Is Geothermal Energy Under-Exploited?

An Interview with Dr. David Nieva Gómez, Chair of the Executive Committee of IEA's Geothermal Implementing Agreement (IEA GIA)[1]

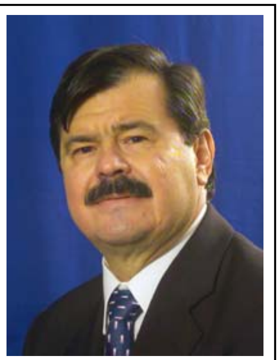
IEA OPEN Bulletin

For readers not too familiar with geothermal, could you briefly explain how and where geothermal heat is created? Also, in what form it reaches the earth's surface and how it is used.

Dr. Nieva Gómez

Geothermal "heat" originates predominately from the gradual decay of long-lived radioactive substances - potassium-40, thorium-232, and uranium-235 and 238 - within the earth. The energy released from this radioactive decay heats the earth's interior to a central temperature of some 6,000 °C, resulting in the outward transfer of heat through conductive heat flow and convective flows of molten material beneath the earth's crust.

Rather than being uniform, the resulting heat flux is concentrated along the tectonic plate boundaries such as the Pacific Ring of Fire, the Mid-Atlantic Ridge, and the African Rift-Valley, where volcanic activity transports the high-temperature molten material (more than 1,000 °C) near to the surface. Although small portions of this molten rock are erupted by volcanoes, much of it remains at depths of between 5 km and 20 km, where it slowly cools, releasing heat to the surrounding rock. Given the proper conditions, water can enter these hot rock regions creating large "reservoirs" of hot water and steam at temperatures of 240 °C - 350 °C and at depths of between 500 metres and more than 3,000 metres. These are known as high-temperature geothermal systems. To harness the vast amount of geothermal heat, wells are drilled into the geothermal systems to access the hot water and steam, which are processed at the surface into steam, which is sent directly to turbines that generate electricity. In many places around the world, geothermal energy is now used with great success for power generation. Leading examples are The Geysers (United States), Wairakei (New Zealand), Larderello (Italy) and Cerro Prieto (Mexico).



Dr. David Nieva Gómez, Chair of IEA GIA's Executive Committee

[1] Full name: International Energy Agency (IEA) Implementing Agreement for a Cooperative Programme on Geothermal Energy Research and Technology (IEA GIA)

Of course, there are also areas, located far from the plate boundaries, where larger than average "heat-flows" occur, notably in France and Eastern Europe. Here, groundwater can "collect heat" by circulating through deep fracture zones and concentrating it in shallow reservoirs insulated by layers of sediments; these again can be accessed by drilling wells. Typically, the water produced is at temperatures too low to generate electricity, but more than sufficient to be used directly, or through intermediary heat exchangers, for heating buildings, swimming pools, etc. In fact, a number of district heating systems using this lower-temperature water have been developed, for example at Klamath Falls in the United States and Reykjavik in Iceland.

The most rapidly growing geothermal application exploits the very shallowest depths of less than 100 metres to provide a source for both heating and cooling through the use of geothermal heat pumps (GHPs). This direct use of geothermal energy can be applied virtually anywhere in the world, as exemplified by the six countries with the largest total installed capacity of GHPs. In decreasing order, they are the United States, Sweden, China, Norway, Switzerland and Canada.

A potentially significant worldwide geothermal resource also exists in deep, but accessible, "hot rock", where no water is present. Development of this type of resource is presently on the "cutting edge" of geothermal research.

IEA OPEN Bulletin

In the past 30 years, the number of countries using geothermal for power generation has more than doubled. To what do you attribute this progress?

Dr. Nieva Gómez

There are several contributing reasons for this growth. One is that geothermal exploration programmes were conducted in many developing countries in the 1970s and 1980s (funded by the United Nations Development Programme) and these programmes identified an abundance of geothermal resources. Another reason is the significant effort made to train geothermal scientists and engineers from around the world in university training schools in Iceland, Italy, Japan and New Zealand. These scientists and engineers went back home and helped promote and develop the use of geothermal energy.

Growth has also been driven by the development of a better understanding of geothermal systems and their behaviour, and by better techniques for exploration and more efficient utilization. For example, binary plant technology employs a secondary working fluid in the power conversion cycle, allowing use of lower-temperature resources.

Thanks to all of these developments, plus advances with the technology for production and generation, capital costs in geothermal development have fallen by about 50% over the last 20 years, making the geothermal option much more attractive. And further cost improvements can be expected. One of the most expensive parts of exploiting geothermal energy remains the drilling. Reducing costs associated with geothermal drilling is among the research tasks of IEA GIA's Annex VII on Advanced Geothermal Drilling Techniques.

Information dissemination by groups such as the IEA GIA has also helped heighten awareness of geothermal energy and its benefits as an environmentally friendly energy option that offers low greenhouse gas emissions, independence from seasonal and weather conditions and reliability as a baseload provider.

Another important factor has been the accelerating cost and uncertainty of supply of all types of conventional energy.

That being said, there remains much potential for expanding use of geothermal energy. A 2005 analysis estimated the worldwide geothermal potential for electricity generation, from "identified" resources, at about 200 GW, with approximately 9 GW currently being generated. In descending order, the largest "identified" potentials are in the United States, Japan, Indonesia, the Philippines, Mexico and Iceland.

IEA OPEN Bulletin

We know that geothermal can fuel power plants up to 100 MW. How would you rate geothermal as an economical option for rural electrification?

Dr. Nieva Gómez

Geothermal is an excellent option for rural electrification where the resource exists within a reasonable distance of demand. This is especially true for countries like Indonesia and New Guinea, where identified geothermal resources are located near small towns, or on isolated islands, where there is either no electricity at all, or only expensive diesel-generated power for a few hours per day. Geothermal power developments incorporating two or three wells and small, specially designed generators using currently available technology can easily generate a few hundred kilowatts of electricity, or as much as several megawatts, which is enough to serve a whole village.

One excellent example of geothermal use for rural electrification is Mexico's Maguarichic village project in Chihuahua State. Here, a 300 kW binary generator, commissioned in 2001, now provides power to a small, isolated, off-grid village. Its 600 villagers used to have *power for only three hours a day from an old, polluting diesel generator. The geothermal development now provides a continuous supply of electricity, which has brought the village streetlights and enabled its people to run refrigerators and other amenities. Geothermal energy can transform people's lives. It can also modernise methods in agriculture and small industry.*

IEA OPEN Bulletin

Geothermal is not entirely without emissions of greenhouse gases. Can this drawback be addressed and eliminated?

Dr. Nieva Gómez

It is true that geothermal power plants emit low levels of CO_2. But amounts are very small, some 1000-2000 times less than emissions from fossil-fuel power plants. These emissions are due almost entirely to the release of CO_2 originally contained in the geothermal fluid, which varies in quantity from geothermal field to field. It is possible to remove the CO_2, and this is being done commercially at Kizildere, Turkey, where the CO_2 collected meets the country's needs for producing carbonated beverages. In New Zealand, CO_2 is removed and used in greenhouses to stimulate plant growth. But it is often possible to completely avoid emissions of CO_2 and other gases by using a binary plant, which allows reinjection of all the gases back into the geothermal reservoir. Many geothermal power stations currently use binary plants. Our IEA GIA Annex I on Environmental Impacts of Geothermal Development is actively investigating ways to deal with geothermal gas emissions.

IEA Geothermal Implementing Agreement (IEA GIA)

The International Energy Agency (IEA) Implementing Agreement for a Cooperative Programme on Geothermal Energy Research and Technology provides an important framework for wide-ranging international co-operation in geothermal R&D. Its activities presently cover five different task areas: Environmental Impacts of Geothermal Development, Enhanced Geothermal Systems, Deep Geothermal Resources, Advanced Geothermal Drilling Techniques and Direct Use of Geothermal Energy.

The programme brings together the following participants: Australia, Germany, Iceland, Italy, Japan, Mexico, New Zealand, Republic of Korea, Switzerland, the United States, the European Commission, ORMAT Technologies, Inc and Green Rock Energy Limited. The GIA welcomes the participation of sponsors from industry in order to strengthen co-operation in geothermal R&D, and Geodynamics Limited is currently completing the process of becoming a participant.
Visit the IEA GIA Web site.

IEA OPEN Bulletin

In the oil and gas drilling industry, one of the challenges is finding ways to drill deeper and deeper. Is this a hurdle to be overcome with geothermal?

Dr. Nieva Gómez

At present, geothermal wells are commonly drilled to depths of less than 3 km. However, there is great interest in drilling deeper for geothermal development, going down to 5 km, or even greater depths. Within existing geothermal fields, it is possible that higher-temperature fluids will be found in this way. Accessing them will help increase power outputs and operating lifetimes; largely because the fluid availability increases, and will hopefully further reduce the cost of electricity generation. The IEA GIA is now investigating this issue in Annex IV on Deep Geothermal Resources.

In the case of enhanced geothermal systems (EGS) development, to which I should like to return later, it is absolutely necessary to drill deeper, to 4-5 km, in order to attain the necessary high temperatures required for economic power generation. EGS is being addressed by the team in our IEA GIA Annex III. But there are extra challenges associated with drilling deeper in geothermal situations, including very high cost, and the need to operate in environments with extremely high temperatures of between 400 °C and 500 °C, and with high pressures. Drilling to such great depths at those temperatures pushes existing technology to its limits and is very expensive. The IEA GIA's Annex VII on Advanced Geothermal Drilling, to which I have already referred, is focusing on this topic. Its research and investigation on all aspects of well construction are aimed at cutting back on the costs associated with this essential and expensive part of geothermal exploration and development.

IEA OPEN Bulletin

Can geothermal be used directly for heating homes and buildings? What about co-generation? And can you enlarge on district heating and cooling, which you have already mentioned?

Dr. Nieva Gómez

The answer is "yes" to all of these questions. For hundreds of years, geothermal energy has been used in its most basic form for heating people's homes and buildings by situating them on thermal ground, as exemplified by the Maoris currently living in Whakarewarewa and Ohinemutu, New Zealand. Geothermal has been harnessed commercially in various countries for over 40 years, Iceland being the prime example and world leader in the use of geothermal energy for district heating. In many cases in Iceland, the hot water used in homes and buildings is actually the hot geothermal water itself. In fact, direct use for heating is the fastest growing geothermal application today. Installed capacity has almost doubled every five years since 1995, amounting to 8,664 MW in 1995, 15,145 MW in 2000 and 27,825 MW in 2005. Utilization increased from 112,699 TWh in 1995 to 261,418 TWh in

2005. The rapid expansion in ground-source heat pump use, which can provide both heating and cooling and is applicable anywhere in the world, has led the growth.

Co-generation is also a part of the geothermal portfolio. Here, separated "reject" water from geothermal power stations is used to heat buildings, greenhouses, in aquaculture, etc. However, there is significant room for further co-generation development, especially through "cascaded" use, where the processes of several consecutive users in turn make use of the gradually cooling water as it passes on from user to user.

It was the need to pursue direct-use applications more actively that prompted the IEA GIA to create Annex VIII on Direct Use of Geothermal Energy in 2003. This Annex is investigating all aspects of the technology, with emphasis on improving implementation, reducing costs and expanding use.

IEA OPEN Bulletin

Is there any alternative means of bringing geothermal heat to the earth's surface from dry or impermeable rocks from which water cannot carry the heat?

Dr. Nieva Gómez

Yes, and this is one of the very exciting current areas of research, which the IEA GIA is pursuing through its Annex III on Enhanced Geothermal Systems (EGS) investigations. As I mentioned earlier, there is a vast, deep resource of heat present in dry, impermeable hot rock and it is available worldwide.

The method for accessing this heat involves "creating" a permeable volume of hot rock by drilling to depths ranging from 4 km to more than 5 km, and pumping water at very high pressures to open and extend pre-existing fractures at depth, and possibly create new ones. The next step is to very accurately drill one or two other wells so they intersect the permeable zone at a reasonable distance from the first well. The goal is then to pump water from the surface to the hot, enhanced-fractured, zone through one well, have it circulate (without major losses) through the fractured zone for a long enough time to attain temperatures of more than 150 °C, then to produce this hot water through the other well(s). The water produced must be hot enough to operate a binary power plant and the technology would be expected to produce up to 5 MW of electricity. IEA GIA Annex III is currently involved in such a project, which is nearing completion at Soultz-sous-Forêts, in north-eastern France.

IEA OPEN Bulletin

Do you see possible ways of using geothermal energy to optimise exploitation of other alternative forms of energy? And can you point to by-products from the geothermal extraction process that have a market value?

Dr. Nieva Gómez

Geothermal power stations normally operate in "baseload" mode, because constant production offers the best performance from wells and generating equipment, and it yields the highest income stream. However, it is possible to operate in a "load-following" mode, where the station provides generation at certain times of the day when more electricity is needed. This has been done, economically, for several years at the Poihipi Power Station in New Zealand. In suitable locations, a similar approach, in which a geothermal station operates in tandem with wind and/or solar stations, could step in to provide power during poor wind and night-time periods.

When it comes to by-products, there are several geothermal fluid constituents that have market value, notably boron, arsenic, lithium, silica and CO_2. But most of them are normally present in such low concentrations that it is not economically feasible yet to extract them and they are reinjected into the earth. However, silica often occurs in quite high concentrations, is easily extracted and can be used in numerous industrial applications, including the manufacture of automobile tyres, high-quality paper and road fill. As I pointed out earlier, CO_2 is economically removed from the unusually high CO_2-loaded fluid at Kizildere in Turkey and used for the country's beverage carbonation. Removal of geothermal fluid constituents is among the research areas of IEA GIA Annex I on Environmental Impacts.

IEA OPEN Bulletin

From what you have said, it seems that geothermal energy offers plenty of unrealised potential to exploit. What do you see as the priorities for advancing geothermal technologies and fostering greater market take-up?

Dr. Nieva Gómez

Much could be achieved through more vigorous information dissemination and transfer of existing technology. Indeed, mature technologies that are commercially exploited in some countries often have yet to be utilized in other regions of the world where they could be applied. On the technology development front, several priorities hold the key to greater *penetration in the global market place. These relate to cost reduction, sustainable use and new applications.*

Among the general priorities for research, development and deployment (RD&D), I would point to a number of broad areas of investigation. Life-cycle analysis of geothermal power generation and direct use systems is one. Also crucial to meeting today's energy challenges is a focus on sustainable production from geothermal resources and improved conversion efficiency cycles for power generation. To expand application, we need to facilitate use of shallow resources for small-scale users. Equally high on the agenda is the study of induced seismicity related to both conventional and EGS power generation. This is needed because, in certain instances, the disposal of separated water from power stations by pumping it into the earth ("reinjection") and the high-pressure pumping of water for creation of EGS reservoirs can "induce" local, low-intensity earthquakes. An understanding of the mechanisms causing this associated induced seismicity and methods to avoid or mitigate it are very important.

In more specific terms, we see some high RD&D priorities. These include commercial development of EGS, development of better exploration, resource confirmation and management tools, as well as development of deep geothermal resources and geothermal co-generation (power and heat). Upstream, a boost in R&D is needed in order to reduce the costs of geothermal well drilling, logging and completion. At the same time, we must work to increase the use of geothermal for space and district heating. And, as we pursue all of these objectives, we need to enhance our understanding of environmental effects and develop ways to mitigate them.

As we have seen, the IEA GIA is actively tackling these issues in its broad range of Annex work, as well as its efforts to secure new membership to expand its capabilities and accelerate its achievements.

IEA OPEN Bulletin

In your view, are these issues that should be addressed by the private sector or by the public sector, or both?

Dr. Nieva Gómez

In order to ensure the greatest success with market take-up, both sectors need to participate. Unfortunately, government funding for geothermal research decreased significantly around the world from the 1980s, and has remained low. This has perhaps been due to the misguided impression that all the major problems associated with geothermal *development had been solved and that any remaining issues should be addressed by the private sector. While it is true that the basic problems associated with geothermal exploration and development have been solved, thus making geothermal a "mature" technology, there are still many important outstanding issues requiring fundamental research that should be publicly funded. I would again cite the need for solving the technological problems associated with EGS, understanding of environmental effects and developing mitigation methods (production-induced seismicity, for example), along with development of better exploration and resource confirmation tools.*

At the same time, a number of priorities I have already cited certainly fall into the domain of the private sector, notably developing improved drilling, logging and completion techniques and equipment (for example, drill bits), increasing utilization efficiency through better design, and commercial development of geothermal co-generation.

Finally, there are also issues that could best be dealt with jointly, such as studies on sustainable production, induced seismicity resulting from production (both conventional and EGS) and development of high-temperature downhole tools.

IEA OPEN Bulletin

We have seen that some countries have decided to discontinue their geothermal R&D programmes. What can be done, in your view, to ensure that the geothermal effort continues?

Dr. Nieva Gómez

Information dissemination is crucial. It is essential to ensure that governments, industry and the public are informed and educated, about geothermal energy, its capabilities and its benefits, as well as the RD&D required to advance its use. It is particularly important to enhance awareness among government policy makers at the highest levels that geothermal holds great promise in relation to the major energy security challenges we face today. Stimulating serious interest in the private sector is another possible means of encouraging government spending, especially if joint public/private projects can be initiated.

IEA OPEN Bulletin

Are there country-specific or region-specific issues to address in promoting use of geothermal?

Dr. Nieva Gómez

Very much so. Geothermal resources are distributed widely around the world. A number of developing countries and regions located in South East Asia, Central and South America and East Africa are endowed with important geothermal resource potential. Efforts should be made to encourage geothermal development where appropriate and part of this effort could include provision of financial support, for example, from the World Bank or United Nations agencies. Awareness is the great catalyst. We need to educate potential users, governments, and the local people who would be directly affected, about geothermal energy and the many benefits it offers.

IEA OPEN Bulletin

Many thanks, Dr. Nieva Gómez. We wish you well with the future work of the IEA Geothermal Implementing Agreement.

Dr. Nieva Gómez

Thank you for the opportunity to speak to your readers about this important energy resource.