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William Pettitt is the New Executive Director of the GRC

The Geothermal Resources Council (GRC) is pleased to announce the appointment of Dr. William Pettitt as the association’s new Executive Director, taking up his duties on July 9.

Dr. Pettitt is an applied geophysicist with both business and technical management expertise. He is an expert in induced seismicity, microseismics and geomechanics. He has been General Manager and Vice President of Itasca Consulting Group in Minneapolis, Minnesota and Operations Manager for Applied Seismology Consultants in the United Kingdom.

Will has focused on helping industry, government and academia solve challenging problems in subsurface engineering. He is the creator of leading commercial microseismic software, and has developed unique data-acquisition equipment. He has published on a wide range of topics, is a frequent keynote speaker, and has participated in government and organizational committees. Will is bringing the combination of his applied science and engineering experience with business management expertise to help the merged GRC and Geothermal Energy Association (GEA) organization develop to the next level, and help support geothermal industry development through our mission of promoting sustainable energy, supporting new science and technologies, and providing resources for education and learning.

"With Will Pettitt’s business acumen, research savvy, and welcoming disposition he is an exceptional person to be our Executive Director" says Maria Richards, President of the GRC. "His strengths compliment the unification of the GRC and GEA. Will’s aptitude for explaining, “How the Earth Works” will be appreciated by the media and public as they ask about the intricacies of geothermal resources.”

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**BELOW GROUND:** Webco manufactures high quality laser seam-welded duplex, nickel alloy, and stainless steel coiled tubing for demanding downhole conditions. Customers rely on LaserLine® products for scale and corrosion inhibition in oil & gas and geothermal well applications.

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**ABOVE GROUND:** Webco manufactures and stocks a full range of straight length carbon steel and corrosion resistant alloy tubing for heat exchanger and pressure tube applications. Value-added services, including u-bending and finning, are available.

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Contents

8 President’s Message
by Andy Sabin

10 Executive Director’s Message
by William Pettitt

12 Communication from the GRC
by Ian Crawford

16 Inside Geothermal: North America, Central & South America, Australasia, Asia, Africa, Europe, Education, Science & Technology, Climate Change
by Ian Crawford

26 Plaine de Garonne Energies (PGE): A New Geothermal District Heating in Bordeaux, France
by Delphine Patriarche, et al

34 Geothermal Energy in the Era of Artificial Intelligence
by Luis Ruano

40 The Vikings & Geothermal Iceland
by Susan Fox Hodgson

48 An Introduction to the GRC Student Committee: Progress and Plans for 2020
by the GRC Student Committee

50 Calendar of Events

52 Not Waste, But Wasted - A Geothermal Paradox
Book Review by Susan Fox Hodgson

53 Publications, Websites, Videos & Maps
by Ian Crawford

55 In Memoriam - Brian Berard, Mike Shook and John Pritchett

The online GRC Library offers thousands of technical papers as downloadable PDF files.

Website: www.geothermal.org
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CalEnergy is proud to support the Geothermal Resources Council

CYRQ ENERGY Announces the Opening of the BRUCE LEVY GEOTHERMAL POWER PLANT

Bruce Levy Visionary and Geothermal Pioneer 1950 - 2018

Lightning Dock, New Mexico
I write this column on the U.S. holiday honoring Dr. Martin Luther King, Jr. who famously said, “We may have all come on different ships, but we are in the same boat now.” This is a sentiment that we all need to embrace as we try to address climate change, endless wars, starvation and a profound inequality of goods and services like food, clean water and basic health care for much of our population. Each of us can contribute in some small way by pursuing our respective jobs to the best of our abilities. Collectively this can yield positive benefits.

Workforce diversity, equality and working together as a team will continue to underpin the ongoing growth and transition of GRC as we enter 2020. Among the many accomplishments of last year, you voted to support bylaws changes as well as two new Directors to our Board, the Navy Geothermal Program Office’s Kelly Blake and the California Energy Commission’s Elisabeth De Jong.

Our Board now has decreased in size to 20 voting members. Eight are women and twelve are men. We work in industry, academia and government in North and South America, Europe, Asia, Australia and Africa.

The bylaws changes you approved are to allow this and future boards the opportunity to dramatically shrink or grow as needed without additional bylaws changes. Current governing boards of organizations like GRC tend to be much smaller than 20. Additionally, we imposed term limits for all Directors. While the GRC has benefited tremendously from the incredible input of former and in some cases long-tenured former Board Members, the last few Boards reasoned that term limits (two consecutive 2-year terms followed by one term off the Board) would generate a more regular turnover and thus create the opportunity for greater diversity.

An alternative to diversity (of gender, talent, culture, perspective) is homogeneity, single-mindedness and in most cases, status quo. These attributes seem to be the relentless pursuit of many of our world’s leaders these days to the unfortunate determent of those who they represent not to mention our entire species. I spent part of the recent holiday season on the South Island of New Zealand where the wonderful people and outstanding sights were blanketed by smoke from the Australian bush-fires, 1,200 miles away! This ongoing tragedy is devastating the inhabitants and the landscapes of much of Australia. As anyone in a fire will tell you, get out of the fire. Then address the causes. I’m not sure what else needs to be said about the causes. Those who understand and accept science already know the answers. Those confusing mythology or politics with science generally arrive much more slowly at the truth, if they ever arrive at all. We really cannot afford them in leadership roles anymore.

Last year I recommended reading the White House’s documents on climate change, Climate Science Special Report: Fourth National Climate Assessment (FNCA), v 1 and 2. I recommend it again especially as uncontrollable wildfires, flooding, droughts and food and water shortages associated with climate change are all described and predicted. As a Department of Defense (DoD)
employee with some role in installation resiliency, the excerpted figure above illustrates the breadth of climate-change vulnerabilities to DoD installations in the United States. These vulnerabilities do not rise to the level of starvation or fires, but climate change is no longer something that DoD leaders can dismiss.

We have the talent and the resources to address many of these problems using geothermal solutions. GRC will play its part as we attempt to sustain and even grow our planet's energy resiliency through geothermal.
Executive Director's Message

by Will Pettitt, PhD

2020 Promises to be an Exceptional Year for Geothermal “on the Hill”

2019 was a busy year for the GRC’s Policy Committee (PC). The GRC and the Geothermal Energy Association (GEA) consolidated the year before, in the summer of 2018, and in doing so created a completely new association. The new GRC took on many of the functions of the GEA, establishing the PC to take on the advocacy role and to start on market research and creating publications that inform on industry statistics and direction. The PC is an independently funded group of interested organizations within the GRC, advocating on behalf of the geothermal community to inform government policy, regulations and decision makers.

The Department of Energy (DOE)’s GeoVision study was published in May last year and was pivotal and far reaching. It highlights the importance of geothermal in the energy mix, not just in electricity generation but also in direct use of heat for domestic and commercial applications and geothermal heat pumps in buildings. The report shows that if we can shorten regulatory timeframes and bring down well costs we can enable geothermal anywhere and see amazing market growth through 2050.

- We can scale up existing geothermal heat pump technologies in residential and commercial buildings, both in new builds and retrofitting existing buildings, to reach 28 million installations.
- We can develop district heating systems that supply heat directly to communities and industries leading to an estimated 17,500 installed systems.
- We can introduce 60 GW of estimated power capacity, which means geothermal will provide 10% of total U.S. electricity demand.

This is a vast potential for economic expansion.

With the PC supporting and informing our policy and decision makers, the GeoVision report was like a call to action for federal lawmakers; 2019 turned out to be a record year for geothermal “on the Hill”. We had three congressional hearings: one in June with the Senate Committee on Energy and Natural Resources; one in September with the House Committee on Natural Resources, Subcommittee on Energy and Mineral Resources; and, one in November with the House Committee on Science, Space and Technology, Subcommittee on Energy. We last had a congressional hearing in 2007.

The chairman of the PC, Paul Thomsen from Ormat Technologies Inc., and our past president, Maria Richards from Southern Methodist University, testified at hearings last year, along with GRC members Kate Young (NREL) and Tim Latimer (Fervo Energy). It was also a busy year for draft legislation that includes geothermal energy.
Senators Cortez Masto (Democrat (D)-Nevada) and Wyden (D-Oregon) introduced the “Geothermal Energy Opportunities (GEO) Act”, which “promotes the growth of geothermal energy by developing stronger public-private partnerships, reducing barriers to leasing public land for geothermal energy use where certain energy extraction activities are already permitted, and promoting the direct development and deployment of geothermal heat pump technologies among large-scale facilities and buildings.”

Senators Murkowski (Republican (R)-Alaska) and Manchin (D-W.Virginia) introduced the “AGILE Act, “The Advanced Geothermal Innovation Leadership Act of 2019”, which “includes provisions for research and development of both existing and enhanced geothermal systems, resource assessment updates, grant program authorization, and improved permitting.”

Senator Risch (R-Idaho) and Congressman Fulcher (R-Idaho) introduced the “Enhancing Geothermal Production on Federal Lands Act”, to “streamline the discovery and permitting process for geothermal energy projects. This bill will bring geothermal to parity with oil and gas exploration on public lands.”

In the house, Congresswoman Johnson (D-Texas) and Congressman Lucas (R-Oklahoma) introduced the “Advanced Geothermal Research and Development Act of 2019” to establish and support advanced geothermal research and development programs at the Department of Energy. Their research vision goes well beyond what is normally included in annual DOE budgets.

The draft legislation had broad appeal and was largely bipartisan. The main threads of the drafts were for increased research, establishing more Enhanced Geothermal Systems (EGS) experimental sites (including east of the Mississippi), streamlining permitting processes, and boosting development of coproduction technologies with the petroleum and mineral industries. The PC has followed this activity with great interest, provided reviews and edits to draft legislation, feedback to staffers and lawmakers, and publicly supported all the drafts.

The Further Consolidated Appropriations Act of 2020 was signed into law in December. The legislation had two impacts on our community. It retroactively revived and extended the full Production Tax Credit (PTC) for geothermal facilities through 2020, continuing U.S. federal support for the geothermal industry. The PTC provides a credit for each kilowatt-hour of energy produced by the taxpayer from qualified renewable energy facilities. The previous PTC for geothermal facilities expired at the end of 2017. This support contributes to the ongoing creation of new jobs in the geothermal industry as well as to the nation’s energy independence.

Secondly, the act increased the budget for DOE’s Geothermal Technologies Office (GTO) from $84M in 2019 to $110M in 2020 – a 30% increase. This money brings increased funding for EGS on top of the existing FORGE project, including at least one demonstration project, and increased funding for geothermal heat pumps and district heating.

The PC commends this legislation and applauds the Federal government for its passage. We look forward to seeing the next steps on the draft bills this year and are excited about 2020 being an even bigger year for us. Please get in touch if you’re interested to hear more about the PC and our activities. More information on the Policy Committee can be found on the GRC website at: https://geothermal.org/Policy_Committee.html
GRC By-laws are Passed

As the same time as the ballot for the new members of the Board of Directors, the GRC membership was asked to vote on three by-law changes. These were all passed.

The aim of the by-law changes is to restructure and modernize the management of the GRC, so it can better function under the legal standards imposed on a California Not-For-Profit Corporation today.

The bylaw changes comprise three main objectives:

1. **Allow a Smaller Board Size**: expand the allowed range of Board size from 20-30 members to 7-30 members; [this took effect January 1, 2020]

2. **Improve Board Election Process and Rotation**: increase Director term from 2 years to 3 years but limit Directors to two consecutive terms followed by term off of the Board, if a Director would like to continue serving; [this took effect January 1, 2020]

3. **Change Officer Structure**: modify the types and terms of the Officers of GRC. The current Officers include a Past-President. The terms of all Officers are 2 consecutive years. Beginning in 2021, the Past-President role will be eliminated and the terms for Officers will change to 1 year; [this will take effect January 1, 2021]

Our reasons for making these changes are to create what we feel will be a more effective and evolving Board of Directors. As our industry grows and evolves, so too should the governing Board of this valuable organization evolve.

GRC Annual Meeting & Expo

Call for Papers - Deadline is May 27th.

The Geothermal Resources Council (GRC) has issued a call for papers for the world’s biggest annual geothermal energy conference of the year.
taking place October 18-21, 2020, at the Peppermill Resort Spa, Reno, Nevada, USA.

The GRC 2020 Annual Meeting planning committee will consider papers for its Technical and Poster Sessions covering a range of topics, both domestic and international.

International participation is key to the success of the technical programs, and geothermal researchers and experts from the USA and around the world are encouraged to submit their work for consideration to be presented at the GRC Annual Meeting.

Anyone who wants to present at the GRC Annual Meeting must submit a paper. The deadline for submission is Wednesday May 27th, 2020.

Additional information about paper requirements and submission forms can be obtained by contacting the GRC at (530) 758-2360 or at https://reno2020.mygeoenergynow.org/

For more information about the GRC Annual Meeting & Expo in Reno, Nevada, USA, visit https://reno2020.mygeoenergynow.org/ or call (530) 758-2360.

For information on how to sponsor this event, contact Anh Lay; GRC at (530) 758-2360 X100 or alay@geothermal.org.

Book Your Hotel Room - Special Rate Ends September 23rd

All the events and accommodation for the GRC Annual Meeting & Expo are in one location, the luxurious Peppermill Resort Spa & Casino, the only resort in the United States whose heating source is totally provided from geothermal energy produced on the immediate property.

The GRC has contracted with the Peppermill for a discounted block of rooms for a limited time. There is a choice of rooms with a king, queen or double beds.

- We strongly recommend making your hotel reservations on-line through a dedicated webpage at https://book.passkey.com/event/50007543/owner/7268/home. The preferred rate is automatically applied.
- OR
- If you make your reservations over the phone make sure you mention you are part of the Geothermal Resources Council group to get the special rate.

The average nightly rate starts at just USD 89 a night plus taxes and fees for a room in the newly remodeled Peppermill North and West Wings. For a room in the award winning luxurious Peppermill Tower offering panoramic views of the majestic Sierra Nevada mountains, the rate is USD 109 a night. At the top of the line, a Tuscany Tower Suite starts at USD 149.

Please make your reservation before September 23, 2020 in order to receive our special rate. Book your room now........

Why Stay at the Conference Hotel?
GRC strongly encourages you to stay at the Peppermill Resort Spa & Casino to gain the benefits of networking with colleagues, being close to the event venues, and relaxing in a nice hotel property.

We make every effort to negotiate the best possible rates. When you stay at the conference hotels, you help GRC meet our contractual obligations, avoid paying financial damages for this meeting, secure suitable venues and preferred dates-and-rates for future conferences.

Joint GRC-SPE Workshop - Registration Now Open!

High-Temperature Well Cementing
“Exploring Geothermal and Oil and Gas Synergies”
March 30 - April 1
Wyndham San Diego Bayside, San Diego, California, USA
The Geothermal Resources Council (GRC) together with the Society of Petroleum Engineers (SPE) are organizing a workshop on high-temperature cementing integrity for the life of production and injection wells in these HT applications.

The GRC and the SPE have decided that a joint workshop would enable both industries to share their experiences, technologies, technical procedures and best practices on this important aspect of well completion. The workshop will highlight cement formulae and slurry blends, placement methods, remedial procedures and result evaluations. Case studies will be discussed and analyzed.

All drilling personnel, both geothermal and oil & gas drilling and production engineers, well-site supervisors, cementing engineers and interested personnel are welcome to attend and participate.

The draft agenda, hotel reservations, and registration, can be found on our new dedicated website at https://cement.mygeoenergynow.org/

Save USD 100 by registering before March 1.
- GRC or SPE Member: USD 990
- Non Member: USD 1,090

In addition, by booking and staying at the Wyndham San Diego Bay Hotel under the GRC room block, the GRC will refund your workshop registration by USD 50 per night for up to 3 nights booked/paid. Make your reservation........

World Geothermal Congress

April 27 - May 1, Reykjavik, Iceland

The program for WGC 2020 has been published. There are short courses available on April 25 and 26, the main core of the meeting from April 27 to May 1 and then some field trips on May 2, 3 and 4.

Members of the Geothermal Resources Council (GRC) are automatically members of the International Geothermal Association (IGA) and are therefore eligible for the IGA Member discount of ISK 150,000. Non-members can register for ISK 175,000 and students pay just ISK 60,000. Register Now........

As of December 31, 2019 the membership of the GRC stood at 1,220 from 43 different countries.
The GRC Membership Directory At Your Fingertips

www.my.geothermal.org

The online membership directory provides the most up to date contact information for all GRC members at your fingertips.

Step 1
Login to the GRC Membership website: my.geothermal.org
(Tip: Bookmark this webpage on your smartphone for easy access)

Step 2
Click on the Directory Tab

Step 3
Search by Name, City, Company, or Country
(Coming soon: search by Expertise)

Step 4
Click on the name of the person and view their public profile.

This feature is only available to current GRC members. If you have not renewed, please contact Anh Lay at alay@geothermal.org to renew your membership and update your profile!
China is Chosen as Host Country for World Geothermal Congress in 2023

The International Geothermal Association (IGA) has announced that China will be the host of the World Geothermal Congress in 2023. The IGA Board voted for China after careful evaluation of three bids from China, Italy and Russia. Global Geothermal News........

The 2020 World Geothermal Congress will be held from 27 April - 1 May, in Reykjavik, Iceland. More information at www.wgc2020.com

NORTH AMERICA

Dan Brouillette is New U.S. Secretary of Energy

Dan Brouillette has been sworn in as the 15th U.S. Secretary of Energy. President Trump nominated Brouillette in November following the announcement of former Secretary Rick Perry’s resignation.

Secretary Brouillette served in the U.S. Army and has three decades of experience in both the public and private sector, most recently as the Deputy Secretary of Energy. Global Geothermal News........

Federal Budget Awards USD 69 Million for Enhanced Geothermal Systems Programs

President Donald Trump has signed off on nearly USD 1.4 trillion in spending that will keep the U.S. government funded through September 30, 2020.

“The agreement provides USD 69 million for Enhanced Geothermal Systems. The agreement provides USD 20 million for the Frontier Observatory for Research in Geothermal Energy (FORGE), with activities to include ongoing novel subsurface characterization, full-scale well drilling, and technology research and development to accelerate the commercial pathway to large-scale enhanced geothermal systems power generation.

Within available funds, USD 10 million is provided to fund at least one demonstration project in an area with no obvious surface expression. The Department is further directed to fund at least one demonstration of geothermal technologies for innovative distribution of heat through ground-source heating and cooling of district heating.”

Global Geothermal News........

Funding Opportunity for Advanced Geothermal Energy Storage

The U.S. Department of Energy Office of Energy Efficiency and Renewable Energy (EERE) Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) program has issued a Funding Opportunity Announcement for approximately USD 40 million in Phase I innovation projects for FY2020.

This year’s topics include one on Advanced Geothermal Energy Storage overseen by the Geothermal Technologies Office (GTO). By adding energy storage capability to geothermal resources, the power produced or offset can be dispatched as necessary based on changing grid conditions, further expanding the usage and utility of geothermal energy. Because deploying advanced geothermal energy storage contribute to grid reliability, flexibility, resilience and security, this technology area also supports DOE’s Grid Modernization Initiative.

In total, USD 110,000 is allocated in FY 2020 to Geothermal Technologies, more than the USD 28,000 initially requested by the Trump administration and more than the USD 84,000 allocated in FY 2019.
The Maximum Phase I Award Amount is USD 200,000. The Maximum Phase II Award Amount is USD 1,100,000.

Questions – Contact: William Vandermeer, william.vandermeer@ee.doe.gov

New Geothermal Entrepreneurship Organization Launched in Texas

With a USD 1 million grant from the U.S. Department of Energy, the Cockrell School of Engineering is launching a unique initiative that aims to make the University of Texas (UT) at Austin a national hub for geothermal energy expertise and startups. The new Geothermal Entrepreneurship Organization (GEO) will bring together engineers, researchers and entrepreneurs to develop technologies and launch companies to help advance the geothermal energy industry.

The organization, led by Jamie Beard and Bob Metcalfe of the Cockrell School’s Innovation Center, aims to leverage areas of excellence in geo-systems and drilling engineering at UT to spur geothermal technology development and maturation. The effort will engage all groups with relevant expertise within the Cockrell School, UT’s Jackson School of Geosciences, the Bureau of Economic Geology, the College of Natural Sciences and the university’s more than 20 energy research centers. Beard and Metcalfe plan to complement that expertise with the vast community of entrepreneurial talent across campus and in Austin.

“It’s a straightforward concept. Drilling technically complex, high-temperature and high-pressure wells is a core strength of the oil and gas industry. Let’s use all of that learning and expertise to drill for heat — tapping a vast CO₂-free, clean energy source,” Beard said. “We want to take advantage of Texas’ existing intellectual capital and leadership in geosciences and drilling to build the future of energy. By leveraging technologies and methodologies developed here over the past century and building upon them with new innovations, Texas can pioneer our clean energy future. And doing this won’t require a moonshot. We can make geothermal energy a ubiquitous utility within a decade.”

DOE Awards for Research in Subsurface Stress and Lost Circulation in Geothermal Drilling Announced

The U.S. Department of Energy (DOE) has selected three new projects to receive up to USD 7 million to research and develop innovative technologies that will reduce the cost of geothermal drilling operations and field development, which is a key step toward achieving geothermal energy’s full resource potential as outlined in the DOE GeoVision study. The selected projects will focus on two significant barriers: understanding the state of stress in the subsurface, and mitigating lost circulation events (LCEs) in drilling.

The projects selected by the Office of Energy Efficiency and Renewable Energy’s Geothermal Technologies Office (GTO) include:

- University of Wisconsin-Madison: WHOLESCALE — Water & Hole Observations Leverage Effective Stress Calculations and Lessen Expenses (Madison, Wisconsin): The goal of the WHOLESCALE project is to establish a protocol that can simulate the spatial distribution and temporal evolution of stress in a geothermal system. The team will develop an integrated technology that incorporates and interprets data from four methods of measurement into a multi-physics model that couples hydrological, thermal, and mechanical processes over spatial scales ranging from the diameter of a borehole to the extent of an entire field.

- RESPEC: Development of a Directional Cooling Induced Fracturing (DCIF) Technology for Near-Wellbore Stress Estimation in Geothermal Reservoirs (Rapid City, South Dakota): RESPEC will develop a borehole-based stress measurement technology that applies local directional cooling to a borehole wall in a high-temperature geothermal reservoir in order to induce fracturing.

- Lawrence Berkeley National Laboratory: Improved Lost Circulation Management for Geothermal Drilling (Berkeley, California): Berkeley Lab will review current empirically-driven geothermal and oil and gas lost circulation practices, and identify case studies for the use of lost circulation material and high temperature plugs for a variety of lost circulation scenarios.

The subsurface state of stress dictates fracture networks that provide the required permeability for a geothermal reservoir; thus an increased understanding of the stress state is valuable for siting wells during geothermal energy development. Lost circulation events (LCEs) can occur during
drilling when fluids pumped from the rig through downhole drilling equipment are “lost” and flow into geological formations instead of returning to the surface to complete a circulation path. Innovative technologies that characterize subsurface state of stress and mitigate LCE issues will reduce geothermal exploration and drilling costs, making geothermal a more viable and accessible energy source. *Global Geothermal News*........

**New Legislation Would Provide Geothermal Technologies Office With Critical Funding and Program Direction**

U.S. House Science, Space, and Technology Committee Ranking Member Frank Lucas and Chairwoman Eddie Bernice Johnson have introduced a bill to advance geothermal energy technologies.

H.R. 5374, the *Advanced Geothermal Research and Development Act*, authorizes enhanced early-stage geothermal research programs at the Department of Energy (DOE). H.R. 5374 prioritizes the fundamental research needed to develop and test advanced technologies to better capture and utilize geothermal energy.

The act provides the DOE’s Geothermal Technologies Office with critical funding and program direction to enable innovative research in advanced geothermal technologies. It will help develop the talent pool needed to implement geothermal energy systems and it will encourage international collaboration. More specifically, it will authorize and expand the Department of Energy’s early-stage research in enhanced geothermal systems and the major facilities needed to support this work. It also authorizes a new program in advanced geothermal computing and data science research and development. This will leverage DOE’s best-in-the-world computational capabilities to provide geothermal researchers with modeling and simulation tools that will allow them to more accurately model complex subsurface systems. *Global Geothermal News*........

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**The GRC Policy Committee wrote a letter in support of the proposed legislation:**

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**Inside Geothermal**

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**December 17, 2019**

The Honorable Eddie Bernice Johnson
Chairwoman
U.S. House Committee on Science, Space, and Technology
2321 Rayburn House Office Building
Washington, D.C. 20515

The Honorable Frank Lucas
Ranking Member
U.S. House Committee on Science, Space, and Technology
2321 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairwoman Johnson and Ranking Member Lucas:

On behalf of the geothermal industry we would like to thank you for introducing the “Advanced Geothermal Research and Development Act of 2019.” We strongly support that legislation to advance geothermal energy as a mainstream source of power and heat across the nation.

As the professional and trade association for the geothermal industry and community, the Geothermal Resources Council (GRC) applauds your leadership in bringing forth the various parts of this act:

- Advanced hydrothermal tools for exploration and characterization of resources and demonstration of advanced technologies for exploitative drilling;
- Central geothermal systems research and development including thermal energy storage, oil & gas technology transfer, and co-production of mineral recovery;
- Support of Enhanced Geothermal Systems (EGS) research, development, demonstration and commercial application;
- Establishing up to four FORUS sites (Frontier Observatories for Research in Geothermal Energy) with $300 Million funding over five years (including more than $50 million from the Mississippi River);
- Advanced geothermal computing and data science research and development covering computer modeling and simulation tools that more accurately model complex subsurface systems;
- Geothermal workforce development by facilitating collaboration between universities and national laboratories, and providing access to the application of geothermal energy tools and technologies.

The GRC Policy Committee wrote a letter in support of the proposed legislation:

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**GRC Bulletin**

18 | www.geothermal.org
Geothermal Technologies Office Seeking Merit Reviewers

The U.S. Geothermal Technologies Office (GTO) is offering opportunities for geothermal stakeholders to get involved as merit reviewers. Qualified reviewers cover a wide gamut, representing academic, industrial, and government sectors. Ideal candidates include engineers, scientists, and management professionals (particularly those with financial or policy backgrounds) from the geothermal, oil and gas, and mining industries. Specific areas of expertise include:

• Geosciences, geophysics, and geochemistry
• Geo-mechanics and fracture mechanics
• Subsurface exploration, resource management, and production
• Direct-use heating and cooling systems
• Rare earth and critical materials
• Data analysis, computational modeling, and machine learning

Interested? If you’d like to get involved, please submit a brief introduction that includes your area(s) of expertise and current resume to DOE. geothermal@ee.doe.gov. Global Geothermal News..........

Company Formed to Develop Geothermal Resource in Alaska

A new geothermal power project may be coming to the Aleutian island of Unalaska. The Ounalashka Corporation and Fairbanks-based Chena Power, LLC have formed a company to develop a geothermal project at Makushin Volcano in Alaska. With city backing, Ounalashka/Chena Power is pursuing a U.S. Department of Energy loan worth USD 350-500 million. The company will use existing research performed at Makushin over the last 60 years, meaning further feasibility investigations aren’t necessary. A test well drilled in the 1980s revealed a hot-water reservoir that could generate at least 12 MW. Global Geothermal News..........

GRC Board Member Starts Up Geothermal Development Company

GRC Board Member Dr. Jeffrey Witter (also Geothermal Canada’s Treasurer), has started a new geothermal development company with two business partners called Conte GeoEnergy. Based in Vancouver, British Columbia, Canada, Conte GeoEnergy Ltd. specializes in the exploration, planning and development of utility-scale geothermal energy facilities. Conte works with its partners to identify locations where quality geothermal resources can be efficiently and economically deployed to meet demand for near zero-emission baseload renewable power. Conte’s team has considerable experience advancing energy projects in British Columbia, including on behalf of First Nations. Global Geothermal News..........

Inauguration of Las Azufres III-2 (Phase 2), Unit 18 Geothermal Power Plant

In late December, President Andrés Manuel López Obrador inaugurated the 27 MW Unit 18 of the Los Azufres Geothermal Power Plant in Michoacán, Mexico. Global Geothermal News..........

Mexican Food Company Uses Geothermal Heat to Dehydrate Product

Geo Food is the only food brand in Mexico that uses geothermal energy to dehydrate food. The food dehydrator uses geothermal heat to dehydrate fruits and vegetables, giving producers a new opportunity to further market their product before it spoils.

The Geothermal Food Dehydrator system, DGA 200 is located in the community of San Pedro Lagunillas, in the state of Nayarit, Mexico, taking advantage of heat from the nearby Dragon Group geothermal power plant. Global Geothermal News..........

Global Geothermal News..........

An interview with Jeff Witter was published in the September/October 2019 GRC Bulletin: A New Boost for the Geothermal Industry In British Columbia? - New insights from the past could re-ignite the South Meager Geothermal project by members of the GRC Student Committee.
AUSTRALASIA

Victoria’s First Geothermal-Heated Public Swimming Pool

Phase two construction at the new Gippsland Regional Aquatic Centre (GRAC) in Traralgon, Victoria, in Australia, has begun with a 620-meter deep injection bore.

The new bore will pump heated water back into the ground at 40°C as part of the AUD 57 million project to build Victoria’s first geothermal-heated public swimming pool. A production bore to pump water up from below the ground at 65°C was recently finished as part of phase one.

The system will use heat energy from the bore water to separately circulate pool water through a heat exchanger.

The geothermal pool will allow Latrobe City Council to slash gas bills and save AUD 370,000 on ongoing operating costs, while reducing 730 tonnes of CO₂ emissions. Global Geothermal News.........

Geo40 and Climeon to Establish Combined Mineral Extraction and Geothermal Power Production Plant

Swedish geothermal module developer Climeon has entered into a collaboration agreement with the New Zealand-based geothermal minerals firm Geo40 to enable an expansion into waste heat recovery at existing geothermal power plants. The companies will be working together to establish a first combined mineral extraction and power production plant during 2020.

Geo40 has developed a technology to extract silica and other minerals from geothermal brine. By extracting and removing the silica and other valuable minerals like lithium, Geo40’s technology reduces operating costs for geothermal power stations, while producing sustainably sourced minerals. The filtered water from Geo40’s application can then be utilized in Climeon’s Heat Power modules to produce clean electricity and increase power output at geothermal power stations. Global Geothermal News.........

ASIA

Japanese Geothermal Power Plant Manufacturers Part Ways

Japanese technology conglomerate Hitachi will withdraw from Mitsubishi Hitachi Power Systems (MHP5), a joint venture it established in 2014 with another power equipment giant, Mitsubishi Heavy Industries (MHI), over a dispute stemming from construction of two massive defect-ridden coal plants in South Africa. MHP5 is a long-term exhibitor at the GRC Annual Meeting & Expo. Global Geothermal News..........

New Geothermal District Heating Network Launched in China

A new geothermal district heating and cooling network has been activated in Shaanxi Province, China. Six plants will provide heating, cooling and hot water for buildings at Xi’an Jiaotong University.

Using metal conduit and a heat exchange medium, heat (but not water) is taken from deep underground (two to three km in depth) where there are stores of geothermal energy at a temperature of 70-120°C. Global Geothermal News..........

Basic Energy to Partner with Thai Company to Develop Geothermal Energy Projects

Philippines geothermal energy developer Basic Energy Corp. will sell unissued shares to Thailand-based Vintage Engineering Public Co. Ltd. (VTE) in line with their joint development of renewable energy projects in the Philippines and abroad.

Under the deal, both parties agreed VTE has the right to invest in the Mabini geothermal project and other projects. Global Geothermal News..........

Muara Laboh Geothermal Power Plant Begins Commercial Operation

French energy company Engie and partner Supreme Energy have announced the commercial operation of the Muara Laboh geothermal power plant, in West Sumatra, Indonesia.

The first phase of the project generates 85 MW sold to state-owned electricity company PLN under a 30-year Power Purchase Agreement. Global Geothermal News..........

Supreme Energy is in talks with PLN and the Energy and Mineral Resources Ministry on the development of the second phase of the power plant, which would add another 65 MW. Global Geothermal News..........

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20 | GRC Bulletin www.geothermal.org
Sumitomo and Engie to Build 220 MW Geothermal Power Plant in Sumatra

Japanese company Sumitomo Corp. has joined with Engie to develop geothermal power projects in Indonesia that could eventually generate 400 MW. If the projects go well, Sumitomo intends to use them as stepping stones into the geothermal power generation business in the Philippines and the U.S.

In 2023, Sumitomo will join Engie and other partners in building a geothermal plant capable of generating up to 220 MW in Rajabasa, at the southern tip of Sumatra. Plans are for the plant to begin operating in 2025. Global Geothermal News.......

AFRICA

Exploration Drilling for Geothermal Energy in Uganda Begins

The Ugandan government has awarded a contract worth Shs 2.3 billion to Royal Techno Industries Ltd to explore for and develop geothermal resources in Hoima and Nebbi districts, in the west of the country.

According to Vincent Kato, the coordinator of thermal energy in the Energy ministry, drilling will start in January 2020. “The exercise will take about two months. Holes with the highest temperature gradient will help site deep exploration wells,” he said. Kato revealed that the project is jointly funded by the Geothermal Risk Mitigation Facility of the African Union Commission. He added that in the next two years, geothermal energy will be ready for use. “We are planning to use well-head technology to generate megawatts as we prepare to construct power plants,” Kato said. Global Geothermal News.......

EUROPE

Hellsisheiði Geothermal Power Plant Carbfix Operations Spun-Off from Parent Company

The Board of Directors of Reykjavík Energy (OR) has approved, subject to the confirmation of OR’s owners, to establish a public limited company around CarbFix operations. The CarbFix process has been successfully operated at the Hellsisheiði geothermal power plant in recent years. CarbFix is the industrial process to capture CO₂ and other sour gases from emission sources and permanently store it as rock in the subsurface. The pending PLC will be entirely owned by OR. Global Geothermal News.......

Helsinki Utility to Start Exploration for Deep Geothermal District Heating Resource

The Helsinki electricity provider Helen Sähköverkko Oy (HELEN) has started surveying for deep geothermal district heating resources within the Helsinki city limits, a first for Finland. The joint operation with the Geological Survey of Finland (GTK) started in early December. The aim is to investigate the bedrock structure to the depth of about 5-8 kilometers. Global Geothermal News.......

Possible Geothermal Energy Reservoir Discovered in Dublin Suburbs

A possible geothermal energy resource has been discovered in the Newcastle suburb, west of Dublin, Republic of Ireland.

As part of the IRE THERM surveying project, magnetotelluric (MT) soundings were carried out in the highly urbanized Dublin suburb in 2011 and 2012, and a description of MT data acquisition, processing methods, multi-dimensional geoelectrical models and porosity modeling with other geophysical data are presented in a new paper in the Geophysical Journal International.

The deeper conductive layers are interpreted as geothermal-fluid-bearing rocks. Porosity and permeability estimations from the lithological borehole logs indicate the geothermal potential of the bedrock, to deliver warm water to the surface. The fluid permeability estimation, based on Archie’s law for porous structures and synthetic studies of fractured zones, suggests a permeability in the range 100 mD–100 D in the study area, which is prospective for geothermal energy exploitation. Global Geothermal News.......

Republic of Ireland Aims for 70% Renewable Energy by 2030

The Republic of Ireland has published the details of its long-awaited Renewable Electricity Support Scheme (RESS) unveiling details of how the country will increase its share of renewable energy capacity to 70% by 2030.

The plan currently will see four (possibly five) auctions held between 2020 and 2027 to deliver on
the targets which will open bidding to a variety of technologies.

The first round will seek to procure 1,000 GWh of renewable energy power and will be launched early 2020. This will be followed by the second auction round with 3,000 GWh on offer in 2020, with further auctions scheduled for 2021, 2023, and 2025 to allocate 3,000 GWh, 4,000 GWh, and 2,500 GWh of capacity, respectively. Global Geothermal News..........

Testing Underway at United Downs Deep Geothermal Project

An update from the United Downs Deep Geothermal Project in Cornwall, south-west England:

"Now that drilling has finished we are entering the third phase of the program; evaluation. Preliminary results from the drilling are promising. Both wells intersected the fault at the predicted depth and the temperature at the bottom of the deeper well is around 190°C, which is also as expected. Downhole measurements have confirmed that there are lots of natural fractures and early indications are that the permeability is promising.

But we need to carry out a series of measurements and hydraulic tests to evaluate the fault structure, make sure the wells are in good condition, and evaluate the amount of geothermal energy we can sustainably harness from the system. We expect this work to be carried out during the first half of 2020.

Between December and February we will be constructing a water storage pond that will allow us to carry out further tests on our deep well UD-1. We need this facility to store water that we produce from the well so that it can be allowed to cool and analyzed before either being re-injected or disposed of offsite.

Once the pond is complete we will mobilize a ‘workover’ drilling rig to the site in March to remove a temporary downhole packer from UD-1, carry out some more downhole ‘logging’ measurements, attempt to collect sidewall cores and carry out the production test."

Trias Westland Launches Trading System for Geothermal Heat in Netherlands

The Trias Westland geothermal district heating network, south of the Hague, has launched an online system to trade geothermal energy between participating customers. By combining advanced web applications with real-time measurement & control techniques in the heat network, software company Anexo has delivered a working smart network called E-Web Geo. In this way, the supply and demand can be aligned and prevent too much heat disappearing back into the source causing a shortage.

The approximately 25 affiliated participants receive more heat for the same price or the same heat for a lower price, says Anexo. E-Web Geo facilitates the source holder so that the traded heat can be properly paid for. Global Geothermal News..........

Drilling Commences at Janssen Pharmaceutica Geothermal Project

Drilling has commenced for the first of two wells for the Janssen Pharmaceutica geothermal project in Beerse, Belgium.

With a target depth of over 2000 meters vertical, the first well (GT-02 Injection Well) will target the Dinantian Reservoir.

Driven by Johnson & Johnson’s pledge to reduce carbon emissions by 20% by 2020 and 80% by 2050, Janssen is looking to become the first industrial developer of a geothermal project in Belgium. Global Geothermal News..........

UD-1 & UD-2 wellheads (otherwise known as Christmas Trees!) Courtesy United Downs Deep Geothermal Project.
Another Geothermal District Heating Project Breaks Ground in Paris Basin

Drilling has begun at the Genyo geothermal district heating network in the suburbs of Bobigny and Drancy north-east of Paris.

Led by Sipperec (Paris inter-municipal union for energy and communication networks) the network should be ready by autumn 2020. Thirty kilometers long, it will supply the equivalent of 20,000 homes with heat. Global Geothermal News........

Schwerin Geothermal Power Project Nears Completion

In 2018, the drilling company Daldrup & Soehne AG signed a contract with the local utility in the town of Schwerin in north-east Germany.

The initial results are promising. The first well of four has reached a depth of 1,300 meters and a reservoir temperature of 56°C. A second well was being drilled in December.

The company envisages to start supplying electricity very shortly. Global Geothermal News........

MB Holding Plans Another 100 MW Geothermal Power Plants in Croatia

Turkish company MB Holding intends to develop another 100 MW of geothermal power projects in northern Croatia as part of a EUR 400 million (USD 447 million) investment plan.

The company’s local unit MB Geothermal, holds licenses for geothermal exploration in four areas in northern Croatia.

In November 2019, MB Holding inaugurated the 16.5 MW Velika 1 geothermal power plant, the first in Croatia. Global Geothermal News........

New National Energy Plan for Greece Plans for 100 MW of Geothermal Capacity by 2030

The new government in Greece has pledged to phase out coal by 2028. To that end it has updated the national energy plan to allow for renewables to supply 35% of the country’s energy consumption by 2030, up from 31% in the previous plan.

Of this, renewable energy systems are set to account for 61% of Greece’s electricity consumption by 2030. Renewables will also provide 43% of Greece’s heating and cooling and 19% of its transportation needs by the end of the coming decade.

Greece’s new national energy plan mandates 7.7 GW of cumulative solar PV capacity by 2030, 7 GW of cumulative wind power capacity, in addition to 3.7 GW of hydropower, 300 MW of biomass and biogas, and 100 MW of geothermal capacity. Global Geothermal News........

SCIENCE & TECHNOLOGY

Studying Energy of Earthquakes Could Help in Deep Geothermal Energy Exploration

Researchers at École polytechnique fédérale de Lausanne (EPFL)’s Computational Solid Mechanics Laboratory (LSMS) and the Weizmann Institute of Science have modeled the onset of slip between two bodies in frictional contact. Their work, a major step forward in the study of frictional rupture, could give us a better understanding of earthquakes—including how far and fast they travel.

These advances in fundamental research could one day be applied to more complex models, such as those representing conditions along tectonic faults, especially where fluids are naturally present or injected into the ground. “Today, several promising technologies in the context of the energy transition—like deep geothermal energy—relies on underground fluid injection. It is important to have a better understanding of how those injections affect seismic activity. I hope to use the tools developed during my Ph.D. to study that impact,” says Fabian Barras, a doctoral assistant at EPFL’s Computational Solid Mechanics Laboratory. Global Geothermal News........

EDUCATION

Registration Opens for 2020 Geothermal Design Challenge

The U.S. Department of Energy (DOE) Geothermal Technologies Office (GTO), in conjunction with Idaho National Laboratory (INL), is hosting the 2020 Geothermal Design Challenge™: geographic information system (GIS) Mapping Student Competition.

The design challenge focuses on a non-technical barrier to geothermal development to foster understanding and share the benefits of geothermal energy technologies.

Student teams of two or three will use GIS mapping to create a compelling infographic/poster or interactive map to discover potential opportunities from this renewable energy source.

The projects will seek to answer the following question: “Geothermal energy is difficult to understand because it is located underground. How can geospatial mapping increase our understanding of this important renewable energy resource? How can GIS improve how we visualize and communicate about geothermal energy?”

CLIMATE CHANGE

Concentrations of Carbon Dioxide in the Atmosphere Hit Record Level

The year 2019 concluded a decade of exceptional global heat, retreating ice and record sea levels driven by greenhouse gases from human activities. Average temperatures for the five-year (2015-2019) and ten-year (2010-2019) periods are almost certain to be the highest on record. 2019 is on course to be the second or third warmest year on record, according to the World Meteorological Organization (WMO).
The WMO provisional statement on the State of the Global Climate, says that the global average temperature in 2019 (January to October) was about 1.1°C above the pre-industrial period. Concentrations of carbon dioxide in the atmosphere hit a record level of 407.8 parts per million in 2018 and continued to rise in 2019. CO₂ lasts in the atmosphere for centuries and the oceans for even longer, thus locking in climate change. Global Geothermal News..........

Countries Need to be Increasingly Ambitious in Pledges to Scale Up Renewables - IRENA

Countries need to be increasingly ambitious in their pledges to scale up renewables and cut energy-related carbon dioxide (CO₂) emissions. The first round of Nationally Determined Contributions (NDCs) pledged under the Paris Agreement have proven inadequate to meet climate goals.

The new NDC round starting in 2020 represents an important chance to strengthen targets for renewables. A brief from the International Renewable Energy Agency (IRENA), released at the global climate meeting COP25 in late 2019, underlines the opportunity to address the climate threat, decarbonize energy use and simultaneously achieve multiple Sustainable Development Goals (SDGs). Global Geothermal News..........

More Companies Commit to Renewable Energy

A significant portion of the private sector is already delivering on the 2015 global climate accord. 285 companies responsible for more than 752 million metric tons of CO₂ equivalent emissions per year from their operations—more than the combined annual emissions of France and Spain—have set greenhouse gas emissions reduction targets in line with what science says is required to avert dangerous climate change and meet the goals of the Paris Agreement. 76 of these companies’ goals are in line with limiting warming to 1.5°C above pre-industrial levels.

A new report published by the Science Based Targets initiative (SBTi) reveals that by meeting their targets, these 285 companies will reduce their emissions by 265 million metric tons of CO₂ equivalent, approximately equivalent to shutting down 68 coal-fired power plants. This represents a 35% reduction in companies’ emissions compared to their base year emissions.

In the European energy sector, the list includes Spain-based Acciona, Iberdrola and Red Electrica de Espana, Dutch firm Eneco, Italy’s Enel, Portugal’s Energias de Portugal, Orsted in Denmark, Sweden’s Vattenfall and Austria’s Verbund.

The group also includes household names from the industrial and consumer goods sectors including BT, Coca-Cola, Deutsche Telekom, Hewlett Packard, McDonalds, Microsoft, Nestle, Nike, Sumitomo Chemicals, Thyssenkrupp and Unilever. Global Geothermal News..........

More extensive renewable power deployment, amounting to 7.7 TW (or 3.3 times current global capacity), could be achieved cost-effectively and would bring considerable socio-economic benefits. (Courtesy IRENA)
ABSTRACT

Plaine de Garonne Energies is a joint venture between Storengy and Engie Cofely in charge of the construction of a large district heating network, mainly supplied by renewable energies, in Bordeaux (France). Geothermal is a major solution planned to provide the new Plaine de Garonne district with heat, on the right bank of the Garonne river.

In 2015, the Bordeaux Metropole called for a geothermal project, for supplying heat to several districts, with the additional ambition to explore deeper formations for even hotter resource, namely the Jurassic expected at a depth of ~1,700m. Storengy proposed its expertise in geosciences and its experience in both exploration and drilling, as well as geothermal project development in Partnership with Engie Cofely.

Through the subsurface studies, Storengy geologists, reservoir engineers and well engineers were able to propose an innovative design of a doublet (of wells), in allowing for both exploring and yet to be characterized deep Jurassic layers, and ensure a fallback to the proven upper lying Cretaceous aquifer. This project is a challenge both technically and in terms of management because of exploration risks, budget constraints, and the upper stringent objective of delivering heat to the district network. To comply with all these objectives, vertical wells were designed with an innovative technical solution with no sidetracking.

This project illustrates that Storengy and Engie companies are fully committed in finding innovative and efficient solutions for deep and shallow geothermal energy supply energy to cities and communities.

1. The Plaine de Garonne Energies project

By choosing geothermal energy as a low-carbon energy source for the heating network that will supply the new neighborhoods being built on the right bank of the Garonne, Bordeaux Metropole has demonstrated a strong commitment...
to a greener future. The city’s elected officials are looking to deep-reservoir exploration to meet their energy needs. The project will build the necessary equipment to provide the public service of generating, transmitting and distributing energy for heating and hot water in the buildings in the areas covered by the contract, namely the communities on the right bank of the Garonne and more specifically the Brazza, Bastide Niel, Garonne Eiffel and La Benauche urban projects (Figure 1). It will supply energy to the equivalent of 28,000 homes.

The contract for the future geothermal heating network was awarded to a consortium formed by Storengy and ENGIE Cofely, that joined forces for the project. They will now study, design, build and operate the facilities over a 30-year period under a public service delegation contract. The project is known as Plaine de Garonne Energies (PGE).

PGE’s shareholders are Storengy, which will contribute with its subsurface and drilling expertise and carry out the geothermal exploration and development, and ENGIE Cofely, which will build the energy production facility and the district heating network.

In 2018, the construction work on the main heating plant has been initiated and the first few kilometers of the network built. The remaining network construction activities will be carried out as the new residential areas are built. The wells will be drilled in the second half of 2019. The geothermal system is set to be commissioned during 2020.

The project is focused on the use of geothermal energy, specifically the resource that is assumed to be present in the Jurassic layer some 1,700 m below the surface. At that depth, the water temperature is expected around 70°C.

The geothermal resource will be confirmed with tests to assess the water flow rate that could be achieved by the production well. Since there are no similar projects in the Bordeaux area, in-situ exploration is the only way to assess actual flow rates, examine re-injection options and determine the physical and chemical properties of the water. The first drilling operation could have two possible outcomes (Figure 2):

• Total or partial success at the Jurassic layer: a well doublet that extends into the Jurassic layer will be implemented. A well, for re-injecting water, will be drilled into the same Jurassic aquifer. Heat pumps will increase the water’s temperature (70°C) and enable the full potential of the resource to be exploited.

• Failure at the Jurassic layer: a fall back solution allowing for the exploitation of a proven reservoir in the Cretaceous layer, which is located 900 m below the surface and has a water temperature of 45°C, will be implemented. A number of wells in the area already use this resource. In this scenario, the well doublet will be performed at the Cretaceous level.

The PGE project key figures:
• Approximately 43 M€ invested
• 2 deep geothermal vertical wells (one doublet)
• Surface network measuring approximately 25 km
• 267 substations connected
• 60 MWth Installed capacity
• 98 GWh/year of heat delivered
• 19,000 t/year of CO₂ emission reduction
If the Cretaceous aquifer is used, the production of geothermal energy will be lower. A biomass heating plant will be added to the facilities to ensure that enough low-carbon energy is generated to meet renewable energy requirement (Figure 3).

In both scenarios, the future PGE heating network will be supplied with heat from the geothermal well doublet. Gas boilers will act as a backup and cover any consumption peaks (in the event of a cold snap), the aim being to supply 82% carbon-free energy.

PGE is a flagship project for several reasons. It is the first deep geothermal district heating project conducted outside Paris the area in 30 years (the most dense geothermal district heating area). It illustrates the expertise of Storengy and ENGIE Cofely in this market to satisfy the communities’ needs and the customers’ requirements.

2. Technical studies

At the beginning of the subsurface studies, we gathered the most complete documentation on 1/ already drilled wells from shallow to deeper ones reaching the bottom horizon for the Jurassic layers), 2/ previously published reports and logs performed describing geology, petrophysical properties and well tests information 3/ published interpretations of the regional and local geology and 4/ exploitation data of the wells such as flow rates and withdrawals over time.

All this information was taken into account in the assessment of the resources and the general sketch of the geothermal doublet (well location etc.), the well design, and to investigate the durability of the doublet.

2.1 Geology

The location of PGE1, the vertical producer well expected to be drilled first in the PGE project, was dictated by the location of the future heat plant. At the beginning of the project, no location was assigned to the injector well (PGE2). The identification of the location of PGE2 was part of the project, depending on the subsurface study and on the available yards on the right bank of the Garonne river; almost the full area being in renovation.

Regionally, around Bordeaux, 9 deep wells were previously drilled. 4 of them reached formations below the Jurassic layers of interest (Figure 4b).
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Nearby the PGE1 location:

- Bouliac is the closest well from PGE project that reached the Jurassic formation. It is located, in the southeast, about 6 km away (Figure 4c). It was performed for oil exploration. The well did not show much water, but has never been properly developed and tested for water production. Other Jurassic wells showed water. No information on water productivity was retrieved from logs and records. Few indications on petrophysical parameters are available and tend to show a heterogeneous formation.

- Wells from Merignac to Lormont were drilled in the early 1980ies, for geothermal purpose. They exploited the Cretaceous Formation (Figure 4a and 4b). Petrophysical and water productivity information are quite well known.

The Cretaceous reservoir layers are constituted from top to bottom of approximately 180 m of dolomite, dolomitic limestone and recrystallized micritic limestone, and approximately 30m of alternating fine glauconitic sandstones and medium to coarse sands, which provides about 75% of the total flow rate (data from offset wells).

The Jurassic reservoir layer is expected to be constituted of 2 sub-layers corresponding to, on one hand, gravelly bioclastic and oolitic limestone (with few sandy to microconglomeratic intercalations) and on the other hand, dolomitized micritic limestone. The porosity of these levels is expected to come mainly from fractures but also from clastic intercalations and dolomitized areas, with an unknown lateral extension.

The seismic data in the region were acquired in the 1970ies, avoiding the urbanized area of Bordeaux (Figure 5c). No new seismic campaign was performed since. From this information, and formation well tops, a structural model was proposed by the BRGM (2014 Figure 5a and 2008 Figure 5b) for the Cretaceous formation. No structural model was available for the Jurassic Formation, and we created our own structural 3D model for the area (Figure 6c), including the Jurassic formation, despite a cruel lack of data for this level.
The 3D geological model (Figure 6c) includes the structural framework and the available petrophysical data. The structural framework encompasses the fault network, the Upper Cretaceous top map and well data (Figure 6a). The underlying structure is inferred from this information and scare data from Jurassic wells; therefore, it presents consequent uncertainty.

The petrophysical model of cretaceous layer is fed by well logs inputs and well tests interpretations. For the Cretaceous, both distributions of net-pay for the calcareous level and the sandy one are obtained from geostatistical simulations, conditioned to well data (Figure 6b). Those realizations allow to derive equivalent porosity and permeability properties. For the Jurassic reservoir layer, scare data do not allow for an identical workflow. The porosity and permeability distributions of the Jurassic are considered constant (although suspected to be heterogeneous). Values are taken equal to the mean properties of the very well-known Paris Basin Dogger formation which appears to be the best analogue a priori (same depth, similar lithology, and also a proven geothermal resource). The two Jurassic reservoir sublayers are identified in the 3D geological model.

2.2 Reservoirs

Given the uncertainties and the respective expected heterogeneities of the reservoir formations for both targeted formations, the 3D dynamical simulations where performed using the geological 3D model as an input. Net-pay realizations for both cretaceous intervals are conditioned to well data measurements. Equivalent permeability (and porosity) could be derived then (Figure 7).

For the Cretaceous Formation, as the aquifer is quite intensively exploited for almost 4 decades, the considered initial conditions correspond to the 1976 map of hydraulic heads. Historical withdrawals of the wells where introduced. The calibration of the permeability field was performed using two well tests performed in 1981: the long duration test of La Benauge (and associated interferences measured on Meriadeck and Lormont wells), and the long duration pumping test of Lormont.

The 3D fluid flow and thermal transfer model indicated the favorable locations for the injector well (as several options were initially available) allowing for a 30-year lifetime (without thermal breakthrough) for the geothermal doublet at the Cretaceous.
Maximal thermal and pressure impacts were assessed for both the Cretaceous (Figure 8) and Jurassic levels, after a 30-year period with the maximum flow rates (250 and 300 m$^3$/h, respectively to the formations) and a 15°C reinjection temperature.

The impact of temperature at the producer well after 30 years is estimated inferior to 0.5°C, and the pressure impact is estimated to -0.6 bar at the closest well, La Benauge (not used since 2011).

2.3 Wells for exploration and development purposes

Considering the complexity of the drilling project, and that reinjection is only possible in the exploited aquifer, all outcomes have been assessed (Figure 9), and the wells were designed to ensure all these outcomes.

2.3.1 Design of the production well

The main principle for the design of the well was to drill in large diameters to allow for all possibilities in vertical wells, with no side tracking, while ensuring well performances to exploit the Jurassic or the Cretaceous.

At the first well (the producer), after reaching the proven layer of the Cretaceous, a short test will be performed to check the expected -proven- resource. The drilling will be then performed to the Jurassic layer and a mixed diameter liner covering entirely the well (except the Jurassic formation) will be installed. This liner will be then cemented but only on the interval separating the Jurassic from Cretaceous. Both aquifers are then isolated, and the well is then producing only the Jurassic aquifer.

If the short and long duration tests of the Jurassic aquifer show performances suitable for geothermal exploitation, then the liner will be cemented through perforations, and the 2nd well will be performed at the Jurassic level too. If not, then the Jurassic at the first well will be closed/cemented, while the mixed liner will be opened at the Cretaceous the upper part of the liner will be cemented, and the Cretaceous completion (with gravel and screens) will be installed (Figure 10).

The design of the second well is somehow similar to the first one allowing for a possible fallback from Jurassic to Cretaceous. In the end, it is necessary to give the possibility for both wells to fall...
back in case of a Jurassic success at the first well but deceiving performances at the Jurassic at the second one.

3. Conclusion
The subsurface studies and the future drilling works (hopefully, successful wells) are part of a large project meant to provide several districts with heat. Despite this paper focuses on the subsurface part, the project has also strong developments on surface installations and network. The joint value of Engie Cofely and Storengy partnership on this project resides on the handling of such a project, as well as the efficiency of interactions at the joint point constituted by interdependence of well heads and wells performances and surface installations.

This project illustrates the commitment of the companies on shallow and deep geothermal to serve the communities.

Acknowledgement
Storengy and Engie Cofely would like to thank the Plaine de Garonne Energies company and the Bordeaux Metropole community, and all their employees involved, now and from the beginning, in the project.

REFERENCES


At a moment when the tide of concern about climate change is reaching flood stage, it’s clear that the world is destined for a significant transformation in the production and consumption of energy. For example, in January, BlackRock CEO Larry Fink declared that “climate risk is investment risk,” and that “…there is no denying the direction we are heading. Every government, company, and shareholder must confront climate change.” Since BlackRock is the world’s largest investment firm, with more than $7 trillion USD under management, Fink’s proclamation that BlackRock will consider the environment as they assess investments may indeed be a turning point. Especially for the Energy industry.

Decarbonization efforts are gaining traction at the same time demand for electricity is increasing. Case in point: the increased commitment by automobile manufacturers to build electric vehicles. Volvo, Mercedes Benz, Porsche, Ford, and Nissan are among the companies that have announced their intentions to build more electric vehicles. Recently, General Motors’ CEO, Mary Barra underscored the trend: "GM believes in the science of global warming. We believe in an all-electric future. It’s not a question of if, but when."

In the context of increasing reliance on electricity for buildings, transportation and manufacturing, and the search for renewable resources as a base load to complement intermittent sources and deliver the energy we need, Geothermal proponents have earned a seat at the power generation table.

Although popular perceptions might position us on opposing sides of the global climate change discussion, what can the Geothermal industry learn from our colleagues in the oil and gas industry? Given the similarities in subsurface challenges and overlapping technologies, can their knowledge, deep pockets and vigorous efforts to transform business operations through “digitalization” yield valuable lessons for Geothermal operators?

One promising possibility is in the field of Artificial Intelligence (AI).

For the oil and gas industry, AI systems are useful at three stages of asset life.
- Early life – exploration phase
- Mid-life – planning and operations
- Mature life – data-driven expansion to obtain the most return from a reservoir or field

How can AI provide assistance to Geothermal operators?

A major pain point for Geothermal operators is cost of drilling to find reservoirs of naturally heated water, or subsurface heat sources into which water can be introduced to enhance reservoir performance. In oil and gas production, the financial risk is mitigated by the long-term value of the commodity produced. Oil is valuable, and a single successful asset can offset the cost of exploration and provide recurring value for
decades. In Geothermal, the value is inherently lower.

Further complicating the problem is the fact that the drilling dynamics for Geothermal differ from oil and gas exploration. Oil and gas tend to be found in softer rock formations, whereas enhanced geothermal systems require drilling in harder igneous rock. Drilling in high temperature environments also increases costs and risks, especially in the exploratory phases.

Geothermal resources such as Hydrothermal Systems, Enhanced Geothermal Systems, and Sedimentary Systems may all benefit from advanced Cognitive AI technology, especially at a time when Diverse Energy Resources (DER) are being integrated into grids by utilities and private enterprise. Predictive demand combined with flexible supply is a viable strategy for energy security, efficient production and distribution, and environmental benefits.

AI Technology from Space, at Work Here on Earth

Beyond Limits, a California-based AI software engineering company, is commercializing cognitive computing and AI software technologies created by Caltech’s Jet Propulsion Laboratory for NASA missions over the last 20 years. There are many similarities between the problems of deep space missions tasked to explore the unknown realms of space and those faced by energy companies exploring the subsurface.

Cognitive computing is the most sophisticated form of artificial intelligence (AI). If you think of AI as a stack of capabilities, at the base layer of the pyramid is data analytics and at the pinnacle is cognitive computing - (see figure above).

Cognitive computing emulates human reasoning and uses knowledge provided by domain experts, not just data, to understand situations, recommend actions, and solve problems. Cognitive AI systems differ from conventional artificial intelligence applications as they can adapt and become smarter over time as they interact with more experts, problems and data. Cognitive AI systems are able to operate in complex situations where uncertainty exists and data may not be as prevalent as we would like, and in such situations, they analyze and solve problems much as a human would.

Beyond purely numeric AI approaches, Cognitive AI systems incorporate symbolic reasoning in the form of knowledge bases from human experts, enabling hypothetical reasoning scenarios based on best practices to arrive at recommendations for human operators. Predictions about the most promising locations to drill are detailed in transparent, evidence-based audit trails documenting confidence, uncertainty, and risk levels. This is known as explainable AI (X-AI) to differentiate from the black-box obscurity of conventional numeric machine learning AI approaches.

The technology is maturing rapidly, and in the energy sector, Beyond Limits is developing and deploying new products for refinery optimization, managing particulates in upstream wells, assisting chemical engineers in formulating lubricants products, and advising reservoir engineers on optimized well locations and in-fill well production rate prediction. As BP (a Beyond Limits customer and investor) recently stated, “Beyond Limits codification of human expert knowledge and use alongside machine learning has the potential to help the energy sector improve operational insight, improve safety, further optimize performance, and introduce additional process automation.” Ultimately, cognitive systems will function in coordination across business domains, fostering collaboration between experts in subsurface and drilling to improve accuracy and efficiency.
To help manage the operations of LNG power plants, especially in grids that need to balance supply and demand with a mix of intermittent power sources like solar and wind, Beyond Limits is developing a system for the worlds’ first power plant guided by Cognitive AI technology. The system will be installed in a new LNG plant to be constructed in West Africa to drive industrial development.

Three AI Use Cases from Oil & Gas with Potential for Geothermal Energy

**Subsurface Modeling and Drilling Location Targeting**

**Solution**
These solutions combine machine learning data into the cognitive reasoner with reservoir engineering knowledge bases.

**Result**
The Beyond Limits system identifies high-productivity wells in physically meaningful reservoir areas in a matter of minutes to hours, rather than traditional approaches that can take days to weeks. The solution rapidly integrates new data and provides fresh recommendations, dramatically reducing cycle time while increasing the number of plausible development scenarios that may be investigated.

**Well Health and Productivity**

**Problem**
In oil and gas wells, high production rates can mobilize particulates into the production stream, damaging equipment over time, decreasing production, and increasing maintenance costs. Operators desired an AI monitoring solution that uses engineering knowledge and heuristics to predict or detect potential particle problems in advance, then recommend changes in operating conditions at the well-level and field-level to meet contractual production constraints and minimize particle production to ensure that volume targets are met.

**Solution**
Beyond Limits employs state-of-the-art machine learning and data science frameworks to evaluate risk associated with well performance such as particle production. Engineering knowledge bases are leveraged by our cognitive reasoner to determine production risks (as well as mechanism and volume levels) to suggest changes to improve operating conditions and efficiency.

**Result**
The Beyond Limits well health system detects major particle production problems with near 100% accuracy, which can significantly reduce downtime and operating costs. The technology also evaluates potential risks in future plans, enabling operators to leverage in-field experience for optimal well operation and production planning.

**Refinery Production Management**

**Problem**
Every day, operations teams strive to manage systems, processes and team performance to optimize outcomes. Unfortunately, the operational state of a refinery often deviates from the assumptions used in the planning process and it requires human intervention and timely decisions to remediate throughput, quality, reliability and profitability risks and return the process to desired performance ranges.

**Solution**
Because refineries operate around the clock, Beyond Limits developed an always-on refinery operations advisory system. The cognitive
decision support system empowers operations teams to improve operations plans through better transparency, communication and collaboration. The system stores, classifies, and leverages lessons learned so operators can uniformly apply best practices at the planning, operations, and management levels of the organization.

Result
Cognitive AI automatically identifies off-plan behavior. And, as data is collected in the system over time, it learns to better predict this behavior. Finally, the system provides guidance and remediation recommendations at the point of decision, based on optimization strategies and actions provided in the plan.

Early and Inevitable
We are in the early days of applying artificial intelligence to help manage and improve performance in oil and gas exploration and production. While there are parallels between oil and gas operations and Geothermal operations, AI systems have not yet been customized to meet the unique demands of the Geothermal industry. Given the strong potential evident in today’s new AI systems for energy production, it’s inevitable that machine learning and AI will become integral components of the Geothermal industry.

Introduction to Cognitive Artificial Intelligence – Beyond Conventional AI
From a high level, artificial intelligence can be broken into two broad camps: Numeric AI (training from data), and Symbolic AI (education from knowledge). With conventional Numeric approaches, you train the system by providing example data (e.g., time series, images) of what you want it to classify. So, if you want it to recognize a cat, you supply it with thousands of different pictures of cats. With Symbolic approaches, you educate it by providing knowledge to understand the subject. So, if you want to create an AI doctor, you supply volumes of medical textbook knowledge that the system ingests.

For data-centric problems, numeric AI has accomplished great things in a variety of areas. However, conventional numeric AI machine learning and neural nets alone are insufficient to solve many complex problems where expert knowledge is a required component of reasoning and decision making, and when results need to be explainable, data is limited, unreliable, or misleading. On the other hand, symbolic reasoning alone is insufficient when data sets are large and clues from the data are needed to solve the problem.

Disadvantages of Using Only Numeric AI
• **Brittle Solutions:** Numeric approaches break when the same question is asked in a slightly different manner or the data changes just a little.
• **Requires Pristine Data:** When data is less than ideal, these systems do not fail gracefully but completely break down because they are unable to reason.
• **Cannot Explain Answers:** Artificial neural networks are statistically based, therefore their decision processes are not easily invertible. In other words, they are black boxes that cannot explain how they arrive at an answer.

For complex problems, AGI (Artificial General Intelligence) is the desired approach, but it is a long way off. Nevertheless, at Beyond Limits, we are working on getting there sooner than you might think.

Meanwhile, how can we solve complex problems today?
The newest generation of AI applications address high-value assets that require human-like understanding of complex domains with systems that can adapt to uncertainty in both their knowledge and data, supporting their answers with human-understandable audit trials (also known as Explainable AI or X-AI).

This requires the integration of different learning and adaptation techniques to overcome the limitations of the individual technologies and achieve synergetic effects through hybridization.
of symbolic and numeric technologies. At Beyond Limits, we have seen the need for a hybrid approach combining numeric machine learning technologies and symbolic reasoners for cognitive intelligence – the stepping-stone to AGI.

The machine learning technologies we use include artificial neural networks, deep learning, Supportive Vector Machines (SVMs), Bayesian networks, and genetic algorithms. Symbolic technologies include knowledge graphs, case-based reasoning and deductive, inductive, abductive, defeasible, and modal reasoning.

As we further develop our hybrid cognitive AI approaches combining the best of both worlds, the result will be self-organizing systems of AI-working-with-AI-working-with-Humans, which orchestrate intricate collaborations between specialized intelligent agents to solve highly complex problems requiring diverse shared expertise.

Benefits of Advanced Cognitive AI Systems

- Understand imprecisely stated problems containing missing and misleading data.
- Significantly reduce the amount of data required to train a neural net.
- Provides answer not generated from predefined interpretations but derived from first principles.
- Use human-like insight to think outside of the box when the answer is not apparent.
- Provide a clear audit trail detailing how the problem was solved, with the ability to reeducate.

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Advertising in the GRC Bulletin means your product or service will be seen in the world’s only publication that deals exclusively with technical topics, legislation, scientific inquiry, special events and educational topics related to the geothermal industry.

The GRC Bulletin reaches nearly 1,200 geothermal professionals six times per year.

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When the Bulletin is published an email announcement is sent to the global geothermal energy community. A banner advertisement is available on this email that will be seen by over 4,500 recipients. The rate for members for this tremendous opportunity is just $500 per issue.

More information on the Bulletin advertising rates, including copy due dates, ad sizes and a full list of rates, can be found at https://geothermal.org/PDFs/Bulletin_Advertising_Rates_2019.pdf

Contact Chi-Meng at cmoua@geothermal.org or 530.758.2360 ext 105.
Islandia, 1585, by Abraham Ortelius. Hand-colored engraving, printed in Theatro d'el Orbe de la Terra, Antwerp, 1602, originally titled Theatrum Orbis Terrarum ("The Terrestrial Globe"). Polar bears still drift to Iceland on ice floes, as seen in the upper right-hand corner. More map details are in the article. Courtesy of the Osher Map Library, University of Southern Maine (oshermaps.org/map/7348.0224)
Why and when did the Vikings come to Iceland—the land of fumaroles, geysers, thermal waters, and volcanic eruptions? And what happened next? It’s quite a story.

Did the Vikings ever imagine so much heat lay beneath the snow and ice around them—although the climate was a bit warmer back then? Probably not, but why should they? Most of them hailed from Norway, a country with geological stability; a land of ancient metamorphic and sedimentary rocks; and one with no signs of heat but for a tiny spot in the far north and another on the ocean floor. Sure, earthquakes rumbled through occasionally and a few warm springs bubbled in that Arctic archipelago, but the pools of water in the quiet Norwegian woods were cold, and the forested mountains didn’t spew vast clouds of steam, ash, and rock high into the sky; turn snow and glaciers into roaring rivers; or extrude flowing, fiery ropes and sheets of immolating lava. The Norwegian mountains were tree-covered and still; they weren’t volcanoes.

Beginning around 863 A.D., or a bit earlier, Viking ships, many from Norway, began making short Icelandic stopovers. The trip from Norway took about four days in good weather.

In about 871 A.D., a large volcanic eruption dusted most of Iceland in a thin layer of volcanic debris, today called the Landnám tephra. (*Tephra is a mixture of fragmented, volcanic products, like ash and cinder.*) The tephra layer helps to date Icelandic settlements around the island, for no indications of Viking life have ever been found beneath this layer—except for one grain of barley pollen near the capital city, Reyjavík.²
The Icelandic Age of Settlement dates from 874 to 930 A.D., a time of great change. In 874 the first group of Viking farmers moved permanently to Iceland. They came from Norway, and their leader, Ingólfur Arnarson and his wife Hallveig Fróðadóttir, brought along family members, farmhands, and seasick sheep and cattle. On reaching the shore, they climbed freezing from the cargo ship, called a knarr, to begin their new lives.

Ingólfur Arnarson chose Reykjavík for his home in an unusual way. Before landing in Iceland, but with land firmly in sight, he tossed his pair of carved, sacred, high-seat pillars overboard—vowing to settle wherever they washed ashore. According to legend, after three years of searching he found the pillars at the edge of a bay he named Reykjavík (“smoky bay”, from the Old Norse) for the active hot springs and fumaroles around it.* Eventually many other Icelandic sites were given geothermal names, as well.

As they stepped on Icelandic soil, they were standing not only on an island with nine active volcanoes, but one with five of the volcanoes close by, arrayed along the southern coastline. From 874 to 930, the Vikings would build many settlements among the five volcanoes—including Ingólfur and his family, who settled down in a place he called Reykjavík.

* Ingólfur Arnarson most likely used a knarr, shown here, for his trip to Iceland. The knarr is a type of Norse merchant ship the Vikings built for long Atlantic voyages. In fact, Knerrir (the still-used plural of knarr from Old Norse) routinely crossed the North Atlantic delivering livestock, like sheep and horses, and other items to the Norse settlers in Iceland. The model is on display at the Hedeby Viking Museum in Germany. Caption and photo from Modell Knoor, Wikimedia Commons

It turns out the Vikings weren’t the first to settle in Iceland. Christianity arrived before them, brought to the island by hermitic Irish monks who lived in caves—possibly inside the lava tubes. Commenting on the long Icelandic days and short midsummer nights, a monk once wrote, “... whatever task a man wishes to perform, even to

Stöng, a reconstructed Viking longhouse in the Tjörósádalur Valley, east of Laugarvatn. Such longhouses were the farm centers for Viking chieftains in the Middle Ages and were used to store food. This replica was rebuilt as closely as possible to the original longhouse specifications. You can see portions of the basic wooden frame, a stone base, and the turf walls and roof. The original building was buried in volcanic ash during an eruption of Mount Hekla in 1104. The site is open to the public. Courtesy of The Commonwealth Farm, www.thjodveldisbaer.is
picking the lice from his shirt, he can manage as precisely as in broad daylight.”

When the Vikings arrived, the monks fled in a hurry, leaving behind many personal effects in the rush to get away.

Mount Hekla, one of the five southernmost coastline volcanoes—and still very active, has erupted well over 20 times since 874 A.D. During the fiery eruption of 1104, huge blankets of tephra destroyed at least 20 farms in southern Iceland. One such farm, named Stöng, has been excavated, rebuilt, and opened to the public. The farmstead is preserved perfectly, like an Icelandic Pompeii. The sod walls were left nearly intact beneath the thick layers of tephra.

Inspired by the 1104 eruption, monks began spreading tales throughout Europe that Mount Hekla was a gateway to Hell. This speculation is illustrated dramatically in books and maps from The Middle Ages—as you can see on the 1585 map of Iceland reprinted above and on page 39. Notice how Mount Hekla, the largest feature on the map and one covered in flame, spews dark smoke and volcanic bombs—the arc of black dots above the smoke.

Back in 930, 201 years before the 1104 eruption of Mount Hekla, the first Icelandic national assembly, called the Althing, met at Thingvellir (“Parliament Plains”) about 50 km from Reykjavík. Today Thingvellir is a National Park and an UNESCO World Heritage Site. Its long and incredible expanses of lava form part of the mid-Atlantic ridge.

The Vikings created the Althing to establish a common code of law suitable for a republic (not a monarchy) and to settle disputes. Here was where the Law-Speaker spoke to the assembled Vikings in front of the great wall of lava. “The riven wall of lava made a splendid sounding-board for speakers’
voices in those days before microphones and amplifiers were invented.”

By the year 1000, just 70 years later, the King of Norway was pressuring Iceland to renounce paganism and accept Christianity. Icelandic political opinion on the matter was polarized into two bitterly opposed factions. War seemed imminent. Sensing a crossroad, the leader of the Christian party, Hall of Siða, asked the Law-Speaker of the Althing, a pagan named Thorgeir Thorkelsson, to arbitrate. Everyone swore to follow his decision.

After considering the situation for a day and night, and in the interests of peace, Law-Speaker Thorkelsson declared that all unbaptized people in Iceland should become Christians and be baptized—meaning they would be submerged in cold water. Now real trouble arose. The Icelanders agreed to become Christians only if hot water was used in the ceremony.

And so it was. People from northern and southern Iceland were baptized in a hot spring named Reykjalaug (later called Vígðalaug, “the consecrated spring”) at Laugarvatn. Those from western Iceland were baptized in a hot spring named Lundarreykjadalur (later called Krosslaug, “the spring of the cross”) at Reykjalaug. Since then, both of these hot springs are said to hold healing powers. 

Native sulfur covers the sides of an Icelandic volcano. Courtesy of Promote Iceland
Iceland lost its independence to the King of Norway in 1262 and together with Norway to the Queen of Denmark in 1388. Toward the end of the thirteenth century, the Norwegian Archbishop of what today is Trondheim apparently won exclusive rights to buy and transport native sulfur from Iceland. The sulfur was collected from locations known today to include high-temperature geothermal fields. Exactly what the sulfur was used for is unclear, as gun powder hadn’t yet been invented. Some say the Catholic Church may have exported the sulfur to European churches so the congregations could grow familiar with the odor of hell. Icelandic sulfur rights — sometimes quite valuable — were controlled by the Danish King for many years until the rights were returned to Iceland in the 1760s.

How many hot springs are in Iceland? The count includes 250 thermal areas and 600 major hot springs. Surprisingly, geothermal expert Ingvar Fridleifsson finds no correlation between natural hot spring locations and the sites where early Vikings chose to build the farmhouses. Even the first settler, Íngólfur Arnarson, built his own farmhouses about 3.5 km away from the nearest hot spring, apparently preferring a good landing beach for his boats to the luxury of nearby hot waters for things like bathing, laundry, and cooking—not his duties, after all. Several years ago, parts of his farmhouse were discovered under the southern end of Reykjavík’s Aðalstraeti (“Main Street”) that runs down to the harbor.

In the eighteenth century, hot springs were considered “nuisances” by some farmers who were quoted in a book titled, Description of the Farmsteads of Iceland, 1703-1714. One farmer said, “A part of the hay field is spoiled by a hot secretion caused by a nearby hot spring.” Another complained, “Storms are fierce so that both houses and haystacks are in danger. The water is warm (read ‘undrinkable’).”

Only one pre-twentieth century archaeological structure exists where hot spring waters may have been used for space-heating. This is in the farmhouse (barely seen in the photo) built behind a hot water pool called, Snorralaug (“Snorri’s bath”), in the village of Reykholt. Snorralaug itself is the only ancient (probably 13th century), man-made bathing structure still standing in Iceland, and it resembles a 4 meter wide, stone-sided, backyard hot tub.

Built by powerful chieftain, famed historian, and writer of sagas, Snorri Sturluson (1178-1241), Snorralaug was heated with steam and hot waters flowing through two conduits from a nearby hot spring, called Skrifla. A third conduit from the hot spring bypassed Snorralaug entirely and went straight to the farmhouse in back. Were at least some farmhouse rooms warmed by geothermal heat? Perhaps, yes.

The hot springs at Leirhnjukur date from an eruption through a fissure in the mid-1970s. Note the abundant patches of native sulfur on the surrounding rocks. The hot springs, photographed in 2008, are about 2 kilometers from the Káfla power plant. During the eruption, a string of lava was produced from a geothermal well nearby. Photo and information by Ronald DiPippo

In 13th century Iceland, Snorri Sturluson built a farmhouse and this heated pool, called Snorralaug. The site was restored in 1858 and 1959. A tunnel dug behind the door allowed Snorri to move quickly from the pool to his farmhouse. The outdoor pool and perhaps the farmhouse were heated by steam and hot water flowing through conduits from a nearby hot spring. The hot water enters the pool from the ditch on the right. Photo from Snorralaug, Wikimedia Commons
We do know that for over a millennium, thousands of Icelanders living in a very cold climate never used the nearby hot waters to warm their houses. In 1908, perhaps the first person to do so was a farmer at Reykir in Mosfellssveit, Stefán B. Jónsson (1861-1928). He brought hot spring waters through a 2.3 km pipeline into his home to heat the radiators. Not long after, in 1911, Erlendur Gunnarsson, from Sturlureykir in Western Iceland near Reykholt, invented a simple mechanism to separate the steam from the hot water in a boiling spring next to his house. He used the steam for cooking and heating. The two installations, invented over a century ago, began the modern era of geothermal development in Iceland.

Selected References

Acknowledgments
Thanks to Brian Billings for helping with the Latin translation, and to Dr. Sigurjón Sindrason for kindly answering my questions.

Addendum: Iceland Today at the GRC
The lineage of modern Icelanders is complex. Perhaps some Icelanders with Viking ancestry are members of the Geothermal Resources Council, and maybe some pictures they’ve taken of modern geothermal Iceland have been Bulletin covers. Here are ones I’ve found—along with the captions and photographers’ names. If there are others, let me know; we’ll print them in the next issue.

The Svartsengi Power Plant, in the Sudurnes area, is the world’s first geothermal power plant to both generate electrical power (361 MWe and 125 MWt) and produce hot water for district heating. It also provides water to the Blue Lagoon, pictured here, a bathing resort attracting tourists worldwide. Photo by John W. Lund, March/April 2006

The Reykjanes Geothermal Power Plant is on the Reykjanes peninsula in southwestern Iceland. To operate the single-flash power plant, brine with the salinity of seawater is extracted from 11 production wells drilled 2700 m deep into a reservoir where the temperatures range from 280 to 316°C.

Continued...
The steam inlet pressure is 18 bars and the tubular condensers are cooled by seawater drawn from 10 wells close to the beach; thus, no cooling towers are needed. The waste brine is mixed with spent cooling water and passed through a concrete canal to the sea.

The power plant, generating 100 MWe from two Fuji 50 MWe turbines, is owned and operated by Sudurnes Regional Heating Corporation. The plant began operating in May 2006 and is connected to the national grid with a 12 km long, 220 kV overhead power line. Much of the power is sold to an aluminum smelter owned by Century Aluminum (Norðurál ehf). Thanks to Sverrir Thorhallsson for caption information. Photo courtesy of Glitnir Bank; Ragnar Th. Sigurdsson, photographer; Nov./Dec. 2007
Well IDDP-1, the first deep well of the Iceland Deep Drilling Project (IDDP), penetrated rhyolitic magma at a depth of 2104 m in the Katla Geothermal Field in northern Iceland (see map). Pictured is the rig (now removed) used to drill the well. The well overlooks Viti, an explosion crater formed in an eruption in 1724. Photo by G. O. Friðleifsson, July/Aug. 2009

View of the 2010 volcanic eruption at Fimmvörðuháls, in southern Iceland. For editorial reasons, the image has been reversed. Photo by Helga M. Halgadóttir, courtesy of ISOR, Jan./Feb. 2012

Drill casings for a new geothermal well. Photo by Cari Covell, Reykjavik University, Iceland School of Energy, Reykjavik, Iceland, Nov./Dec. 2015. First place in the 2015 GRC Photo Contest


“Northern Lights Reflection” taken at Theistareykir Geothermal Field. Located in northern Iceland, the photo shows the Northern Lights reflected in the hot springs and mud pots associated with geothermal activity. Photo by Bastien Poux, Reykjavík, Iceland, Nov./Dec. 2016. Peoples’ Choice winner in the 2016 GRC Amateur Geothermal Photo Contest

A rig called Thor was used to drill the supercritical well IDDP-2 at Reykjanes, Iceland. Photo courtesy of Wilfred A. Elders, Mar./Apr. 2017


"Flow Test at Theistareykir, Iceland." The picture was taken in February 2016 during a massive flow test for several wells at the Theistareykir Geothermal Field. Photo by Bastien Poux, Pontoise, France, Mar./Apr. 2018. Honorable Mention in the 2017 GRC Photo Contest.

"The Power of Thor." The rig used to drill well IDDP-2 at the Iceland Deep Drilling Project is named Thor. This supercritical drill hole shows the way to the future of geothermal power. At right is the lighthouse on the Reykjanes Peninsula, Iceland, showing the way to safe passage at sea. Photo by Robert Zierenberg, Davis, USA, July/Aug. 2018. GRC Photo Contest 2017.


The most recent Icelandic cover photo is on the cover of this issue.
The GRC Student Committee is dedicated to building a support system for early career geothermal stakeholders. The committee has been establishing structures that reflect the overall mission of the GRC: to help with fundraising for student support such as scholarships, and generate interest in bringing in more fresh talent to the industry. The student committee is relatively new, and we thought the start of the New Year would be an excellent time to spread awareness of our cause and update the community on what we’ve been pursuing.

**How Does the Student Committee Work?**

The GRC Student Committee helps support students in the form of industry exposure, scholarship offerings, and centralized planning.

The committee is made up of volunteer students and industry professionals; there are 15 involved in the 2019/2020 committee hailing from 6 different continents. Each year the committee builds on the progress of the previous year and reports to the GRC Board of Directors. Decisions and goals are reflective of the overall mission and vision of the organization:

**Vision:** The steady infusion of new talented, informed, enthusiastic, and innovative geothermal advocates into the workforce and broader scientific community.

**Mission:** Support, promote, and connect students and early career individuals as they build their futures and professional networks to advance geothermal energy.
Goals meant to help achieve the mission and vision are as follows:

1. Attract and retain students and early career individuals as GRC members.
2. Publicize and exchange technical knowledge about geothermal resources to students and early career individuals, and ultimately to the public.
3. Keep students and early career individuals abreast with developments in geothermal technologies and opportunities to enhance their technical and professional growth.
4. Bridge the gap between students, early career individuals and geothermal professionals by creating an active support network within the GRC.
5. Ensure sufficient funding to support the committee’s planned activities.

These high level goals drive the rest of our planning and structural development. Currently, the student committee is made up of three subcommittees that are meant to delegate responsibilities amongst members. The article and communications subcommittee highlights student projects and industry events by writing articles for the GRC Bulletin. In the future, we will also be more responsible for student-specific communications and outreach as the capabilities and networks of the committee expands. The fundraising subcommittee is responsible for generating funds to support student members of the GRC; these funds help with scholarship opportunities and educational events. Finally, the student chapter subcommittee coordinates with universities in order to maintain contact with local chapters and provide support. Cooperation between these chapters and the committee helps keep strong bonds between the central organization and local chapters.

What Have We Done This Year? 2019/2020

Committee Activity

The current committee has made progress towards achieving the mission and vision in a variety of ways. This includes continuing previously established practices as well as the development of new ones. All of the subcommittees have made contributions to this progress, and support and advice from external professionals has been integral in decision-making.

The article and communications subcommittee has been active in article writing and expansion of responsibilities. A great interview report, spearheaded by Antonina Calahorrano, on the Mt. Meager Geothermal site in Canada can be found in the September/October 2019 GRC Bulletin. This subcommittee has recognized that an online presence is important for engagement and awareness. In light of this, progress has been made towards setting up communications capabilities such as a presence on LinkedIn for the committee to communicate with fellow geothermal stakeholders - stay tuned in 2020 for an expansion of these activities.

The student chapter subcommittee has been focused on centralized planning and reviving university interest in local chapters. Many local student chapters of the GRC only continue with extremely motivated local individuals - the committee aims to foster a strong central program which can provide support. The mission/vision statements and goals are a part of a strategy document that has been created to help guide future committees and build progress year-over-year. Another step has been to identify universities where it is likely that student chapters may be started or successfully revived. This subcommittee has also focused on connecting regional universities: Iceland, South America, and different states within the US. These regions are promising leads, however, we are hoping to expand our reach to other countries.

The fundraising subcommittee held its second annual trivia contest at the GRC Annual Meeting last fall. We built upon the feedback from the inaugural competition and are looking forward to improving the efficacy and appeal of the event in the coming years. If you are going to be at GRC 2020, start getting a team together and look to win prizes! Also, keep an eye out later this year for a GRC Student Day - the idea for this event has been developed over the two previous GRC student committees and spearheaded by past presidents Garen Thomas and Clinton Smith. We will be rolling out more details soon.
In May 2020 the student committee will change over to a new group of dedicated students. It is our hope that this new group will keep building on the progress of the 2019/2020 group and previous student committees. We will transfer the work we’ve done, but it is important to keep the rest of the community up-to-date and engaged with our activities. The geothermal industry has a bright future and early career individuals need to hear about it.

Interested in Helping Support the Student Committee?

We are happy to have the support and advice of experienced industry members and are already working with several professionals. Please reach out if you have any suggestions or would like to help. Some examples of topics that would be useful include:

- Academics interested in starting and supporting chapters at their universities.
- Academics leading ongoing chapters that do not have any students directly affiliated with the GRC Student Committee
- Announcements for internships and other opportunities
- Potential learning and workshop opportunities for curious students that are not familiar with the geothermal industry.

We are very open minded as a committee and are hoping to build a strong foundation. Student support is integral to the future of any industry, and it is our hope that in the future we can have strong systems capable of providing that. This will help to attract and develop new talent which will in turn help everyone in the industry.

Please reach out to the current committee president Zach Zody (zzody@mymail.mines.edu) if you are interested in helping. Additional information on the student committee can be found at https://geothermal.org/students.html

Cases of Events

GT’2020 Türkiye Jeotermal Kongresi
5-6 February, Ankara, Turkey
https://geothermalturkey.org/

Geo-Energy for Petroleum Engineers (IGA Academy)
5-6 February, Aberdeen, Scotland, UK
https://www.geothermal-energy.org/event/geothermics-for-petroleum-engineers/

Stanford Geothermal Workshop - 45th Annual
10-12 February, Stanford, California, USA
https://geothermal.stanford.edu/events/workshop

GEMex Final Conference (GEMex Project)
18-19 February, Potsdam, Germany
http://www.gemex-h2020.eu/

European Geothermal PhD Days (EGPD 2020)
24-26 February, Pamukkale University, Denizli, Turkey
http://www.pau.edu.tr/egpd2020/en

Geothermal Production Technology (IGA Academy)
4-5 March, Amsterdam, The Netherlands
https://www.geothermal-energy.org/event/geothermal-production-technology/

GeoTHERM - Expo & Congress
5-6 March, Messe, Offenburg, Germany
https://www.geotherm-offenburg.de/de/geotherm_messe_kongress_geothermie

Geothermal Project Development, Economics and Risks (IGA Academy)
11-12 March, Basel, Switzerland
https://www.geothermal-energy.org/event/geothermal-project-development-economics-and-risks/

MEET Geothermal Spring School 2020 (MEET Project)
16-20 March, CY Cergy Paris University, Cergy, France
DGG/SEG Joint Geothermal Workshop: Geophysical Exploration from Fossil to Geothermal Reservoirs
27 March, Munich, Germany

Joint GRC-SPE Workshop - High Temperature Well Cementing
“Exploring Geothermal and Oil and Gas Synergies”
30 March - 1 April, San Diego, California, USA
https://www.cement.mygeoenergynow.org/

9th ITB International Geothermal Workshop 2020
1-2 April, Bandung, Indonesia.
https://geothermal.itb.ac.id

World Geothermal Congress 2020
27 April - 1 May, Reykjavik, Iceland
www.wgc2020.com/

EGU General Assembly 2020
Including session: Exploration, utilization and monitoring of conventional and unconventional geothermal resources
3-8 May Vienna, Austria
https://www.egu2020.eu/

Geothermal Regulations, Legislations and Incentives (IGA Academy)
6-7 May, Basel, Switzerland
https://www.geothermal-energy.org/event/geothermal-regulations-legislations-and-incentives/

The 7th International Meeting on Heat Flow and the Geothermal Field (GFZ German Research Centre for Geoscience)
12-14 May, Potsdam, Germany
http://www.ihfc-iugg.org/meetings/2020-potsdam

GEOHeat 2020 (Research Geotechnological Center of Far Eastern Branch of Russian Academy of Sciences)
1-4 September, Petropavlovsk, Kamchatksy, Russia
http://www.igc-geoheat.com

Geothermal Volcanology Workshop 2020 (Institute of Volcanology and Seismology)
5-9 September, Petropavlovsk, Kamchatksy, Russia.

1st Inaugural Canadian Geothermal Summit 2020 (UAlberta Geothermal Research Group)
Commercialization and research of Canada's vast geothermal resources
9-10 September, Edmonton, Alberta, Canada
https://www.cgsummit2020.com/

Geothermics for Petroleum Geoscientists (IGA Academy)
16-17 September, London, UK
https://www.geothermal-energy.org/event/geothermics-for-petroleum-geoscientists/

44th GRC Annual Meeting & Expo
18-21 October, Reno, Nevada, USA
https://reno2020.mygeoenergynow.org/

Eighth Africa Rift Geothermal Conference (ARGeo-C8)
2-8 November, UNEP headquarters, Nairobi, Kenya
http://theargeo.org/

COP 26 - Climate Change Conference
9-20 November, Glasgow, Scotland, UK
https://unfccc.int/

Geothermal for Heating and Cooling (IGA Academy)
18-19 November, Warsaw, Poland
https://www.geothermal-energy.org/event/geothermal-for-heating-and-cooling/

45th GRC Annual Meeting & Expo
3-6 October, 2021, San Diego, California, USA
https://www.mygeoenergynow.org/

After reading the excellent summaries ending all nine chapters, I had new respect for the flexibility of geothermal systems and two questions: who decides what low and high mean in an energy project and what is a low-temperature energy system? As it turns out, the project designer decides on the amount and type of heat needed by any energy system. As for the definition of a low-temperature system, it boils down to this. Low-temperature energy is whatever remains (no matter how hot or cold) after a higher-temperature energy source (no matter how hot or cold) has cooled down too far to be of use in the primary project. The cooler energy, still viable, is usually called waste. The authors object, saying this is not waste energy but wasted energy. How we can use “wasted energy” is the focus of the book, and the authors offer many suggestions and engineering diagrams.

Speaking for all of the authors, Dr. DiPippo says, “There is no sharp line to define ‘low-temperature’ but the particular situation will determine when it is feasible to seek exploitation of the appropriate waste energy.

“The book will develop a deeper understanding of the processes involved in converting low-temperature geothermal energy into useful applications. We authors will consider our work successful if the book is found useful in educational and training courses for students at technical universities and for technologists in industry. The book describes many ways that waste heat can be at least partially captured and put to use, thus saving a measure of primary energy and mitigating the environmental impact of the energy usage.

“Although renewable energy sources such as solar, wind, biomass, and geothermal are being developed and deployed widely, much of the thermal energy derived from conventional energy sources, like coal, oil, natural gas, and nuclear, and even renewable energy, is being wasted. On a broad average, about two-thirds of the thermal energy from conventional fuels ends up being discharged to the environment in the form of medium-to-low-temperature heat.”

In summary, the book emphasizes that end-of-cycle temperatures (no matter how warm or cold) should not be wasted because their many potential uses can contribute in a sustainable and environmentally friendly manner to the energy needs of humankind. We must learn how to apply them in the domestic, commercial, and industrial realms—the places where a vast amount of low-temperature energy is wasted.

The book offers a variety of effective ways—not just one—to capture this energy. “Heat pumps are now playing an important role in the low-temperature domain,” writes Dr. DiPippo. “Through this book, we hope to point the way to even more applications for heat pumps.”

Throughout the book, cut and dried solutions are eschewed in favor of innovative ways to use waste energy in a great many residential, commercial, and industrial processes. The book features end-of-chapter review questions and exercises, as well as numerous worked examples.

For more information, including a table of contents, a book summary, and ordering and pricing details, click on: https://www.elsevier.com/books/low-temperature-energy-systems-with-applications-of-renewable-energy/redko/978-0-12-816249-1
In affiliation with the International Geothermal Association (IGA) the GRC offers a discount to the professional journal *Geothermics*, which publishes articles on the theory, exploration techniques and all aspects of utilizing geothermal resources.

For the year 2019 the subscription rate to a combined print and electronic subscription to the Journal is USD 133 for individual members and USD 305 for corporate/institutional members. Please note that the member subscription rate does not include any sales or similar taxes required by law, which may be billed by the Elsevier as appropriate.

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Members can also reach Elsevier Team by phone: (+1) 877 839 7126 or (+44) (0)1865 843434
Brian Berard

Brian passed away in his sleep around Christmas. He was at his home in Brawley, California.

Brian was originally from Louisiana and trained as a geologist and geophysicist. Prior to Brian’s three decades in geothermal, he served in the Navy and worked in the oil and gas industry of Louisiana and Texas. Encouraged by his step-father, Brian and his brother, Greg, he moved to Ridgecrest, California during the drilling and development of the Coso geothermal project. He contributed much to the Coso and Salton Sea fields, and explored Nevada’s geothermal resources for a couple years. He spent most of his career working for California Energy, now CalEnergy, and retired as the Geothermal Resource Manager in June 2017.

Brian was always a gentlemen, found time to listen, and enjoyed life. He is missed.

(Thanks to Jon Trujillo)

Mike Shook
(1957-2020)

Geothermal and petroleum reservoir engineer and tracer expert George Michael Shook passed away on January 1, 2020 following a brief battle with pancreatic cancer. He leaves behind his wife, Linda, and daughter Erin, as well as siblings Patti, Terry, Steve, Jeff and Richard.

He was born July 25, 1957 in Santa Monica, California, and grew up near NASA’s Johnson Space Center in Nassau Bay, Texas (a suburb of Houston) during the 1960s heyday of the Gemini and Apollo manned space missions. His father was part of the aerospace engineering community.

Mike earned his BS and MS in Petroleum Engineering at The University of Texas at Austin in 1984 and 1988, followed by two years of doctorate work in reservoir engineering. He was renowned in both the geothermal and oil industries for his understanding of both the theoretical and actual field behaviors of fluids in oil and geothermal reservoirs. Through his outstanding and unparalleled work, Mike was well known across the subsurface energy resource communities worldwide.

Most recently, Mike offered consulting to both the geothermal and oil industries through Mike Shook and Associates LLC (Houston, Texas). His specialty was reservoir tracer design and interpretation for oil, gas and geothermal energy development, and providing training and technology transfer. Throughout his career he built in-depth knowledge of reservoir management and simulation, including:

- Field characterization, development and optimization;
- Project engineering and planning;
- Assessment of heterogeneity and optimization of volumetric sweep efficiency; and
- Development of analytical reservoir engineering tools.

From 2006 to 2015, Mike served as Senior Advisor for Enhanced Oil Recovery (EOR) at Chevron at Houston, Texas, where he specialized in reservoir simulation. His work included full field reservoir modeling, tank models, and tracer test design in the development and deployment of novel methods of optimizing waterflood sweep efficiency for EOR applications. He earned a high level of respect throughout the oil industry for his unique design, forecasting, and interpretation of tracer tests and associated modeling.

Mike taught several short courses on tracers for reservoir development during his work at INL and Chevron at locations spanning the globe, from Scotland to Kazakhstan, and Angola to Dubai and Indonesia – as well as stateside.
Before joining Chevron, Mike served as Senior Advisory Scientist in Geothermal Geosciences at the U.S. Department of Energy’s Idaho National Laboratory (INL) at Idaho Falls, Idaho (1990-2006). He brought new insights to reservoir simulation modeling through development of tracer test interpretation methods and thermal front velocity estimation for porous and fractured media. He also managed field-scale simulations in a variety of geothermal geophysical inversion studies. Along with geothermal modeling, he developed and conducted the integration of flow to geophysical models for oil and gas, and applied EOR technology to environmental remediation.

Mike published scores of papers and reports, and presented his work at several geothermal and petroleum industry meetings. Researchgate.net reports 40 citations in the public record, including 15 papers and talks as author/co-author at the Stanford Geothermal Workshop and 11 more for the Geothermal Resources Council (GRC) (Citations in the Geothermal Library). In addition, he offered nine presentations at Society of Petroleum Engineers events and published three papers in the SPE Journal. Mike is also named on eight patents at INL and one patent application at Chevron.

He was a stalwart supporter of the GRC, leading, teaching and participating in many workshops in the early 2000s, and he served as volunteer Technical Program Chairman for GRC Annual Meetings in 2002 and 2004. In recognition of his insights and efforts, Mike was honored with a GRC Special Achievement Award in 2005 for his outstanding work on tracers in the development of geothermal resources.

A superlative and exacting scientist, Mike’s intuitive math and engineering skills served his passion for understanding the nature of fluid reservoirs deep within the earth. His contributions to the fields of reservoir engineering and the use of tracers to characterize and develop both geothermal and petroleum resources will be sorely missed.

(Ted Clutter, Joel Renner, Eric Hass, Sabodh Garg, Kit Bloomfield, GRC staff and the Shook family contributed to this article)

**John W. Pritchett**

An obituary will appear in the March/April issue of the *Bulletin*.  

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