IGA NEWS

Newsletter of the International Geothermal Association

Quarterly No. 76

IGA ACTIVITIES

Message from the President

Ladsi Rybach

Dear IGA member

This is the sixth message from your President.

In my function as IGA President I am frequently invited to give presentations, keynote lectures and the like. Since my last message such events have taken place in Trieste/Italy (ICS-UNIDO Workshop, 10-12 December 2008), Cape Town/South Africa (IASPEI 2009 General Assembly, 11-16 January), Istanbul/Turkey (WB GeoFund-IGA Workshop, 16-19 February), Offenburg/Germany (GeoTHERM 2009 Conference, 5-6 March - supported by IGA), and Freiburg/Germany (5th International Geothermal Conference, 27-28 April - also supported by IGA). In addition, two joint presentations with Beata Kepinksa (delivered by her) were given at the UNFCC COP 14 Conference in Poznan/Poland on 8 and 9 December 2008.

The joint IEA GIA-IGA Workshop "Geothermal Energy - Its Global Development Potential & Contribution to Mitigation of Climate Change" was particularly interesting. This Workshop took place in Madrid/Spain on 5-6 May and aimed to discuss thoroughly the future development and deployment of geothermal energy in the sense of an opinion building process, thereby contributing to the Geothermal Chapter of the planned IPCC Special Renewable Energy Report - to be written by GIA and IGA experts. Most IGA BoD members attended the Workshop; the presentations and the conclusions will soon be available through the IEA GIA website www.iea-gia.org.

The IGA Committee meetings and the 47th BoD meeting followed immediately on 7 and 8 May. All meetings in Madrid were generously arranged and hosted by APPA (the Spanish Renewable Energy Association) in cooperation with IDEA (Spanish Institute for Energy Diversification and Saving). The Committees worked intensively and efficiently and came to the BoD with clear suggestions that the BoD discussed and accepted. To sum up just the key items: the Membership Committee reported that 14 Affiliation Agreements are up for renewal. Membership Committee Chairman Roland Horne, assisted by IGA Executive Director Arni Ragnarsson, are now in the process of renewing the agreements. Treasurer Colin Harvey presented the 2009 budget, which was approved. Arni Ragnarsson reported on the completion of the deliverables based on the World Bank-IGA contract.

Contents

Education Committee Chairman Horst Rueter, along with Gordon Bloomquist and Arni Ragnarsson, and assisted by the Finance Committee, are now preparing a new contract with the World Bank, especially in the fields of GeoFund and ARGEO. The new contract will need a special handling instrument; for this purpose, the IGA Service Co. Ltd. will be established. Devising an appropriate management structure and coming up with a sensible business plan as well as a draft budget will be key to the successful establishment of this new body.

Another key agenda item at the Board meeting was the presentation of bidders to host World Geothermal Congress 2015. There are three comparably well-qualified candidate venues: Reykjavik/Iceland, Munich/Germany, and Melbourne/Australia. The Program & Planning Committee under Miklos Antics is working intensively on evaluation of the proposals and on the selection process.

The next IGA Committee meetings have been scheduled for 28 October, with the 48th BoD meeting and the Annual General Meeting 2009 on 29 October, to take place in El Salvador, at a venue near the Comalapa International Airport.

Finally the ongoing preparations of WGC2010 were presented by OC Secretary General Surya Darma. Short Courses, Field Trips, etc., are now all set; the Conference website (www.wgc2010.org) presents all the necessary information such as the 2nd Announcement, Exhibitors' and Sponsors' Manuals, and Fellowship Application Forms. Over 1,300 Abstracts have been submitted for the Technical Program; the deadline for draft papers is 31 May and for final papers 31 October.

The entire IGA membership now needs to steam up for WGC2010! I look forward to continuing to work with you in our joint effort to promote geothermal and thank you all for your support.

UPCOMING EVENTS

GEA/GHC Direct Use / Small Power Finance Workshop, 12-13 August 2009, Klamath Falls, Oregon, USA. Contact: Kathy Kent Kathy@geoenergy.org

WPRB, IGA/GCES Joint Geothermal Workshop, Chengdu, Sichuan, China, 19-22 September 2009. Check the IGA website www.geothermal-energy.org

RENEXPO 2009, Augburg, Germany, 24-27 September 2009. Website: www.renexpo.de

GRC 2009 Annual Meeting, Reno, NV, USA, 4-7 October 2009. Website: www.geothermal.org

Renewable Energy World Asia Conference & Exhibition 2009, 7-9 October 2009, Bangkok, Thailand. Website: www.renewableenergyworld-asia.com

Renewable Energy Indonesia 2009 Trade Show, 14-17 October 2009, Jakarta, Indonesia. Website: http://www.allworldexhibitions.com/images/shows/2009 0174_Renewable Energy 2009 Brochure.pdf

2009 GSA Annual Meeting-Session T32 "Survey of International Geothermal Development 2009", 18-21 October 2009, Portland, Oregon, USA. Website: www.geosociety.org/meetings/2009/

GTR-H: International Geothermal Conference, 27-29 October 2009, Dublin, Ireland. Contact: rpasquqli@csa.ie

World Energy Engineering Congress (WEEC), 4-6 November 2009, Washington, DC, USA. Website: www.energycongress.com

2009 Australian Geothermal Energy Conference, 10-13 November 2009, Brisbane, Australia. Website: www.impactenviro.com/au/ausgeothermal/

31st New Zealand Geothermal Workshop, Auckland, New Zealand, 16-17 November 2009. Website: www.science.auckland.ac.nz/uoa7science/about/research/gei/workshop.cfm

Der Geothermiekongress 2009, 17-19 November, Bochum. Germany. Contact: info@geothermie.de

35th Stanford Workshop on Geothermal Reservoir Engineering, 1-3 February 2010, Stanford, California, USA. Website: http://pangea.stanford.edu/ERE/research/geoth/conference/workshop.html

World Geothermal Congress 2010, Bali, Indonesia, 25-29 April 2010. Website: www.wgc2010.org

Participants in the 47th IGA Board Meeting, Madrid 2009

EUROPE

Integrated geophysical exploration method tested at different geothermal sites: The European I-GET project

D. Bruhn, E. Huenges, A. Spalek, H. Milsch, G. Muñoz (International Center for Geothermal Research at GFZ, Potsdam, Germany); A. Fiordelisi (Enel Produzione, Pisa, Italy); A. Manzella (Istituto di Geoscienze e Georisorse, Pisa, Italy); A. Mazzotti (University of Pisa, Italy); H. Fabriol (BRGM, Orléans, France); K. Árnason (Iceland Geosurvey/ÍSOR, Reykjavík, Iceland);W. Bujakowski (Polish Academy of Science, Krakow, Poland); and other members of the the I-GET consortium

Since the mining cost (exploration and drilling) to access geothermal resources often represents over 60% of the total investment, a reduction in these costs would increase the competitiveness of geothermal energy significantly. This goal can be achieved if the presence of fluids inside the natural and/or Enhanced Geothermal Systems (EGS) could be detected before any drilling operation.

This was the focus of the European project I-GET (Integrated Geophysical Exploration Technologies for deep fractured geothermal systems), co-funded by the European Commission within the 6th Framework Programme for Research and Technological Development. Eleven partners from 6 European countries (see table below) joined forces, coordinated by GFZ, with the objective of developing a methodology to improve the detection, prior to drilling, of fluid-bearing zones in naturally and/or artificially fractured geothermal reservoirs.

The basic idea of the project I-GET was to integrate data and measurements from several existing geophysical methods into one final reservoir model. This approach was tested in four European geothermal systems with different geological and thermodynamic reservoir characteristics: two high enthalpy (metamorphic rocks in Travale, Italy, and volcanic rocks in Hengill, Iceland), and two lower enthalpy geothermal systems (deep sedimentary rocks in Gross Schönebeck, Germany, and Skierniewice, Poland). All data acquired in both field measurements and laboratory tests have been integrated to construct the static and dynamic three-dimensional model of the geothermal reservoirs. The input of the results of new geophysical prospecting into reservoir modelling was a crucial test of the quality of the new exploration method.

At the end of the project, a Final Conference was organised at GFZ Potsdam in February 2009, where the project results were presented to an international audience from science and industry. In addition, keynote presentations on the state of the art in geophysical exploration methods (active and passive seismic and MT) for geothermal resources were presented, as well as case studies from all over the world.

One hundred and twenty participants from 20 countries came to Potsdam to take part in the I-GET Final Conference at GFZ, February 2009.

120 participants from 20 countries came to Potsdam to take part in the I-GET Final Conference at GFZ, February 2009

From the data and the experience collected within the project, a best practice guide for geothermal exploration of deep geothermal reservoirs (with or without surface manifestations) has been developed. The experience presented in the best practice guide is based on a collection of European data existing prior to and collected during the project.

I-GET Factsheet	
Partners	**Country**
GFZ Potsdam (co-ordinator)	Germany
Enel Produzione	Italy
BRGM	France
CNR-IGG	Italy
ÍSOR	Iceland
Università di Pisa	Italy
CRES	Greece
Freie Universität Berlin	Germany
Geowatt AG	Switzerland
GTN Germany	Germany
Polish Acdemy of Science (PAS)	Poland
Funding period	Nov. 2005-April 2009
Budget	3.8 Mio. €
EC contribution	2.7 Mio. €
www.i-get.it	

Experiences from 4 representative test sites

At Travale, an existing 3-D seismic dataset was reprocessed for a joint interpretation with all the available geological, geophysical, and well logging data. Besides an accurate reconstruction of the structural and geological model, the interpretation was aimed at identifying any seismic signal possibly associated with fractured systems inside the deep geothermal reservoir. To this end, the detection of the post-stack high amplitude signals and pre-stack AVO analysis brought important information for locating drilling targets. In addition, azimuthal analysis of the amplitudes of seismic signals reflected from the geothermal targets provided further information about preferred fracture orientation. These measurements visualized a distinct reflector as a potential target horizon, which coincided with a productive zone containing dry steam.

Moreover, new and old magnetotelluric (MT) data were processed and modelled, taking into account geological and seismic information. Modelling results indicated a main conductive anomaly in some areas of Travale at the depth of the geothermal reservoir, but with no clear relation to mineralogy, lithology and seismic parameters, and only partially related to the evidence of more productive areas. The occurrence of brine partially in a liquid phase inside the pore network was considered, and research is underway.

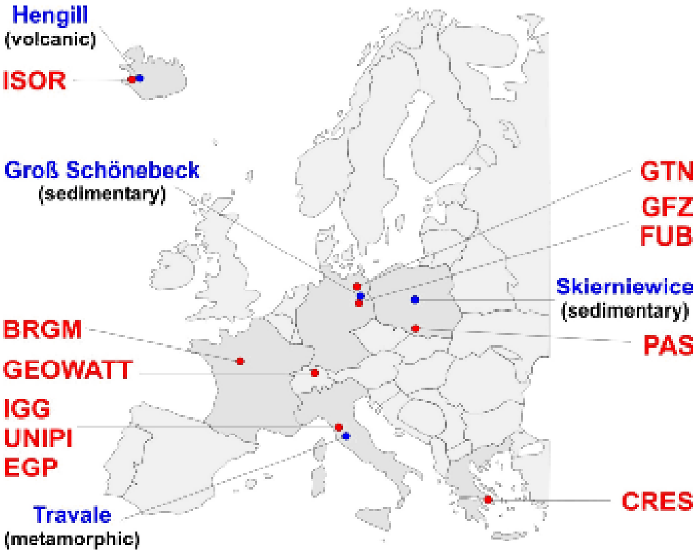

Fig. 1. Map of I-GET field sites (blue) and partners (red)

Hengill, Iceland

At Hengill, Iceland, within the I-GET project, a total of 70 MT soundings were made in the Hengill area in addition to 59 pre-existing soundings and 30 soundings funded by Reykjavik Energy. The I-GET project therefore included a total of 159 MT soundings in the Hengill area. All the MT soundings were made at locations previously visited by TEM soundings which were used for static shift corrections of the MT data. Joint 1D inversion of all MT and TEM soundings in the Hengill area was performed and a 3D resistivity structure was compiled from the individual 1D models. A full 3D inversion was performed for 60 static shift corrected MT soundings covering the Hengill volcanic complex. The 3D inversion delineated deep conductors that correlate with transform tectonics revealed by intense seismicity between the years 1990 and 2000. The deep conductors are thought to be dykes and intrusions which are heat sources of the geothermal system.

In addition to electromagnetic measurements, a broad-band passive seismic survey was carried out. Seven broad-band seismic stations were installed in the summer of 2006 in and around the most seismically active part of the area and recorded continuously for four months. The data base includes 662 earthquakes recorded by at least four of the stations. Four hundred and twenty four of the recorded events were micro-earthquakes with clear P and S waves. Finally, 19 low-frequency earthquakes were recognised with sharp onset and resonance having a large peak at about 1.5 Hz. Three hundred and thirty nine micro-earthquakes with clear P- and S- arrival times detected by at least 4 stations were inverted to apply tomography inversion of the compression P-wave and shear S-wave structure of the geothermal reservoir.

The velocity structure of the Hengill area, as revealed by the joint 3D tomography inversion, was compared to other geophysical data. The location of high P-wave velocity coincides with an area where a deep conductor is at shallowest depth (about 3 km), according to the results from the 1D inversion of TEM and MT soundings and 3D inversion of MT soundings acquired within the I-GET project. No sign of attenuation of seismic S-waves is observed under the Hengill area, indicating the absence of extensive magma chambers at depth. The area where high velocity bodies are found correlates with positive Bouguer anomalies, indicating dense rocks at depth.

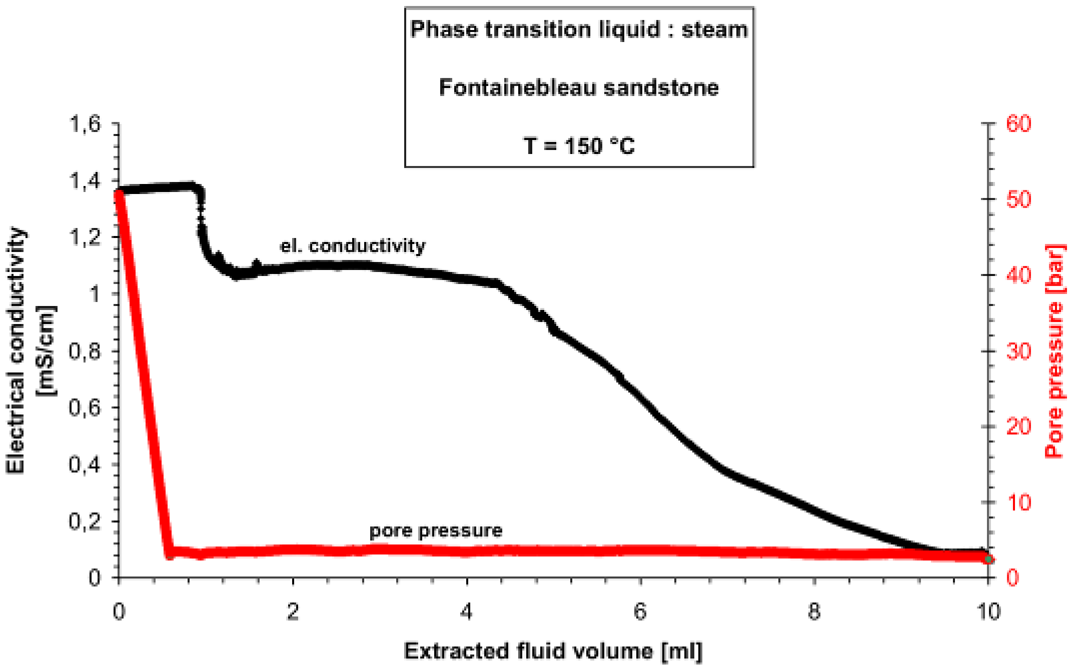

Fig. 2 Experimental observation of change in electrical conductivity with phase transition of pore fluid. As the pore pressure was decreased (red line), the fraction of steam in the pore fluid increased, causing a drop in conductivity (black line)

The seismicity was found to concentrate at the upper boundary of the high velocity body SE of Mount Hengill. This area corresponds to the NW-SE oriented low resistivity anomaly at the depth of 3-5 km, under which was the location where the intense seismic activity during 1991-2001 revealed distinct transform tectonics. The anomaly is under an area of wedges where E-W oriented faults meet N-S oriented faults. Synthetic Aperture Radar Interferograms (InSAR) show that between 1993 and 1998 there was considerable uplift (up to about 18 mm/year), with the centre of the uplift SE of Mount Hengill.

Gross Schönebeck, Germany

At Gross Schönebeck, activities were centered around a former gas exploration well (4.3 km deep). Both seismic and MT data were acquired in parallel along a 40 km long profile to derive a regional 2-D seismic model of the potential reservoir layers and overlying sediments. The profile is oriented parallel to the estimated strike of the regional stress field. Second, a star-like arrangement consisting of 4 profiles each of 6 km length was deployed and a low-fold (low budget) 3-D seismic experiment was conducted to identify fractures around the geothermal well location.

In addition to the surface geophysical measurements, borehole geophysics was used to complement the set of field data. For this purpose, a chain of seismometers was located in the well GrSk 3/90 while stimulation tests were performed in the other well at the same site. The data of this test give a clear image of the fractures created during the stimulation.

MT data was collected along a 40-km long main profile (55 stations) and a 20-km long parallel profile located 3 km to the east. Electrical resistivity models obtained from two-dimensional inversion of the data identify two conductive anomalies at the level of the reservoir (Rotliegend) which seem to be correlated to anhydrite-rich salt layers. High fracturing in the anhydrites could be responsible for higher fluid content, enhanced permeability and corresponding electrical conductivity.

Skierniewice, Poland

At Skierniewice, seismic lines and MT profiles were measured in a grid around an existing well of 4.5 km depth. The seismic survey covered an area of about 36 km^2. The datasets obtained are of high quality in the centre of the seismic image where the homogeneous fold exists. Processing of seismic data was performed by standard procedures similar to those being used in hydrocarbon exploration with additional extension for geothermal purposes. Despite non-uniform offset distribution and fold area inside the bins, the final migration has very good quality and is comparable with results of standard 3D seismic processing. The MT survey was carried as continuous profiling with MT/AMT/CSAMT soundings. CSAMT measurements were added to control and supplement MT/AMT data as the survey area was highly noisy. Even two remote reference stations could not reduce the noise problem to an acceptable limit. CSAMT helped to fix the top part of the MT profile. These measures helped to improve greatly the subsurface image of the potential reservoir around the well. The integrated seismic and MT interpretation supported by the borehole data resulted in construction of the 3D geological model. The fractured zones were identified in order to select the optimal areas to locate new geothermal boreholes.

Laboratory petrophysics

Parallel to in-situ data acquisition, petrophysical and geomechanical properties of the investigated rocks have been defined by laboratory measurements at high pressure and temperature at the high pressure laboratory at GFZ Potsdam. Conditions in the reservoirs have been simulated, with controlled pressure, temperature and pore pressure as well as pore fluid salinity. Rock samples from Iceland, Italy and from Germany were subjected to conditions comparable to those in the geothermal reservoirs investigated, while electrical conductivity and seismic velocities were determined on the cores. By varying the difference between pore pressure and confining pressure at a given temperature, the transition from liquid to steam in the pore fluid was simulated while changes in physical properties were observed (Fig. 2). The raw ultrasonic velocity data acquired by these experiments have been further analysed and interpreted in terms of their elastic properties

Detailed results will be presented at WGC 2010. A special volume of results is in preparation in Geothermics, where project results are presented. This volume will be in press most likely late 2009/early 2010 (Volume 38, No.4).

Further project information at www.i-get.it/

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Italy

A New Publication on Geothermal Energy. A Critical Review

Raffael Cataldi, Honorary President of UGI/Italian Geothermal Union

Printed by CRC Press (Taylor&Francis Group - Informa business), a new geothermal publication appeared about one year ago (April 2008), Low-Enthalpy Geothermal Resources for Power Generation, consisting of xx+150 pages (format 25 x 17 cm) and hardbound. It is authored by Dornadula Chandrasekharam and Jochen Bundschuh, scientists well known to the international geothermal community, whose CV is found in the first section of the book.

As its title points out, the publication deals with an emerging issue of geothermal energy, which in recent years has taken increasing importance in relation to the possibility of widening the generation of electric energy from high (>150° C) to intermediate and low temperature resources (150-80° C).

The technical part of the book consists of 10 chapters: 1) Introduction; 2) World electricity demand and source mix forecasts; 3) Worldwide potential of low-enthalpy geothermal resources; 4) Low-enthalpy resources as a solution for power generation and global warming mitigation; 5) Geological, geochemical and geophysical characteristics of geothermal fields; 6) Geochemical methods for geothermal exploration; 7) Geophysical methods for geothermal resources exploration; 8) Power generation techniques; 9) Economics of power plants using low-enthalpy resources; and 10) Small low-enthalpy geothermal projects for rural electrification.

The first 5 chapters, enriched with tables and figures partly in color, exhaustively summarize the geothermal situation at the global, continental and regional scale, the different types of geothermal systems and the countries where they are found, and the economical resources extractable from depths less than 3 km, with particular reference to those at intermediate-to-low temperature. The electric energy which could be produced from such resources is then compared with the present electricity demand, and with the higher demand which is estimated by 2030 in the various continents and regions of the world, accompanied by an evaluation of the CO_2 avoided with respect to the equivalent amount of electricity produced from fossil fuels.

Chapters 6 and 7 deal with the geochemical and geophysical methods used to locate resources amenable to electrical generation, and with sampling techniques and in-hole logs applied to characterize the buried geological formations. Chapter 6, in particular, exhaustively describes the geochemical methods applied in geothermal investigations, including geo-thermometric techniques; therefore it represents an excellent summary of such methods and techniques, and a useful reference tool also for subject-matter experts.

Chapter 8 summarizes the thermodynamic cycles of the binary plants by which intermediate-to-low temperature fluids are used to produce electric energy. Mention is made, in particular, of the selection criteria of the working fluids of the ORC (organic Rankine cycle) plants, the heat exchangers and the Kalina cycle.

The economical aspects of the geothermal-electric generation from low-enthalpy fluids are dealt with in chapter 9, with particular reference to the drilling costs as a function of depth, productivity of wells vs. reservoir temperature, and size of power plants vs. flow rate and temperature of fluids. A comparison is then made between the different construction costs of two groups of power plants, supplied by high- and intermediate-to-low temperature fluids, respectively.

In the last chapter (number 10), the possible technical simplifications and the notable reduction of costs are discussed for electrification projects with geothermal units in isolated rural areas with small electricity demand, mostly those in developing countries; afterwards, a number of examples are given of small power plants (<2 MWe) supplied by intermediate-to-low temperature fluids in Argentina, China (Tibet), Iceland, Thailand, Taiwan, and the USA.

All chapters are introduced by a "symbolic sentence" succinctly expressing a significant concept of geothermal energy. They form together the quintessence of the expected development of the Earth's heat and of the reasons why it should be pursued; therefore, they are all worthy of quotation here[1] .

1. *The latest studies show that it is cheaper to invest in climate protection than to pay for the losses that result from inactivity. It is thus prudent to act now from an economic perspective as well.*
2. *World electricity generation nearly doubles in the IEA reference case from 2004 to 2030. In 2030 generation in the non-OECD countries is projected to exceed generation in OECD countries by 30 per cent.*
3. *Earth's current and potentially available reserve of geothermal energy is a quantity of astonishing magnitude - vastly greater, in fact, than the resource bases of coal, oil, gas, and nuclear energy combined… Although only a fraction of this geothermal bounty can now be tapped, with innovative technology it will remain available for our descendants long after the last drop of oil is produced.*
4. *More recently, there has been a seismic shift in how climate change is perceived, and is widely considered to be the greatest market failure ever. This is in part due to the fact that many of the effects of climate change are beginning to manifest, and that the threats posed by continuing warming will affect - and possibly disrupt - the operation of markets, societies, ecosystems and cultures.*
5. *There is reason to be optimistic about geothermal energy. The exciting period is beginning where anomalous sources of heat are treated as systems. To develop geothermal energy as an important resource one must identify anomalous thermal sources and understand their genesis and geometry.*
6. *The ultimate objective of any exploration programme is to locate a resource that can be economically developed. Despite differences in the type of resources and their geological setting, a certain exploration philosophy has been built up over many decades. This philosophy is based on the concept that the prospector begins to search in a large area and narrowing down to a more specific location.*
7. *Of course, energy is not a single challenge that can be answered with a piece of technology as clean, appealing and profitable as an iPod. It is three intertwined challenges, each vexing and complex in its own right...*
8. *The opportunities for geothermal energy to play a much larger role in overall energy production in the future require technical innovation, reduced start up costs, public education, and a level*

[1] *The source of each sentence (publications and speeches by important personalities) is quoted in the relevant chapter of the book in question.*

economic and regulatory playing field with other energy technologies…

9. *Today, over two billion people in developing countries live without any electricity. They lead lives of misery, walking miles everyday for water and firewood, just to survive. What if there was an existing viable technology that when developed to its highest potential could increase everyone's standard of living, cut fossil fuel demand and the resultant pollution…*
10. *All developing countries have a stake in energy sustainability, but in the Asian region especially large populations aspiring to greater prosperity will strongly test our ability to deliver energy sustainability. Collectively, we will need to distill all available wisdom on the policies, market structures, pricing arrangements and technologies that can lead us to our goals. These issues are also the ones which pre-occupy industrialized countries.*

The last part of the book includes a reference list with over 200 quotations from generally recent works, and two thematic indexes: the first to list the main concepts dealt with in the book (over 1300 entries), and the second to recall the geographical localities, the lithostratigraphic units and the tectonic and structural elements quoted.

In short, not only does the book in question depict the global potential of moderate-to-low temperature geothermal resources, but it also shows how energy requirements could be successfully supplemented by tapping them profitably in many areas of the world. Therefore, it is a book from which policy-makers, territory planners and environmentalists from all over the world could draw useful ideas, especially when dealing with energy problems of developing and energy-starved developed countries.

On the other hand, from the scientific viewpoint, the book is a publication of current and actual interest, which all geothermalists and scholars of geothermal energy should have in their library.

AMERICAS

Mexico

General features of the Cerritos Colorados geothermal project, Mexico

Luis C.A. Gutiérrez-Negrín

In the last issue of IGA News (Number 75) it was reported that the environmental study for the Cerritos Colorados geothermal project, Jalisco, Mexico, had been approved. This is the first step by the CFE (Comisión Federal de Electricidad) to resume the development of this field after 20 years of adjournment. As mentioned, in March 1989 "CFE had to suspend all of its development activities in the field due to the environmental impacts … on the pine-oak forest where the geothermal field lies." (Gutiérrez-Negrín, 2009). The following outlines the main features of the geothermal field, formerly known as La Primavera, and of the project, whose first stage is the construction and installation of a 25-MW condensing power unit.

The geothermal field

Cerritos Colorados is located in the western-central part of Mexico, at the periphery of Guadalajara City, capital of the state of Jalisco and the second largest city in the country (Fig. 1). Geologically, it lies in the western portion of the Mexican Volcanic Belt, near the junction of three major continental structural elements: the N-S Colima Graben, the E-W Chapala Graben, and the NW-SE Tepic Graben, that have been regarded as extension zones (Nelson and Sánchez, 1986).

The field is inside a Quaternary volcanic caldera (the La Primavera caldera) whose formation began at least 120,000 years ago, when an ascending magma chamber extruded the first rhyolitic domes and lavas. Then, 95,000 years ago, a series of explosive eruptions produced huge pyroclastics flows, flooding the surrounding valleys and forming the Toba Tala ignimbrites that presently cover an area estimated at 700 km^2. The aftermath of these eruptions, representing an evacuated magma volume of 20 km^3 (Mahood, 1980), was the collapse of a roughly circular area of 11-13 km in diameter, forming the La Primavera caldera, inside of which a lake was formed. During 25,000 years lacustrine sediments covered the lake floor, and then, 70,000 years ago, a differential resurgence took place in the magma chamber, so forming the present sierra and extruding further domes and lavas. The youngest rhyolitic domes are dated at 20,000-25,000 years.

Superficial evidences of the present, deep geothermal system include fumaroles at the central-south part of the caldera and perennial hot springs at 65° C and of sodium-bicarbonate geochemical type.

The subsurface lithology of the field can be grouped into five units, the fourth of them hosting the geothermal fluids. This unit is composed of three parts, from top to bottom: a sequence of andesites and tuffs, a thin layer of rhyolites and another sequence of andesites with minor basalts, with a combined thickness of 2,317 meters and an age from Late Miocene to Early Pliocene. The unit rests on a granodioritic basement, with a radiometric age of at least 7.3 Ma (Late Miocene) (Superintendencia General Guadalajara, 1989).

There is a deep fault system with a NW-SE trend that affects the rocks of the fourth unit but does not seem to present a superficial expression. Some shallower systems, mainly due to the collapse and resurgent processes, are represented by some ring caldera fractures and some high angle fractures and normal faults with NW-SE and NE-SW trends (Superintendencia General Guadalajara, 1989).

The natural thermodynamic state of the system corresponds to a compressed liquid reservoir. The vertical pressure profile is almost hydrostatic at shallow depths and

Fig. 1. Location of the Cerritos Colorados geothermal field.

higher than hydrostatic below 1,750 meters depth. At shallow depths, fluids flash in the formation adjacent to wells, and then appear as two-phase flow within the wells. At greater depths, fluids enter in the liquid phase and flash inside the wells. The average porosity has been estimated at 10% in the first 1,500 meters depth. Below this depth, the average falls to around 6%, but the fracture permeability is as high as hundreds to thousands of milidarcys (Suárez, 1995).

The up-flow of the geothermal system seems to be located adjacent to wells PR-1, PR-8 and PR-9, from where geothermal fluids tend to move towards the west. Interaction between these fluids and the host rocks has produced medium temperature hydrothermal mineral assemblages, including calcite, quartz, clay minerals, chlorites and pyrite. Some relatively scarce epidote was found, mainly in the well PR-1. In cuttings and core samples from several wells, the original rocks have been intensely altered (Gutiérrez-Negrín, 1988).

CFE started the exploration studies in the 1970s, including 13 exploration and development wells at depths between 689 and 2900 meters. Six of these wells have been assessed with a combined production of 220 tons per hour (t/h) of steam and 440 t/h of brine at 8 bars of separation pressure. A preliminary assessment of the potential was 75 MW (JICA, 1989).

The geothermal-electric project

Since the production wells were drilled long ago, the first activity must be to check their mechanical condition. In March 2008 two of the production wells (PR-9 and PR-12) were closed with cement-plugs because the mechanical conditions of their casings were considered unsafe. Thus, the casings of the remaining production wells (PR-1, 8, 11 and 13) will be reviewed during 2009, and then repaired if necessary. After that the wells will be re-assessed to define the current production conditions of the field. Additionally, the well PR-7 will be deepened since its construction had been suspended before reaching its final depth and the probable injection wells PI-1 and PR-2 should be deepened and checked, respectively, and then tested to determine their current injection capacity.

The initial stage of the project consists of the construction and installation of a condensing unit of 25 MW of net capacity. Gross steam consumption is estimated at around 8 t/h per MWh, and thus the unit will require 200 t/h of steam, at an admission pressure of 8 bar(a). Taking into account that the steam possibly available with the remaining production wells is ~140 t/h, it will be necessary to drill at least two additional production wells and one injection, all of them of directional type to be constructed on the already existing pads. The estimated brine to be injected is between 300 and 400 t/h.

The power unit will be installed on a surface of 200 x 40 meters, near the production wells where there are no trees. The steam pipelines will follow the existing roads arranged in an integrated design. The gas content in the steam, at 8 bar(a), is estimated between 4.4 and 7.3% in weight.

All the brine should be returned to the reservoir through the injection wells PI-1 and PR-2 after their re-conditioning and at least a third injection well will be drilled on the PR-2 pad. It is estimated that the separated brine will present average enthalpy of 1200 kJ/kg, pH 8.5, and a mean contents of 730 ppm of Cl, 430 ppm of HCO_3, 910 ppm of SiO_2, and 14 ppm of As, among other components.

Considering that the geothermal project is to be developed inside a forest registered as a Flora and Fauna Protection Area (which is part of the Mexican system of natural protected areas), it is strictly required to avoid and/or minimize any environmental impact. Thus, the design criteria of the project include:

- Use the minimum room for the superficial installations.
- Use expansion joints instead of omega-expansions in the steam pipelines.
- Use the already constructed pads to drill new, additional wells.
- Use the already constructed roads.
- Install abatement systems for H_2S emissions.
- Use hot-injection of the brine to avoid cooling ponds and the further disposal of silica precipitates.

The project also includes the construction of an electric transmission line 14.5 km long at 69 kilovolts (kV). 8.5 km of the total length of the line will be inside the forest, also following the already existing roads.

Conclusions

Twenty years ago CFE had to stop its development plans in the Cerritos Colorados geothermal field, because of the environmental impacts caused by the exploration and drilling activities. Then, CFE carried out a complete program to mitigate and restore the impacts on the small, 0.6 km^2 area affected, and unsuccessfully tried to resume the development of the field - whose potential had been already assessed in 75 MW. Finally, in January 2009 CFE got the green-light from the environmental authorities to do that. It's about time to take advantage of this geothermal resource and so continue geothermal development in Mexico.

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USA

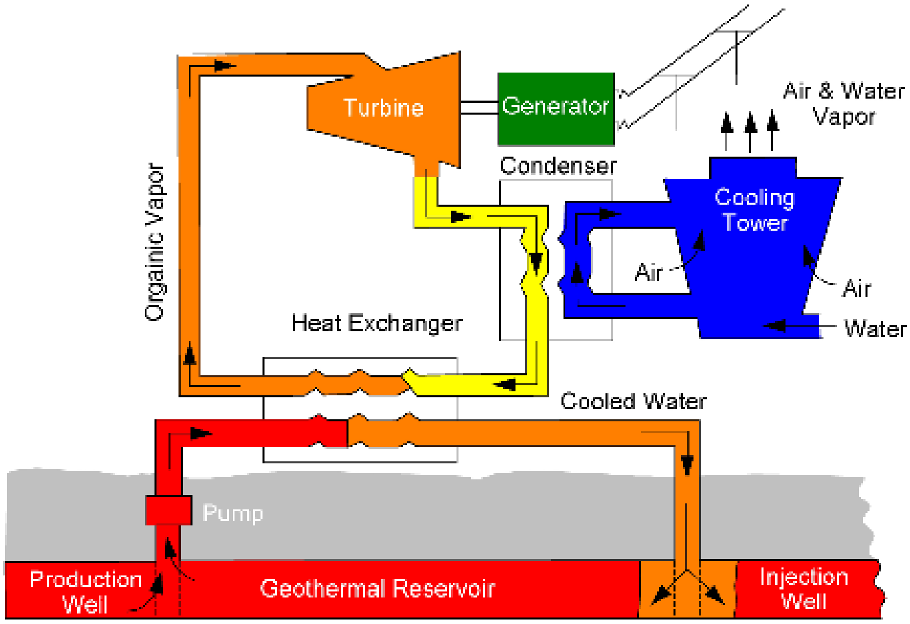
Imminent Geothermal Power Production at the OIT Campus

John W. Lund, Director, GeoHeat Center

As you may know, the OIT campus has been heated with geothermal energy since it was moved to the present location in the early 1960s. Three production wells, up to 1,800 feet (550m) deep, were drilled on campus property at the time, producing 192°F (89°C) water, at a maximum flow of 700 gpm (44 L/s) and an average of 250 gpm (16 L/s) providing all the heating and domestic hot water needs of campus. This renewable energy use saves the campus an estimated $1 million per year. Two injection wells were drilled in the 1990s to recharge the geothermal reservoir, as wasting the water to surface drainage was no longer allowed by a city ordinance.

Based on new technology, the campus is in the process of developing the geothermal resource for electric power generation - to satisfy all the electric needs of campus, thus making the campus the first in the world to have all of its energy needs met using geothermal energy from a resource on campus property. We will then be an "all green" energy campus.

To produce the electrical energy for campus, we have drilled a deep (5,300 feet - 1615 m) geothermal well to intersect the high angle normal fault on the east side of campus. The geothermally heated fluid upwelling along the fault is already tapped by our existing geothermal wells. Based on surface water geochemistry (analyzing the existing well water) researchers predict that up to 300°F (150°C) geothermal fluids might exist at depth. Thus we



Binary (Organic Rankine Cycle) Geothermal Plant

hope to supply a 1.0 MWe (gross) geothermal power plant to provide electrical energy for campus.

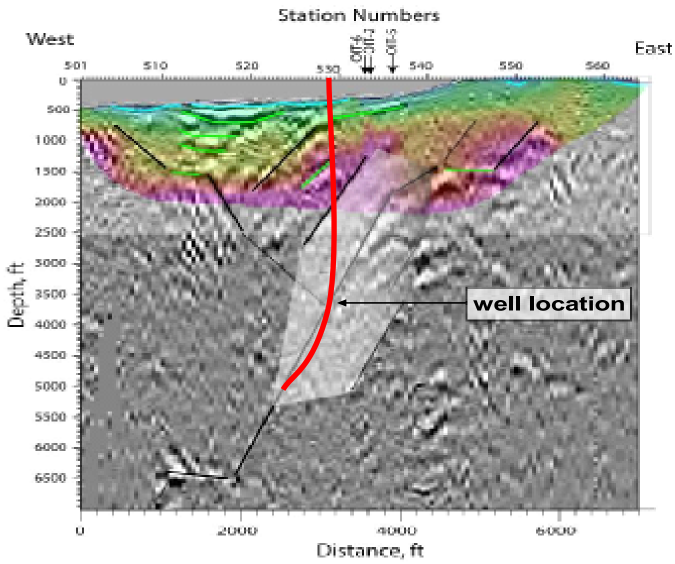
The 1.0 MWe power plant (gross) would probably be of a binary type (organic Rankine cycle using a secondary low boiling point hydrocarbon) supplying around 800 kWe (net) to campus, enough to cover most of the electric energy requirements. This would save the campus around $500,000 per year.

The cost of the well and 1.0 MWe power plant would be around $9.0 million. However, the "waste water" from the power plant at around 175°F (80°C) could then be sold to adjacent property owners or used to supplement the existing and new OIT heating demands, generating additional income or savings. Funding for the project comes from a US Department of Energy grant, and from Oregon State bonds and grants. Additional support may come from the Energy Trust of Oregon and the Oregon Business Energy Tax Credit.

Last year we contracted for and completed a seismic survey of campus to better locate the fault and so position the drilling site. Approximately 64 2.2 lb (1 kg) dynamite charges were set off at 18 feet (6 m) depth on campus and the surrounding property to bounce energy waves off subsurface structures. The seismic survey can be viewed at http://geoheat.oit.edu/oit/Seismic_Final_Report.pdf. This investigation determined the optimum drilling target at about 3,000-4,000 feet (900 to 1,040 m) depth. The drill site is in the southeast corner of the upper parking lot. As part of the USDOE grant, we completed an environmental assessment (EA) under the NEPA requirements. The final EA can be viewed at http://geoheat.oit.edu/oit/OIT-Deep-Geothermal-Well-and-Power-Plant-Project-FEA_0908.pdf. A Request for Proposal (RFP) for drilling the deep well was prepared and a contract was awarded to ThermaSource, Inc. of Santa Rosa in December.

The surface conductor pipe of 30-inch diameter was set in early January by Roger Chancellor Drilling and Pump Company of Klamath Falls. A 40-foot, 36-inch diameter hole was drilled in the upper parking lot through the surface "chalk rock" (a mixture of diatomaceous earth and volcanic ash). The casing was then cemented in place and a 2-foot deep by 6 x 6 foot cellar was constructed around it.

The ThermaSource, Inc. rig was trucked onto site in early January, 2009, with 24 large truck loads of parts and additional loads of drill pipe and casing. The 105-foot rig, #105, was set up with the associated trailers, diesel generators and mud (drilling fluid) mixing tanks. The 26-inch diameter hole for the 20-inch diameter casing was spudded, drilled to 300 feet and the casing cemented. The official "ribbon cutting" ceremony was on the 24th of January. President Chris Maples, Vic Chancellor Bob Simonton, ThermaSource CEO Louis Capuano, Jr. and



E-W seismic profile of the proposed drilling target.

Start of drilling for surface casing.

Oregon Senator Ron Wyden spoke and officially opened the well drilling project. Drilling was completed on March 10th to a depth of 5,300 feet (1630 m).

The casing program after the 20-inch pipe was followed by a 13-3/8-inch casing in a 17-1/4-inch hole to 2,500 feet (770 m) which was then cemented to the surface. Finally the well was drilled with a 12-1/4-inch bit to 5,310 feet, with a 9-5/8-inch casing with 500 feet (150 m) of perforations set to 5,030 feet (1550 m). This later casing could not be set to full depth due to some obstruction around the 5,000-foot depth. At 3,284 feet (1010 m) the well was deviated with a directional motor and bit to better intersect the inferred fault. The maximum deviation was 25.5 degree from vertical. Thus, the 5,310-foot hole had a true vertical depth 5,215 feet from surface. Whereas the drilling to around 3,300 feet was done using normal drilling mud, below this point aerated mud was used in order not to seal any potential aquifers. A number of lost circulation zones were encountered (as indicated by reduced mud return to the surface), indicating potential permeable zones for fluid. An initial temperature and gamma radiation log was run at this point, but results were mixed, with maximum temperatures around 200°F.

The well was then air lifted to remove any mud from the hole and open potentially permeable zones. This was followed by a final temperature and pressure log. Then, the drilling rig was removed and in approximately two weeks a full scale pump test was carried out in order to determine flow, temperature and surface water draw-down.

The pump test was performed on April 24, 2009. A line-shaft pump was used and waste water was piped uphill to a natural sump between the 3 existing geothermal wells on campus. Pumping rates started at 300 gpm, and then progressed to 500, 1,000 and 1,500 gpm (95 L/s). Maximum drawdown observed was 23 feet (7 m), which is small, and the maximum temperature was 196°F (91°C). Unfortunately, although permeability and fluid production looked good, we were not able to increase the pumping rate due to equipment limitations. Based on projections, it is estimated that 2,000 gpm (126 L/s) could be pumped

The drilling rig being set-up.

Drill rig at night looking southwest.

with only 47 feet (14 m) drawdown and producing approximately 200°F (93°C). At 1,500 gpm and 196°F, approximately 750 kWe gross (600 kWe net) could be generated, and at 2,000 gpm and 200°F approximately 1,000 kWe (1 MWe) gross (800 kWe net) could be produced. An additional pumping test will be required by the Oregon Department of Water Resources in order to obtain our water rights. At that time the adjacent wells will be monitored for interference, and rates of 2,000 to 2,500 gpm will be attempted.

Once the well is completed and tested, and we know the temperature, flow rate and mineral content, the power plant will be designed - through a competitive solicitation (RFP). This should take approximately six months to a year, and so the plant should be ordered and on site sometime in late 2009 or early 2010, and operational soon after that. The plant will be instrumented so that any agency, campus, etc. can monitor the operation and output of the plant.

Finally, we have also installed a low temperature power plant, also of the binary type, to use the existing geothermal wells. This unit, supplied by United Technology Corporation of Connecticut, is 280 kW gross and will use the 192°F (89°C) water. This plant will be up and running by late May or early June. The "waste water" from the power plants, after providing space heating, could also be used to provide heat to greenhouses and aquaculture projects to be constructed on campus, using the spent water at around 140°F (60°C).

All of these power plant installations will be available to the public for tours and, more importantly, available to students of the Renewable Energy Program for class projects. Hopefully, the information gained from these plants will provide "spin-off" for other project in the State of Oregon and other western states. Oregon and OIT will become a leader and show-case for geothermal energy development and use as well as the first to use geothermal energy for electricity in the state.

Sen. Wyden at the controls of ThermaSource Rig #105

Additional information of these power projects and the proposed greenhouse and aquaculture projects can be found at http://geoheat.oit.edu/greenoit.htm.

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ASIA/PACIFIC RIM

Australia

Hot sedimentary aquifer resource in southeast Australia

Graeme Beardsmore, Hot Dry Rocks PTY LTD

Six companies are exploring for Hot Sedimentary Aquifer (HSA) geothermal resources within Cretaceous aged basins in southeast Australia. Of these, two have begun to publicly quantify their resource base with statements of Geothermal Resources compliant with the Australian Code for Reporting of Exploration Results, Geothermal Resources and Geothermal Reserves ('The Geothermal Code'). Greenearth Energy Limited has done so for parts of the Gippsland Basin and the eastern Otway Basin in Victoria, while Panax Geothermal Limited has done so for a large area of the western Otway Basin in South Australia (Figure 1). The reported resource estimates are vast by comparison with virtually any other energy source. It is important to note, however, that these figures are estimates of the total thermal energy in the ground. There is as yet no firm basis for determining the 'recovery factor', or proportion of thermal energy that might ultimately be recovered from the HSA reservoirs and converted to electrical energy.

The Geothermal Code was officially launched at the Australian Geothermal Energy Conference in Melbourne in August 2008. It is now mandatory for member companies of the Australian Geothermal Energy Association to comply with the Geothermal Code when reporting geothermal exploration results, resources or reserves. Since August, a number of companies have completed resource estimates and made public statements under the Geothermal Code. Some of these have been for 'hot rock' type resources covering vast areas and volumes of rock. Only the two mentioned above have been for HSA targets.

The Resources within sedimentary reservoirs are estimated in terms of the total 'stored heat'. That is, the

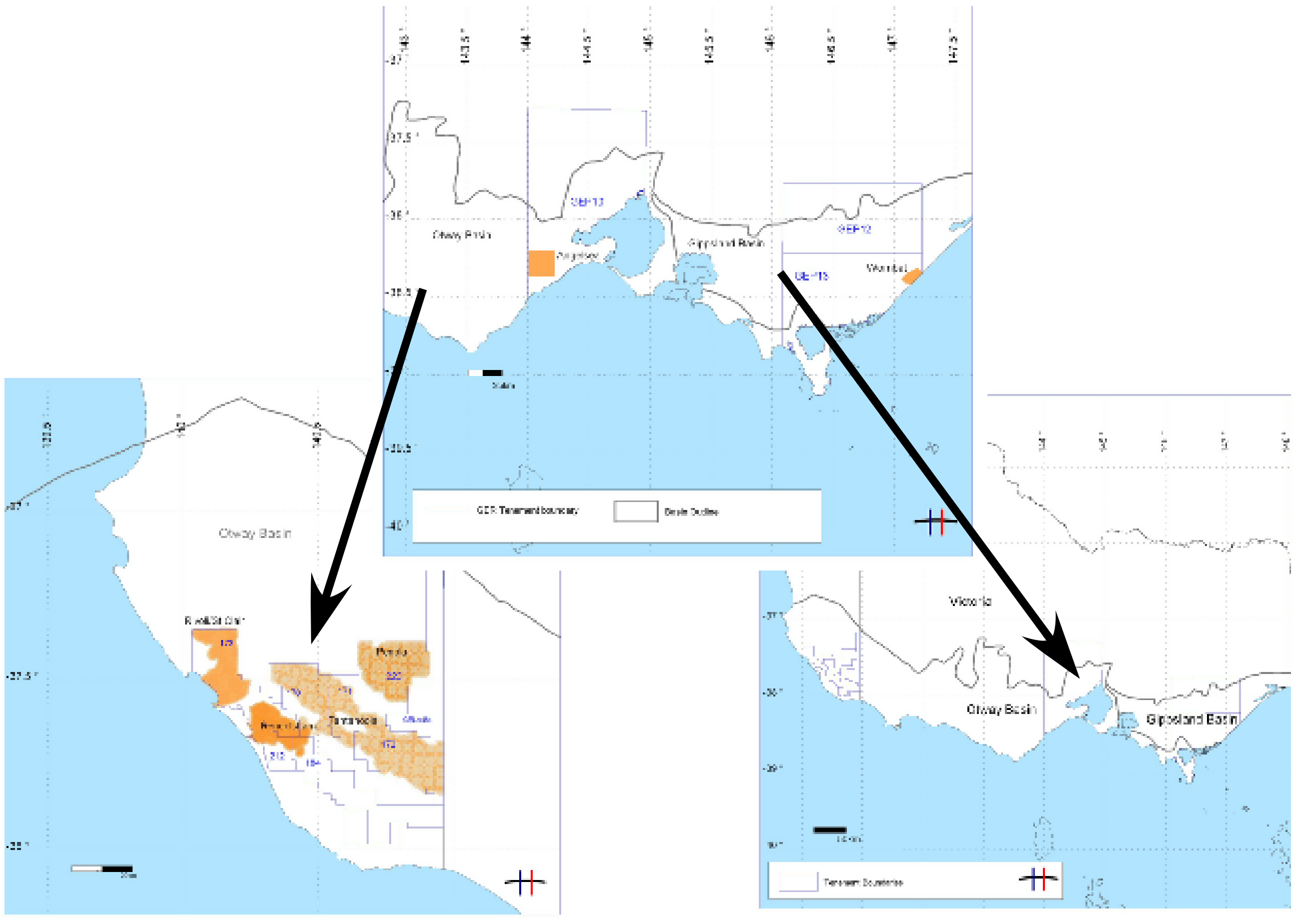

Figure 1. Locations of Geothermal Resource estimates in SE Australia (orange areas). 'Tenement boundaries' refers to the extent of exploration licences for Panax Geothermal (left) and Greenearth Energy (right).

Table 1. HSA Geothermal Resources reported to date in southeast Australia ('PJ' = petajoule of stored heat):

Panax Geothermal Limited		
Tantanoola Geothermal Play	130,000 PJ	(31 March 2009)
Rivoli / St Clair Geothermal Play	53,000 PJ	(28 January 2009)
Rendelsham Geothermal Play	17,000 PJ	(28 January 2009)
Penola Geothermal Play	132,000 PJ*	(18 February 2009)
Greenearth Energy Limited		
Wombat Geothermal Play	3,600 PJ	(5 January 2009)
Angelsea Geothermal Play	40,000 PJ	(4 December 2008)

* Includes 11,000 PJ 'Measured' and 32,000 PJ 'Indicated' resource

amount of heat that is theoretically available to be extracted based on assumptions of cut-off and base temperatures. The magnitude of any Geothermal Resource is intimately linked to its temperature, but in most cases the target reservoirs in southeast Australia have not been penetrated for direct measurements of temperature. For this reason, in most cases the Resource temperatures have been estimated by indirect means, and the Resources have been classified as 'Inferred' under the Geothermal Code. In Panax Geothermal Limited's 'Penola Geothermal Play', historical petroleum exploration wells have penetrated into the target geothermal reservoirs and provided direct temperature and reservoir property measurements. In this case alone, some of the Geothermal Resource has been classified in the higher confidence categories of 'Indicated' and 'Measured.'

Temperature data from deep petroleum exploration wells scattered throughout southeast Australia show no compelling evidence of convection. Stored heat Inferred Resource estimates have, therefore, relied on an assumption of conductive heat transfer within the basin sequence. Target resource temperatures (typically >150°C) are predicted at drillable depths in the Gippsland and Otway Basins because of the slightly higher than average surface heat flow (~75 mW/m^2) and thick sections (exceeding 2000 m in places) of Cretaceous clay-rich rocks providing thermal insulation. The Eumeralla Formation is the insulating unit in the Otway Basin, while the equivalent in the Gippsland Basin is the Strzelecki Group. The inferred HSA reservoirs are constrained to porous and permeable sandstone formations near the base of the Cretaceous sections.

As the 'Competent Person' who signed off on all the Panax Geothermal and Greenearth Energy resource reports to date, the author is in a unique position to describe the process of resource estimation in these basin settings. Temperature prediction within the reservoirs was constrained by observations of surface heat flow, surface temperature, and the thermo-physical properties (thermal conductivity, specific heat, density) of the geological strata. My company, Hot Dry Rocks Pty Ltd, measured the majority of these parameters. Purpose-written, numerical, 3D-conductive-heat-flow modeling software was used to derive the simplest temperature distribution consistent with the observed surface heat flow. The software subsequently integrated the modeled temperatures and assigned density and specific heat values to derive a stored-heat estimate for the target reservoir formations. The Resource estimates reported to date are shown in Table 1. The variation in the numbers in Table 1 largely reflects the different volumes of rock being assessed.

As a comparison, Australia's estimated 'recoverable reserves' of natural gas in 2001 amounted to about 160,000 PJ. This has inevitably led to some concern in the investment market as to how to compare the large resource numbers being reported by geothermal companies with the generally much smaller resources reported for individual petroleum reservoirs. These concerns can only be addressed by determining the proportion of the geothermal resource that might ultimately be extracted. It is unrealistic to expect that all 'stored heat' can be extracted, even for the relatively confident 'Measured Resource' estimates. But what proportion is realistic?

There is little doubt that the geothermal resource base within hot sedimentary aquifers in southeast Australia is huge. Commercial exploitation of that resource, however, requires that the heat be extracted. Dynamic reservoir modeling will go some way towards predicting reservoir behavior and the efficiency of heat extraction, but, ultimately, the answer will only come from reservoir performance data from several real commercially producing reservoirs.

WORLD

Renewables Global Status Report

Arni Ragnarsson, IGA Executive Director

The report Renewables Global Status Report 2009 Update was recently published by REN21 (Renewable Energy Policy Network for the 21st Century). A press release from REN21 states that the global power capacity from new renewable energy sources (excluding large hydro) reached 280,000 MW in 2008 - a 16 percent rise from 2007. More renewable energy than conventional power capacity was added in 2008 in both the European Union and United States for the first time ever. At least 64 countries now have some type of policy to promote renewable power generation.

The report says the following about the development in geothermal electricity generation: "Geothermal power capacity reached over 10 GW in 2008. The United States remains the world development leader, with more than 120 projects under development in early 2009, representing at least 5 GW. Other countries with significant recent growth in geothermal include Australia, El Salvador, Guatemala, Iceland, Indonesia, Kenya, Mexico, Nicaragua, Papua New Guinea, and Turkey. Geothermal development was under way in over 40 countries, with at least 3 GW in the pipeline beyond the United States".

Direct use of geothermal energy is described as follows: "Geothermal (ground source) heat pumps accounted for an estimated 30 GWth of installed capacity by the end of 2008, with other direct uses of geothermal heat (i.e., for space and greenhouse heating, agricultural drying, industrial, and other uses) reaching an estimated 15 GWth. At least 76 countries use direct geothermal energy in some form".

For more information on REN21 and download of the report please visit their website: www.ren21.net/globalstatusreport

Table R1. Renewable Energy Added and Existing Capacities, 2008 (estimated)

	Added during 2008	Existing at end of 2008
Power generation (GW)		
Large hydropower	25–30	860
Wind power	27	121
Small hydropower	6–8	85
Biomass power	2	52
Solar PV, grid-connected	5.4	13
Geothermal power	0.4	10
Concentrating solar thermal power (CSP)	0.06	0.5
Ocean (tidal) power	~0	0.3
Hot water/heating (GWth)		
Biomass heating	n/a	~250
Solar collectors for hot water/space heating	19	145
Geothermal heating	n/a	~50
Transport fuels (billion liters/year)		
Ethanol production	17	67
Biodiesel production	3	12

Source: Renewables Global Status Report 2009 Update

IGA News

IGA News is published quarterly by the International Geothermal Association. The function of IGA News is to disseminate timely information about geothermal activities throughout the world. To this end, a group of correspondents has agreed to supply news for each issue. The core of this group consists of the IGA Information Committee:

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