The International Energy Agency - Geothermal Implementing Agreement

3rd Term Achievements and 4th Term Aspirations

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ABSTRACT

The International Energy Agency (IEA)-Geothermal Implementing Agreement (GIA), founded in 1997, provides a versatile structure for wide-ranging international cooperation on geothermal research and technology under the auspices of the IEA. It links important national and industry programmes for exploration, development and utilization of geothermal resources. Emphasis is placed on enhancing effectiveness through establishing direct cooperation among experts in member countries, industries and organizations. The GIA provides participants with opportunities for information exchange; participation in R&D projects and in the development of techniques, best practices, databases, models and handbooks; and exposure to global perspectives on geothermal issues and sustainable development strategies. The GIA emphasizes production and dissemination of impartial, authoritative information. As one of 41 Implementing Agreements, the GIA supports the IEA's efforts to help ensure the provision of reliable, affordable and clean energy to its 28 member countries and beyond. The IEA aims to develop a sustainable energy policy that incorporates energy security, economic development, environmental awareness, and engagement with non-member countries to find solutions to shared energy and environmental concerns.

The GIA completed its 3rd term in February 2013, and the IEA has extended the GIA's mandate for a 4th 5-year term, continuing its activities to 2018. The GIA's 3rd Term efforts were guided by this Mission: *To promote the sustainable utilization of geothermal energy throughout the world by improving existing and developing new technologies to render exploitable the vast and widespread global geothermal resources, by facilitating the transfer of know-how, by providing high quality information and by widely communicating geothermal energy's strategic, economic and environmental benefits, and thereby contribute to the mitigation of climate change.* To realize this mission, the GIA worked in six diverse topic areas: Annexes: I- Environmental Impacts of Geothermal Energy Development, III- Enhanced Geothermal Systems, VII- Advanced Geothermal Drilling Techniques, VIII- Direct Use of Geothermal Energy, Annex X- Data Collection and Information, and Annex XI- Induced Seismicity; the latter two Annexes added in the past three years.

Highlights of the GIA's 3rd Term achievements include: contributions to the geothermal chapter of the IPCC SRREN (Special Report on Renewable Energy) and the IEA Technology Roadmap on Geothermal Heat and Power; editorship of and contributions to the ***Geothermics*** Special Issue on Sustainable Utilization of Geothermal Energy; publication of a Handbook of Best Practices for Geothermal Drilling; joint convener of the GIA-IGA Workshop on Global Development Potential and Contribution to Mitigation of Climate Change; preparation of a Protocol for Induced Seismicity; convener of international workshops on topics such as sustainability, induced seismicity and environmental mitigation; participation at various annual international conferences and the World Geothermal Congress 2010; publication of comprehensive GIA annual reports; publication of a new annual GIA report on Trends in Geothermal Applications; and re-development of the GIA public website as a facility for growing information dissemination. Of particular significance was the establishment of a project proposal funding scheme, which generally supports completion of substantive Annex outputs, such as reports and workshop proceedings. GIA publications are made freely available to the global community on the GIA public website.

Future planned activities include: continuation of current initiatives (active Annexes); addition of new studies where important new global issues, problems, or technologies are identified; joint work with the IGA to collect/publish annual country geothermal energy utilization data/information; expansion of GIA's seminar/workshop programme, with venues planned for prospective Member countries (e.g., the Philippines and China); and continued support of the IEA through workshop participation and contribution of articles to the

IEA OPEN Bulletin and the IEA Energy Journal. Development of the GIA website will also continue.

During GIA's 3rd term, membership increased from 14 to 20. It now includes: 14 countries (Australia, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Norway, Republic of Korea, Spain, Switzerland, United Kingdom, United States), the EC, 3 industry members (Geodynamics, Green Rock Energy, Ormat Technologies) and 2 national organizations (CanGEA [Canada] and Geothermal Group APPA [Spain]). The GIA will continue its efforts to seek new members able to contribute to the achievement of its mission and extend its global geothermal collaboration.

A review of the current global energy scene, including relevance to climate change, is presented. The IEA and GIA structures and operations are briefly described; details of GIA's major achievements for promoting sustainable geothermal utilization are discussed; and future plans for a 4th 5-year Term are reported.

1. INTRODUCTION

This paper presents a description of the IEA-GIA and its activities for its 3rd Term of operation, 2007-2013. The organization's significant achievements for this period are discussed and plans for the 4th Term are described. The IEA and its r*aison d'être* are reviewed and geothermal's potential contribution to meeting global energy demand growth in the context of the current energy scene are outlined.

More details about the IEA and the recent work of the IEA-GIA can be found in the GIA 2007-2013 End of Term Report (GIA EoT, 2012), Strategic Plans for 2007-2013 (GIA SPb, 2006) and 2013-2018 (GIA SPa, 2012), and in the comprehensive IEA-GIA annual reports available on the IEA-GIA website. Note that all website addresses are included in the Reference section.

2. CURRENT GLOBAL ENERGY SCENE

Though the total global demand for energy has grown nearly every year between 1971 and 2008 (Figure 1), there was a slight (~1%) decrease in the 2009 worldwide total primary energy supply to 12,150 Mtoe (508.7 EJ_{th}) compared to 2008 (12,267 Mtoe, 514 EJ_{th}) and a ~0.6% decrease in electricity generation to 20,055 TWh (IEA, 2010; 2011), probable consequences of the global financial crisis. However, this slight lull was overwhelmed by the extraordinary ~5% increase in primary energy demand in 2010 to 12,717 Mtoe and associated CO_2 emissions of 30.5 Gt, an increase of 5.3% over 2009 (Birol, 2011; 2012). This exceptional annual growth is now raising real concern about the possibility of achieving the global climate change objective of limiting the temperature increases this century to 2 °C above the pre-industrial levels (*ibid*.). In addition, an unacceptable 20% of the world's population, ~1.3 billion, still remain without access to electricity.

Further challenges have arisen since 2010 (WOE, 2012), including: the revival of oil and gas production in the United States; worldwide expansion in unconventional gas production; continued increases in fossil fuel subsidies that promote wasteful consumption to about US$ 523 billion in 2011 (six times more than renewable energy subsidies); growing global energy intensity; turmoil in the Middle East and North Africa casting doubts about the reliability of global energy supplies; and the reduction or elimination of nuclear power in some countries as a consequence of the Fukushima Daiichi nuclear disaster in Japan. Compounding these issues is the shift of government focus to concerns about economic growth and the financial integrity of several European countries and so away from energy policy and climate change.

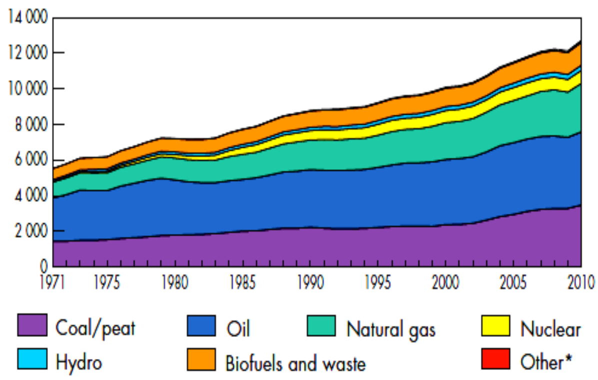

Figure 1: World total primary energy supply by fuel (in Mtoe) for the period 1971-2010 (IEA, 2012a) [* Geothermal is part of "other"].

Assuming that recent government policy commitments are implemented in a cautious manner, termed the New Policies Scenario (WOE, 2012), energy demand will grow by 30% between 2010 and 2035 as a consequence of a global population increase of 1.7 billion people and global economy growth of 3.5%/yr. About 90% of the population and energy demand growth occurs in non-OECD countries, with China becoming the largest energy consumer and energy consumption rates in India, Indonesia, Brazil and the Middle East growing even faster than in China. Though the demand for all fuels increases, the fossil fuels share decreases from 81% in 2010 to 75% in 2035. However, natural gas has an increased share in the global mix. Renewable energies, mainly hydro and wind, provide about 50% of the new installed power capacity. The outcome of the New Policies Scenario leads to a temperature increase of 3.6 °C, compared to the Current Policies Scenario, which results in a temperature increase of ≥6 °C and associated incomprehensible environmental and economic consequences (WEO, 2012).

To achieve the 2 °C limit as formulated in the 450 Scenario (450 ppm CO2-eq greenhouse gas concentration), 80% of the total energy related CO_2 emissions permissible by 2035 are now "locked-in" by the existing capital stock of power plants, buildings, factories, etc. Furthermore, if no new action is taken by 2017, all of the CO_2 emissions allowed by the 450 Scenario up to 2035 will be generated by the energy related infrastructure then in place. Consequently, only extremely costly "zero-carbon" power plants, factories and other infrastructure could be added between 2017 and 2035 (WEO, 2011).

Therefore, urgent and tough action is required to attain the climate change objective, with global emissions per unit of output needing to be reduced by 65% by 2035 (*ibid*.). Major energy efficiency improvements are needed and could contribute 50% of the required energy emissions reductions; and if rapidly deployed, could postpone from 2017 to 2020 the total CO_2 "lock-in" resulting from continued inaction to reduce CO_2 emissions. The fossil fuel subsidies must be abolished and more carbon emission disincentives, such as sufficient carbon pricing, need to be established to support more low-carbon technologies. Also of great importance is the scale-up and protection of energy sector R&D. Technologies based on renewable and nuclear energies, and carbon capture and storage (CCS), all have important and large roles to play, providing 60% of the global electricity production in 2030 in the 450 Scenario.

Awareness of the current global energy situation and possible dire future climate change outcomes are strong incentives for urgent action, particularly for expanding the use of clean, renewable energy resources. Providing affordable, reliable and clean energy to meet future needs while mitigating major climate change is an enormous challenge, and geothermal energy can make an important contribution.

3. GLOBAL GEOTHERMAL POTENTIAL AND CURRENT STATUS

Geothermal is classified as a renewable energy, and has the potential to make a significant contribution to present and future energy demands, while helping mitigate climate change. Geothermal resources essentially consist of the heat stored beneath the earth's surface and that discharging from it. The main sources for geothermal energy are the heat flow from the earth's core and mantle and that generated by the gradual decay of radioactive isotopes in the earth's continental crust. Together, these result in an average terrestrial heat flow rate of 44 TW_{th} (1,400 EJ/yr). Of this total, ~315 EJ/yr (22%) is sourced from beneath continental land masses, and this renewable surface heat flow alone represents nearly 60% of the 2010 worldwide total primary energy supply of 533 EJ_{th}/yr. The theoretical stored heat energy (to 5 km depth) under continents has been estimated to range between 56 and 140 million EJ (Goldstein *et al.,* 2011). Though the world's geothermal heat resources (both stored and discharging) are enormous and ubiquitous, it is difficult to accurately determine economic and technically feasible potentials on a global basis due to their generally *hidden* nature (subsurface). This uncertainty is exacerbated because the technologies used to develop geothermal resources are evolving, extending capabilities and reducing costs, and thereby increasing technical and economic potentials. Therefore, there are considerable uncertainties in estimating the global geothermal resource potentials, and revisions are expected as more information and new technologies become available.

Recent estimates of global geothermal technical potential (Figure 2) (Bromley *et al*., 2010) for identified hydrothermal resources (i.e., identified geothermal resources located along tectonic plate boundaries and near volcanic hot spots) are in the range of 1.4-6.0 EJ_e/yr, or an average of 3.7 EJ_e/yr (1,028 TWh/yr, or 130 GW_e running at 90% capacity factor). This is about 5% of the total electricity generated in 2010 (21,431 TWh/yr, or 77EJ/yr) (IEA, 2012). This estimate is in good agreement with that of Stefansson (2005), who obtained 6.5 EJ_e/yr (240 GW_e) as the "most likely technical potential" for identified geothermal resources by relating the number of active volcanoes with the technical potential of high temperature geothermal fields. Incorporating approximations for as yet hidden/unidentified resources increases these estimates by factors of 5-10 (Bromley *et al*., 2010; Stefansson, 2005), raising the probable contribution from hydrothermal resources to ~46 EJ/yr, or about 1,700 GW_e. In addition, with current conversion efficiencies (capacity factors) increasing, and now ranging up to 90%, power generation potentials are increasing.

In addition to hydrothermal resources, several other potentially significant geothermal sources capable of power generation and direct heat use exist: 1) binary generation from the use of the hot water discharged from conventional plants (co-generation) and that available from the lower temperature geothermal resources (75-130 °C); 2) the cascaded use of hot water discharged from geothermal power stations for direct heat applications; 3) the massive geothermal energy potential available within drilling depths (3-10 km) in the hot rock of the earth's crust using enhanced geothermal systems technology (EGS); 4) the energy resources in the form of super-critical fluids inferred to exist deep (3-5 km) beneath hydrothermal systems; 5) hot water produced from oil and gas wells; 6) hot water present in deep sedimentary basins; 7) off-shore (under-sea) hydrothermal resources located along the submarine rifts and identified by the presence of hydrothermal vents and 8) the ubiquitous shallow geothermal resources utilized by geothermal heat pumps for heating and cooling, and available almost anywhere on the earth's surface.

Recent pragmatic estimates of future geothermal deployment potential for electricity generation (Goldstein *et al.,* 2011) indicate that using current technology, hydrothermal resources, available at some 10-15% of the earth's surface and home to ~15% of the world's population, could provide 70-80 GW_e by 2050 (i.e., ~6 times current installed capacity of ~12 GW_e) (Figure 3). In addition, development of other geothermal resources using “advanced” technologies, including: EGS, super-critical fluids, co-produced hot water, hot sedimentary aquifers, and off-shore resources could deploy another 80 GW_e by 2050, resulting in a total global geothermal power deployment of some 160 GW_e generating 1,260 TWh/yr by 2050. This would provide an estimated 8% of the world’s electrical power and save about 1 Gt of CO_2 emissions (Mongillo and Bromley, 2010b).

Direct use technical potential has been assessed at up to 320 EJ/yr, with a probable deployment of 815 GW_{th} and utilization of 8.35 EJ/yr by 2050 (*ibid.*).

Geothermal development for electricity generation and direct use has experienced a high growth rate worldwide for the past few years and future prospects continue to look very positive.

Geothermal is a significant global renewable energy resource, with many valuable characteristics, including its: extensive global distribution, environmentally friendly character, independence of season, immunity from weather effects, indigenous nature, contribution to development of diversified power, effectiveness for distributed application, sustainable development capabilities and small areal foot-print. Though geothermal predominantly operates as a baseload provider of electricity with availability and load factors typically well above 90%, it can also operate in a load-following capacity, although at lesser efficiency.

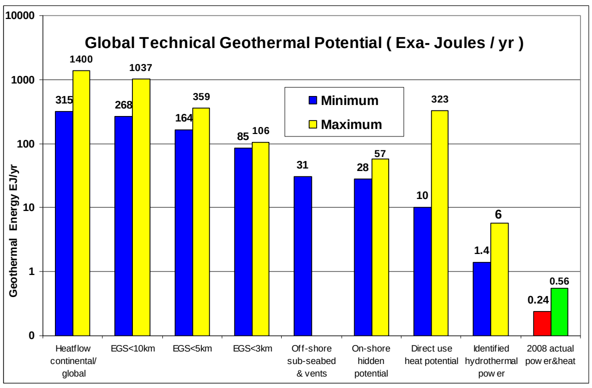

Figure 2: Global geothermal technical potentials for EGS (to 3, 5 and 10 km), offshore, onshore hidden and identified hydrothermal, direct use potential, and current power and direct use (Bromley et al., 2010).

Geothermal resources have the potential to make a considerable contribution towards meeting the world’s current and future energy needs well into the future, while contributing to the reduction of emissions and the mitigation of climate change. The global geothermal potential is enormous; however, attaining its maximum deployment requires continued R&D.

In 2010, the worldwide geothermal installed power capacity was 10.7 GW_e, distributed across 24 countries, with 67.2 TWh generated (Bertani, 2010). By May 2012, global capacity grew to 11.2 GWe (GEA, 2012). Since this installed capacity amounts to only ~8% of the estimated total global technical potential (137 GW_e) of identified hydrothermal resources (~0.6% if estimates of as yet hidden/unidentified resources are included), there is certainly potential for a large increase in conventional (hydrothermal) geothermal development to meet future growing demand for renewable energy in the plate boundary and hot spot active regions.

The total direct use installed capacity at the end of 2009 was about 50,583 MW_{th}, with a total thermal energy usage of 438,071 TJ/yr (121,696 GWh/yr) (Lund *et al*., 2010). In 2009, an estimated 2.94 million geothermal heat pumps (GHPs) were installed in 43 countries, with 35,236 MWth of installed capacity and 214,782 TJ/yr utilization (*ibid.*). As for power generation, the potential for increased direct use is huge. Currently, only 2% of the estimated minimum technical potential (10 EJ/yr) is being used. Recent estimates indicate that by 2050, the total deployment could increase to 815 GW_{th}; with utilization amounting to 8.35 EJ_{th}/yr. GHPs would be expected to dominate the future growth due to their ability to be used for both heating and cooling almost anywhere on earth.

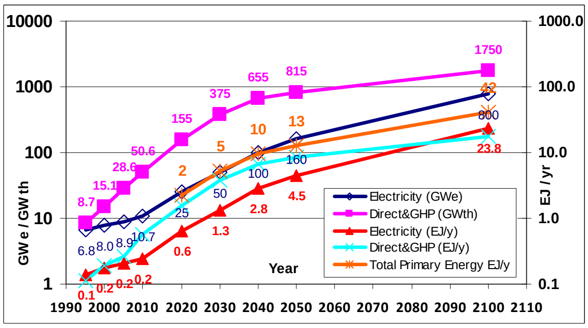

Figure 3: Actual and projected global geothermal deployment showing installed capacity (GWe) and energy supplied per year (EJ/yr) (Bromley et al., 2010).

4. THE INTERNATIONAL ENERGY AGENCY (IEA) AND IMPLEMENTING AGREEMENTS

The International Energy Agency (IEA) is an autonomous intergovernmental organization based in Paris, France (IEA website). Formed in 1974, in response to the 1973-74 oil crisis, the IEA now acts as an energy policy advisor to its 28 member countries. The IEA aims to help ensure the provision of reliable, affordable and clean energy to its member’s citizens.

In addition to its initial role of coordinating measures in times of oil supply emergencies, the IEA’s mandate has broadened and now includes: energy security, economic development and environmental protection- the major components of balanced energy policy making. Significant joint measures include developing alternative energy sources, increasing efficiency of energy use and assisting with the integration of energy and environmental policies. IEA's current work concentrates on market reform, energy technology collaboration, climate change policies and outreach to the wider global community. The IEA pursues an extensive programme of data compilation, energy research, publications and public dissemination of the most current energy policy analysis and good practices recommendations.

International energy technology cooperation can provide a cost-effective way to help guarantee energy security and address climate change issues. The IEA encourages such international collaboration in a variety of areas, including renewable energy technologies, through a network of 41 Implementing Agreements (IAs). The IAs provide a management framework and legal mechanism for guiding the IEA's collaborative program activities. Countries, industries and organizations may be IA members.

IA activities, or *tasks*, are defined and organized in *annexes*, which specify task objectives, schedules and funding provisions (if any), and identify participants and define their obligations. An Executive Committee (ExCo), consisting of one representative from each member, manages the activities of the IA. Each annex is led by an Operating Agent, usually an institution.

5. THE IEA GEOTHERMAL IMPLEMENTING AGREEMENT (GIA)

2.1 Overview

The GIA was founded in 1997 with an initial operating period of five years. It has since had its operations extended for three further 5-year terms, beginning its 4th 5-year term in March 2013.

The GIA provides a versatile and powerful framework for wide-ranging international cooperation in geothermal research and technology by connecting national and industry programmes for exploration, development and utilization of geothermal resources. It establishes direct cooperative links among the geothermal experts in the participating countries, industries and industry organizations. The general scope of the GIA's activities consists of international collaborative efforts to: *compile and exchange improved information* on global geothermal energy R&D, *develop improved technologies* for geothermal energy use, and *improve the understanding of the environmental benefits* of geothermal energy utilization and ways to avoid or minimize its environmental impacts. Collaboration within the GIA provides members opportunities to participate in R&D projects and assist with the development of databases, models and handbooks. There are also opportunities for information exchange via meetings, workshops and networking; and participation provides an international perspective on geothermal issues. New studies and activities are implemented when needs are established.

As of March 2013, there were 20 members in the IEA-GIA, including: 14 countries (Australia, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Norway, Republic of Korea, Spain, Switzerland, United Kingdom, United States), the EU, 3 industries (Geodynamics Limited, Green Rock Energy Limited, Ormat Technologies, Inc.) and 2 national organizations (the Canadian Geothermal Energy Association [CanGEA] and the Geothermal Group of the Spanish Renewable Energy Association [GG-APPA]).

The GIA ExCo, which consists of one voting representative from each member, supervises the overall operation of the organization. It meets twice each year to report on and discuss the organization's activities; and prospective new members and guests are invited to describe their geothermal pursuits and interests. Annex meetings are also held in association with the ExCo meetings.

The GIA ExCo Secretariat, currently based in New Zealand, conducts the regular administrative work for the organization, including: communication with GIA participants and IEA Secretariat, organization of the ExCo meetings and preparation of minutes, as well as maintenance of the website, preparation of the annual reports, support to the ExCo's information dissemination programme (publications/presentations describing and promoting GIA activities), and contribution to/review of IEA publications. The operational expenses for the GIA Secretariat and other common costs of the ExCo are provided from a Common Fund to which all members contribute through a share apportionment system.

GIA membership provides many valuable benefits, including:

- Increase joint R&D capabilities
- Avoid duplication and unproductive research
- Develop skills and knowledge
- Improve R&D cost effectiveness by sharing information and technical resources
- Provide easier access to key information, research results and technological capabilities
- Provide impartial information and analysis to help guide national policies and programmes
- Provide the opportunity to review current issues, on-going and future research directions
- Investigate barriers to implementation
- Contribute to the development of energy policies

To date, all Annex activities have been conducted through task sharing, i.e., Annex participants and Operating Agents provide resources and personnel to conduct their portion of the work at their own expense. Participants also pay their own expenses associated with participation and attendance at ExCo and Annex meetings. By arranging Annex meetings in conjunction with the ExCo meetings, or other events, travel costs are minimized. Though exact figures are not available, the total Annex "in-kind" efforts in 2012 are estimated at over 6 person-years/year.

5.2 3rd Term Strategic Direction

During its 2nd and 3rd Terms, the GIA has continued to pursue the abovementioned scope of activities and concentrate its efforts on encouraging, supporting and advancing the development and use of geothermal energy worldwide both for power generation and direct-heat applications (GIA SPb, 2006); through recognizing the importance of energy security and more explicitly identifying "actions" and stressing the importance of sustainable development and climate change in its 3rd Term. Important objectives are to improve and develop new technologies and to increase awareness of geothermal energy and the benefits of its sustainable utilization. Participants of the IEA-GIA saw it as an organization that can take the lead in these efforts, and embraced them its 3rd Term Mission:

To promote the sustainable utilization of geothermal energy throughout the world by improving existing and developing new technologies to render exploitable the vast and widespread global geothermal resources, by facilitating the transfer of know-how, by providing high quality information and by widely communicating geothermal energy's strategic, economic and environmental benefits, and thereby contribute to the mitigation of climate change.

To realize this mission, six strategic objectives were devised to guide the GIA's 3rd Term efforts:

- To actively promote effective cooperation in geothermal RD&D through collaborative work programmes, workshops and seminars
- To collect, improve, develop and disseminate geothermal RD&D policy information for IEA member and non-member Countries
- To identify geothermal energy RD&D issues and opportunities, and improve/develop geothermal energy technologies and methods to deal with them
- To increase membership in the GIA
- To encourage collaboration with other international organizations and appropriate IEA implementing agreements
- To broaden and increase the dissemination of information on geothermal energy and the GIA's activities and outputs to decision makers, financiers, researchers and the general public

6. 3RD TERM ACTIVITIES

The GIA's major activities encompass a range of geothermal topics, chosen to help achieve the above strategic objectives and realize its mission, and organized and implemented through "Annexes" (for more information see: IEA-EoT, 2012; Mongillo and Bromley, 2012; Bromley and Mongillo, 2012). New research topics (i.e., Annexes) may be added when the needs and opportunities arise; while ones that have attained their goals are closed.

The GIA's 3rd Term began with four diverse research topics continued from the 2nd Term:

Annex I: Environmental Impacts of Geothermal Energy Development- to determine the environmental effects of geothermal development and develop and implement methods to avoid or minimize their impacts. Four tasks include: to examine the impacts on natural features, to study the problems associated with discharge and (re)injection of geothermal fluids, to examine methods of impact mitigation and produce an environmental manual, and develop sustainable utilization strategies.

Annex III: Enhanced Geothermal Systems (EGS)- to investigate new and improved technologies to access the huge heat resources present at depth in continental land masses, by engineering heat exchangers in order to allow the extraction of geothermal energy at commercially viable rates. Three tasks include: to modify the use of conventional and develop new geothermal technology for EGS; to collect and make available information needed for decision making, design and realize commercial EGS projects; and to develop a handbook on the current state-of-art reservoir understanding, stimulation and analysis.

Annex VII: Advanced Geothermal Drilling and Logging Technologies- to promote ways and means to reduce the cost of geothermal drilling through developing an understanding of drilling and logging needs, elucidating best practices, and sharing methods to advance the state-of-the-art. Three tasks include: to compile geothermal well drilling cost and performance information, and store it in an accessible database, to hold an international best practices drilling symposium, and to monitor and exchange information on drilling technology development and new applications.

Annex VIII: Direct Use of Geothermal Energy- to address all aspects of direct use technology with emphasis on improving implementation, reducing costs and enhancing use. Four tasks include: to characterize resources, to collect and assess cost and performance data for installations, to identify barriers and opportunities, and to develop design configurations and engineering standards.

About mid-way through the 3rd Term, two new activities were initiated:

Annex X: Data Collection and Information- to collect essential data on geothermal energy development, use and trends in member countries, and publish an annual overview, which is made widely available.

Annex XI: Induced Seismicity- to determine the steps needed to make EGS/fluid injection a safe, useful and economic technology that is publically acceptable in order to facilitate and to accelerate the development of geothermal energy. Tasks include: develop a set of risk mitigation strategies and best practices (protocols), and to use induced seismicity to help optimize production.

All GIA Members are required to participate in at least one Annex, with all Country Members also required to take part in Annex X.

7. ACHIEVEMENTS FOR 3RD TERM

A few examples which demonstrate the range of GIA's work and highlight some of its major accomplishments are presented here.

7.1 Membership Growth

The GIA has grown its membership from 14 to 20 members during the 3rd Term, thus expanding its base for collaboration and information collection and dissemination. The GIA's activities bring together many of its participants' key national R&D laboratories/organizations (most designated by their Governments) and representatives with links to governments from most of the major geothermal countries, with major geothermal companies (Sponsors) from the USA and Australia and international industry organizations from Canada and Spain. This directly connects important geothermal R&D laboratories and researchers allowing discussion and information exchange, and establishment of collaborative projects. It also fosters important R&D/industry links, which help identify the needs of industry to research laboratories, and raise awareness of governments to important R&D that requires funding, thus leading to more targeted collaboration, hence, reduced R&D and development costs.

7.2 Funding of Supplementary Activities

Successful growth in membership has led to reasonable financial security for the GIA, with some surplus funds available for targeted supplementary activities. Consequently, in 2009, the ExCo established a mechanism to fund approved supplementary activities. Proposals are submitted requesting funding from the Common Fund for ExCo initiatives and Annex efforts to stimulate more joint activity by participants, and create more tangible products, particularly those that would otherwise be stifled by lack of funding from other sources. To date, about 10 such proposals have been funded.

7.3 Significant Information Dissemination

During the 3rd Term, the GIA ExCo and Annex participants have been particularly active and successful in their information dissemination and exchange endeavours, and have communicated their activities and results to a broad audience comprising: the lay-public, government institutions, industry and the scientific community. Results from Annex activities were presented in reports and papers published in scientific/technical journals and presented at conferences, meetings and workshops.

GIA ExCo members and Annex participants contributed papers to the European Geothermal Congress 2007 (Unterhaching, Germany); the Renewable Energy Congress 2008 (Busan, Korea), where it also sponsored an exhibition booth; the GRC 2009 (Reno, USA) and 2010 (Sacramento, USA) meetings; Stanford Geothermal Reservoir Workshops; and New Zealand Geothermal Workshops (2007-2012). The GIA also had a major presence at WGC 2010 (Bali, Indonesia), with several papers presented. Our overview paper "*IEA-GIA International Efforts to Promote Global Sustainable Geothermal Development & Mitigate Climate Change*" (Mongillo *et al.*, 2010) was chosen as a keynote address and the GIA exhibition booth attracted many visitors.

A wide range of promotional and less technical material is also produced by the GIA for the public, and government and financial institutions, including: annual reports and associated executive summaries. They provide up-to-date information about the organization, member's geothermal activities and Annex efforts, and include End-of-Term Reports [comprehensive description of the GIA's activities for the Term] and Strategic Plans, non-technical presentations, colour posters and other reports. A new "Trend" report prepared by Annex X, presents GIA member country geothermal development and use data, along with analyses, and is available from 2010.

The GIA's comprehensive public website (www.iea-gia.org) was re-developed in mid-2012, and provides up-to-date information about the organization and its Members, access to its publications, and geothermal energy to GIA members and the public. It is also an important and easily accessible means for distributing and reviewing GIA documents and other international publications.

7.4 Highlighted Efforts

GIA contributions to IEA Activities & Publications- The GIA has maintained strong support for the IEA during the 3rd Term through increased participation at IEA workshops, meetings and seminars, by direct participation and the provision of material for distribution; and by contributing to IEA publications. The GIA participated at three IEA Networks of Expertise in Energy Technology (NEET) workshops designed to encourage the uptake of more environmental-friendly renewable energy and promote membership in appropriate IAs (including the GIA): two in Beijing, China (2007 and 2012) and one in Moscow, Russia (2008).

The GIA also regularly provided information for IEA publications, including two articles for the IEA OPEN Bulletin (Bromley and Mongillo, 2008 [subsequently referenced in Wikipedia as a useful summary article on induced seismicity] and 2010). The Bulletin is a web-based quarterly newsletter designed to create wider awareness, both within and outside IEA Membership, of advances in energy technology development and deployment associated with work within the IEA Community. It is distributed to >12,000 subscribers. In addition, the GIA assisted the IEA to produce the IEA Geothermal Energy Essentials brochure (IEA Geo, 2010) and made significant contributions to the development of the IEA Technology Roadmap for Geothermal Heat and Power (see below).

Of particular note is the appointment of GIA Sponsor Member, Lucien Bronicki, CTO Ormat Technologies Inc., to membership on the IEA Renewable Energy Industry Advisory Board (RIAB).

Sustainable Utilization- The GIA adopted the promotion of sustainable geothermal development/use for realizing the huge global geothermal potential as a clean, economic and secure energy resource that could contribute to the mitigation of climate change as the core of its 3rd Term mission, and has maintained it as such for its 4th Term. Many papers were presented by Annex I participants on improved sustainability strategies at annual New Zealand Geothermal Workshops, annual Stanford Geothermal Workshops, annual Geothermal Resource Council meetings, the Renewable Energy Congress 2008 (Busan, Korea), and other meetings around the world. Of particular significance was the publication of a ***Geothermics*** Special Issue on Sustainable Utilization of Geothermal Energy in 2010 (Geothermics, 2010). This issue comprised 11 articles covering both power generation and direct use, and included case histories and modelling results illustrating various sustainable utilization methods for many of the major developed geothermal fields with long periods of power and direct use production.

Climate Change Mitigation- One of the GIA's most important aims is to encourage geothermal development and utilization in a manner that contributes to the mitigation of climate change. The GIA has pursued several activities during the 3rd Term that support this aim. In May 2009, a well-attended joint GIA-IGA (International Geothermal Association) Workshop on *Geothermal Energy- Its Global Development Potential & Contribution to Mitigation of Climate Change* was held in Madrid, Spain (Mongillo, 2010), an outcome of the assessment of a scoping study of the possible role and contribution of geothermal energy to the mitigation of climate change (Fridleifsson *et al*., 2008).

The results of this joint GIA-IGA workshop provided valuable input into the Inter-Governmental Panel on Climate Change (IPCC), Special Report on Renewable Energy Sources and Climate Change Mitigation (IPCC SRREN, published in May 2011), for which five GIA participants made substantial contributions to the chapter on Geothermal Energy over a period of two years (Goldstein *et al*., 2011). Of particular importance in this document was the comprehensive global assessment of the potential and possible deployment for a range of conventional and non-conventional geothermal resources, including: hydrothermal, EGS, deep sedimentary aquifers, super-critical temperature systems, off-shore resources, etc.

Reduced drilling costs- Drilling, logging, and completing geothermal wells are essential and expensive components of geothermal exploration, development, and utilization, because of the high temperatures and hard, fractured formations typically encountered. Because drilling and well completion can account for more than half of the capital cost of a geothermal power project, reducing their costs can have impressive impacts on the viability and success of geothermal projects. Consequently, a significant contribution to the international geothermal community was made through Annex VII's preparation and publication of the *Handbook of Best Practices for Geothermal Drilling* (Finger and Blankenship, 2010), with financial support from the US DOE.

IEA Geothermal Roadmap- There is clear recognition that development of advanced energy technologies must be accelerated in order to deal with the challenges of providing clean energy in a sustainable manner, while mitigating climate change. The G8 countries acknowledged this at a meeting in 2008, where they requested the IEA to develop roadmaps to advance innovative energy technologies. Consequently, the IEA has undertaken the development of a series of global technology roadmaps, and with the impetus provided by the GIA, included geothermal energy in the roadmap programme. GIA participants made significant contributions to three international roadmap workshops held in Paris (April 2008), Sacramento (October 2010) and Indonesia (November 2010), and to several draft reviews, which culminated in the publication of *the IEA Technology Roadmap for Geothermal Heat and Power* in June 2011. As an IEA document, the geothermal roadmap has potential for great influence on geothermal deployment because of the IEA's high regard internationally and its extensive, high level communication capability.

Induced Seismicity- Induced seismicity associated with fluid injection into geothermal systems is of international importance and Annex XI has made some inroads while working collaboratively with the International Partnership for Geothermal Technology (IPGT) Induced Seismicity Working Group and other research groups, for example, the 'Geothermal Engineering Integrating Mitigation of Induced Seismicity in Reservoirs' (GEISER). Progress has been made in refining appropriate protocols for project operators (Majer, 2011), improved understanding of mechanisms, and devising avoidance or mitigation strategies.

Global Review of Geothermal Reporting Technology- A recent highlight of Annex III (EGS) activities has been the completion of a report addressing the need for global consistency in reporting geothermal resources and reserves, particularly with respect to stored heat assessments.

8. 4TH TERM DIRECTIONS AND ASPIRATIONS

Geothermal power and direct use development continue on a significant growth path in many countries, though the global growth rates in power capacity declined in 2011 (Worldwatch, 2013; GEA, 2012). In spite of geothermal's huge potential and valuable characteristics, growth in its development is outstripped by solar PV and wind. Clearly, geothermal continues to face serious obstacles, including technical, political, financial and perceived barriers. These must be overcome if geothermal is to realize its huge potential and make the more rapid contribution to renewable energy deployment that it is capable of. During its 4th 5-year term operating under the auspices of the IEA, the GIA aims to give geothermal appropriate recognition among the other renewables, and to help overcome these barriers.

Though the GIA will be continuing with substantially the same mission as for its 3rd Term, its strategic objectives have been revised and extended:

- To actively promote effective cooperation on geothermal RD&D, including with industry partnership, through collaborative work programmes, workshops and seminars
- To provide policy makers with information about the newest developments in geothermal energy and highlight its advantages for sustainable development, the environment and economy
- To inform and educate international financial institutions about the value and hurdles specific to geothermal deployment
- To identify and deal with geothermal energy RD&D issues and opportunities, and encourage collaboration to improve/develop cost-effective methods and technologies
- To increase membership in the GIA with particular emphasis on encouraging non-IEA Member countries with significant potential geothermal resources
- To encourage collaboration with other international organizations and appropriate implementing agreements
- To be an unbiased source of reliable, current worldwide information about geothermal energy and increase its dissemination to the IEA family and global decision makers, financiers, researchers and the general public.

With these objectives in mind, the GIA will initially focus on the following key areas:

- Refine global geothermal resource potential estimates and development costs
- Improve strategies for sustainable development and optimized performance
- Devise cost-effective EGS reservoir stimulation technologies that minimize potential adverse effects of induced seismicity
- Continue development of the database for geothermal drilling costs and publish the spreadsheet calculator and seminar on geothermal drilling best practices
- Collect current resource & development data/information, and provide on the web
- Promote benefits of geothermal and contribution to mitigation of climate change
- Participate in major international and IEA meetings
- Convene international workshops and seminars
- Continue Membership growth, especially encouraging Indonesia, the Philippines, China, India, Russia, Turkey and Kenya to join.

9. CONCLUSIONS

The GIA has enjoyed considerable success and gained an excellent reputation through its international collaborative efforts during the past 15 years.

Participants of the GIA agree that geothermal will contribute significantly to the provision of energy to help satisfy the growing global demand, however, it is necessary to improve and develop new technologies, to promote the benefits of geothermal and its long-term sustainable use, and to stress the contribution that geothermal can make to the mitigation of climate change.

This will require significant effort, and the GIA is well-placed to help lead this international effort well into the future. There is a bright future for geothermal, and the GIA invites and encourages new membership from those who wish to contribute, to join us in the venture.

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