.gov

**APPENDIX 8: Annex I Environmental Impacts Report to Paris Meeting**

# IEA GIA Annex I

**ENVIRONMENTAL IMPACTS OF GEOTHERMAL ENERGY DEVELOPMENT**
**2003 ANNUAL REPORT**
***Prepared by Task Leader Chris Bromley (IGNS, Wairakei, New Zealand)***

## Annex 1. Environmental Impacts of Geothermal Energy Development

### 1. Introduction

Environmental effects of energy use are a world-wide concern. Geothermal is generally regarded as a benign energy source. There are, however, some environmental problems associated with its utilization. To further the use of geothermal energy, possible environmental effects need to be clearly identified, and countermeasures devised and adopted to avoid or minimize their impact. Annex I (Task 1) of the GIA was set up to address this. The goals of this Task are: to encourage the sustainable development of geothermal energy resources in an economic and environmentally responsible manner; to quantify any adverse or beneficial impacts that geothermal energy development may have on the environment, and to identify ways of avoiding, remedying or mitigating such adverse effects. The term "development" here is used in a broad sense to encompass not only energy production but also use for social and economic purposes such as tourism.

Plans for the period 2002-2005 include:

- Data collection and analysis of environmental effects;
- Expansion of material presently on the IEA Web site (http://www.iea.org/tech/gia/gia-env.htm) and the organization of lectures and courses to widen the understanding of environmental impacts among technical non-specialists;
- Further publications in journals and conferences, and preparation of an Environmental Manual;
- Appropriate dissemination of information to the general public.

Specific objectives are:

- To study the effects that existing geothermal developments have had on the environment and determine their cause.
- To identify the most likely and serious adverse effects that geothermal developments can have on the environment.
- To identify the development technologies that have proven to be environmentally sound.
- To publish the results of the studies in international journals and present the results at international forums.
- To improve communications between individuals and organizations in different countries, and between different professional groups involved in geothermal development by involvement in collective presentation of the results in international forums.

During 2003, five countries were participating in Annex I: Iceland, Japan, Mexico, New Zealand, and United States of America. The participation of other geothermal countries that may join the IEA GIA agreement in future (particularly Turkey, China, Philippines and Russia) was actively encouraged.

The Operating Agent for Annex I is the Institute of Geological & Nuclear Sciences (IGNS), a Crown Research Institute owned by the New Zealand Government. The Task Leader is Chris Bromley, replacing Dr Trevor Hunt who retired in October 2002.

***2. Subtasks***

The Annex is sub-divided into three Sub-Tasks:

1. Sub-Task A: Impacts on natural features. Leader: Chris Bromley (NZ),
2. Sub-Task B: Discharge and reinjection problems. Leader: Trevor Hunt (NZ)
3. Sub-Task C: Methods of impact mitigation and Environmental Manual . Leader: Chris Bromley (NZ)

## 3. Work performed in 2003

### 3.1 General

Some results of ongoing environmental work have been published in 2003 (see below).
Information about environmental tasks for the Internet website is undergoing further preparation.
Organisation of a further Special Issue of *Geothermics* journal on geothermal environmental matters has continued.

Planned general work tasks in 2003 were:

- *Continue website development to inform the general public about the aims of the Task and results obtained.* Further material was collected, but needs to be processed for the website.
- *Continue collecting material for a further Special Issue of Geothermics journal.* Six draft papers collected and currently under review. Further attempts were made to encourage other authors to submit suitable papers
- *Organize a Session on Environmental Aspects of Geothermal Development at WGC-2005 geothermal conference, and plan another Environmental Short Course for international participants at the Geothermal Institute, Auckland University.* Still under discussion.
- *Provide support for collaborative publications on topical geothermal environmental issues at leading international workshops in New Zealand (NZGW), Philippines (PNOC-EDC), United States (GRC, Stanford), Japan (JGA) and Iceland (IGC-2003).* Papers were produced at NZGW and IGC-2003.
- *Define longer-term R&D needs.* Discussions with geothermal industry representatives (both developers and regulators) have identified new research requirements, particularly in the areas of monitoring $CO_2$ and convective heat flux from naturally steaming ground, classification of the vulnerability of thermal features to reservoir pressure changes, testing of mitigation and remediation methods, and development of bioremediation methods to remove arsenic from waste water discharges..

### 3.2 Sub-Task A: Impacts on Natural Features

This Sub-Task focuses on documenting known impacts of geothermal developments on natural geothermal features such as geysers, hot springs and silica terraces. The aim of this Sub-Task is to provide a sound historical and international basis on which to devise methods to avoid or mitigate the impacts of development on such natural geothermal features which generally have significant cultural and economic value.

Projects which examine the effects of geothermal developments on natural geothermal features occur in Iceland, Japan, New Zealand and United States of America.

### 3.3 Sub-Task B: Discharge and reinjection problems (Sub-Task Leader: Dr Trevor Hunt, Institute of Geological & Nuclear Sciences (Wairakei), New Zealand)

Work in this Sub-Task is focused on identifying and determining methods of overcoming the impacts of geothermal developments on other aspects of the environment. This includes the effects of gas emissions from geothermal power plants, effects of toxic chemicals in waste fluid that is discharged both into the ground and into rivers, effects of ground subsidence, and induced earthquakes.

Projects have been organised which examine the problems associated with disposal of waste geothermal fluids from existing geothermal developments in Iceland, Turkey and New Zealand. The effects of $CO_2$, Hg and $H_2S$ gas emissions in Italy, New Zealand, Iceland and USA, and Mexico are being investigated. The effects, causes and possible remedies for subsidence have been researched in New Zealand and Iceland.

**3.4 Sub-Task C: Methods of impact mitigation and Environmental Manual (Sub-Task Leader: Chris Bromley, Institute of Geological & Nuclear Sciences (Wairakei), New Zealand**

The objective of this Sub-Task is to contribute to the future of geothermal energy development by developing an effective, standard environmental analysis process. Field management strategies that result in improved environmental outcomes will be identified and promoted based on operational experience. Successful mitigation schemes that provide developers and regulators with options for compensating unavoidable effects have also been identified, documented and promoted.

**4. Highlights of Annex Programme Work for 2003**

- Attendance and participation of environmental task participants in the IGC2003 conference in Iceland during September, which facilitated discussions on recent research results, and future plans.
- Development of improved carbon dioxide and heat flux monitoring techniques in areas of steaming ground.
- Improvements in subsidence modelling, which will provide a more reliable basis for future predictions, and possible mitigation, remediation or avoidance strategies.
- Advances in understanding of the processes involved in reducing hydrogen sulphide and mercury emissions, and removing arsenic from waste water.

**5. Work Planned for 2004**

- Continue website development to inform the general public about the aims of the Task and results obtained.
- Continue processing papers for a Special Issue of *Geothermics* journal.
- Provide support for collaborative publications on topical geothermal environmental issues at leading international workshops in New Zealand (NZGW), Philippines (PNOC-EDC), United States (GRC, Stanford), Japan (JGA) and Turkey (WGC2005).
- Provide support and contacts for collaboration between geochemical researchers in Italy, Iceland, USA and New Zealand to study means of more reliably monitoring natural CO2 emissions from thermal areas, in order to quantify the net long-term effects of geothermal development on global warming through CO2 emissions.
- Encourage collaboration between researchers investigating the potential for thermophilic bacteria to reduce toxic chemical contaminants from geothermal waste waters by bio-remediation.

**List of specific ongoing projects by country:**

**Iceland:**
1. Interpretation of TIR imagery over geothermal areas. (Arnason, Kristmannsdottir; *Univ Iceland*).
2. Changes to natural thermal features as a result of development. (Armannsson, Torfason, Kristmannsdottir).
3. Environmental effects of surface water disposal in Iceland. (Thorhallson, Kristmannsdottir).
4. Production-induced ground subsidence and gravity changes in Iceland. Eysteinsson, Kristmannsdotti*r*).

**Japan:**
1. Environmental effects of acidic fumarole gases on rainwater chemistry (Itoi, Kyushu Univ.)
2. Chemical changes in hot spring waters (Oue, Beppu)

**Mexico:**
1. Chemical and isotopic monitoring of atmospheric sulfur associated with $H_2S$ emissions from geothermalsystems in the Mexican Volcanic Belt. (Verma *et al*, *IIE*)

**New Zealand:**
1. Documentation of renewed hydrothermal activity in Rotorua from bore closures (Scott; *IGNS*)
2. Numerical modelling of production-induced changes to hot springs and subsidence. (Hunt, Bromley, *IGNS*)
3. Natural and induced variations to geothermal features. (Bromley, *IGNS*)
4. Quantification of heat and CO2 flux changes from steaming ground (Bromley,Hochstein,Mroczek,Werner *IGNS*)
5. Impacts of developments on thermophyllic vegetation (Sylvester, *Waikato Univ*)
6. Biodiversity and biomineralisation associated with thermophyllic bacteria in waste water from geothermal power plants (Mountain, *IGNS*)

**Turkey:**
1. Environmental changes at Kizildere field (Simsek, *et al*)
2. Removal of boron from Kizildere waters (Badruk *et al*)

**USA:**
1. Abatement of H2S emissions from power plants (various)
2. Injection of CO2 into underground aquifers (various)

**6. Recent Outputs (publications, meetings, workshops)**

Proceedings of International Geothermal Conference (IGC2003), September 2003, Reykjavik, Iceland:

*Andresdottir A,. Sigurdsson O., Gunnarsson T.* "Regulatory framework and preparation of geothermal power plants in Iceland- practical experience and obstacles"

*Armannson H.* "CO2 emission from geothermal power plants"

*Axelsson G, Stefansson V. "*Sustainable management of geothermal resources"

*Bromley C.J* "Practical methods of minimizing or mitigating environmental effects from integrated geothermal developments, examples from New Zealand"

*Gallup D. "*Simultaneous hydrogen sulphide abatement and production of acid for scale control and well stimulation"

*Lawless J. Okada W. Terzaghi S. White P. Gilbert C. "*Two-dimensional subsidence modelling at Wairakei-Tauhara, New Zealand."

*Wetang'ula G. , Snorrason S.* "Ecological risk assessment of Nesjavellir co-generation plant wastewater disposal on Lake Thingvallavatn, SW-Iceland"

Proceedings of the 25th New Zealand Geothermal Workshop, Nov. 2003:

*Brockelsby M* "Issues facing Waikato Regional Council in managing geothermal resources."

*Bromley C. Currie S.* "Analysis of subsidence at Crown Rd Taupo, a consequence of declining groundwater."

*White S. Allis R, Moore J, Chidsey T,Morgan C. GwynnW., Adams M,* "Injection of CO2 into an unconfined aquifer located beneath the Colorado Plateau, Central Utah."

**APPENDIX 9: Annex III Enhanced Geothermal Systems Report to Paris Meeting**

GRE
Institute for
GeoResources and Environment

# Report and Work Plan of Enhanced Geothermal System Task

**Isao Matsunaga**
**National Institute for Advanced Industrial Science and Technology, AIST**
**matsunaga-isao@aist.go.jp**

# Hot Dry Rock Task (Annex III)

- **Object:** Address new and improved technologies, which can be used to artificially simulate a geothermal resource to enable commercial heat extraction.
- **Participating countries and organization :** Australia, Germany, Japan, Switzerland, USA, Italy, and EC.
- **Subtasks**
  - Subtask B: Application of Conventional Geothermal Technology to Hot Dry Rock Technology (Joel Renner, Idaho National Engineering and Environmental Laboratory, USA)
  - Subtask C: Data Acquisition and Processing (Thomas Mégel, Geowatt AG, Switzerland)
  - Subtask D: Reservoir Evaluation (Tsutomu Yamaguchi, AIST, Japan)

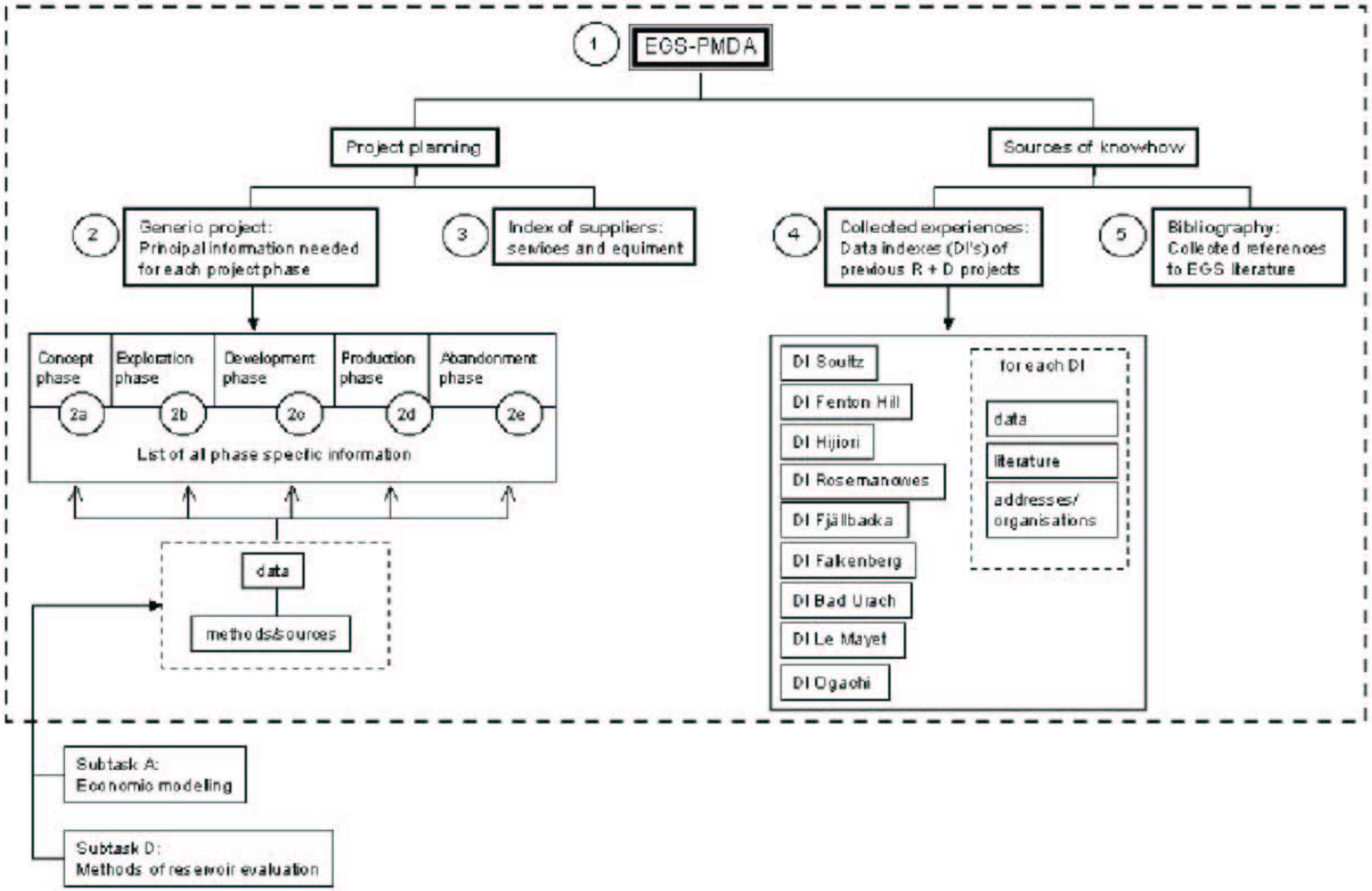
# Subtask B activities

- **U. S. DOE sponsored activities using hydrothermal technology for enhanced geothermal systems. New projects for Subtask B and Subtask D.**
  - **Drilling:** A new down-hole motor was tested for horizontal drilling at The Geysers geothermal filed.
  - **Enhancement of productivity in the Coso geothermal field:** The stress pattern and fractures in anticipation of conducting a MHF.
  - **Shear-wave splitting:** The current phase of work has been completed. Apply in the Coso MHF test.
  - **Injection into depleting steam reservoirs:** Analyze the effect of injection into The Geysers reservoir. Conducted laboratory tests.
  - **Tracers for heat transfer characterization in fractured reservoirs:** Extend the techniques currently available for test analysis.

# Subtask C activities

- **Compiling a Project Management Decision Assistant (PMDA)**
  - Document the experiences of various R&D projects
  - A list of literature references
  - An index of potential suppliers, service operators and consultant
  - An overview of data requirements during planning and construction of a commercial EGS plant.
- **Developing the presentation format of PMDA**
  - A loose-leaf ring binder containing the output of Subtask C

# The structure of the assembly of data collections making up the PMDA



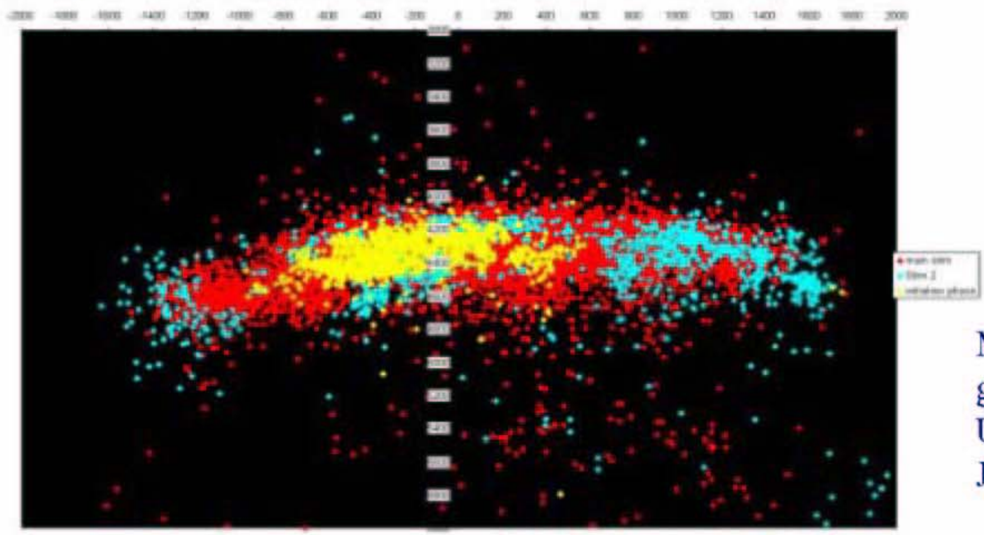
# Subtask D activities

- **Questionnaire**
  - Compile and make clear what kind of methods, techniques and tools are effective for reservoir evaluation, and then establishing the evaluation method that can be applied to develop a new HDR site, through the Internet questionnaire
  - Answers were not sufficient to complete the task
- **Compile and review of R&D activities in Hijiori**
  - AIST compiled major data acquired at Hijiori test site. This data consists of drilling, acoustic emission, hydraulic fracturing, and simulation/simulation
  - The working group has discussed and reviewed technological aspect and problems of overall design, site characterization, reservoir creation, circulation-heat extraction based on the R&D program at Hijiori

# Activities in Australia

## ■ Cooper Basin project

- ➢ The Australia's first geothermal well **Habanero 1** was completed at a depth of 4421m on 18 September. Bottom-hole T ≥ 250ºC.
- ➢ Hydraulic stimulation took place over November and December 2003.
- ➢ The stimulated reservoir is up 3000m by 1000m by 350m thick forming a flat pancake shape



Monitored by a group of Tohoku U., CRIEPI, JAPEX, and AIST

# Activities in participating countries

GRE
Institute for GeoResources and Environment

- **Germany**
  - European HDR Project Soultz
  - GeneSys Project
  - Bad Urach Geothermal Project
  - Resources for Geothermal Power Production in Germany
- **JAPAN**
  - Except for IEA/GIA participation, all R&D fund for EGS from NEDO will be terminated at the end of March
  - Activities will be kept by a small in-house budget of AIST and Science Grants of MEXT to Tohoku University

# Work plan in 2004

- **Subtask B**
  - MHF at the Coso geothermal field.
  - Complete a high temperature acoustic televiewer
  - Two R&D, injection in depleted fields and tracer analysis will be continued
- **Subtask C**
  - Dissemination of the PMDA classifiers and assembling of the feed-back
  - Analyze fee-back, compile the inputs and updating PMDA classifier
- **Subtask D**
  - The report of Hijiori reviews will be published in 2004. The summary of this report will be translated and distributed by a media of CD-ROM.

**APPENDIX 10: Annex IV Deep Geothermal Resources Report to Paris Meeting**

Project Management Organization Jülich Jülich, 01/23/2004
Division Renewable Energies EEN
Dr. Dieter Rathjen

# Annex IV – Deep Geothermal Resources

## 1. Introduction

### a) Brief description

The Deep Geothermal Resources Task was started in 1997 as a four-year international collaborative program under the IEA Geothermal Implementing Agreement (GIA). The continuation of this Annex was approved by the Executive Committee (ExCo) in 2001.

### b) List of participants

Australian National University, Australia
US Department of Energy, USA
ENEL Green Power SpA, Italy
Forschungszentrum Jülich GmbH, Germany
Institute Geolocical & Nuclear Sciences, New Zealand
Instituto de Investigaciones Electricas, Mexico
Philippines (Non-Member)

### c) Operating Agent

Forschungszentrum Jülich GmbH, Germany
Task Leader

| | |
|---|---|
| Andrea Ballouk | in 2003 |
| Dr. Dieter Rathjen | in 2004 |

## 2. Subtask Names

### A) Exploration Technology and Reservoir Engineering

Leader: to be appointed

The objective of subtask A is to carry out collaborative research on exploration technology, including geothermal modelling, geophysical, geological and geochemical explorations and on reservoir engineering, Including reservoir characterization and reservoir modeling. As of December 2001 four countries were participating in Subtask A:
New Zealand, Mexico, Italy and Japan.

### B) Drilling and Logging Technology

Leader: to be appointed

The objective of Subtask B is to carry out collaborative research on drilling and logging technologies, including the reviews of drilling and logging reports of deep geothermal wells, and exchange of information on improvements in drilling and logging tools. There are 13 organizations in the subtask B network, from Australia (1), Italy (2), Japan (4), Mexico (1), USA (4) and Philippines (1).

**C) Reservoir Evaluation**

Leader: to be appointed

No information about the situation in the subtask C.

## 3. Work Performed in 2003

**Australia**

<u>Remarks on the energy policy:</u>

- Australia's industry is currently in a state of flux
- National energy policy is under review what will lead to a restructuring process
- By now it is accepted that renewable energy supply will play an increasing role on a global basis
- HDR geothermal energy is still in the pioneering stage in Australia and is therefore not yet considered "mainstream"
- T he HDR project of Geodynamics, namely "Habanero", is the attempt to enable the production of electricity at lower costs than other mainstream renewable energy resources due to the sufficiently high rock temperatures

<u>Habanero</u> #1

- First deep geothermal well in Australia and the deepest well ever drilled on onshore Australia
- One of the hottest (290 °C) geothermal resources 4,9 km under the Cooper Basin
- Costs: 5,4 Mio. $
- Second well Habanero #2 is planned
- Heat bearing granites were intersected at a depth of 3.675 m
- Next important step is the development of the underground heat exchanger:
- Hydraulic stimulation program will include a short duration high pressure pumping test ("Super Leak-off Test");
    - Stimulation will be done by Halliburton;
    - Water (5.000 m3) will be used as high pressure agent
- The micro seismic acoustic monitoring network is developed:
    - It consists of geophones in four 100 m deep drilling holes in a distance of 5 km from Habanero #1, two close area network sondes in 850 m deep drill holes 2 km away from Habanero 1 and one deep sonde in 2.350 m depth nearby McLeod.
- The progress at Habanero #1 was slower than expected due to the discovery of over-pressures in the target granites:
    - The over-pressured joints in the granites indicates the presence of inter-connected joints over a wide area, which bodes well for the development of an underground heat exchanger, designed to allow the flow of water (and heat energy) between wells;
    - On the other hand the over-pressure leads to unforeseen expenses i. e.
        - Additional safety management etc.
- The 7 inch casing was cemented up to a depth of 4.135 m (467 m below the top of the granite):
    - In consequence the well is now effectively isolated and secured from oil and gas-bearing over-pressure zones present in the overlying sedimentary rocks
- Prior to the setting of the 7 " casing an electrical logging was done:
    - Horizontal joints and fractures were found with positive effect on the development of the horizontal heat exchanger

- Last message of Doone:
- On account of the overpressure it was not possible to maintain the drilling performance as expected. A problem is the movement of the joint planes due to the overpressure.
  - The mud weight must be maintained above 15 ppg.
  - Hundreds of barrels of mud are lose into the granite.
  - As result formation water influx comes back (with the same pressures).
  - This breathing process in the well cannot be controlled.
  - The well has actually a depth of 4320 m, primary target is now 4400 m and an open hole section of 250 m (for hydraulic stimulation).

**USA**

USA does not have any activities in the area of "Deep Geothermal Resources".
Future: Program "enhanced Geothermal Systems" ongoing.

**Italy**

Deep drilling activities in Italy in the past 5 years

| Year | Number of wells with depth 3000÷4000 m | Number of wells with depth > 4000 m |
|---|---|---|
| 1999 | 2 | 1 |
| 2000 | 1 | 2 |
| 2001 | 3 | 1 |
| 2002* | 1 | 1 |
| 2003* | 1 | 1 |
| Total | 8 | 6 |

* In the year 2002 ENEL has also drilled the well **GPK_3** at Soultz-sous-Forêts (France) for the "European HDR/HFR project". The depth of this well is 5092 m.

**New Zealand**

New Zealand didn't report any activities.

**Mexico**

The Instituto de Investigaciones Eléctricas (IIE) worked on:

1. Updating of the conceptual models of the Mexican geothermal fields with deep reservoirs:

- Analysis of data from 42 wells of the Los Humeros geothermal field
- Estimation of temperature and pressure profiles for the unperturbed reservoir fluids
- Development of 1-D and 2-D models

2. The rigorous simulation of heat and mass transport in high temperature reservoirs and especially the simulation of the effect of high no condensable gas concentrations was done with a new developed FORTRAN code based on the equation of state (EOS) for the system H2O-CO2-CH4. The code delivers following possibilities:

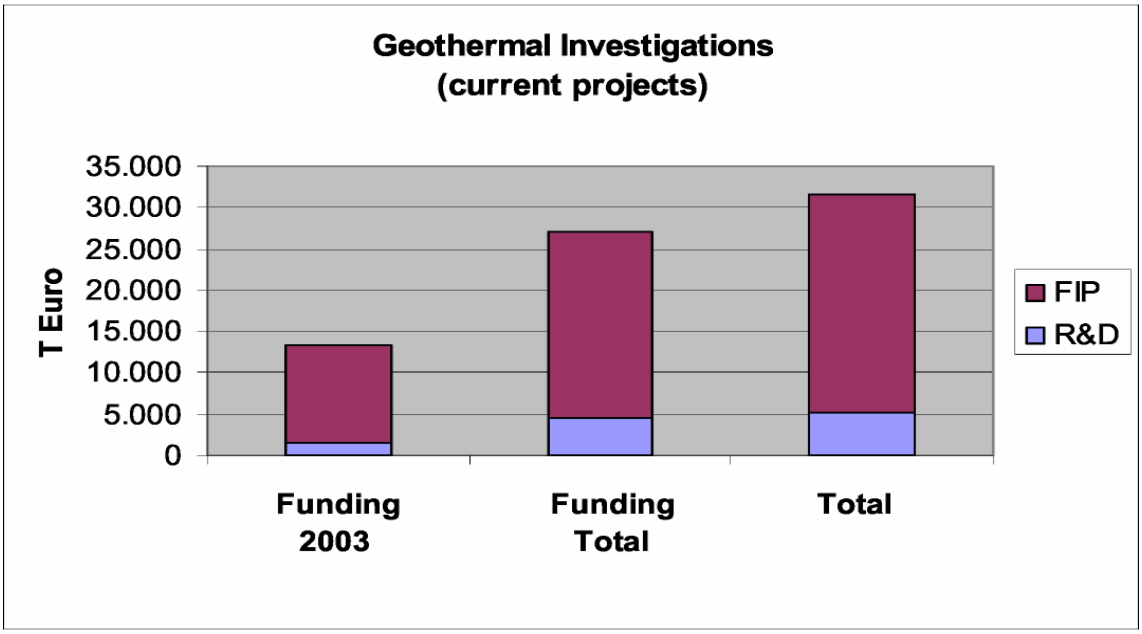
- Mathematically modeling of two-phase, two-component flow (pressure and composition of the gas phase)
- Calculation of phase equilibria and/or molar volumes of H2O and binary mixtures (pressure and temperature);
- Calculation of phase equilibria for ternary mixtures (pressure, temperature, mole fraction of water in gas phase)
- The accuracy of EOS was extensively tested by comparison with experimental data in the range of 50-1000 °C and 0-1000 bar.

**Germany**

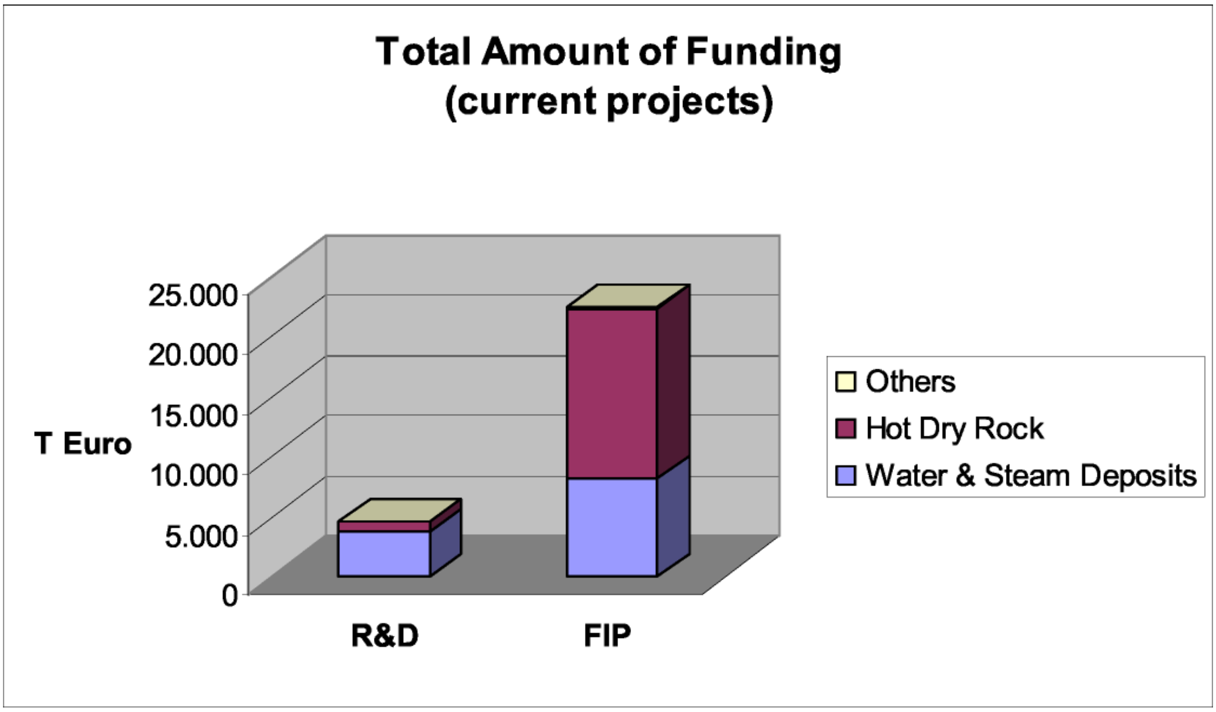
Remarks on the Development of Renewables Energies (government strategy)

**Past:**
Federal Economy Ministry and Federal Environment Ministry were both responsible for funding of renewable energies in the R&D-Program and the Future Investment Program (FIP).

**Present:**
Federal Environment Ministry alone is responsible for funding of renewable energies;
R&D-Program still exits, the decision if the FIP will be continued in the sense that additional money is given will come end of 2003.



**FIP Future Investment Program:**




**Current Projects:**

**1. Bad Urach**

Task: Development, verification and demonstration of location independent HDR concepts for the production of electricity and heat (HDR pilot plant)

Status: First borehole is drilled, stimulation tests are done, production rate increased, an heat exchanger is created in depths between 3300 m and 4200 m, temperature is 170°C.

Costs: 6,7 Mio. Euros Total project costs 6,5 Mio. Euros Funding FEM

**2. Soultz-sous-Forêts (Alsace, France)**

Task: Installation of a scientific geothermal pilot plant (first phase), European project is funded by funding agencies of EC, France and Germany and by the industry.

Status: Three boreholes are drilled, stimulation tests were with very much success, two heat exchangers in two horizons were created, there is no connection between the two exchangers, and temperatures are 165°C and 200°C.

Actually the fourth borehole is drilled without any problems.

Costs: 9,1 Mio. Euros Total project costs (for Germany only) 8,4 Mio. Euros Funding FEM (before FELM) (The costs accumulated over all parties amount to 30 Mio. Euros.)

**<u>Law on Energy Supply (Energie-Einspeise-Gesetz EEG)</u>**

To promote the use of "regenerative electricity" the German government introduced the Law on Energy Supply (from 2000-04-01).

Operating companies that supply the public net with regenerative electricity get a guaranteed minimum payment. See the payment below:

| | |
|---|---|
| Electricity by wind: | 6,1 – 9,0 €-Ct/kWh |
| Electricity by photovoltaic: | 48,1 €-Ct/kWh |
| Electricity by water: | 6,65 – 7,67 €-Ct/kWh |
| Electricity by biomass: | 8,6 – 10,1 €-Ct/kWh |
| Electricity by geothermal: | 7,16 – 8,95 €-Ct/kWh |

## 4. Highlights of Annex IV Programme Work for 2003

No Information

## 5. Work Planned for 2004

The Soultz project is ongoing with phase II. Planned is a time of 3 years (2004–2006) with government aid of the EC, France and Germany (if EC decision regarding funding is positive, still outstanding). Approx. 6,2 Mio. Euros are funded by the German government for the German project partners.

The content of the renewable energy program stays as it is, but the amount of funding will be reduced (for geothermal energy one can assume that an amount of 5 Mio. Euros per year will be allocated ).
International Conference for Renewable Energies, Bonn, Germany, 01.-04.06.2004,

Project Bad Urach: The second borehole is planned and will be drilled soon (depth 4500 m).

## 6. Outputs

International Congress Geothermie, Reykjavik 2003

Australia

- Reports and Announcements (Quarterly Reports) about the geothermal well Habanero 1

Mexico

- An updated conceptual model of the Los Humeros geothermal reservoir (Mexico) J.Volcanol. Geothermal Research 124 (2003) pp. 67-88
- HCO-Ternary: A Fortran code for calculation P-V-T-X properties and liquid vapor equilibria of fluids in the system $H_2O$-$CO_2$-$CH_4$ Computers & Geosciences 29 (2003) pp. 469-485

Germany

- Fachkongress Geothermischer Strom 12.-13.11.2003 in Neustadt-Glewe (only in the German language)
- Kreuter,H.; Harthill,N. Geothermal Power Generation in the Upper Rhine Valley-The Project Offenbach/Pfalz Reykjavik 15.-17.09.2003
- Harthill,N. A New Interpretation of the Rhine Graben Geothermal Region, Siena, 24, 27.09.2003

- Baria,R.; Baumgärtner,J.; Gerard,A. European Hot Dry Rock Programme 2001-2004 2nd Year Report for the EC; October 2003


## 7. Websites Related to Annex IV

**Australia**
www.geodynamics.com
www.geodynamics.com.au/IRM/content/05 investor/05.5.html

**Italy**
http://www.enea.it/com/ingl/default.html

**Mexico**
www.iie.org.mx

**New Zealand**
www.Reap.org.nz

**Germany:**
www.bmu.bund.de
(Federal ministry for the Environment, Nature Conservation and Nuclear Safety)
www.Renewables2004.de
(International Conference for Renewable Energies, Bonn, Germany, 01.-04.06.2004)
www.fz-juelich.de/ptj/
(Forschungszentrum Jülich, Project Management)
www.Soultz.net
(EU-Project in Soultz-sous-Forêt)
www.geothermie.de/badurach2.html
(Project in Bad Urach; only German)

## 8. Authors of the Annex Report


Dipl.-Geol. Andrea Ballouk
Dr. Dieter Rathjen
Forschungszentrum Jülich
Project Management Organization Jülich
Division Renewable Energies EEN
52425 Jülich
Germany

Phon: +49-2461-61-4233
Fax: +49-4261-61-2840
mailto: dieter.rathjen@fz-juelich.de

## APPENDIX 11: Annex VII Advanced Drilling Techniques Report to Paris Meeting

### Minutes of the Meeting of GIA Annex VII, 17 March 2004

### Geothermal Implementing Agreement
### Annex VII Meeting Notes - 17 March 2004

**Introduction**

Interested parties for Annex VII of the IEA Geothermal Implementing Agreement met in Paris on 17 March 2004. The meeting, which had been scheduled for 10:00 am, was rescheduled for 1:00 pm to allow more participants to attend. The following persons attended the meeting, either as a participant in the Annex or as an observer:

Sverrir Thorhallsson, Orkustofnun, Iceland (participant)
Satoshi Kubo, NEDO, Japan (participant)
David Nieva, IIE, Mexico (observer)
Aldo Baldacci, Enel Green Power, Italy (observer)
Jeroen Schuppers, European Commission (participant)
Roy Baria, EEIG, France (observer)
Colin Harvey, IGNS, New Zealand (participant)
Allan Jelacic, DOE, United States (participant)

Five of the six participants in the Annex were represented at the meeting; CFE (Mexico) was unable to send a representative. John Finger, representative of Sandia National Laboratories the Operating Agent for the Annex had retired, and his replacement was unable to attend. Allan Jelacic assumed the role of the Operating Agent and chaired the meeting.

Each attendee provided brief introductory remarks and indicated his organization's interest in geothermal drilling in general and Annex VII in particular.

The principal objectives for the meeting were to update progress on the sub-tasks and to determine further actions needed to maintain progress. A summary of the discussions of the three sub-tasks, points raised in discussion about them, and actions assigned at the meeting are given below. (Note that at the meeting Subtask B was discussed first, but for continuity of these notes the subtasks are presented in their usual order.)

***Subtask A: Compile Geothermal Well Drilling Cost and Performance Information***
***Subtask Leader: The New Energy and Industrial Technology Development Organization (NEDO), Japan.***

Data on well cost are difficult to obtain. Thus far, the cost database only has information for 3 Japanese wells, 3 Mexican wells, and 1 US well. Information for 3 more Mexican wells was in preparation as of the last meeting in Reykjavik, but the current status of that data is unknown.

Well performance data, especially well depth versus drilling time, are much easier to obtain than cost data. The database contains performance information on 27 wells from Iceland. New Zealand may be able to offer data from six wells, and the European Commission can provide data from two wells at Soultz. Sandia has thus far been unsuccessful in obtaining data from U.S. companies.

Satoshi Kubo informed the participants that he would be leaving NEDO at the end of March. Kubo-san had been an active leader of Subtask A, and he will be missed. Apparently, NEDO has not named a replacement, and they intend to withdraw from the Annex. NEDO's departure leaves the question of who will succeed as Subtask Leader. David Nieva indicated that he would consult with CFE about becoming the leader.

***Actions to be taken for Sub-task A:***

David Nieva will determine whether CFE would be willing to serve as Subtask Leader. Action due: 15 April 2004
Allan Jelacic will see if Sandia can assume the leadership should CFE decline.
All Participants will provide additional well data for the database from their available sources. Action due: 01 June 2004
Colin Harvey will contact sources in the Philippines and Indonesia for possible well data from those countries.

***Subtask B**: **Geothermal Drilling Best Practices***
***Co-Subtask Leaders: Comisión Federal de Electridad (CFE), Mexico (Electricity); Orkustofnun – Iceland (Direct use)***

David Nieva, reporting for CFE, indicated that enough material exists to move ahead with a Handbook of best practices, but the subtask needs support in the form of funding for CFE researchers or an outside contractor.

The Handbook will document practices that have been found safe, efficient, and cost-effective in international geothermal drilling. Sverrir Thorhallsson pointed out that Iceland is drilling over 200 meters per day; the Handbook would be quite useful in helping to reduce costs. Colin Harvey indicated that in New Zealand a code of practice exists; the code might serve as a reference for the Handbook.

At the meeting in Reykjavik, two steps were proposed for this subtask: attempt to identify existing literature references that are applicable to various sections of the Handbook, and post the Handbook outline on the GIA web site and solicit comments. No progress was reported on these items.

Two options for completing the Subtask were discussed: (1) compile a set of references that would serve as a guide to the literature of best practices; (2) proceed with the Handbook as originally planned. Option (1) could be accomplished with nominal cost; option (2) would require the establishment of a common fund. No decision was made as to which option to pursue, but the participants felt that references could be obtained without difficulty.

***Actions to be taken for Sub-task B:***

Allan Jelacic will check on the status of posting the Handbook outline on the website. Action due: 15 April 2004
All Participants will provide a list of references to best drilling practices in their countries. Action due: 01 June 2004
Allan Jelacic will provide the name and coordinates of a contact person at Sandia to whom the references should be sent

***Subtask C**: **Advanced Drilling Collaboration***
*Subtask Leader: Sandia National Laboratories - USA*

Sverrir Thorhallsson reported on activities in Iceland that may affect this subtask. The Iceland Deep Drilling Project (IDDP) provides an excellent opportunity for collaboration in the testing of a variety of new tools. He expressed specific interest in memory tools. Besides the IDDP, other wells in Iceland could be used for field testing. Iceland has experience with fracture stimulation and thermal stress cracking by pumping water over a wide range of flow rates. Sverrir reported improvements due to stress cracking in 5 of 6 wells.

Allan Jelacic pointed out that interest in collaboration would depend on the facilities being offered to conduct the collaborative testing. A full description of those facilities would be helpful for a participant to decide on whether to collaborate.

***Actions to be taken for Sub-task C:***

Sverrir Thorhallsson will provide a description of facilities available in Iceland for future collaboration by participants. Action due: 01 May 2004
David Nieva will inquire as to what CFE may be able to offer for collaboration.

**Other Actions Resulting from the Meeting**

Aldo Baldacci will obtain a decision on whether Italy wishes to join the Annex.

**Next Meeting**

No meeting was scheduled, pending a decision on the next ExCo meeting.

## APPENDIX 12: Letter of Invitation to Join and Description of Annex VIII

SAMORKA
Samtök raforku- hita- og vatnsveitna

*__Doone Wyborn__*
Geodynamics Limited
PO Box 2046
Milton
Queensland 4064
AUSTRALIA

Reykjavík 11.03.2004

Dear Sir

The Executive Committee of the I.E.A. Geothermal Implementing Agreement has decided to establish a new annex of Direct Use of Geothermal Energy. The Federation of Icelandic Energy- and Waterworks (Samorka) has agreed to be the Operating Agent for this Annex. The main objectives of the Direct Use Annex are according to the proposal:

(a) define and characterize the direct use applications for geothermal energy, with emphasis on defining barriers to widespread application
(b) identify and promote opportunities for new and innovative applications
(c) define and initiate research to remove barriers, to enhance economics and to promote implementation
(d) test and standardize equipment
(e) develop engineering standards.

In the proposal (see attached document) 5 subtasks are further described.

A kick-off meeting is planed in the autumn either in Iceland or along with Executive Committee Meeting. With this letter your country is encouraged to participate in this Annex, nominate participant, the main subtask you would like emphasis on and state if you would like to undertake a subtask leadership.

On behalf of Samorka
Sincerely

______________________________
Einar Gunnlaugsson

**Orkuveita Reykjavíkur**
einar.gunnlaugsson@or.is
einarg@or.is
Bæjarháls 1
110 Reykjavík
Iceland
tel: +354 516 6680
fax: +354 516 6608
mobile: +354 617 6680

**APPENDIX 13: Description of Annex VIII**

# <u>Draft for Review by the Executive Committee</u>

## Proposal for a new Annex to the Geothermal Implementing Agreement

## Annex VIII: Direct Use of Geothermal Energy

### 1. Definition

Geothermal energy can be used directly as heat for many applications such as building and district heating, industrial process heating, commercial uses such as greenhouse heating and temperature control of water for fish farming, bathing and swimming, and many other uses. Many applications are well developed and are economically viable, while others are challenged by implementation difficulties and unfavorable economics. The Direct Use Annex will address all aspects of the technology with emphasis on improving implementation, reducing costs and enhancing use.

### 2. Objectives

The objectives of the Direct Use Annex are:

(a) define and characterize the direct use applications for geothermal energy, with emphasis on defining barriers to widespread application

(b) identify and promote opportunities for new and innovative applications

(c) define and initiate research to remove barriers, to enhance economics and to promote implementation

(d) test and standardize equipment

(e) develop engineering standards

### 3. Means

The Participants shall share the coordinated work necessary to perform this task:

(1) The proposed objectives of the Direct Use Annex will be achieved by the Participants in the following subtasks:

(a) Subtask A: Resource Characterization - definition of available resources in various Participant countries.

(b) Subtask B: Cost and Performance database - collect, analyze and disseminate the characteristic cost and performance data for installations in Participant countries, with emphasis on establishing a baseline and then validating the improvements from innovative components and better designs.

(c) Subtask C: Barrier and Opportunity Identification - based on subtasks A and B, define the barriers which must be overcome to gain widespread use of geothermal heat for various applications. Define and initiate the needed research activities necessary to take advantage of these opportunities.

(d) Subtask D: Equipment Performance Validation - 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. The testing can be at multiple sites or can be round robin.

(e) Subtask E: Design Configurations and Engineering Standards - develop and characterize standardized designs for various applications, with the goal of minimizing the engineering related to various applications. Develop engineering standards for designs, equipment and controls.

(2) Subtask Leaders: The subtask leader for each of the foregoing Subtasks shall:

(a) coordinate the work performed under that Subtask
(b) assist the Operating Agent in preparing the detailed Program of Work;
(c) direct technical workshops and provide the Operating Agent with written summaries of workshop results; and
(d) edit technical reports resulting from the Subtask, and organize their publication.

Each subtask Leader shall be a Participant with a high level of expertise who undertakes substantial research and development in the field of the Subtask. Each Subtask Leader shall be designated by the Operating Agent with the unanimous approval of all the Participants in the Annex.

**4. Results**

The Primary results of the Direct Use Task will be improvements in systems and equipment, reduction in cost of delivered heat and an increase in the number of direct use applications. Further, enhanced cooperation between the countries and increased exchange of technical and scientific information within the field of direct use of geothermal energy.

Results of this Task shall include:

(a) development of an international database on direct use applications by each of the Participant countries. The database will be based on standardized instruments and reporting techniques.

(b) Reports on state-of-the-art in direct use of geothermal energy, including areas needing improvement.

(c) Cooperative research to accomplish the needed improvements.

(d) Participant reports on the status of research and development in new and improved technology which shall be presented in appropriate journals and meetings.

**5. Time Schedule**

This Annex shall commence on the day the agreement enters into force and shall continue for a period to be determined by the Participants, acting in unanimity. Within the limits of the terms of the Agreement, this Annex may be extended by two or more Participants, acting in the Executive Committee and shall thereafter apply only to those Participants.

## 6. Specific Obligations and Responsibilities of the Participants

In addition to the obligations enumerated in Article 8 of this agreement:

(a) Each Participant shall provide the Operating agent with detailed reports on his country's experience in relevant direct use technologies and applications, and

(b) Each participant shall participate in the editing and review of draft reports on the task.

## 7. Specific Obligations and Responsibilities of the Operating Agent

In addition to the obligations enumerated in articles 4 and 8 of this Agreement, the Operating Agent shall:

(a) Prepare and distribute the results mentioned in paragraph 4 above;

(b) Organize workshops, seminars, conferences and other meetings, as provided in the annual Program of Work for the task;

(c) Prepare the detailed Program of Work for the Task in consultation with the Participants and submit the Program of work for approval by the Executive Committee;

(d) Provide, at least annually, reports to the Executive Committee on the progress and the results of the work performed under the Program of Work;

(e) Provide to the Executive committee, within six months after completion of all work under the Task, a final report for its approval and transmittal to the Agency;

(f) In coordination with the Participants, use the best efforts to avoid duplication with activities of other Tasks of this Agreement and other related programs and projects implemented by or under the auspices of the agency or by other competent bodies;

(g) Provide the Participants with necessary guidelines for the work they carry out, ensuring minimum duplication of effort;

(h) Coordinate the efforts of all Participants and ensure the flow of information within the Task; and

(i) Perform such additional service and actions as may be decided by the Executive Committee, action by unanimity.

## 8. Funding

The collaborative direct use technology research to be carried out under this Annex will involve cost sharing and task sharing. A common fund will be established to cover the special duties of the Operating Agent as presently indicated in the Implementing Agreement (Article 7):

(a) Publications: The cost of publishing the reports and summary assessments as described in paragraph 4 shall be borne by the Operating Agent using common funds.

(b) Database: the cost of maintaining and distributing the cost database described in paragraph 4 shall be borne by the Operating Agent using common funds. The costs associated with collecting the information in the database shall be borne by the respective Participants

(c) Individual Financial Obligations: Each Participant shall bear all costs it incurs in carrying out the Task activities, including reporting and travel expenses.

(d) Task-Sharing: The level of effort to perform the work specified in this Annex is estimated to be no more than one person year per year for each Participant.

**9. Operating Agent**

The Operating Agent shall be The Federation of Icelandic Energy- and Waterworks.

**10. Participants**

The Contracting Parties acting as Participants in this Task are the following:

The Federation of Icelandic Energy- and Waterworks
The United States Department of Energy (DOE, USA)
The New Energy and Industrial Technology Development Organization (NEDO, Japan)
Italy
New Zealand
Others ?

**Reference - Proposed Timeline**

**2003-2004:** Refine the subtasks in a complete work plan, conduct an organizing workshop, form a steering committee of interested Participants. Adopt final subtasks and work plan, obtain agreement from Participants and gain approval from the Executive Committee

**2004-2005:** Complete compilation of the database for resource characterization and the baseline database for cost and performance of current applications in Participant countries.

Organize a special session for presentations of results at the World Geothermal Congress, with reports to the Executive committee.

Define the opportunities for improvement and initiate research to provide the bases for accomplishing the opportunities.

**2006-2007**: Conduct an annual workshop of Participants in association with an important international geothermal meeting. Participants continue research in their respective countries per the work plan. Report results to the Executive Committee.

Prepared by:

**APPENDIX 14: Germany Country Report**

# International Energy Agency (IEA)

# Geothermal Implementing Agreement (GIA)

# 2004

## Progress Report Germany

Author: Dieter Rathjen, Germany

Forschungszentrum Juelich GmbH
Project Management Organization Juelich
Department of Renewable Energies (EEN)
D-52425 Juelich

d.rathjen@fz-juelich.de

## Overview on the Actual Projects

| Location | Operator | Wells | Depth [m] | Temperature [°C] | Volume [$m^3$/h] or Power [W] |
|---|---|---|---|---|---|
| Bad Urach | Stadtwerke Bad Urach (swbu) | 1<br>1 | 4.450<br>2.600 u.c. | 170 | 1 MWel. |
| Bruchsal | Energie- und Wasserversorgung Bruchsal | 1<br>1 | 1.932<br>2.542 | 135 | 50 $m^3$/h |
| Groß Schönebeck | GeoForschungsZentrum Potsdam | 1<br>1 | 4300<br>u.c. | 140 | 25 $m^3$/h<br>MS 75 $m^3$/h |

## Overview on the Actual Projects

| Location | Operator | Wells | Depth [m] | Temperature [°C] | Volume [$m^3$/h] or Power [W] |
|---|---|---|---|---|---|
| Hannover | Bundesanstalt für Geowissenschaften und Rohstoffe & Partner | 1 | 4.000 u.c. | 120 | MS 50 $m^3$/h |
| Neustadt-Glewe | LanGeo / ErdwärmeKraft Neustadt-Glewe | 1<br>1 | 2.455<br>2.335 | 98 | 40-100 $m^3$/h<br>6,75 $MW_{therm}$ |
| Soultz-sous-Forêts (F) | Bundesanstalt für Geowissenschaften und Rohstoffe & inter-/nat. Partner | 1<br>1<br>1<br>1 | 3.590<br>5.000<br>5.000<br>5.000 | 165<br>202<br>198<br>198 | 360 $m^3$/h<br>10,0 $MW_{therm}$ |

Explanations:
u.c. = under construction
n.r. = not realized
MS = Milestone
test= in the first test phase 2 wells, both ~ 3,590 m deep, deliver 10 $MW_{therm}$

## APPENDIX 15: New Zealand Country Report

### Progress Report for New Zealand

Colin Harvey and Chris Bromley
Institute of Geological and Nuclear Sciences Limited, New Zealand.

### 1. Introduction

Geothermal energy continues to play a significant role in both electric power production and direct uses in New Zealand. The NZ government signed the Kyoto Protocol in 2003 and this policy will encourage further development of geothermal.

The drop in natural gas reserves, combined with increases in gas and coal prices and problems with the reliability of hydro resources due to El Nino weather patterns places great emphasis on the development of geothermal resources.

### 2. New Zealand National Policy

#### 2.1 Strategy

Energy supply planning for New Zealand anticipates that geothermal power will at least double over the next 10 years to replace depleting gas supplies. Even more geothermal production will be needed by 2020 to meet increasing demand without resorting to coal, and thereby compromising New Zealand's commitment to the Kyoto Protocol of reducing greenhouse gas emissions. Research objectives are expected to help achieve this goal.

The government has a number of policies in place designed to encourage more development of renewable energy resources, including geothermal. These initiatives include:

- **The National Energy Efficiency and Conservation Strategy (NEECS)**

This strategy aims to improve energy efficiency by 20%, and increase use of renewables, including geothermal, which has been identified as one of the priority sectors.

- **The National Climate Change Policy Package (CCPP)**

This is designed to reduce $CO_2$ emissions by reducing dependence on fossil fuels and placing more emphasis on renewable sources.

- **Sustainable Development Programme of Action for Energy**

One of the outcomes of this programme is to ensure that renewable sources of energy are developed and maximised.

- **Resource Management (Energy and Climate Change) Amendment Bill**

This bill seeks to align national energy objectives (such as those described above) with local government plans. If passed, the bill will require decision makers to have regard to efficient energy use, climate change, and consider the benefits of renewable sources of energy.

- **Development of Geothermal Assets Owned by the Crown**

The Crown has indicated that it would like to develop its geothermal assets further.

- **Energy Outlook to 2025**

This document, published by the Ministry of Economic Development, projects that use of geothermal energy for electricity generation will increase to 600 $MW_e$ by 2025.

## 2.2 Progress Towards National Targets

With at least three power companies currently actively exploring and developing geothermal fields there was some progress towards achieving national targets in 2003.

# 3. Current Status of Geothermal Energy Use

## 3.1 Electricity Generation

The total installed geothermal generating capacity for the 2002 March year was 431$MW_e$, with the total electricity generated amounting to 2,643,888 MWh.

Geothermal drilling during 2003 was conducted by Century Drilling (Wairakei) and Parker Brothers of New Plymouth. Several work-overs of existing wells were carried out. Four new wells in the producing fields of Rotokawa and Mokai were drilled during 2003 with more planned for 2004.

Magneto-telluric surveys were carried out at the Putauaki Project, adjacent to the developed Kawerau field during 2003 to guide the planned 2004 drilling.

The geothermal installed capacity amounted to about 5% of New Zealand's total, with geothermal contributing about 7% of the total generation.

## 3.2 Direct Use

At the Kawerau geothermal field, production of geothermal steam to the local pulp and paper mill has continued at a level of 210 $MW_t$. In addition, surplus steam and hot water have been used to generate electricity. The electrical equivalent of the total geothermal energy output is about 40 $MW_e$. Deep pressure drawdown over the life of the field has been very small and local Maori land owners are intending to expand field development to the east of the existing borefield.

Direct use of heat from reinjection pipelines at Ohaaki geothermal field is presently being used for drying timber at the old lucerne drying facility.

At Wairakei, the Prawn Farm continues to use heat from reinjection pipelines to maintain temperatures in prawn breeding ponds. In addition, a new tourist facility has been established by diverting waste hot water from the drains into the historic *Te Kiri o Hinekai* thermal stream; and by using separated water from the reinjection line to create artificial silica terraces and a geyser.
At Mokai, some of the surplus direct heat is used in glasshouses for horticulture.

In addition, geothermal is used for bathing purposes at many thermal pool establishments.

# 4. Market Development and Stimulation

The costs associated with well drilling are a significant portion of total geothermal development costs. In New Zealand, the average cost of a typical geothermal well, drilled to a depth about 2 km, is about NZ$ 3 M.

The capital costs for geothermal development in New Zealand amount to about US$ 3,200/kW for a 25 $MW_e$ development and about US$ 3,000/kW for a 50 $MW_e$ development.
Operation and maintenance costs are about US$ 93/kW/year (station + steamfield).

## 5. Development Constraints

Environmental regulations are relatively strict but manageable. However, the Resource Management Act has limited the scale of geothermal development, in part due to the costs associated with the long regulatory process.

## 6. Economics

### 6.1 Trends in Geothermal Investment

There has been a very definite increase in geothermal investment in both developed and undeveloped fields.

### 6.2 Trends in the Cost of Energy

The cost of energy continues to rise. The Ministry of Economic Development predicts that the wholesale price of electricity is likely to be in the range of 6.5 NZ cents/kWh (5 US cents/kWh) to 8 NZ cents/kWh (US 6 cents/kWh) for the next 10 years.

## 7. Research Activities

New Zealand's geothermal research budget was about $NZ 2,000,000 (US$ 1,400,000) in 2003. This NZ Government funded research has been focussed into four target areas: deep high-temperature resources, use of low-enthalpy resources, better use of waste geothermal fluids and environmental effects. Special emphasis has been placed on the application of deep MT to exploration/development of geothermal fields. There has also been potential interest in deep geothermal development.

## 8. Geothermal Education

Due to the withdrawal of New Zealand Government funding for the Geothermal Institute in 2002, there were no students enrolled in the diploma course. However, several graduate students were supervised in the MSc and PhD programmes in engineering and geology at the University of Auckland.

Other geothermal educational events included the 25th annual NZ Geothermal Workshop, which was successfully held at Auckland University in November 2003, attracting the usual large number of local and overseas participants; and The New Zealand Geothermal Association's 7th Annual Seminar held in Taupo in June 2003.

## 9. International Cooperative Activities

New Zealand has collaborative research relationships and links with many international agencies including: USGS (USA), KIGAM (South Korea), GSJ (Japan), AEA (Switzerland), University of Utah, Energy and Geoscience Institute (USA), University of Alberta (Canada) and Tohoku University (Japan).

## 10. References

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Thain, I.A., Dunstall, M. (2000) 1995-2000 update on the existing and planned use of geothermal energy for electricity generation and direct use in New Zealand. *Proceedings of the World Geothermal Congress 2000*: 481-489.

White, B.R. (2003) Some recent and current government initiatives related to geothermal energy. *Proceedings of the 25th New Zealand Geothermal Workshop 2003*: 1-8.

## APPENDIX 16: Open Energy Technology Bulletin Document (from Marry Harries White)

**GETTING VALUE FROM THE**

***OPEN ENERGY TECHNOLOGY BULLETIN***

**- Information When and Where it is Needed -**

### What is the *OPEN* Bulletin?

The *OPEN Energy Technology Bulletin* is a service providing **O**n-line **P**ublication of **E**nergy **N**ews. Issued periodically *from* the IEA Secretariat bye-mail, it circulates news of activities, findings, events and publications originating within the " IEA Family"[1], and notably within entities coming under the guidance of the IEA's Committee on Energy Technology Research and Technology (CERT). It is a vehicle to generate broader cross-fertilisation of energy technology information and ideas between different players in the energy policy community, between different energy technology disciplines and among different countries, both within and outside IEA membership. Its goal is to create wider awareness of the results of work carried out within the IEA Family.

### Why the *OPEN* Bulletin format?

According to a survey carried out among members of the IEA energy technology network, some 80% of respondents prefer to receive information of this sort through electronic bulletins offering summaries and links to more detailed material. Conducted as part of the CERT's broader Communication, Information and Publications Strategy *(CW),* this survey sought feedback on how best the IEA Secretariat could respond to the widely felt need *for* speedier, more systematic circulation of information.

### How can Implementing Agreements benefit from the *OPEN Bulletin?*

The *OPEN Energy Technology Bulletin* offers enhanced visibility *for* the programmes and achievements of Implementing Agreements. Such visibility can be crucial if new membership and funding is sought. News of your activities is broadcast spontaneously to other IEA Implementing Agreements and to members of the CERT, the--CERT Working Parties and their expert groups, also to a. world-wide readership outside the IEA Family. Similarly, regular, updated news *from* other Implementing Agreements, and *from* the CERT network in general, is delivered direct to your screen, creating an instantaneous link to a wide range of sources. Implementing Agreements thus benefit also *from* a steady incoming flow of broad-based, recent information on energy technology R&D developments in a variety of sectors.

### How does the *OPEN Bulletin* function?

You can send information items to the *OPEN* team at IEA Headquarters easily, using a dedicated electronic input *form.* This can be found at: http://spider.iea.org/impag/cip/form.htm.(To be reminded of the password, contact: mary.harries@iea.org)._You will be asked to suggest a headline and a summary, and to provide a link giving access to the source material in question. The *OPEN* editor will process items of input and integrate them into a forthcoming issue of the *OPEN Energy*

[1] The term " IEA Family" signifies the network *of* IEA Committees, Working Parties, Implementing Agreements, Expert Groups and subsidiary bodies that represent IEA Member countries and are served by the IEA Secretariat.

*Technology Bulletin.* Each issue will be e-mailed to subscribers both inside and outside the IEA Family. Contributors themselves are responsible for deciding which items of their material should be given wide circulation via the *OPEN* network.

**What information can be contributed?**

Information should be related to energy technology research, development, demonstration and deployment (RDD&D); it should originate from within the IEA Family; and it should be of interest to subscribers in both IEA member countries and non-members of the IEA. The objective is to provide updated information on energy technology status, technology availability and markets- and notably information produced or collected by the IEA Implementing Agreements - as well as RDD&D policy studies and analysis. For example, so long as there is an IEA -connection of some sort, items can report on the following:

- Technology breakthroughs;
- Surveys of technology development status, technology availability, market information;
- Awards for technology achievements (e.g. to industry for energy-efficient appliances); Upcoming events - workshops, conferences, seminars, symposia - in which IEA entities are organisers;
- Proceedings from such events;
- Forthcoming publications, including technical data books; lists of already existing publications; Ongoing projects (Implementing Agreement programmes, links with other national/international projects );
- Initiation of new projects, both within the Implementing Agreements and under other national or international auspices;
- Initiatives by national governments (e.g. partnerships with industry);
- National energy technology programmes and results of studies and analysis.

**How should input be presented?**

To ensure homogeneity, but also to protect ownership and raise the profile of IEA energy technology activities, a few simple guidelines need to be followed. *OPEN Bulletin* contributors from. IEA Implementing Agreements are notably requested to ensure that their source material includes:

- A clear statement of the origin of the material (for example, where applicable, the name of the Implementing Agreement, the number and title of the annex);
- An acknowledgement that the work is the output of an IEA Implementing Agreement, plus a brief description of the IEA’s collaborative programme (for example, "This report was produced by the Implementing Agreement on . . . , which forms part of a programme of international energy technology collaboration, undertaken under the auspices of the IEA.");
- Links, where appropriate, to further relevant information.

Information provided for distribution through the *OPEN Energy Technology Bulletin* will be freely available to any subscriber, in both IEA Member countries and non-Member countries. Implementing Agreements wishing to restrict the availability of reports to participants in their programmes may prefer to provide access to only an abstract or summary through the *OPEN* Bulletin.

The IEA Secretariat welcomes feedback on the service provided by the *OPEN Energy Technology Bulletin,* which has been designed to help meet your information requirements. You can contact the *OPEN* Bulletin's editor: mary.harries@iea.org.

To consult back issues, visit *OPEN's* Archive at:
http://spider.iea.org/impagr/cip/archived bulletins/index.htm.

# APPENDIX 17: Report from the IEA Secretariat (prepared by Peter Tulej)

**11th Executive Committee Meeting**
**of the Geothermal Implementing Agreement**

**Report from the IEA Secretariat**

Prepared by P. Tulej, Desk Officer

This note includes brief information on the developments within the IEA Secretariat and issues related to the Geothermal Implementing Agreement.

**1. Renewable Energy Working Party**

**1.1. Strategy and Mandate 2004-2006**

In November 2003, the CERT approved the REWP Strategy and Mandate for the years 2004-2006. The full text of the document can be obtained from the Desk Officer. Below the major points are presented.

1.1. Mission of the REWP.

REWP's mission is to help achieve steady and significant increases in renewable energy's technological performance and market share by:

- supporting and adding value to its Implementing Agreements;
- collaborating with other public, private, and multilateral organisations;
- helping to educate the various publics on the status and value of renewable energy and the conditions necessary for its market success;
- supporting the leadership efforts of the IEA, its Committees and Working Parties.

1.2. Vision of the REWP.

Through the next several decades, renewable energy technologies, due to their continually improving performance and cost, and growing recognition of their environmental, economic and social benefits, will grow increasingly competitive with traditional energy technologies, so that by the middle of the 21st century, renewable energy, in its various forms, should be supplying half of the world's energy needs.

1.3. Objectives

REWP defined the following four objectives:

(a) <u>Objective 1:</u> Primary source of information and analysis on renewables
(b) <u>Objective 2:</u> Oversight and support of the renewable Implementing Agreements
(c) <u>Objective 3:</u> Identify and describe policies, financial and other market-related factors
(d) <u>Objective 4:</u> Develop and help implement accelerated market deployment

1.4. Strategic focus 2004-2006
The Strategic focus of the REWP in the coming years will concentrate around the following areas:

(a) RE Technology Issues such as buildings, power, heat and transport, and also cost, learning, intermittency and renewable energy scenarios.
(b) Cross-cutting/enabling Technologies such as hydrogen (as a follow-on to the Seminar in 2003), DG, storage and grid interconnection.
(c) Market Mechanisms Analysis: Tradable Renewable Certificates, Green Power, CDM, taxes, externalities.
(d) Organisational and institutional issues including consistency of membership vis-à-vis new challenges, funding for REU projects, visibility within and outside the IEA and institutional structure vis-à-vis new programmes.
(e) RE industry engagement.
(f) Implementing Agreements including co-ordination of REWP and IA Strategies, facilitation of inter-IA co-operation, higher profile collaborative projects with REWP/REU, outreach to new membership, private sponsorship vs. national prerogatives and interaction with Desk Officer and IEA bodies.

**1.2. 45th Meeting of the Renewable Energy Working Party**

The 45 Meeting of the REWP took place on 2-3 March 2004 in Paris. The main points of the meeting included:

- Review of Public Seminar on Distributed Generation on 1 March 2004.
- Presentation by Vice Chairman Bob Dixon of the activities and expected deliverables of the Hydrogen Coordination Group.
- A presentation on hydrogen produced from renewable resources by Dr. A. Bauen of Imperial College.
- A discussion about IA issues and possible areas of collaboration. These issues included the end-of-term process and schedule for 2004 – 2006, the proposed R&D Seminar at REWP 47, and a review of possible topics for collaborative action.
- Discussion of a new Implementing Agreement for Renewable Energy Technology Deployment.
- Review of Hydrogen Implementing Agreement End of Term Report.
- An update of the preparations the 2004 International Conference for Renewable Energies in Bonn (1-4 June) and discussion of options for IEA involvement.
- Status of Renewable Energy Unit projects.
- Preparations for WEO 2004 and ETP Scenarios.
- REWP leadership update.

<u>Information</u>
For more details please contact the Desk Officer.

**2. International Conference for Renewable Energies, Bonn, 1-4 June 2004**

From June 1 to 4, 2004, Germany will host the International Conference for Renewable Energies, as announced at the World Summit on Sustainable Development in September 2002 in Johannesburg. The conference is expected to generate further impetus for the global development of renewable energy. It is also expected to add to the momentum of the coalition of like-minded countries for promotion of renewable energy known as the Johannesburg Renewable Energy Coalition (JREC).

The conference will address the following main themes:
* Financing instruments and market development
* Formation of enabling political framework conditions
* Capacity building (education, research, networks, cooperation, etc.)

The IEA is considering organising a side event during the conference to highlight IEA activities in renewables. On the part of the Secretariat, the IEA/REU would present the findings of the Policies and Measures Analysis Project which provides analysis of the efficacy of various policies and measures being used to stimulate renewable energy markets in IEA Member countries. In addition, the IEA/REU is planning to launch a new database on renewable energy policies and measures in the JREC countries. We would like to invite the Renewable Energy Implementing Agreements to participate in this side event, as well. We believe that the Bonn Conference would be a good venue to present the activities of the IAs, and to invite the participation of IEA Non-Member Countries and the private sector in those activities, according to the new rules and procedures.

<u>Action</u>
If GIA is interested in making a presentation at this planned IEA side event, please communicate with your Desk Officer.

**3. R&D Seminar at REWP 47 (Spring 2005)**

One of the priority projects identified by the REWP and the Implementing Agreements is The Report on Renewable Energy R&D Priorities that would define with mid to long term R&D priorities for renewable energy. In collaboration with RE Implementing Agreements, IEA/REU intends to explore R&D needs in the domain of renewable energy. The IEA/REU proposes a 1 day seminar with a working title “Reaching Towards Large Scale: Electricity, Hydrogen, Fuels and Heat” on the margins of the 47th REWP meeting.

Annex a presents a tentative programme of the Seminar.

<u>Action</u>
GIA is requested to communicate to the IEA Secretariat interest in attending and speaking at the Seminar. GIA is also requested to consider the tentative programme and provide comments or suggestions as to the contents of the sessions

**4. New potential collaborative projects IA-REWP-REU**

**4.1. Renewable Energy Statistics**

Efforts will be made to improve the quality and coverage of renewable energy statistics in collaboration with the IEA Energy Statistics Division. This effort will focus on understanding and reconciling the current data, comparing differing sources as cross-validation and looking at national data collection to see if best practice can be identified.

<u>Action</u>
As in previous years, IEA/REU will communicate with your Implementing Agreement on the upcoming Renewables Information 2004.

### 4.2. Renewables Scenarios Analysis

Scenarios for renewable energy will be developed to provide information on renewables' costs and benefits at different levels of market growth as well as about the implications of resulting energy portfolios. One of the threshold issues regarding renewables is a cost/benefit understanding of the investment needed to bring renewables into more widespread use, and the implications for fossil fuel demand, and potential reduced emissions. Several scenarios will be developed based on different investment assumptions.

Principal sources of data for the analysis include the Energy Technology Perspectives analysis (ETP) and renewable energy Implementing Agreements (IAs). The effort will extend to non-Member Countries, resulting in a global renewables scenario.

Action
The Secretariat has already requested Implementing Agreements to review the initial ETP information. The Secretariat would like to thank GIA for provided input to this project.

### 4.3. Distributed Energy Resources (DER)

The Secretariat will work on the project where recent examples of the treatment of renewables in the context of distributed generation in liberalised markets in IEA Member countries will be reviewed and options to treat renewables in will be developed. The objective is to review the treatment of distributed renewables in electricity network organisation in selected OECD Member Countries and to identify "best practice" distributed generation rules that recognise the specific technical characteristics of distributed renewable energy resources. The study will take into account the results of the IEA seminar on distributed generation and its role.

The study will explore novel technological approaches in the areas such as electricity generation by DER, the role of hydrogen, and the potential DER contribution to the creation of sustainable energy markets in collaboration with the Renewable Energy Implementing Agreements.

Action
The Secretariat will be seeking contributions from all IAs.

### 4.4. Analysis of Renewable Energy Policies and Measures

Further work on analysis of policies and measures will be undertaken after additional statistics and data has been compiled. An assessment and analysis of renewable energy policies and measures will provide insights as to the cost-effectiveness of various types of policies.

Action
The Secretariat may be soliciting from the GIA their input on technologies.

### 4.5. Renewable Constraints: Seasonal Fluctuations and Intermittency

Electricity network organisation, regulation and pricing are undergoing rapid change, particularly in liberalised markets. In many cases, this has led to new conditions for feeding electricity from renewable energies into the grid. Recent examples of the treatment of renewables in IEA countries will be reviewed, and options to treat renewables will be developed. Implications for the operation and technical design of electric grid in the future will be investigated. The role of back-up power and storage will also be addressed.

Action
GIA will be contacted and requested to provide technology information.

### 4.6. Energy Security Implications of Renewables

Renewable energy is considered to contribute to energy security to a certain extent: (i) it is domestic, in the sense that every IEA country hosts some potential cost-effective resources, and (ii) it is frequently deployed in a distributed modality, making it a less likely target of terrorists. The Secretariat proposes to assess these factors, and other energy security aspects and implications of renewables, as part of a more robust, diversified portfolio of energy resources.

Action
The Secretariat will be seeking input from the GIA into the report.

### 4.7. Highlights of Implementing Agreements

In 2004 another IEA publication Highlights on IAs is planned.

Action
The Secretariat will be requesting the GIA to provide their valuable input.

### 4.8. The IEA OPEN Energy Technology Bulletin

The Bulletin now has 4,000 subscribers world-wide. The Secretariat would like to report on news from IEA Implementing Agreements. Examples: announcements and proceedings of workshops, conferences (as long as your programme is an organiser), publications (especially downloadable free of charge), technology status reports, awards, new annexes.

IEA/REU supports the renewable energy IAs in providing information items to the OPEN team and is encouraging using OPEN Bulletin as an information tool for the IAs.

Action
GIA is requested to consider providing information to the OPEN Bulletin. It is also possible to have a special issue of the Bulletin on geothermal energy. For details please contact the Desk Officer.

## 5. Ongoing Projects

### 5.1. Renewable Hydrogen

The objective of the project is to provide comprehensive analysis of technological feasibility, cost level, and likely market entry time scale of various renewable energy technologies to produce hydrogen and to identify the renewable technologies and R&D needs specific to them to contribute to accomplish large scale hydrogen supply in the most ambitious timeframe.

The project will investigate and report on the long-term potential for renewables to generate hydrogen on a cost-competitive basis, and the technical solutions that might soonest become available.

The activities include desk research on technological and cost feasibility, desk research and interaction with Implementing Agreements on R&D needs specific to renewable hydrogen supply and verification of the findings with the relevant IAs.

Action
GIA is requested to consider providing support to this project by sharing information and experience with the IEA Secretariat and by verifying the reports. Please contact the Desk Officer for more details and to communicate your interest in this project.

**5.2. Implications of Intermittency on Renewable Energy Market Potential**

The project will assess the degree to which renewable energy resources are limited by their intermittency, and technical options and regulatory strategies to overcome them. The resulting paper will address the R&D needs for storage, interconnection and grid controls, and the degree to which these options can enlarge the ultimate market potential.

The report will focus on the significance of the issue as a limiting factor to market potential, costs associated with overcoming it through technical solutions and regulatory strategies. A goal will be to provide input to scenarios that are being elaborated by the IEA.

Action
GIA is requested to consider providing support to this project by sharing information and experience with the IEA Secretariat and by verifying the reports. Please contact the Desk Officer for more details and to communicate your interest in this project.

**6. Use of the IEA Logo**

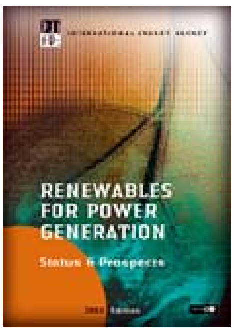
The Implementing Agreements are welcome to use their own logo for events (such as workshops, conferences, seminars etc.) that they are supporting. However, the IEA Office of the Legal Counsel would like to remind all interested parties that the use of the IEA logo is restricted.

The IEA logo must not be used without proper authorisation from the IEA Secretariat. The Secretariat will however entertain solicitations from interested Implementing Agreements to use the IEA logo for the events they are supporting.

Information
For more details please contact the Desk Officer.

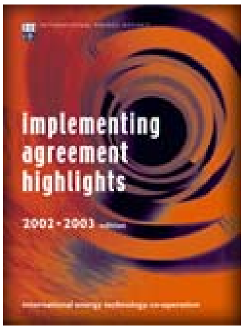
**7. IEA Publications**

**7.1. Renewable Technologies for the Power Industry**




This book assesses the outlook for six leading renewable energy technologies: small hydro power, solar photovoltaic, concentrating solar power, biopower, geothermal power and wind power. It provides an update on current costs and analyses what future costs might be under different market scenarios. It looks at how these rapidly evolving technologies and their markets are developing, how the technologies complement each other and how they fit within the overall energy sector. It also identifies key areas for further research and development.

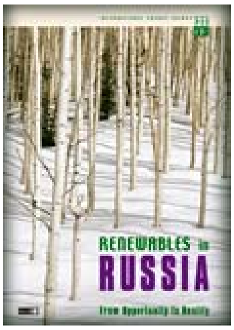
### 7.2. Highlights of Implementing Agreements




This publication provides information on results and achievements of the IEA Implementing Agreements in 2002/2003. Almost three decades of experience have shown that these international collaborative projects are contributing significantly to achieving faster technological progress at lower cost. Co-operation of this sort eliminates technological risks and duplication of effort, while offering further benefits like swifter expansion of the knowledge base and easier harmonisation of standards.

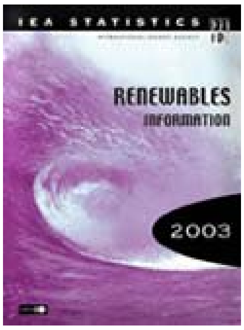
The Secretariat wishes to thank all the Implementing Agreements for their valuable input.

### 7.3. Opportunities for Renewable Energy in Russia




The report defines the potential contribution of RE in a more open, market-based Russia. It shows areas where policy makers can adapt energy policy and legislation in order to fully capture the benefits of renewable energy. The report shows that Russia’s RE potential is enormous and is spread over many resources: wind; geothermal; biomass; hydro; and solar energy. It demonstrates market applications that can yield immediate economic returns with very small initial investments.

### 7.4. Renewables Information 2003




This annual publication of comprehensive information on the use of renewables and waste in the OECD region was first published in 2002. The report addresses a need for development of reliable statistics on this energy form. Support for increasing renewable energy's role in the energy sector has never been greater, and this publication seeks to increase understanding of the current market and trends over recent years. The report contains analysis of renewables and waste energy supply, electricity production and installed electricity generating capacity in OECD countries.

Information
The publication is available free of charge in PDF format on the or in a paper copy from the Desk Officer.

### 8. New Staff at the IEA Secretariat.

Mr. Antonio Pflüger has been appointed Head of the Energy Technology Collaboration Division of the International Energy Agency. Mr. Pflüger, a German national, has been Head of the Energy and Environment Division in Germany's Federal Ministry of Economics and Labour since 1999. He has been with the Ministry since 1990, where he has held various positions.  He was also co-spokesperson for the Ministry in 1992-1993.  Prior to that, he worked on research and development projects for energy conservation in the Federal Ministry for Research and Technology's Division for Renewable Energies and Rational Use of Energy.  He has written a number of publications and articles on issues such as combined heat and power, wind energy, and sustainable energy supply.

Ms Carrie Pottinger, an American national, was appointed to the post of the Energy Technology Co-ordinator in the Office of Energy Efficiency, Technology and R&D.  Ms Pottinger's principal duties include co-ordination relating to the IEA Implementing Agreements, overseeing the IEA Implementing Agreements database and liaison between IEA Desk Officers.  Ms Pottinger was previously responsible for collecting and publishing energy statistics, including RD&D budgets, short- and long-term forecasts, monthly/annual oil supply and demand, basic energy statistics/balances, and energy prices and taxes.

Mr. Timur Gül, a German national, joined the Renewable Energy Unit in 2003 and is doing research work on the projects such as "Renewable Hydrogen" and "Implications of Intermittency on Renewable Energy Market Potential".  Mr Gül is a graduate of the Stuttgart University where he specialised in Energy, Air Pollution and Flue Gas Cleaning, Biological and Chemical Process Engineering.  He will soon graduate in Environmental Engineering and Sustainable Infrastructure from the Royal Institute of Science and Technology in Stockholm, Sweden, as well.

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*For more detailed information regarding the IEA Secretariat, CERT, Working Parties, upcoming events and publications please contact your Desk Officer.*

**<u>Annex 1</u>**

**Proposed Programme for a**
**Joint Seminar of the IEA Renewable Energy Working Party and**
**IEA Renewable Energy and Hydrogen Implementing Agreements on R&D Priorities**

**"Towards Large Scale Renewables"**

| | |
|---|---|
| 9.30 | Welcome Address |
| 9.45 | **Introduction and Objectives of the Seminar**<br>Roberto Vigotti, REWP Chair |
| 10.00 | **Session 1**<br>**Setting the Context and the Vision**<br><br>Session 1 is to provide context for the seminar and provide a critical look at technological and economic resource potential for renewable energy technologies by 2050.<br><br>The first speaker will present a vision of renewable energy technologies market share and cost in 2050, including the hydrogen vector and a distributed and decentralised energy infrastructure.<br><br>The second speaker will present an industry vision of practicalities of the transformation of the energy systems by 2050.<br><br>The third speaker will present a vision policy and regulatory framework aspects of the paradigm shift which is required to meet the 50% share of renewables in 2050.<br><br>A discussion will follow.<br><br>Moderator:<br>Rapporteur:<br><br>Speakers: (15 minutes per presentation, discussion 15 minutes)<br>TBA<br>TBA (industry)<br>TBA (policy think-tank) |
| 11.00 | Break |
| 11.30 | **Session 2**<br>**Electricity from Renewables - Technology Path for Distributed and Decentralised Generation**<br><br>Session 2 is to present and discuss of the potential and application of selected renewable energy technologies in electricity generation and the R&D needs to meet the 2050 vision.<br><br>The speakers will present ultimate and economically-recoverable resource potential, current and future costs, technology R&D challenges and priorities for medium and long term work for large scale integration of renewable energy, |

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| | especially through distributed and decentralised generation modalities.<br>Moderator:<br>Rapporteur:<br><br>Speakers: (15 minutes per presentation, discussion 15 minutes)<br>Geothermal<br>Hydropower<br>Ocean Energy<br>Solar Photovoltaics<br>Wind Energy |
| 13.00 | Lunch |
| 14.30 | **Session 3**<br><br>**Heat and Fuels from Renewables - Technology Path for Production of Heat and Fuels, including Hydrogen**<br><br>Session 3 is to present and discuss of the potential and application of selected renewable energy technologies in production of heat and fuels and the R&D needs to meet the 2050 vision.<br><br>The speakers will present technical and economic potential of production of heat and fuels, including hydrogen by means of renewable energy, focusing on both the "fast-track" options for near-term, cost-competitiveness, as well as the options that are only possible in the mid to longer term. The speakers will outline the current state of R&D and will outline the needs, priorities and challenges to create a renewable option to contribute to an emerging infrastructure.<br><br>Moderator:<br>Rapporteur:<br><br>Speakers: (15 minutes per presentation, discussion 15 minutes)<br>Bioenergy<br>Concentrating Solar Power and Chemical Energy Systems<br>Hydrogen<br>Solar Heating and Cooling |
| 15.45 | Break |
| 16.15 | **Rapporteurs Panel**<br>Rapporteurs will provide summaries of the sessions and will draw key conclusions and recommendations for future R&D collaborative work and its priorities.<br><br>Consultant:<br>Rapporteur 1:<br>Rapporteur 2:<br>Rapporteur 3: |
| 16.45 | **Plenary Discussion**<br>Following the Panel Discussion, the floor will be open to the audience.<br>Moderator: |
| 17.30 | **Conclusions and Next Steps**<br>Roberto Vigotti, REWP Chair |

**APPENDIX 18: E-mail re. Greece's Withdrawal from the GIA**

From: "Costas Karytsas" <kkari@cres.gr>

To: "David Nieva" <dnieva@iie.org.mx>

Cc: "Ladsi Rybach" <rybach@geowatt.ch>; "Mike Mongillo" <mongillom@reap.org.nz>

Subject: GREECE WITHDRAWING FROM GIA

Date: Tuesday, 24 February 2004 22:17

Dear Sirs,

This is to inform you that, since GREECE is not in agreement, in principle, with the constitution of a Common Fund for the Geothermal Implementing Agreement (GIA) of the IEA, GREECE is obliged to withdraw from the GIA of the IEA.

Sincerely yours,

Dr. C. Karytsas
CRES-GREECE