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IEA-Geothermal: Reflecting on 18 years of Successful International Collaboration with a View to the Future

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ABSTRACT

April 2015 sees the International Energy Agency- Geothermal Implementing Agreement (IEA-Geothermal, also known as IEA-GIA), completing its 18th year of operation. The organization's 3rd Term efforts and achievements were recognized by the IEA in February 2013, with their decision to extend its mandate for a 4th 5-year term. IEA-Geothermal, which operates under the auspices of the IEA, provides a formal, but flexible framework for international cooperation on a broad spectrum of contemporary geothermal research and technology topics. Direct collaboration among experts of member countries, industries and organizations increases capabilities; avoids duplication of efforts; improves cost effectiveness through information sharing and joint effort; provides easier access to key information, research results and technological resources; and more. Emphasis is placed on the collection, analysis and dissemination of impartial, authoritative data and information. IEA-Geothermal thereby contributes to the IEA's efforts to promote global sustainable energy policies that help ensure the provision of reliable, affordable, clean energy, while contributing to the mitigation of climate change. To achieve its goals and attain its 4th Term mission: to promote the sustainable utilization of geothermal energy worldwide by optimizing international collaboration to improve technologies, thereby rendering exploitable the vast and widespread global geothermal resources, by facilitating knowledge transfer, by providing high quality information and by widely communicating geothermal energy's strategic, economic and environmental benefits, hence contributing to the mitigation of climate change, IEA-Geothermal is currently pursuing activities in seven topics, or Annexes: I-Environmental Impacts, III-Enhanced Geothermal Systems (EGS), VII-Advanced Geothermal Drilling and Logging Technologies, VIII-Direct Use, XI-Induced Seismicity, XII Deep Roots of Volcanic Geothermal Systems, and X-Data Collection and Information.

IEA-Geothermal's achievements since WGC-2010 include: a) major contributions to the IEA Technology Roadmap on Geothermal Heat and Power and the geothermal chapter of the IPCC SRREN (Special Report on Renewable Energy); b) editorship of, and contributions to, the Geothermics Special Issue on Sustainable Utilization of Geothermal Energy; c) publication of a Handbook of Best Practices for Geothermal Drilling; d) support for preparation of a Global Review of Geothermal Reporting Technology; e) convener of international workshops and seminars covering topics related to induced seismicity (Iceland), the mitigation of environmental impacts of geothermal development (New Zealand), the modelling of sustainable utilization (Iceland), geomechanical challenges associated with geothermal drilling, stimulation and production (USA), innovative ways to enhance permeability, reduce drilling costs and sustain geothermal production (Philippines); f) participation at international conferences (GRC, NZGW, Stanford Workshop, European Geothermal Congress); g) publication of comprehensive annual reports and a recently introduced annual Trends in Geothermal Applications report; h) co-produced with IEA the IEA Renewable Energy Essentials: Geothermal brochure, providing articles for the IEA Open Energy Technology Bulletin, and technical support for several other IEA reports; and i) re-development of the GIA public website as a facility for growing information dissemination. Of special significance was the establishment of a project proposal funding scheme in late-2009, which has supported ten projects associated with Annex efforts, including the publication of reports and financial assistance for participation at relevant workshops. IEA-Geothermal publications are freely available to the global community on the GIA public website (www.iea-gia.org).

IEA-Geothermal membership currently comprises: 14 countries (Australia, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Norway, Republic of Korea, Spain, Switzerland, United Kingdom, United States), the European Commission, two industry members (Green Rock Energy, Ormat Technologies) and two national organizations (CanGEA [Canada] and Geothermal Group APPA [Spain]). The GIA continues to seek new members who can contribute to the achievement of its mission, increase its expertise, and extend its global geothermal collaboration.

A brief review of the current global energy scene and its relevance to climate change is presented. The structure and operation of IEA and IEA-Geothermal are briefly described, details of our major achievements for promoting sustainable geothermal utilization and growth in activities are discussed, and future plans are outlined.

1. INTRODUCTION

This paper presents a significant update of the IEA-GIA paper presented at the WGC 2010 (Mongillo *et al*., 2010) and other recent papers and presentations by Bromley and Mongillo (2012) and Mongillo and Bromley (2013, 2012). 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 (IEA-GIA EoT, 2012), Strategic Plan for 2013-2018 (IEA-GIA SP, 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 AND CLIMATE

The rapid expansion of renewable energies, especially solar and wind, was a very encouraging world highlight for the 2011-2012 period (IEA PRa, 2013). Regrettably, it was overshadowed by the relentless growth in global demand for energy; the continuing, distressingly slow global progress towards a low-carbon energy system; as well as the apparent loss of "drive" to clean-up the global energy system as the result of national government austerity plans overriding renewable energy policy support (*ibid.*). The world continues to be off-track in its efforts to attain the internationally-agreed target to limit the average global temperature increase to 2 °C above the pre-industrial global average by the end of this century.

The total global demand for energy in 2011 continued its virtually uninterrupted growth trend of the past 40+ years, barring the ~1% decrease that occurred in 2009- a probable consequence of the global financial crisis (Figure 1) (IEA, 2013). The global total primary energy supply (TPES) in 2011 reached 13,113 Mtoe (549 EJ_{th}), more than 3.1% higher than in 2010 (12,717 Mtoe), which itself had grown by ~5.3% from 2009 (Birol, 2011, 2012). Similarly, the global electricity production in 2011 increased to 22,126 TWh, about 3.2% higher than that in 2010 (IEA, 2013).

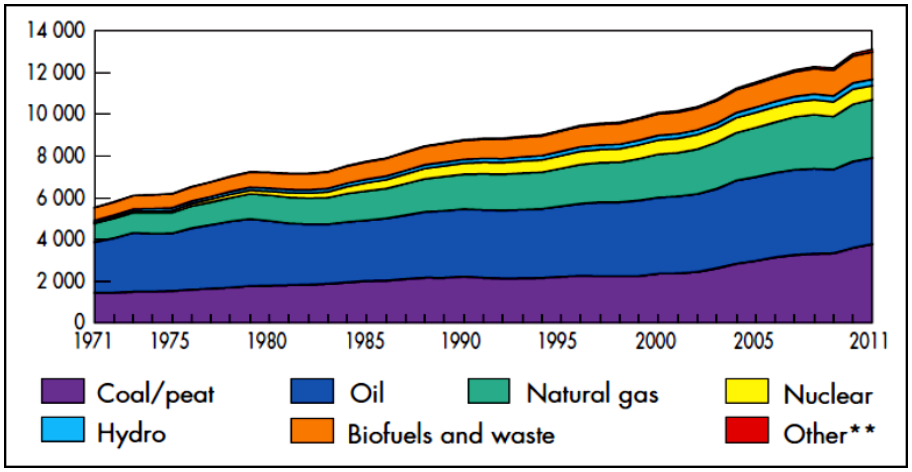

Figure 1 World total primary energy supply from 1971 to 2011 by fuel in million tonnes of oil equivalent (Mtoe) (IEA 2013). [Other includes geothermal, solar, wind, heat, etc.]**

Associated with this growth in energy supply is an increase in CO_2 emissions, which reached 31,342 Mt in 2011, an increase of 1,016 Mt, or 3.4%, over the 2010 value (Figure 2) (IEA, 2013). IEA estimates for 2012 are higher again, at 31,600 Mt, a record high, but the result of a slightly more favourable lower growth rate (IEA PRb, 2013) (Figure 2). Non-OECD countries accounted for 60% of global emissions. China contributed the largest increase, 300 Mt, but this growth was one of the smallest in a decade as a consequence of its deployment of renewable energies (REs) and the major improvement in energy intensity of its economy. Emissions from the USA reduced by 200 Mt, the result of switching from coal to gas for power generation. Though Europe increased its use of coal, the economic contraction, growth in REs, and cap on emissions, led to emissions dropping by 50 Mt. Less favourable was Japan's increased use of fossil fuels to compensate for reduced nuclear power, thus increasing emissions by 70 Mt. The ~40% of global emissions contributed by the OECD countries in 2012 is down from 55% in 2000 (IEA, 2013b).

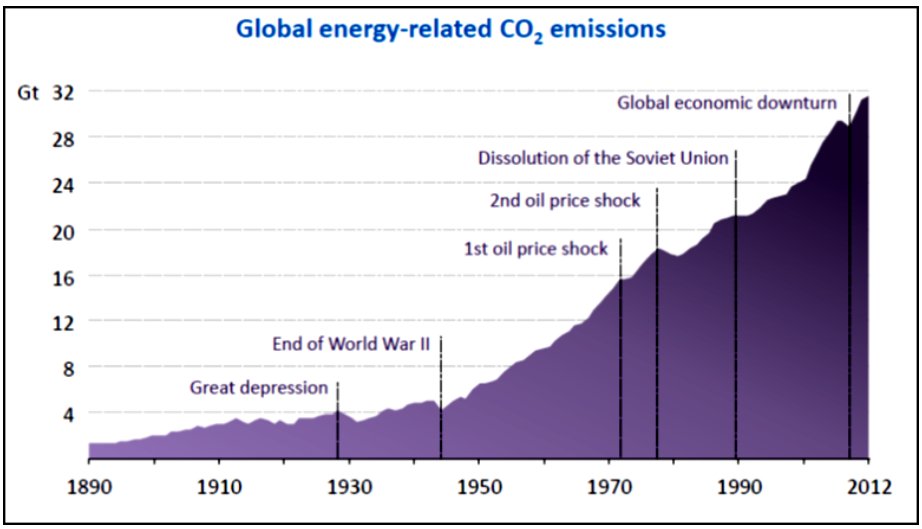

Figure 2 Global energy-related CO2 emissions from 1890 to 2012 (IEA 2013a).

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 to about US$ 523 billion in 2011 (six times more than renewable energy subsidies); growing global energy intensity (e.g., ratio of energy consumption to another metric, typically national GDP); continuing 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 more national concerns about economic growth and the financial integrity of several European countries, and so away from energy policy and climate change.

Continuing along the current path of relentless growth in global demand for energy; the continuing, distressingly slow global progress towards a low-carbon energy system; as well as the apparent loss of "drive" to clean-up the global energy system as the result of national government austerity plans overriding renewable energy policy support (*IEA PRa, 2013*); will result in the potentially "catastrophic" warming of the planet and associated damaging consequences. The average global temperatures have already increased by 0.8 °C, and without further action, the additional long-term increase is likely to be 2.8-4.5 °C, making a total temperature increase relative to pre-industrial values of 3.6-5.3 °C. Already, there is strong evidence that the climate is changing, and "extreme weather' events, such as storms, floods, heat waves, etc., should be expected to become more frequent and intense, along with increasing temperatures and rising sea levels.

Even considering the gains being made through the current positive policies, global energy-related GHG emissions in 2020 are estimated to be ~4 Gt of CO_2-equivalent higher than consistent with the 2 °C target. Consequently, such exceptional growth is raising major 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 (Birol, 2011, 2012). In addition, 20% of the world's population, ~1.3 billion, still remain without access to electricity.

International climate negotiations have led to an agreement to reach a new global agreement on climate change by 2015, which is to come into effect by 2020. However, serious action is required before 2020 if the global temperature rise limit of 2 °C has a reasonable chance of being achieved. The IEA has developed a range of "scenarios" to investigate various viable options for the reduction of emissions in order to attain the 2 °C target. The most recent developed, and still very encouraging one, is termed the *Four-for-2 °C Scenario*, which at this late stage, can reduce the growth in emissions by 3.1 Gt by 2020, or ~80% of the savings needed for the 2 °C path, and at no net economic cost (IEA, 2013b). This scenario comprises four policies: 1) Adopt specific energy efficiency measures, e.g., energy performance standards for lighting, new appliances and heating/cooling equipment (provides 49% of CO_2 emissions savings, 1.5 Gt). 2) Limit the construction and use of the least-efficient (sub-critical) coal-fired power plants; with greater use of gas and REs increasing from 20% today to 27% in 2020 (contributes 21% of the reduction, 640 Mt in 2020). 3) Minimise CH_4 emissions from upstream oil&gas production from venting and flaring, which amounted to ~1.1 Gt CO_2-eq methane released in 2010 (reduction of 18%). 4) Accelerate the partial phase-out of subsidies to fossil-fuels consumption, which amounted to US$ 523 billion in 2011, or 6 times the support to REs (12% reduction of CO_2 emissions, 360 Mt). These policies 1) can deliver significant reductions in energy-sector emissions by 2020, 2) rely only on existing technologies, 3) have already been adopted and proven in several countries, and 4) taken together would not harm economic growth in any country or region AND provide valuable "time while international climate negotiations continue (in preparation for the Conference of Parties meeting in Paris in 2015) and the national policies necessary to implement an expected international agreement are put in place" (*ibid.*).

In addition to the important IEA studies and reports, the results of two recent significant investigations have been published. The first is the *IPCC Fifth Assessment Report (AR5)* [on Climate Change] (website: http://www.ipcc.ch/report/ar5/), which is provided in 3 sections: 1) AG1: Climate Change 2013- The Physical Science Basis, 2) WGII: Climate Change 2014- Impacts, Adaptation and Vulnerability, and 3) WGIII: Climate Change 2014- Mitigation of Climate Change; with a Synthesis Report due in October 2014. Second is the *Third National Climate Assessment: Climate Change Impacts in the United States* report, which is a three-year effort that collected, assessed and integrated observations and research on climate change in the US. It focuses on current changes and those that can be expected to 2100 (Melillo, et al, 2014). Both of these reports support the general findings of the IEA- that man-made climate change is "real", that the world is now suffering some of the impacts of climate change, and that in addition to all efforts made to reduce emissions from now on, certain adaptive measures are necessary to deal with the extant changes.

Awareness of the current global energy situation and possible calamitous future climate change outcomes are strong incentives for urgent action, especially for expanding the use of clean, renewable energy resources. Two recent international reports: the *IEA Technology Roadmap for Geothermal Heat and Power* (IEA, 2011) and the *IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation, Chapter 4 Geothermal* (Goldstein, et al., 2011), both to which the GIA made significant contributions, conclude that geothermal energy can make a substantial contribution by providing long-term, secure, baseload energy and greenhouse gas (GHG) emissions reductions. The IEA roadmap (IEA, 2011) envisages geothermal deployment for electricity generation to reach 1,400 TWh/yr, or ~3.5% of global demand by 2050, and so avoiding about 800 Mt/yr of CO_2 emissions. IEA also foresees that, by 2050, geothermal will provide an annual 5.8 EJ (1,600 TWh) of thermal energy, or ~3.9% of the global heat demand (IEA, 2011). The IPCC report is in general agreement, concluding that the technical potential of geothermal energy is estimated to be 118 EJ/yr (to 3 km depth) to 1,109 EJ/yr (to 10 km depth) for electricity generation and from 10-312 EJ/yr for direct thermal uses; and by 2050, deployment could provide >3% of worldwide electricity demand and ~5% of the demand for heat (Goldstein, et al., 2011).

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

The International Energy Agency (IEA) was created in 1974 in response to the 1973-74 oil crisis. The IEA is an autonomous intergovernmental organization based in Paris, France (IEA website) and now acts as an energy policy advisor to its 29 member countries Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, The Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic,

Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States, and beyond. 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 assisting countries to coordinate measures in times of oil supply disruptions, the IEA's directive has broadened and now includes: energy security, economic development, environmental awareness and global engagement- 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 efforts concentrate 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.

4. THE IEA GEOTHERMAL IMPLEMENTING AGREEMENT (GIA)

4.1 Foundation and Strategic Direction

The GIA was founded in 1997, with an initial operating period of five years. It has since had its operation extended for three further terms following rigorous IEA term reviews, and began its 4th 5-year term in March 2013.

When originally established, the primary goal of the GIA activities aimed "at the coordination of the ongoing national [geothermal] activities in participating countries" to encourage wider use of geothermal energy (Rybach and Garnish, 2002). The fundamental objectives of the organization were also incorporated within Article 1 of the GIA's implementing agreement document (IEA GIA, 2011), and consist of international scientific collaborative efforts to:

- Compile and exchange information on geothermal energy research and development worldwide concerning existing and potential technologies and practices
- Develop improved technologies for geothermal energy utilization
- Improve the understanding of the environmental benefits of geothermal energy and ways to avoid or ameliorate environmental impacts
- Coordinate activities with other IEA Implementing Agreements as well as with those of other competent bodies

Now, well into its 4th Term (2013-2018), the GIA continues to pursue the abovementioned general scope of activities and concentrates its efforts on encouraging, supporting and advancing the worldwide development and deployment of geothermal energy both for power generation and direct-heat applications (GIA SP, 2012), and by recognizing the significance of energy security, stressing the importance of sustainable development, and contributing to the mitigation of climate change. Participants in the IEA-GIA see the organization as a leader in these efforts, and have embraced them its current (4th) Term Mission:

To promote the sustainable utilization of geothermal energy worldwide by optimizing international collaboration to improve technologies, thereby rendering exploitable the vast and widespread global geothermal resources, by facilitating knowledge transfer, by providing high quality information and by widely communicating geothermal energy's strategic, economic and environmental benefits, hence contributing to the mitigation of climate change.

To realize this mission, the GIA has adopted seven strategic objectives:

- 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

4.2 Membership and Administration Expand

When the IEA-GIA was officially formed in early March 1997, there were five Member Countries: Japan, New Zealand, Switzerland, the United Kingdom (UK) and the United States of America (USA), plus the European Commission; five months later, three more countries: Greece, Mexico and Australia had joined, bringing total membership to eight (Rybach, 1998). Since then, GIA membership has more than doubled to its current (May 2014) 19 Members, comprising: 14 countries (Australia, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Norway, Republic of Korea, Spain, Switzerland, United Kingdom, United States), the European Commission (EC), two industries (Green Rock Energy Limited, Ormat Technologies, Inc.) and two national organizations (the Canadian Geothermal Energy Association [CanGEA], 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, discuss and assess the organization's activities, and prospective new members and guests are invited to describe their geothermal pursuits and interests. Annex meetings and workshops are frequently held in association with the ExCo meetings.

During the 1st Term (1997-2002), the regular administrative work of the organization was performed on a voluntary basis by ExCo Members. However, as the organization's activities grew, this mode of operation became unviable. Consequently, the ExCo established the IEA-GIA Secretariat in March 2003, to deal with the regular administrative work, help manage the organization, contribute to the information dissemination process (e.g., preparation of the GIA Annual Reports, maintenance of the website, etc.) and assist with other activities of the organization as directed by the ExCo (see Mongillo and Bromley (2013) for details). The IEA-GIA Secretariat has been based at GNS Science, Wairakei Research Centre, in New Zealand, since its creation; its operational expenses plus other costs for organizational activities are provided from a Common Fund to which all members contribute.

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 have grown to an estimated >6 person-years/year.

5. GIA ACTIVITIES GROW TO ADDRESS NEW CHALLENGES

At its inception in 1997, GIA's activities covered three broad topics: Annex I Environmental Impacts of Geothermal Energy, Annex III Hot Dry Rock, and Annex IV Deep Geothermal Resources (Rybach, 1998). Since this time, there has been a growing recognition of the contribution that geothermal energy can make as a renewable energy source that can be sustainably developed, and a consequent significant growth in global interest and deployment. This situation, along with GIA's reputation for successful international collaboration, has led to significant growth in membership, which has expanded the organization's expertise, and identified new relevant topics. To address these growing interests, the GIA has expanded its efforts, which now cover seven broad topics (Annexes) (Table 1): 1) Annex I activities have continued unabated, 2) Annex III has been re-structured several times as EGS technology has advanced, and its name changed to Enhanced Geothermal Systems; 3) Annex VII Advanced Geothermal Drilling and Logging Technologies was activated in 2009, 4) Annex VIII Direct Use of Geothermal Energy was started in 2003, 5) Annex X Data Collection and Information was established in 2009, 6) Annex XI Induced Seismicity was initiated in 2010, and 7) most recently, in early 2014, Annex XII Deep Roots of Volcanic Geothermal Systems was opened. With the goals of Annex IV achieved, it was closed in 2006. A brief description of the current seven Annexes follows.

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 to 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. Two 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. Five tasks include: new and innovative direct use applications, communication, guidelines for geothermal direct use statistics, guidelines on statistics of GHP applications, and updating of the list of design configurations and engineering standards.

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.

Annex XII: Deep Roots of Volcanic Geothermal Systems- to advance knowledge on the nature and characteristics of the heat sources and heat transfer in the roots of volcanic geothermal systems through dissemination of information and research methods, with possible future utilization in mind; and to improve methods for exploration and modelling of the roots by facilitating co-operation and information sharing between scientists involved in such research. Three tasks include: the compilation of conceptual models of the roots of volcanic geothermal systems and associated research methods, the dissemination of information on advances in methods applicable for deep geothermal exploration, and aid in the advancement of methods for modelling conditions and processes in deep geothermal resources.

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

Table 1. GIA Annex management, participation and operational period information as at May 2014.

Annex Number	Annex Title Operating Agent (OA) Annex Leader (AL); Affiliation; Contact E-mail Participants	Status
I	**Environmental Impacts of Geothermal Development** OA: GNS Science (GNS), New Zealand AL: Chris Bromley; GNS, New Zealand; c.bromley@gns.cri.nz Participants: Australia, EC, France, Iceland, Italy, Japan, Mexico, New Zealand, Switzerland, USA	Initiated: 1997, Extensions: 2005-2018 (Ongoing)
II	**Shallow Geothermal Resources**	Closed
III	**Enhanced Geothermal Systems** OA: Geodynamics Limited, Australia, to September 2011; then US Department of Energy (DOE) ALs: Jay Nathwani; jay.nathwani@ee.doe.gov and Doone Wyborn; Doone.Wyborn@geodynamics.com Participants: Australia, CanGEA, EC, France, Geodynamics, GG-APPA, Germany, Green Rock Energy, Italy, Japan, Norway, ORMAT, Republic of Korea, Spain, Switzerland, UK, USA	Initiated: 1997, Extensions: 2005-2018 (Ongoing)
IV	**Deep Geothermal Resources**	Closed 2006
V	**Sustainability of Geothermal Energy Utilization**	Draft
VI	**Geothermal Power Generation Cycles**	Draft
VII	**Advanced Geothermal Drilling and Logging Technologies** OA: Sandia National Laboratories, for US DOE, United States AL: Stephen Bauer; Sandia National Laboratories, USA; sjbauer@sandia.gov Participants: Australia, CanGEA, EC, Iceland, Mexico, New Zealand, Norway, USA	Initiated: 2001, Extensions: 2005-2018 (Ongoing)
VIII	**Direct Use of Geothermal Energy** OA: Federation of Icelandic Energy and Waterworks, Iceland AL: Einar Gunnlaugsson, Reykjavik Energy, Iceland; einar.gunnlaugsson@or.is Participants: CanGEA, France, GG-APPA, Iceland, Japan, New Zealand, Norway, Republic of Korea, Spain, Switzerland, UK, USA	Initiated: 2003, Extensions: 2007-2018 (Ongoing)
IX	**Geothermal Market Acceleration**	Closed
X	**Data Collection and Information** OAs: Leibniz Institute for Applied Geophysics, Germany, and Federal Office of Energy, Switzerland AL: Britta Ganz, Leibniz Institute for Applied Geophysics, Germany; britta.ganz@liag-hannover.de Participants: Mandatory country membership; Australia, CanGEA, EC, France, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Norway, Republic of Korea, Spain, Switzerland, UK, and USA	Initiated: 2009, Continued through 2013 2013-2018 (Ongoing)
XI	**Induced Seismicity** OA: Lawrence Berkeley Laboratory, for US DOE, United States AL: Ernie Majer, Lawrence Berkeley Laboratory, USA; ELMajer@lbl.gov Participants: Australia, France, Germany, Iceland, New Zealand, Republic of Korea, Switzerland, USA	Initiated: 2010, Continued through 2013 Extensions: 2013-2018 (Ongoing)
XII	**Deep Roots of Volcanic Geothermal Systems** OA: Orkustofnun, The National Energy Authority of Iceland, Iceland AL: Gudni Axelsson, Iceland GeoSurvey, Iceland; gax@isor.is Participants: Iceland, New Zealand, Switzerland	Initiated: 2014; Continuing to 2018 (Ongoing)

6. SUCCESSFUL COLLABORATION

The GIA's enduring strength arises from its flexible framework for pursuing wide-ranging international cooperation in geothermal research and technology by connecting national and industry programmes for exploration, development and utilization of geothermal resources; and the direct cooperative links established and maintained among the geothermal experts in the participating countries, industries and industry organizations. The successful collaboration thus engendered provides members with important benefits and produces the organization's contributions to both members and the international geothermal community.

6.1 Membership Benefits

Collaboration within the GIA continues to provide members with opportunities to participate in R&D projects, and contribute to the development of databases, models and handbooks. Also of significant value are the many on-going opportunities for topical and up-to-date information exchange via meetings, workshops and networking. Participation also provides valuable international perspective on geothermal issues. New studies and activities have been implemented as needs have been established throughout the course of GIA's existence.

GIA membership provides many benefits, including:

- Increases joint R&D capabilities
- Avoids duplication and unproductive research
- Improves R&D cost effectiveness by sharing information and technical resources
- Provides easier access to key information, research results, and technological capabilities
- Provides impartial information and analysis to help guide national policies and programmes
- Provides the opportunity to review current issues, and on-going and future research directions
- Investigates barriers to implementation
- Contributes to the development of energy policies

6.2 Activities, Contributions and Achievements

A few examples that demonstrate the range of GIA's activities and highlight some of its major contributions and accomplishments are presented here. For more details see GIA annual reports and End-of-Term reports available on the GIA website, and Mongillo et al. (2005, 2010) and Mongillo and Bromley (2013).

6.2.1 Contributions to IEA

Fundamentally, the GIA's *raison d'être* is to support the vision, mission and strategic objectives of the IEA (section 3 above), as a "representative" of geothermal energy, considered to be one of the important low-carbon, baseload, renewable energy sources. In its position as an Implementing Agreement, the GIA has been able to raise the profile of geothermal energy among the many other renewable energy sources, on the international political and financial scene through the support of the IEA, who are recognized providers of energy information, energy policy, etc., to governments.

The GIA's participation with the IEA has grown significantly over the years, with increased participation at IEA workshops, meetings and seminars; through direct participation and the provision of GIA material for distribution at IEA events; and by contributing to the growing number and variety of IEA publications. The GIA has 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 has also regularly provided information and articles for IEA publications, e.g., *Tapping into Vast, Unused Heat Resources* (IEA, 2007), *Keeping the Heat On* (IEA, 2010), as well as reviewed several reports and geothermal contributions to them. The GIA has also contributed articles to the IEA OPEN Bulletin (Mongillo and Nieva, 2003; Bromley and Mongillo, 2008; and Mongillo and Bromley, 2010), a web-based quarterly electronic 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 over 12,000 subscribers. One of these articles, *Geothermal Energy from Fractured Reservoirs: Dealing with Induced Seismicity* (Bromley and Mongillo, 2008) is referenced in Wikipedia as a useful summary article on induced seismicity. In addition, the GIA made important contributions to the development of the *IEA Technology Roadmap for Geothermal Heat and Power* by participating at associated workshops in Paris (France), Sacramento (USA) and Bandung (Indonesia), by providing written material and reviewing various drafts of the document and by contributing financial support for its production. Most recently, the GIA contributed to the IEA's Energy Technology Initiatives 2013 report (IEA, 2013c), with information for a short article entitled: *Drilling Down Geothermal Costs*, which highlights the importance of reducing drilling costs through the efforts of Annex VII Advanced Geothermal Drilling and Logging Technologies and their most recent publication: *Handbook of Best Practices for Geothermal Drilling* (Finger et al., 2010).

6.2.2 Cooperation with Other International Groups

As the GIA's expertise and reputation have grown, its interaction with other international organizations and programmes has increased. A few examples include:

Intergovernmental Panel on Climate Changes' (IPCC) Special Report on Renewable Energy Sources and Climate Change Mitigation (SRREN) - Four members of the Executive Committee were nominated by their governments to participate in the preparation of Chapter 4: Geothermal Energy of the IPCC SRREN, one as Coordinating Lead Author and three as Lead Authors. Another ExCo Member and the Executive Secretary were Contributing Authors. The full IPCC SRREN report was released on 9 May 2011 in Abu Dhabi (available at: http://srren.ipcc-wg3.de/report).

International Partnership for Geothermal Technology (IPGT) - The GIA, through Annex XI, is collaborating closely with the Induced Seismicity Group of the IPGT on activities that address important international issues associated with induced seismicity.

US DOE Geothermal Technologies Peer Review 2011 and 2012- Several GIA ExCo Members and the Secretary participated as invited geothermal experts in June 2011 to conduct an expert review of US DOE geothermal projects as part of the oversight and monitoring of its research, development and demonstration.

International Geothermal Association (IGA)- the GIA (Annex VIII and X) and IGA are working together to collect and share geothermal data and information from GIA member countries and IGA member countries so that a large part of the global geothermal data can be published on an annual basis, rather than every 5 years for the World Geothermal Congress.

6.2.3 Information Dissemination

Figure 3 Range of GIA publications.

Since its establishment, the GIA has continued to emphasize and develop its information dissemination and exchange efforts, with the aim of communicating its activities and results to as wide an audience as possible, including the lay-public, government institutions, industry and the scientific community. The GIA ExCo and Annex participants have had growing success with their participation in major international renewable energy and geothermal conferences, meetings and workshops. The earliest papers describing the GIA's activities were presented at the New Zealand Geothermal Workshop (NZGW) in 1997 (Rybach, 1997) and at the Geothermal Resources Council Annual Meeting (GRC) in 1998 (Rybach, 1998). Since then, the GIA has had a history of international participation, including at: Renewable Energy Conferences (RE2006 Japan; and RE2008 Korea), and regularly at GRC Annual Meetings, NZG Workshops, Stanford Geothermal Reservoir Workshops, European Geothermal Congresses (2007 and 2013); and most significantly, at three World Geothermal Congresses (2000, 2005, 2010). These conferences have provided continued valuable opportunities for extensive discussion and information exchange with other geothermal professionals. In fact, 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. Of particular value and success has been the GIA's sponsorship of exhibition booths at RE 2010 (Busan, Korea), WGC 2000 (Japan), 2005 (Antalya, Turkey) and 2010 (Bali, Indonesia), GRC 2009 (Reno, USA), and EGC 2013 (Pisa, Italy), where a comprehensive exhibit of GIA's activities and publications are shown, distributed and discussed with the range of visitors from lay people and students to scientists and engineers. These efforts are continuing with the GIA's participation at the WGC 2015, with several Annex and a general GIA paper to be presented and a large exhibition booth sponsored.

The GIA has also actively contributed to *Geothermics* journal, through the Guest Editorship of three Special Issues: two covering Environmental Aspects of Geothermal Development ([ed. T. Hunt]: 29, 4/5, 2000; 34, 2, 2005) and one on Sustainable Utilization of Geothermal Energy in 2010 (eds. M. Mongillo and G. Axelsson).

A wide range of promotional and less technical material has also been produced by the GIA for the public, and government and financial institutions. 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 annual "Trend" report, prepared by Annex X, presents GIA

member country development and use data, along with analyses, and has been available from 2010. Much of this information is available from the GIA Secretariat on CD-Rom, memory stick and also as downloads from the GIA website.

The GIA has sponsored/co-sponsored several successful international geothermal workshops and seminars as part of its efforts to grow membership, encourage more participation in its activities and disseminate technical information that will encourage sustainable geothermal development. The first was *The International Geothermal Sustainability Modelling Workshop*, held in New Zealand in November 2008; and the second, the GIA co-sponsored the *IEA-GIA~IGA Workshop Geothermal Energy Global Development Potential and Contribution to Mitigation of Climate Change* held in May 2009, in Madrid, Spain. Others include: the *IEA-GIA~IPGT Induced Seismicity Workshop held in* May 2011 in Paris, France; the *How to Mitigate Environmental Impacts of Geothermal Development*, held in New Zealand in June 2012; the *IEA-GIA Work on Sustainable Use of Geothermal Resources* session at the 53rd SIMS Conference in Reykjavik, Iceland; and the *Joint IEA-GIA~EDC Seminar on Innovative Ways to Enhance Permeability, Reduce Drilling Costs and Sustain Geothermal Production*, held in Manila, Philippines in September 2013. The GIA also supported international participation at the *Geomechanical Challenges Associated with Geothermal Drilling, Stimulation and Production* Session of the 47th US Rock Mechanics/Geomechanics Symposium held in June 2013, in San Francisco, USA.

The GIA's comprehensive public website (www.iea-gia.org), initiated in the early 2000s, has been re-developed twice, once in 2005, and most recently in mid-2012. It is the perennial public face of the organization, providing up-to-date information about the organization, its activities, and its Members; as well as access to its publications. In addition to the public platform, there is a password protected Members' area, which provides a means for distributing and reviewing GIA documents and other international publications.

6.2.4 Funding of Supplementary Activities

Successful growth in membership has led to reasonable financial security for the GIA, allowing some surplus funds to be made 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, 10 proposals (at US$ 10 k each) have been funded, covering a range of efforts from support to the GIA Secretary for his joint Guest Editorship (with Gudni Axelsson) of the Geothermics Special Issue on Sustainable Utilization of Geothermal Energy, to funding for participants at several international technical meetings, and for partial support for the preparation of topical reports on global review of geothermal reporting terminology and investigation of direct use applications and opportunities/barriers.

7. FUTURE DIRECTIONS AND ACTIVITIES

Geothermal power and direct use development continue on a reasonable growth path in many countries, with the GEA reporting a global gross geothermal power installed capacity of 11,765 MW as of August 2013, expected to reach 12,000 MW by the end of 2013, and 14,000 MW by the end of the decade (GEA, 2013), an average annual growth rate of <3.5% to 2020. In spite of geothermal's huge potential and valued characteristics, particularly, its baseload operating capability, its growth continues to be outstripped by solar PV (growth of 20.3% between 2012 and 2013; expected 20.9% growth in 2014, amounting to ~44.5 GW capacity) and wind (grew 12.5% in 2013, with global installed capacity of 318 GW). 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 a more rapid and substantial contribution to renewable energy deployment.

During its 4th 5-year term operating under the auspices of the IEA, the GIA aims to raise geothermal's recognition among the other renewables, to help overcome the barriers it continues to face, and to vigorously encourage sustainable geothermal development. Pursuing its strategic objectives, information dissemination, exchange and communication will remain major activities, with a specific focus on the following key areas:

- Continue efforts to refine global geothermal resource potential estimates and development costs
- Improve strategies for sustainable development and optimized performance
- Investigate cost-effective EGS reservoir stimulation technologies aiming to minimize potential adverse effects of induced seismicity
- Continue development of the database for geothermal drilling costs and publish the spreadsheet calculator and hold an international seminar on geothermal drilling best practices
- Expand our collection of current geothermal resource and development data/information, and work with IGA to add as much non-GIA member country information as possible in order to provide a more comprehensive and timely annual report on GIA and IGA websites
- Promote the benefits of geothermal energy and its contribution to mitigation of climate change
- Continue to convene GIA international workshops and seminars, especially in potential member countries
- Participate in major international renewable and geothermal meetings
- Expand our already strong ties with the IEA by, e.g., providing more articles for the globally distributed IEA OPEN Bulletin and other IEA publications

- Continue our efforts to grow membership, especially encouraging countries with significant geothermal power and direct use experience: Indonesia, the Philippines, China, India, Russia, Turkey and Kenya to join.

In the near-term, the GIA will be participating in the up-coming WGC 2015, which affords a great opportunity to target several of the above efforts. Several GIA papers will present a range of its activities and results. In addition, we will be sponsoring an exhibition booth, at which several posters describing the GIA, its Annex activities and achievements, and Member Country and Sponsor activities will be displayed; many IEA and GIA documents will also be available. GIA participants will also be present to meet and talk with booth visitors.

In 2013, the GIA ExCo decided to expand its efforts to encourage new membership by holding some ExCo and Annex meetings and associated workshops in potential member countries. Positive experience was gained from the first of these efforts: the 30th ExCo Meeting and associated Annex meetings were held in Tagaytay, Philippines, in September 2013; with an associated one-day Joint IEA-GIA~EDC Seminar at which a dozen presentations covered innovative ways to enhance permeability, reduce drilling costs and sustain geothermal production. Consequently, the GIA will continue this mechanism as part of its information dissemination and for encouraging new membership.

8. CONCLUSIONS

The worldwide demand for energy has increased significantly in the past few years, with growth in global total primary energy supply in 2011 more than 3.1% higher than in 2010, which was more than ~5.3% higher than in 2009. Electricity production in 2011 was about 3.2% higher than that in 2010. Such substantial growth is expected to continue over the next several decades, especially with the expanding economies of the developing countries, particularly China and India. In the face of these challenges, it is important that affordable, reliable and clean energy is provided to all of the world's people. However, unless energy savings and renewable energy options are implemented, energy security problems and significant climate change effects are likely. To meet these challenges will require massive input from renewable energies, including that from the vast and ubiquitous geothermal resources.

As recognized in the WGC 2010 IEA-GIA overview paper (Mongillo et al, 2010), "…to realize geothermal's huge potential contribution, it is essential to improve existing and develop new technologies; and to promote the benefits of geothermal energy, its sustainable utilization and the contribution it can make toward climate change mitigation." Success will require substantial international effort.

The GIA has demonstrated considerable success and earned an excellent reputation through its international collaborative efforts during the past 18 years. These achievements give the GIA confidence that it 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.

For further information about the IEA-GIA, please contact the IEA-GIA Secretary and/or visit the GIA website at: www.iea-gia.org.

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