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Geothermal's Rising Fortunes

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Bali (Indonesia) was the venue for the World Geothermal Congress 2010. The 25-30 April gathering was the fourth in the series, bringing together the world's geothermal community to update on geothermal energy's global advances against an evolving scientific, technological, political, environmental and regulatory backdrop. The IEA Geothermal Implementing Agreement (IEA GIA) presented a number of papers updating on promising developments with this form of renewable energy since the last World Geothermal Congress in Antalya (Turkey) in 2005. Mike Mongillo and Chris Bromley are, respectively, Secretary and Chair of this IEA collaborative programme's Executive Committee. They report here on highlights from the Bali World Geothermal Congress.

Some striking figures emerged from the World Geothermal Congress 2010 in Bali (Indonesia) on 25-30 April. Since 2005, geothermal energy's contribution to global power generation has grown by an impressive 20%. Today, 24 countries are generating power from geothermal sources. Installed capacity totals 10,715 MW_e and produces 67,246 GWh per year. Growth has accelerated a significant 75% to 350 MW_e/year. In five countries, geothermal now produces between 14% and 25% of power supplies.

IEA Geothermal Implementing Agreement (IEA GIA)

The International Energy Agency (IEA) Implementing Agreement for a Cooperative Programme on Geothermal Energy Research and Technology provides an important framework for wide-ranging international co-operation in geothermal R&D.
IEA GIA activities presently cover five different task areas: Environmental Impacts of Geothermal Development; Enhanced Geothermal Systems; Advanced Geothermal Drilling and Logging Techniques; Direct Use of Geothermal Energy; and Data Collection and Information. The programme's participants are listed on the IEA-GIA's website: www.iea-gia.org . The IEA-GIA is an IEA collaborative programme.

Direct use of heat from geothermal fluid, which means applications without conversion to electricity as in geothermal heat pumps, swimming pools and space heating, was reported by 78 countries. In the past five years, global installed capacity has increased by 79% to 50,583 MW_{th}, and usage by 60% to 438,071 TJ/year.

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[1] The IEA *OPEN Energy Technology Bulletin* is a free, web-based periodical newsletter published by the International Energy Agency (IEA). Views expressed in *OPEN Bulletin* articles or interviews do not necessarily reflect the views or policies of the IA Secretariat or of all its individual member countries.

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Since 1995, the world's geothermal experts have gathered every five years at World Geothermal Congresses (WGC) to present and discuss the current state of global geothermal science, technology, development, deployment and investment. The theme of this year's 4th WGC was *Geothermal: Energy to Change the World.* It reflected the need to change the current global dominance of fossil fuels and their environmental consequences and to consider how the world's ubiquitous, environmentally friendly geothermal resources can contribute to meeting large, growing energy demand while bringing societal improvements, not least helping to mitigate climate change.

Hosted by the Indonesian Geothermal Association (INAGA) and the Indonesian Ministry of Energy and Mineral Resources, WGC 2010 was officially opened by President Susilo Bambang Yudhoyono of Indonesia. Other high-level governmental participants included President Olafur Ragnar Grimsson of Iceland. With well over 2,000 participants from more than 85 countries, the turnout for WGC 2010 was the largest for WGCs to date. Five days of presentations featured 650 papers and 280 posters. Discussions covered a comprehensive 39 topics, including all the relevant science applications, technology, environmental and societal aspects. Authors looked at sustainability, exploration, resource assessment, case histories, drilling and completion technology, education, legal and regulatory topics, as well as economics and financing. Country updates provided recent data and information on the status of geothermal power and direct-use development. All the WGC 2010 papers can be accessed here.

Rachmat Witoelar, Chris Bromley and Paul Quinlivan at the WGC 2010
(Photo courtesy of *WGC 2010 Daily News*, Issue 5, 29 April 2010, p.1)

Over 80 exhibition booths were sponsored by geothermal organisations, including the IEA Geothermal Implementing Agreement (IEA-GIA), and by geothermal development companies, equipment manufacturers and service providers.

IEA-GIA at the Congress

The IEA-Geothermal Implementing Agreement (GIA) enjoyed the honour of a keynote slot for its presentation *The International Energy Agency Geothermal Implementing Agreement- International Efforts to Promote Global Sustainable Geothermal Development and Help Mitigate Climate Change*. The full paper can be accessed here.

As part of a 1.5 hour panel session entitled *International Efforts to Promote Global Sustainable Geothermal Development,* the IEA-GIA presentation reviewed the IEA's work, the IEA Geothermal programme's mission, its current activities and achievements, especially its focus on sustainability, global geothermal potential and curbing climate change.

Guðni Johannesson, Director of the Icelandic National Energy Authority, discussed the International Partnership for Geothermal Technology (IPGT). Paul Quinlivan of SKM described geothermal energy's place in the Clean Development Mechanism (CDM). Rachmat Witoelar, Executive Chair of the Indonesian National Council on Climate Change, reviewed Indonesia's role in promoting sustainable development and addressing climate change. Lively ensuing discussions covered current and future research and international collaboration, as well as exchanges on the Copenhagen accord's movement towards an economic transformation programme rather than an environmental treaty. Delegates considered estimates that the potential of geothermal energy could amount to as much as 8% of global energy demand by 2050 using known hydrothermal resources and advanced technologies like enhanced, or engineered, geothermal systems (EGS). Participants looked at geothermal's currently small portion (0.4%) of the global market for clean development mechanism (CDM) activity and possible ways to increase it.

Chris Bromley, Yoonho Song and a visitor at the IEA-GIA exhibition booth at the World Geothermal Congress 2010 (Photo courtesy of Mike Mongillo)

Congress papers describing the efforts and achievements of GIA projects are listed in the box below.

IEA-Geothermal Implementing Agreement Papers Presented at the World Geothermal Congress 2010

Mongillo, M.A. and Bromley, C.J. 2010. The International Energy Agency Geothermal Implementing Agreement - International Efforts to Promote Global Sustainable Geothermal Development and Help Mitigate Climate Change (Presentation, paper). Proceedings WGC2010 Bali, Indonesia, 25-30 April 2010, 10p.

Bromley, C.J. 2010. Promoting Beneficial Environmental Effects and Improving Long-Term Utilization Strategies Through IEA-GIA Collaboration. Proceedings WGC2010 Bali, Indonesia, 25-30 April 2010, 4p. (Presentation, Paper).

Axelsson, G., Bromley, C.J., Mongillo, M.A. and Rybach, l. 2010. The Sustainability Task of the International Energy Agency's Geothermal Implementing Agreement. Proceedings WGC2010 Bali, Indonesia, 25-30 April 2010, 8p.

Muraoka, H., Gunnlaugsson, E., Song, Y., Lund, J., Bromley, C.J. and Rybach, L. 2010. International Database of Hydrothermal Chemistry: a Case of Task-A of Annex VIII of IEA-GIA. Proceedings WGC2010 Bali, Indonesia, 25-30 April 2010, 6p.

Song, Y., Gunnlaugsson, E., Bromley, C.J., Rybach, L. and Lund, J. 2010. Barrier and Opportunity Identification in Geothermal Direct Use: A Task of Collaborative Research under IEA-GIA. Proceedings WGC2010 Bali, Indonesia, 25-30 April 2010, 5p.

Gunnlaugsson, E. 2010. IEA-GIA Annex VIII - Direct Use of Geothermal Energy. Proceedings WGC2010 Bali, Indonesia, 25-30 April 2010, 3p.

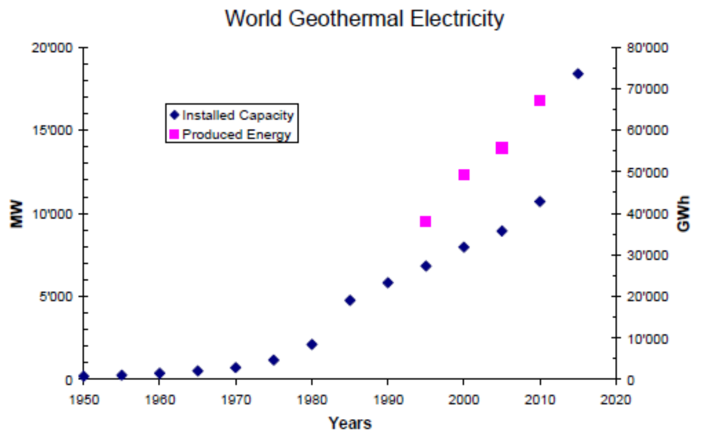
Bauer, S.J., Blankenship, D. and Nathwani, J. 2010. Geothermal Implementing Agreement, Annex VII: Advanced Geothermal Drilling and Logging Technology. Proceedings WGC2010 Bali, Indonesia, 25-30 April 2010, 4p.

All WGC 2010 papers available at: http://www.geothermal-energy.org/304,iga_geothermal_conference_database.html.

Where does geothermal stand today?

One of the WGC's most important efforts is its five-yearly collection and publication of comprehensive, up-to-date geothermal information for every known user country. For the WGC 2010, most of this information was provided from 68 country update reports; two major review papers presented summaries of the global results for geothermal power generation and direct use applications. In 2010, 24 countries produced electricity from geothermal resources. Total global installed capacity was 10,715 MW_e, producing 67,246 GWh/year. Installed capacity increased at an average rate of 350 MW_e/year since the last report in 2005, significantly faster than the 200 MW_e/year pace between 1985 and 2005.

Some interesting facts emerge from the detailed findings. For instance, geothermal power generation for a gold mine on Lihir Island in Papua New Guinea recently expanded from 6 MW_e to 56 MW_e. Germany, for its part, currently has geothermal power plants at Landau (3.0 MW_e), at Neustadt-Glewe (0.23 MW_e) and at Unterhaching (3.36 MW_e), including CHP plants providing an extra 55 MW_{th} heat to district heating schemes. At Chena Hot Springs, Alaska (United States), three ORC binary cycle plants generate 730 kW_e using 74°C water. Treated sewage effluent piped to the Geysers (California, United States) in pipelines 48 km and 66 km long adds 177 MW_e capacity for power generation.



Geothermal installed capacity from 1950 to 2010 (estimated for 2015), and electricity generated (GWh) from 1995 to 2010 (Bertani, WGC 2010)

At national level, Papua New Guinea, Tibet, Kenya, Nicaragua and Guadeloupe all obtain more than 5% of their electricity from geothermal. Costa Rica and New Zealand generate about 14% and São Miguel Island (Azores), Tuscany (Italy), Iceland, El Salvador and the Philippines range between 17% and 40%.

Direct use applications from geothermal fluid – the use of fluid heat without conversion to electricity – was reported by 78 countries at the end of 2009, with total global installed capacity of 50,583 MW_{th} and thermal energy use of 438,071 TJ/year (121,696 GWh/year). Worldwide installed capacity has grown 79% since 2005, with a corresponding 60% increase in use of this application.

Total use of geothermal direct heat is made up as follows: geothermal heat pumps or GHPs (49%); bathing/swimming/balneology (24.9%); space heating (14.4%) – 85% being from district heating; greenhouse/open ground heating (5.3%); industrial process heat (2.7%); aquaculture pond/raceway heating (2.6%); agricultural drying (0.4%) and snow melting/cooling (0.5%).

The highest levels of direct use installed capacities were reported for the United States (12,611 MW_{th}), China (8,898 MW_{th}), Sweden (4,460 MW_{th}), Norway (3,300 MW_{th}) and Germany (2,485 MW_{th}). Together they account for 60% of global capacity and 55% of use. Of particular note is that geothermal direct use provides 89% of Iceland's space heating needs, and Turkey has the largest geothermal installed capacity for district heating at more than 2,080 MW_{th}.

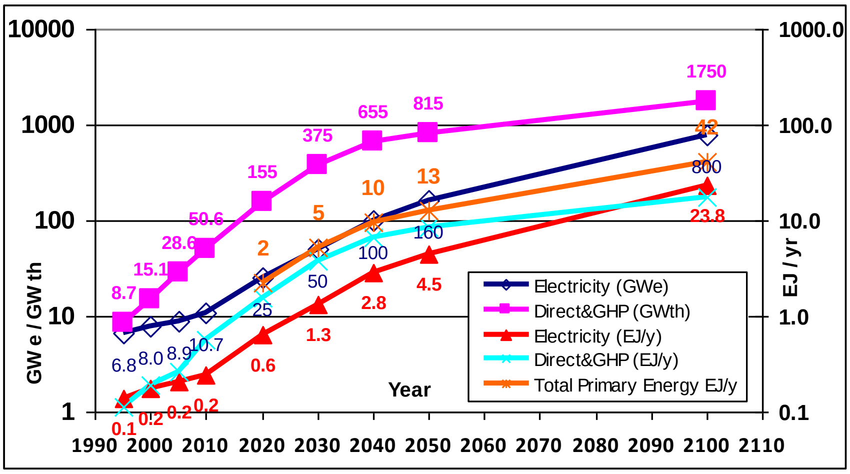
GHPs are the dominant direct use application with 70% of the total installed capacity and 49% of the total use, representing increases of 18% and 19.7%/year (compound rates) respectively, due to the growing popularity of GHPs and their widespread applicability globally. Assuming a reasonable average equivalent of 12 kW per GHP unit, an estimated 2.94 million GHPs were in place worldwide at the end of 2009. Estimated worldwide savings in carbon, CO_2, SO_x and NO_x emissions from the direct use of geothermal energy are provided in the table above.

Geothermal Use	Fuel Oil (Mtoe)	Carbon (Mt)	CO_2 (Mt)	SO_x (Mt)	NO_x (Mt)
As Electricity	46.2	46.6	148.2	0.98	0.28
As Direct Heat	23.1	23.2	74.1	0.49	0.14

Worldwide savings in fuel oil, carbon, CO_2, SO_x and NO_x emissions from geothermal direct use (Lund, Freeston and Boyd, WGC 2010)

Geothermal's prospects

Climate change mitigation concerns have meant closer examination of the potential of many renewable energy forms. For geothermal, it is clear that the worldwide "technical" geothermal potential, or resources accessible with current technology, is massive, albeit difficult to determine with precision. For conventional power generation using hydrothermal systems alone, the technical potential is estimated at 1-2 TW_e. For direct heat applications using the lower temperature resources (<130°C), it is 22-44 TW_{th}. Although concentrated along the plate tectonic boundaries and over hot spots, resources cover some 10%-15% of the earth's surface, home to about 15% of the earth's



Actual (1995-2010) and projected (2020-2100) installed capacities (GW) and energy supplied (EJ/year) for global geothermal deployment (Mongillo and Bromley, WGC 2010) population. Recent assessments estimate that deployable geothermal power from hydrothermal resources using current technology could be 70-80 GW_e by 2050.

Indeed, conventional hydrothermal resources could be dwarfed by global potential from other types of geothermal resources requiring "advanced" technologies. Estimates indicate their total global technical potential at over 300 EJ_e/year (12 TW_e), with deployment of 80 GW_e by 2050. Total global deployment of geothermal power, (hydrothermal plus advanced), could thus be about 160 GW_e of installed capacity generating 1,260 TWh/year by 2050 (see the chart above). A successful outcome would have geothermal providing as much as 8% of total global electricity supply, serving 17% of the world's population and providing 40 countries with a large share of their power from geothermal resources, offering CO_2 savings of an estimated 1 Gt/year.

Real, significant CO_2 reductions in association with power production are a possibility if CO_2 can be used instead of water as the "heat transmission" fluid to access the heat in EGS developments. Preliminary assessment indicates that the quantity of CO_2 "used" for generating electricity from a 1,000 MW_e EGS-CO_2 power plant after 36.5 years would be equivalent to 24 years of CO_2 emissions from a 1,000 MW_e coal-fired power plant.

Recent assessments place the worldwide direct use technical potential at up to 323 EJ/year, with a probable 2050 deployment of 815 GW_{th} and utilisation of 8.35 EJ_{th}/year. GHPs are expected to dominate growth. Assuming fuel oil is displaced to produce electricity to run the GHPs, 880 Mtoe would be replaced, with an equivalent CO_2 savings of 2.8 Gt/year.

Challenges in realising geothermal's potential

A look at the past 30-year global growth rate underlines the challenges for deploying installed geothermal capacity of 160 GW_e and generating 1,260 TWh/year by 2050. From linear between 1980 and 2005 at about 200 MW_e/year, growth increased to about 350 MW_e/year for the period 2005-2010. Although impressive, such trends are insufficient to fully exploit geothermal's capabilities, which can only be realised through a steep learning curve ensuring rapid deployment of advanced technologies like EGS, under-sea resources and super-critical or hyper-saline fluids.

The high geothermal growth rates indicated above will call for major R&D, requiring large government investment on a global scale, in addition to industry R&D. The lead has been taken both in the United States, with President Obama's US$ 350-400 million American Reinvestment and Recovery Act stimulation package to expand and accelerate geothermal development and deployment, and in Australia with federal and state funds amounting to hundreds of millions of US$ for geothermal exploration, demonstration and deployment. Other countries and organisations are also providing important financial support through such tools as feed-in-tariffs, portfolio standards, Clean Development Mechanism credits, drilling risk mitigation and development insurance.

It will also be necessary to raise public and government awareness of geothermal energy and its benefits. These include: high capacity and availability factors (> 90% for new plants); independence from local weather, seasonal and climate changes; baseload operation ability; on- or off-grid power provision capability; small carbon and land-use footprints (0.35 km^2/100 MW_e); and, finally, its environmentally-friendly, and socially-acceptable characteristics.

Geothermal has a bright future and can provide very large amounts of energy to satisfy growing global demand. Existing technologies must be improved, however, and new technologies developed. The benefits of geothermal and its long-term sustainable use must be promoted, with emphasis on the contribution that geothermal can make to the mitigation of climate change. Major efforts on an international scale will be required. In this, the IEA-GIA is well placed to contribute its convening power and its expertise to take geothermal onwards into a new phase of yet stronger growth.