GEOTHERMAL RESOURCES COUNCIL

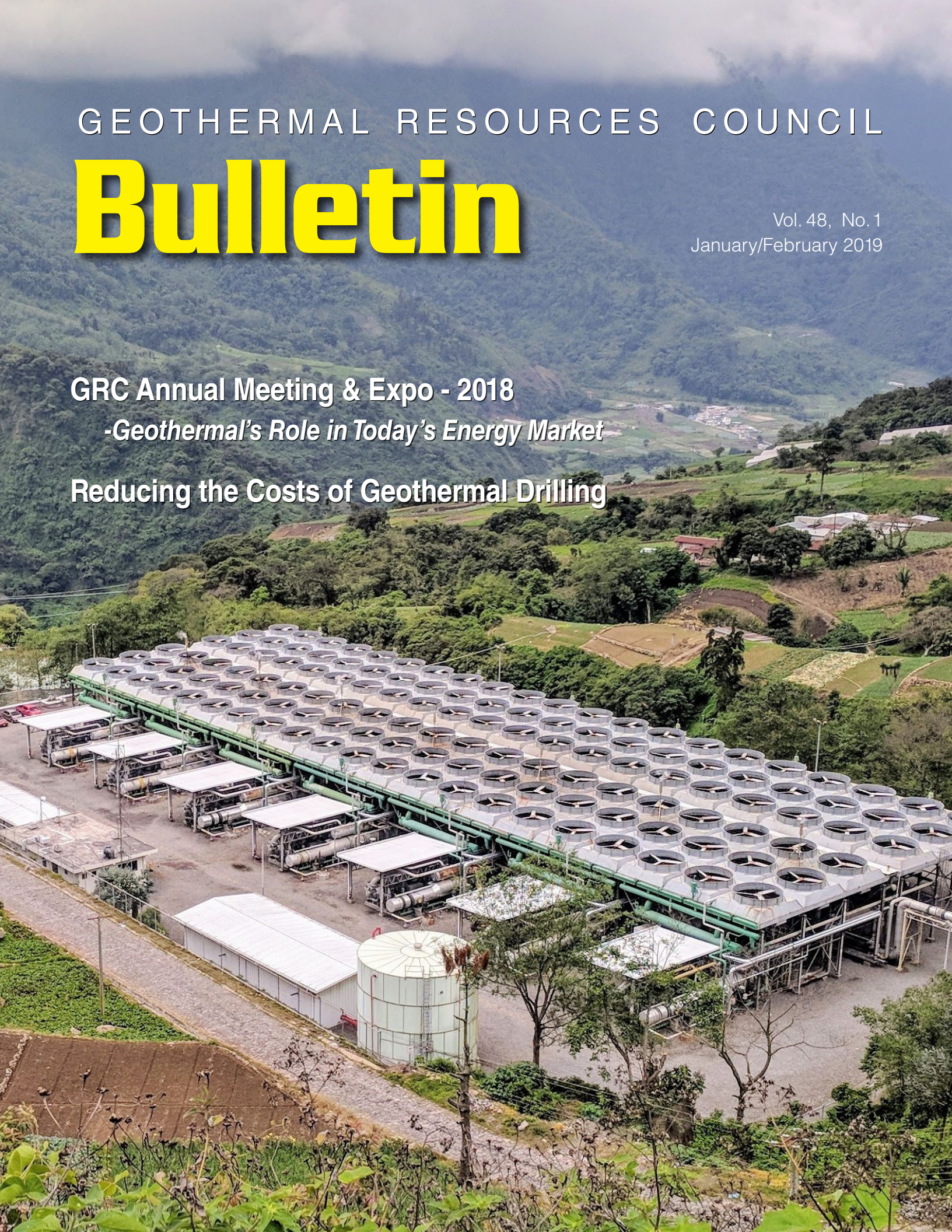
Bulletin

Vol. 48, No. 1
January/February 2019

GRC Annual Meeting & Expo - 2018

-Geothermal's Role in Today's Energy Market

Reducing the Costs of Geothermal Drilling



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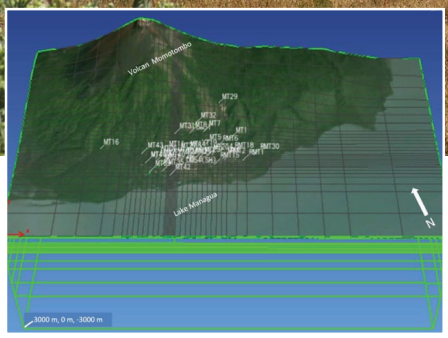

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Bulletin

Vol. 48, No.1
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The Geothermal Resources Council (GRC) *Bulletin* (ISSN No. 01607782) is published as a service to its members and the public, with six issues per annual volume. The GRC is an international, non-profit educational association whose purpose is to encourage research and environmentally sound exploration, development, and utilization of geothermal-energy resources worldwide through cooperation with governmental agencies, academic institutions, and the private sector. The GRC *Bulletin* provides a forum for information transfer to the public and among professionals in many fields related to geothermal resources, including geology, exploration, development, electric-power production, and direct-use technologies. The views and opinions expressed by authors in this publication do not necessarily reflect those of the GRC or its members. For changes of address or membership information, please contact us.

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President's Message

by Andrew Sabin

A Brief Retrospective and a Look Ahead

2018 was a year of transition for the Geothermal Resources Council (GRC). Many of you know that we filled a year-long vacancy for GRC's Executive Director (ED) by hiring Dr. William Pettitt last summer. Will has already brought a tremendous amount of knowledge, professionalism and passion to the GRC and we look forward to continued excellence from Will and his staff in everything that GRC does.

We also consolidated the GRC and the former Geothermal Energy Association (GEA). The roles and responsibilities of the former GEA now reside in the Policy Committee (PC), a special committee within the GRC. Now both major American geothermal associations are under one roof. This allows us to have a stronger and more unified voice. We should be able to more efficiently and effectively serve our community. Both the hiring of Will and the GRC-GEA consolidation took a tremendous amount of time and work. On behalf of the community that we serve, I want to thank our entire Board of Directors, led by outgoing President Maria Richards, the GRC staff and everyone else involved in both of these hard-won efforts. I am certain that this work will pay dividends for all of us.

We are also welcoming 6 new members to our Board of Directors: Andrea (Andy) Blair (Upflow Ltd., New Zealand); Lara Owens (Ormat Technologies, Inc., Nevada, USA); Robert Podgorney (Idaho National Laboratory, Idaho, USA); Jefferson W. Tester (Cornell University, New York, USA) and Hildigunnur (Hidda) Thorsteinsson (Reykjavik Energy, Iceland). The sixth new Board member is Paul Thomsen (Ormat Technologies, Inc., Nevada, USA). Paul was selected by the PC to be their representative to the Board, per the newly modified structure of the GRC. While it was difficult to lose 6 Board members with their decades of collective experience, these new Directors bring their own unique experiences, diversity and views to the Board. I know that they will serve our community well in the coming years.

The final piece of a transition initiated in 2018 involves a look inward by our Board. The outcome may yield changes to the future size (smaller), composition (required diversity) and terms (term limits) of current and future Directors. The GRC Board of Directors feels strongly that all of these steps - a new ED, the GRC-GEA consolidation and Board restructuring - are required if we are going to best serve our community and meet their evolving demands.

Please contact Will, me or any other Board member if you have any questions, thoughts or suggestions for how we might better support and serve you and this vitally important industry.

****

2019 also brings renewed hope, continued growth and more hills to climb for GRC and our entire industry. In that vein, I'd like to recommend New Year's reading for our geothermal community.

You may recall a few months back when the White House released the *Climate Science Special Report: Fourth National Climate Assessment (NCA4), vols. 1 and 2* hoping that a Friday release

date, typically a slow news consumption day, would minimize the report's dramatic message in the public's eye. As it turns out, this ruse wasn't even necessary. Very few will even try to look at this massive, 2 volume report much less read it. They should. And so should you. Here's why.

1. An understood selling point of geothermal power is that it displaces carbon that would otherwise be released into the atmosphere by the combustion of fossil fuels. An equally understood phenomenon is that many of our elected officials and at least one popular "news" network work diligently to deny and misrepresent science, especially climate change science. A combination of reasons including money and integrity (or lack thereof) explains this behavior but that is beside the point. Our charge as scientists should be to understand, embrace and discuss this science for the sake of our industry, not to mention our way of life on this planet. We should never undersell the total value of geothermal.

2. This report is easy to read, comprehensive and incredibly alarming. The training and culture of most scientists in our industry is captured by what you hear in our National Parks, "Take pictures and leave footprints." Our community should not allow this culture and geothermal science to be decoupled from climate change science, regardless of how politically unpalatable it can be for some. When you understand and discuss science you are not taking a side in an argument, you are doing your job.

3. The *NCA4* illustrates data trends, presents conclusions and most importantly, provides references so that everything in this report can be assessed, tested and even refuted if necessary. Unlike belief systems or the manufactured mythology hawked by climate deniers, data presented in *NCA4* can be tested. Testing data is the fundamental difference between science and beliefs. We are a community of scientists and engineers. We employ verifiable data in every aspect of everything we do. If someone in our community chose to rely on hunches, beliefs and biases (especially if sourced from some breathless television "news" personality) in his daily decision-making, he would quickly become unemployed and likely unemployable. Climate science data and geothermal data are compatible and should be.

4. Our industry, like climate science, has a messaging problem. Too few in the public as well as key decision makers truly understand the value or the applicability of geothermal. Minimally, each of us should strive to be as well-educated as possible about what we are and what our potential can be. In addition to baseload power, potentially dispatchable power and competitive economics, our message has to include why the relative cleanliness of geothermal matters.

5. Finally, mid-career and younger employees plus college students are our future. They understand and generally accept conclusions of climate change science. It is important to them. If we can't fully understand, acknowledge and embrace the value of climate change science in our own profession, then these future employees and future leaders will seek out an industry that does. We need to acknowledge the future by understanding and discussing the science in front of us.

You can easily download both volumes of this report at https://www.globalchange.gov/nca4. The *NCA4* is not something you'll read in one sitting or even one month. Bookmark this site and take small bites out of it as you have the time. You'll be doing yourself and your community a service. ■

Executive Director's Message

by Will Pettitt, PhD

Local Geothermal Sections are Connecting our Members

As we begin the new year we welcome a new President, Andy Sabin, and new Board members to the GRC. Andy is well known to many of our members, having been in the geothermal community throughout his career, and is an accomplished scientist and leader. As always, the new board members are a diverse group of recognized, high-quality, professionals with a wide range of experience that continue to strengthen our organization. I congratulate all the new board on their success and welcome them to an exciting time of growth for our organization and the community we represent. I would also like to thank the outgoing board members for their time served on the Board. They have contributed hugely to the community through their volunteer efforts and I hope they all continue to work with the GRC as part of our extended volunteer network.

This month I was fortunate enough to attend a meeting of the new Southern California Section of the GRC in Imperial Valley, giving a brief presentation on our vision regarding the GRC and Policy Committee. The meeting was very well attended and the attendees were clearly getting a lot of value from the opportunity to gather together. The thriving local section also illustrates how vibrant the local geothermal community is in that area and reinforces the huge potential the valley has for geothermal energy production in the future. As well as believed to be one of the largest untapped hydrothermal resources in the world, the Imperial Valley also has new opportunities for development of Enhanced Geothermal Systems (EGS), joint solution mining of Lithium, and using geothermal power for desalination. These opportunities, amongst other opportunities that

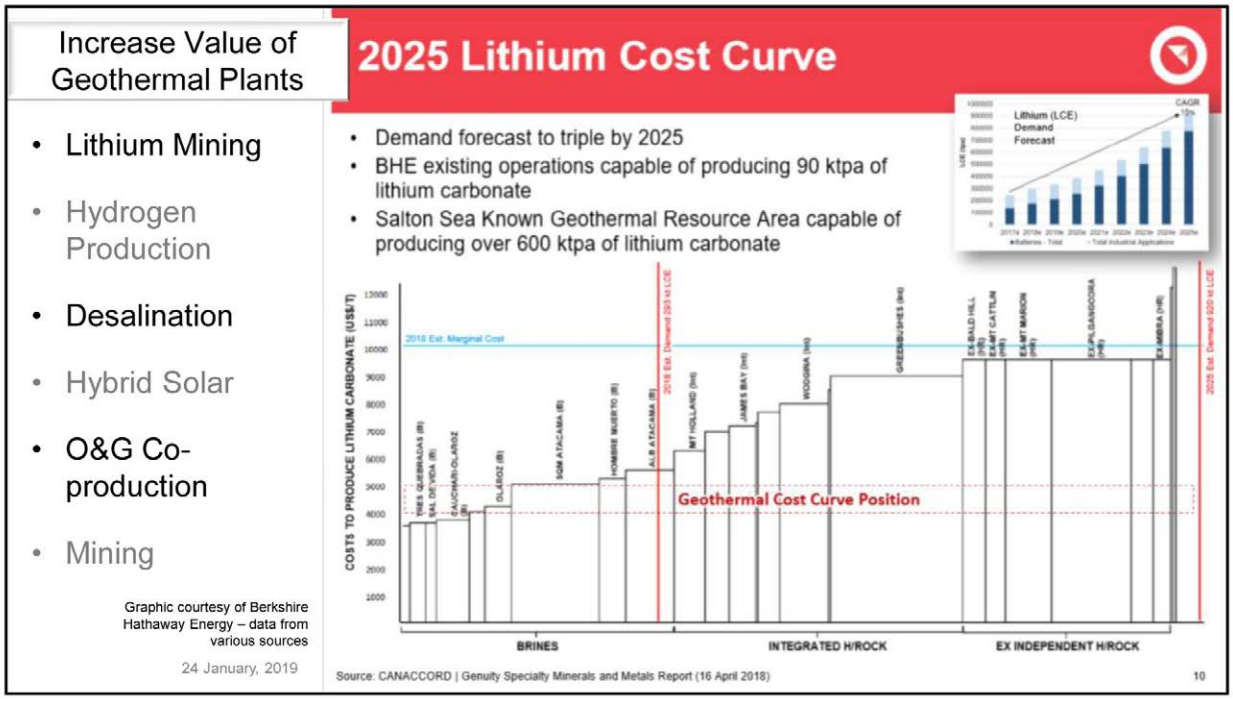


Figure 1: Opportunities for increasing the value of geothermal energy production through operation with other products and services. Graphic on lithium production economics courtesy of Berkshire Hathaway Energy and originally presented at a California Energy Commission (CEC) workshop on lithium recovery from geothermal brine, November, 2018.

could apply in other locales (Figure 1), bring additional value to geothermal projects and allow our industry to be more cost competitive with solar and wind.

The GRC's local Sections (or Chapters) are not new to the organization - having first been explored in the 1980s. The section concept is being reinvigorated as part of our strategy to better connect with local geothermal communities and increase the value the GRC brings to our members. In November of last year I was equally fortunate to attend, and present at, a meeting of our Geysers Northern California Section. The Geysers is the largest geothermal field in the world and likewise has huge potential for the future with another thriving local community. The new Section is a continuation and integration of the Geysers Geothermal Association that has a long history in that area and thus brings a lot of experience in geothermal industry development, both at the technical and policy levels. We plan to continue developing Local Sections across the USA, or collaborate closely with existing local associations, so as to connect more and more with folks on the ground in the geothermal community and bring greater awareness to the local general public. Information on donating towards our local sections, as well as towards student memberships and our Foundation Funds, can be found on the membership renewal form (https://geothermal.org/membership.html) and the my.geothermal.org website at https://my.geothermal.org/GRC/Donate/GRC/Donate/Choose_a_Fund.aspx.

If you want to talk about our association and the geothermal energy community you can contact me at wpettitt@geothermal.org or 916.758.2360 ext. 103. ■

Communication from the GRC

by Ian Crawford
Director of Communications

New President of the Geothermal Resources Council

At the next meeting of the GRC Board of Directors on February 10th, the GRC will welcome **Dr. Andrew Sabin** as the **27th President** of the global geothermal energy organization, succeeding Maria Richards.

Dr. Andrew Sabin works with the **Navy Geothermal Program Office** in Ridgecrest, California. Andy's career has spanned more than 30 years and has included ore deposits, geotechnical, environmental and geothermal work.

He earned degrees in geology from the **University of Maryland**, the **University of Pittsburgh** and the **Colorado School of Mines.** Like many of his colleagues in the geothermal energy community, Andy has been a long-time member and supporter of the GRC. He also currently serves on the Board of Directors for the International Geothermal Association (IGA).

New Members Elected to the Geothermal Resources Council Board of Directors

Five new members join the GRC Board of Directors

The Geothermal Resources Council (GRC) is governed by a Board of Directors, elected by the general membership to 2-year terms. To provide continuity, half of the Board is elected every year. All GRC members are eligible for election to the Board of Directors.

The global GRC membership took part in the ballot in November, and the result was that five new members of the Board were elected: **Andrea (Andy) Blair, Lara Owens, Robert Podgorney, Jefferson W. Tester and Hildigunnur (Hidda) Thorsteinsson (see image below).**

They join eight other members who have been re-elected to the Board of Directors: **Louis Capuano III, Tim Conant, Warren T. Dewhurst, James Lovekin, Leland "Roy" Mink, Jon Trujillo, Jeff Witter, Shigeto Yamada** and **Katherine (Kate) Young.**

In addition, a sixth new Board member, **Paul Thomsen** was selected by the GRC Policy Committee to be their representative to the Board, per the newly modified structure of the GRC

The diverse membership of the Board of Directors reflects the mission of the GRC to represent the entire global geothermal community.

William Pettitt, Executive Director of the GRC commented "We would like to congratulate all the new members of the Board on their success in the election and express our appreciation for them standing up to be a Director of the GRC. It is a great honor for us to work with them all and we look forward to starting towards our schedule of 2019 goals for increasing awareness of geothermal energy across society, in the USA and abroad."

Photos of the new Board of Directors can be seen on the GRC Website at www.geothermal.org/BOD.html





2019 GRC Annual Meeting & Expo

Geothermal: Green Energy for the Long Run

Call for Papers Issued -

Deadline for submission is Friday, March 15th

The Geothermal Resources Council (GRC) 2019 Annual Meeting planning committee will consider papers for its **Technical and Poster Sessions** covering a range of topics, both domestic and international:

Business Development / Finance/ Market Analysis; Drilling; Direct Use / Heat Pumps; Enhanced Geothermal Systems (EGS); Emerging Technologies; Exploration / Resource Assessment; Field Operations / Production Technologies; Geology; Geochemistry; Geothermal Education and Community Engagement; Geothermal Energy Associated with Oil and Gas Operations; Geothermal Project Case Studies; Geophysics; Power Operations / Flexible Generation / Maintenance; Regulatory / Environmental Compliance / Policy Issues; Reservoir Engineering/ Reservoir Management/ Modeling; Sedimentary Basins; Utilities and Transmission; Country Updates (example: East African Rift / Philippines), and Regional Updates (example: Salton Sea / Basin & Range / Cascades).

In addition, there is an opportunity to submit papers in **special themed topics:**

Advancements in Resource Development, Wellbore Construction & Completion; Diversity within the Geothermal Industry; EGS Collab Project; Experimental & Modeling Techniques for Geology, Geophysics & Hydrology; Geothermal Growth in East Africa; Geothermal Policy; Geothermal Well Integrity Technologies; Harnessing Energy & Water in the Salton Sea; Mineral Extraction From Geothermal Fluids; Modernizing Steam Controls; Production Well Automation Upgrades; Remote Sensing for Exploration & Resource Assessment; Spanish Language (Papers will be written & presented in Spanish); Statistics in Geothermal Exploration; Technology Transfer Between Oil & Gas and Geothermal Applications; Uncertainty & Risk Analysis to Inform Geothermal Project Decisions, and Wellhead Assembly Equipment, Maintenance & Best Practices.

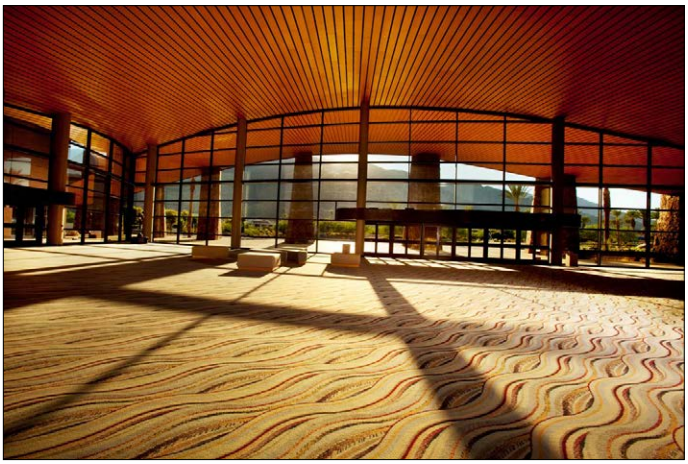
International participation is key to the success of the technical programs, and geothermal researchers and experts **from the USA and around the world** are encouraged to submit their work for consideration to be presented at the GRC Annual Meeting.

Anyone who wants to present at the GRC Annual Meeting must submit a paper. The deadline for submission is Friday, March 15th, 2019.

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

Book Your Booth

Exhibitors who desire a booth at the Expo should contact Anh Lay at alay@geothermal.org or (530) 758-2360 for more information. All the essential information will also be available on the GRC Annual Meeting website at: www.geothermal.org/meet-new.html.



The lobby of the Palm Springs Convention Center. (Courtesy Palm Springs Bureau of Tourism)

Reserve Your Hotel Room

The GRC Annual Meeting & Expo will be held in the **Palm Springs Convention Center** and the contracted hotels are either connected to the convention center or just a short walk away.

The GRC has contracted for a discounted block of rooms at two host hotels. The **Renaissance Palm Springs Hotel** and the **Hilton Palm Springs Hotel.**

Attendees can make their reservations on a secure website prepared specially for the GRC. The links are available from the GRC Annual Meeting website at: geothermal.org/Annual_Meeting/hotel.html

A guestroom at the Renaissance Palm Springs Hotel.

The lobby at the Hilton Palm Springs - just one block from the convention center.

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GRC Transactions

Technical papers from the **2018 Transactions Volume 42** are now available through the *Geothermal Library* website. **More than 180 papers** that were presented at the GRC Annual Meeting in Reno, Nevada are available for members only, at https://www.geothermal-library.org/. Papers from previous years are also available for all.

Our database contains **over 40,000 records** on all aspects of geothermal energy, including exploration, reservoir engineering, power plant design and operation, direct use, geothermal heat pumps, regulatory issues, energy policy, energy markets, news briefs, and more.

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GRC Membership

It's time to renew your GRC membership!

Notices were sent out in November. Please complete the form and send it back as soon as possible. Alternatively, you can go online on the my.geothermal website and renew your membership quickly and easily. There is also a PDF file of the Membership Application form to download and print.

Member Application Form (PDF).....

My.geothermal.org.....

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Nominations Open for International Geothermal Association Board

The **International Geothermal Association (IGA)**, recently removed to Bonn, Germany, has announced the opening of nominations for the IGA Board.
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Nominations for **2020-2023 IGA Board Term** are now open. **The deadline is Tuesday, 16 April 2019.**

The IGA is an ´Association of Associations´ and acts as the umbrella organization for 35 affiliates. In total, the IGA currently has around 4,500 members. The majority of the membership is funneled through affiliated associations (about 4,200) and about 300 are direct individual members, institutional members and corporate members. The Geothermal Resources Council is the largest of these affiliates and provides 11 of the current IGA Board Members. BoD Nomination Guideline (PDF) ■

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Have Your Say!

If you would like to comment on any column or article in the *GRC Bulletin* or have an opinion on a topical subject that will interest our readers, please email the editor, **Ian Crawford** at icrawford@geothermal.org or mail to Geothermal Resources Council P.O. Box 1350, Davis, CA 95617-1350.
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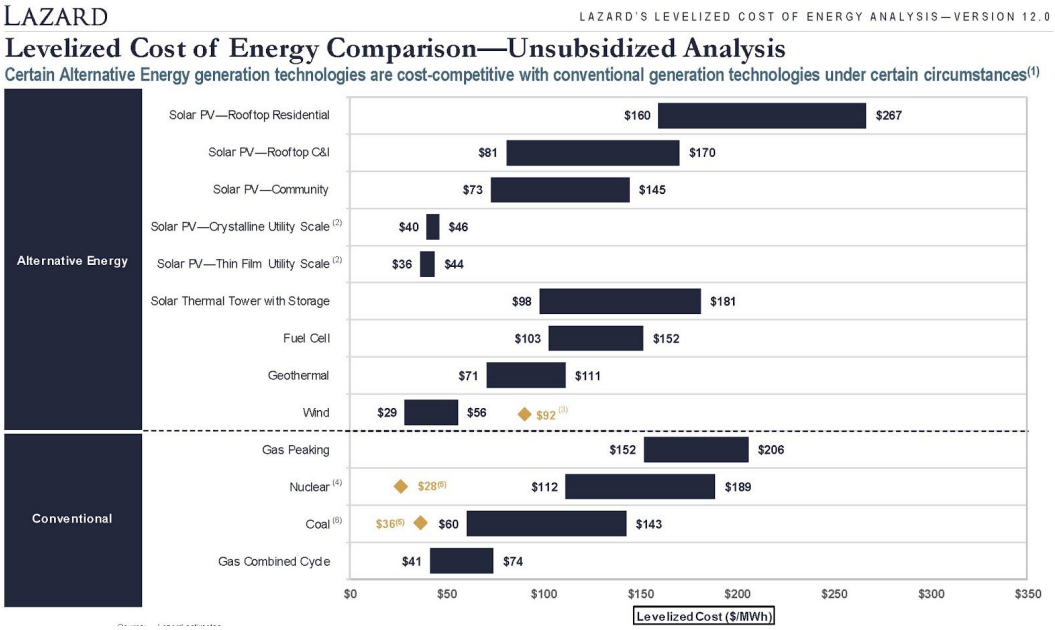
Inside Geothermal

Another Levelized Cost of Energy Analysis Shows Geothermal Energy is Competitive

Lazard's latest annual *Levelized Cost of Energy Analysis* (LCOE 12.0) shows a continued decline in the cost of generating electricity from alternative energy technologies, especially utility-scale solar and wind. In some scenarios, alternative energy costs - **including those of geothermal energy** - have decreased to the point that they are now at or below the marginal cost of conventional generation. Download the Report (PDF)..... *Global Geothermal News.....*



Over USD 50 Million Available for Renewable Energy Projects in Developing Countries

The Abu Dhabi Fund for Development (ADFD) and the **International Renewable Energy Agency (IRENA)** are inviting applications for more than USD 50 million in funding through the seventh funding cycle for the **IRENA/ADFD Project Facility.** The ADFD-financed initiative is available to government-guaranteed renewable energy projects in developing countries that seek to increase energy access, improve livelihoods and advance sustainable development.

ADFD has committed **USD 350 million** (AED 1.285 billion) in concessionary loans over seven annual funding cycles to renewable energy projects recommended by IRENA.

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ABU DHABI FUND FOR DEVELOPMENT

The facility welcomes proposals for projects – especially those submitted by ministries, public utility entities and rural electrification agencies – that are able to obtain a government guarantee for the ADFD loan.

Summary applications for the seventh cycle will be accepted until 17:00 GST on 14 February 2019. *Global Geothermal News.....*

NORTH AMERICA

Funding Available for Research Into Downhole Tools to Enable Enhanced Geothermal Systems

The U.S. **Department of Energy**'s (DOE's) **Advanced Research Projects Agency-Energy (ARPA-E)** has announced its latest funding opportunity designed to support early stage, transformative energy technologies. The "Solicitation on Topics Informing New Program Areas" funding opportunity enables ARPA-E to investigate potential new program areas while highlighting energy challenges of critical interest to American competitiveness and security.

This first round calls for innovative technologies include one for **high temperature sensors for downhole geothermal exploration**. ARPA-E will award up to **USD 18 million** to project teams spread across standard and small business (SBIR/STTR) solicitations.

The application for funds for research into Downhole Tools to Enable Enhanced Geothermal Systems (EGS) has a full application submission deadline of 6:30 AM PT, February 18.

ARPA-E seeks novel low-cost sensor technologies capable of mitigating risks and lowering costs in EGS development by better

SBIR·STTR
America's Seed Fund

characterizing rock formations and fluid enthalpy at depth. Technologies of interest include but are not limited to fiber-optic sensors and enthalpy measurement devices, as well as companion electronics and communications equipment. Successful projects will facilitate reservoir creation and maintenance, reduce unexpected reservoir behavior, and ultimately lower costs associated with EGS. Successful technologies developed for this purpose may also offer side benefits in applications including O&G, subsurface energy/CO_2 storage, aerospace and automotive engineering, nuclear energy, and space exploration. *Global Geothermal News.....*

Opportunity for Geothermal Energy to Help in Desalination Research

The U.S. **DOE** has also announced **USD 100 million** to establish an **Energy-Water Desalination Hub** to address water security issues in the United States.

The Hub will focus on early-stage research and development (R&D) for energy-efficient and cost-competitive desalination technologies including manufacturing challenges, and for treating non-traditional water sources for multiple end-use applications. **Geothermal energy has been touted for providing the power for such processes. Concept papers are due on February 7.** *Global Geothermal News.....*

Increase of 5.4% Year-on-Year for Geothermal Electricity Generation in USA

There are some interesting geothermal energy statistics to be gleaned from a recent *Electric Power Monthly* from the U.S. **Energy Information Administration (EIA).**

In the year to date to September 2018, the USA generated **12,477 Gigawatt hours (GWh) of electricity from geothermal resources**, an **increase of 5.4%** on last year, from **2,499.3 MW of net capacity.**

For individual states:

- California - 9,001 GWh (+2.9%) from 1,854.0 MW
- Nevada - 2,677 GWh (+15.9%) from 498.2 MW
- Utah - 350 GWh (+3.6%) from 73.0 MW
- Hawaii - 240 GWh (-1.1%) from 43.0 MW
- Oregon - 140 GWh (+6.0%) from 19.5 MW
- Idaho - 59 GWh (-0.5%) from 10.0 MW
- New Mexico - 9 GWh (-6.5%) from 1.6 MW

The average capacity factors for utility scale generators in 2017:

- Nuclear - 92.2%
- **Geothermal - 74.0%**
- Landfill Gas and Municipal Solid Waste - 68.0%
- Other Biomass Including Wood - 57.8%
- Conventional Hydropower - 43.1%
- Wind - 34.6%
- Solar Photovoltaic - 25.7%
- Solar Thermal - 21.8%

Global Geothermal News.....

U.S. Government Plans to Strip Protections for Sage Grouse

The Trump administration is planning to open nine million acres to drilling and mining by stripping away protections for the sage grouse, an imperiled ground-nesting bird that oil & gas, and even geothermal energy companies, have long considered an obstacle to energy reserves in the American West.

A male Greater sage-grouse (Centrocercus urophasianus) in full display mode! Courtesy Wikipedia Commons - Public Domain.

In one stroke, the action would open more land to drilling than any other step the administration has taken, environmental policy experts said. It drew immediate criticism from environmentalists while energy-industry representatives praised the move, saying that the earlier policy represented an overreach of federal authority. *Global Geothermal News.....*

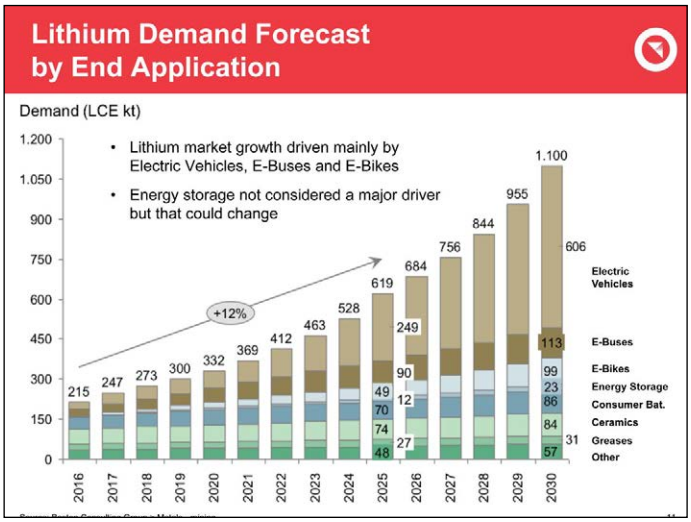
Presentations from Workshop on Lithium Recovery from Geothermal Brine

Two interesting PowerPoint presentations from a workshop facilitating a conversation about **lithium recovery from geothermal brine** have been made available. The workshop, facilitated by **California Energy Commission (CEC)** Lead Commissioner for Renewable Energy, **David Hochschild**, was held on Thursday, November 15, 2018.

- Berkshire Hathaway Energy Overview
- Lithium Market Overview (Bloomberg NEF)

Other documents associated with the workshop including the WebEx recording, agenda, transcript, workshop questions, and public comments can be found on the CEC website at: https://www.energy.ca.gov/geothermal/grda_workshops/.

Global Geothermal News.....



From the Berkshire Hathaway Energy (BHE) Overview.

Imperial County Recommends a "Lithium Task Force" to Bring Together Stakeholders in Extraction Efforts at the Salton Sea

The **Imperial County Board of Supervisors** has approved a comment letter to the **California Energy Commission** regarding the prospect of **recovering lithium from geothermal brine** at the **Salton Sea**.

"This potential new industry holds a great deal of promise for new job creation and economic development here in Imperial County. In addition, it could serve to provide an important domestic source of a critical resource that is a key component in batteries that can be used to improve electric grid reliability and electric vehicle deployment in the state of California.

"In addition, mineral extraction, in conjunction with other renewable energy development around the Salton Sea, should contribute to ongoing efforts to address issues around the troubled body of water," the county wrote in a comment letter signed by county Supervisors Chairman **Ray Castillo**.

In the process of mining geothermal energy, hot brine is extracted from the earth, and minerals such as lithium, zinc and manganese are present in the hot fluid, Deputy County Executive Officer **Andy Horne** said. Collecting those minerals has long proven a reality, but doing so on a large-scale, commercially and economically feasible basis has yet to be done.

Horne said county officials were to meet with **Berkshire Hathaway Energy** (which owns **CalEnergy geothermal operations** at the Salton Sea) officials to talk about lithium recovery. "I think our board is very optimistic about this. It's been talked about for some time, but it's gathering momentum to move this forward at some very high levels, and I think that's encouraging," Horne said. *Global Geothermal News.....*

Hell's Kitchen 2, by **Darrell Cornett.** *Hell's Kitchen Geothermal Fields Salton Sea California 2017.Third Place GRC Photo Contest 2017.*

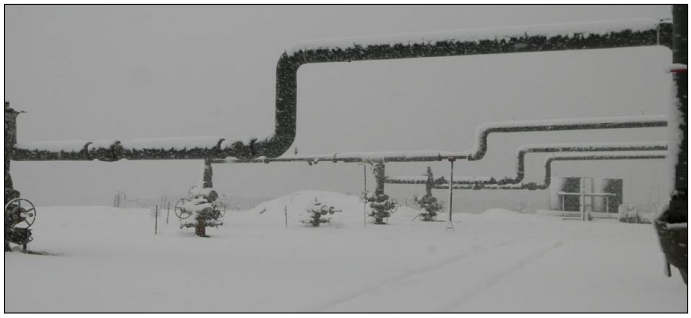
New Field-Scale Thermoelectric Generator to be Tested at Bottle Rock Geothermal Power Plant

AltaRock Energy, Inc. has provided more details of an R&D project to build and test a new field-scale **thermoelectric generator (TEG)** at the **Bottle Rock Power** geothermal facility near **Cobb, in The Geysers geothermal field, California.**

TEGs produce electrical energy when a strong enough temperature difference exists across the generator (a phenomenon known as the **Seebeck**

effect). AltaRock says this will be the first TEG developed specifically to generate electricity from a geothermal resource with the goal of making renewable geothermal electricity more competitive in the marketplace.

This project will not only prove the feasibility of using TEG materials with a geothermal resource but also develop how this technology can be installed in an operating field. This project is supported by a generous grant from the **California Energy Commission's Electric Program Investment Charge (EPIC)** program. *Global Geothermal News.....*



February steam lines. Bottle Rock Power Plant in the Geysers steam field, Northern California, by **Betsy Phillips**, *GRC Photo Contest 2011.*

Geothermal Expert is New Director of U.S. National Energy Technology Laboratory

Brian Anderson *is the new director of the National Energy Technology Laboratory.*

GRC Member **Brian Anderson,** former director of **West Virginia University (WVU)'s Energy Institute**, has joined the U.S. **Department of Energy (DOE)** as director of the **National Energy Technology Laboratory (NETL).**

Anderson founded WVU's Energy Institute in 2014 to foster collaborative research and development of new technologies. *Global Geothermal News.....*

McGinness Hills Geothermal Power Plant Capacity Increased to 138 MW

Ormat Technologies Inc. has announced that the third phase of its **McGinness Hills** geothermal complex located in **Lander County, Nevada** has begun commercial operation.

The **48 MW net capacity** power plant started selling electricity to **Southern California Public Power Authority (SCPPA)** under the Ormat Northern Nevada Geothermal Portfolio *Power Purchase Agreement.* SCPPA resells the entire output of the plant to the **Los Angeles Department of Water and Power (LADWP)**. The third phase is expected to generate approximately USD 30 million in average annual revenue.

McGinness Hills geothermal power plant (Courtesy Ormat Technologies)

The third phase utilizes just two **Ormat Energy Converters (OEC)** instead of three, as would have been the case in the past. The improved design will increase the efficiency, capacity, and availability of the power plant. Additionally, Ormat expects the economies of scale at the McGinness Hills complex will further increase the complex performance. *Global Geothermal News.....*

Ormat Plans Solar PV to Compliment Tungsten Mountain Geothermal Power Plant Production

Ormat Technologies, is planning to **add solar energy** to the **24 MW Tungsten Mountain geothermal power plant** located in Churchill County, Nevada. The Nevada Bureau of Land Management (BLM) is reviewing whether to approve the project.

The **18 MW photovoltaic (PV) solar installation** will cover the geothermal plant's parasitic, or operational energy consumption, freeing up power

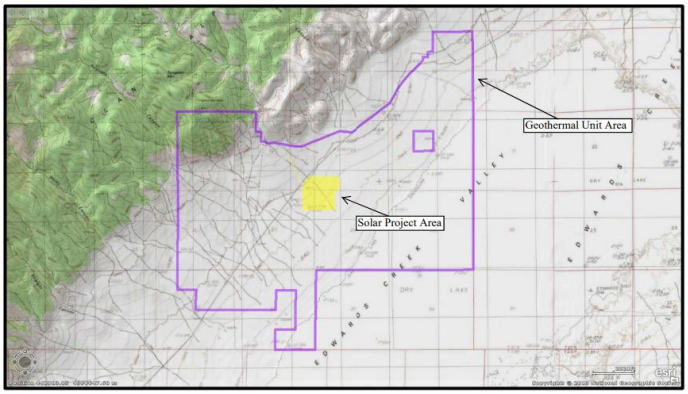


Figure 2: Tungsten Mountain Solar Project Area

The project area at Tungsten Mountain, Nevada.

that Southern California Public Power Authority (SCPPA) agreed last year to purchase at **USD 75.50/MW-hour.**

Since the geothermal plant does not operate as efficiently at high mid-day temperatures, the PV, which peaks at mid-day, will boost the energy output to maximize the energy sold to SCPPA. *Global Geothermal News.....*

Access to Puna Geothermal Venture Power Plant Regained

The lower East Rift Zone eruption of the **Kīlauea volcano** on the **Big Island** of **Hawai'i** began on May 3, 2018 and forced the **Puna Geothermal Venture (PGV)** power plant to shut down.

After the eruption lava covers part of the Puna Geothermal Venture site (U.S Air National Guard Photo by Tech. Sgt. Andrew Jackson)

For several dramatic weeks, lava threatened to inundate the power plant and officials scrambled to prevent a potential catastrophic interaction between the volcanic activity and the resource wells. Ultimately, most of the plant was saved with only a few minor structures affected. The wells were quenched and sealed. (See *Lava Eruption Disrupts the Puna Geothermal Venture - The Background* from the July/August 2018 *Bulletin.*

PGV has been offline ever since. However, work on cutting **a "pioneer road"** over the large lava channel to regain access to the power plant **was completed on December 14.**

According to **Mike Kaleikini,** senior director of Hawaiian affairs for Ormat Technologies, PGV **could restart operations about 18 months after the road is built**. *Global Geothermal News.....*

In addition, Hawaii **Governor David Ige** signed a fifth supplementary emergency proclamation providing additional time for Puna Geothermal Venture to re-establish, or begin to reestablish, the regulatory framework under which it is required to operate. *Global Geothermal News.....*

Open Access Lab Dedicated to Geothermal Energy Opens in Quebec City

The **Institut National de la Recherche Scientifique (INRS)**, has created the **Laboratoire Ouvert De Géothermie (LOG)** or "Open Geothermal Laboratory" in **Quebec City, Canada.**

The LOG is not only home to the latest technology, but is also designed to be accessible to all, much like free software.

Outside partners can use the LOG equipment for free. They can come analyze their rock samples or even test innovative new materials for thermal conductivity and other geothermal properties. *Global Geothermal News.....*

The Laboratoire Ouvert De Géothermie. (Courtesy INRS)

Canadian Geothermal Energy Project Drills First Test Well

Deep Earth Energy Production Corp. (DEEP) announced in late November that it had commenced drilling on the first well for a **5 MW geothermal power** facility in **Estevan** in southeast **Saskatchewan.**

The well was subsequently drilled to a **depth of 3,530 meters** (11,581 feet).

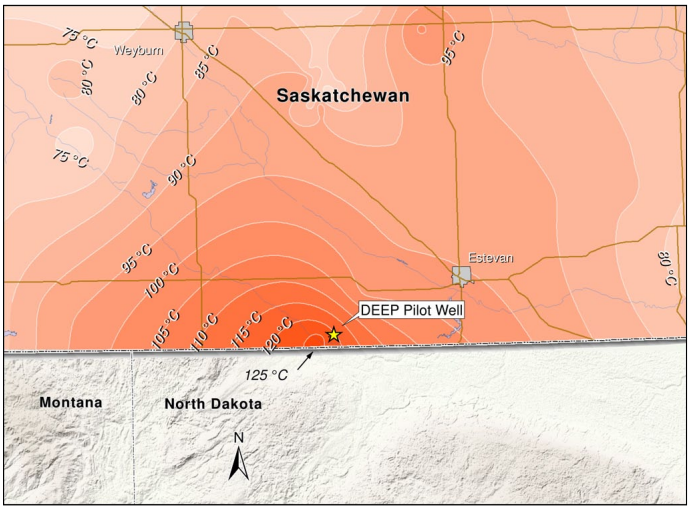
"We are thrilled to announce these amazing steps forward for the DEEP project," said **Kirsten Marcia**, President and CEO of DEEP. "This project will deploy conventional drilling and proven power generating technology that, when paired together, will introduce an entirely unique renewable power resource for the province of Saskatchewan."

"This is exciting. **This is the first geothermal project for Canada**. I love the fact it's marrying our local technology and our local expertise, but in a brand new way. We're taking this world-class oilfield expertise and paring it on a clean, renewable energy project. I think that's great."

DEEP has secured a *Power Purchase Agreement* (PPA) contract with **SaskPower, the first PPA in Canada issued for a geothermal power facility.**

This drilling program is supported by a private placement from one of the founding partners of **Epoch Energy Development**, a company established to commercialize geothermal resources in partnership with municipalities, First Nations, resource companies, industry, and food growers.

In January, **Prime Minister Justin Trudeau** announced **CAD 25.6 million in funding** for the first 5 MW phase. *Global Geothermal News.....*



DEEP's project is located in southeastern Saskatchewan, a few miles north of the US border near the city of Estevan. Analysis of thousands of public well records revealed the presence of a vast,"pancake-like' **Hot Sedimentary Aquifer (HAS)** *in the Williston Basin.* (Courtesy DEEP)

Additional Funding for Geothermal Energy Development in the Eastern Caribbean

The **Caribbean Development Bank (CDB)** in partnership with the **Inter-American Development Bank (IDB)** has mobilized **USD 85.6 million** to increase the region's energy security through geothermal energy development.

On December 13, CDB's Board of Directors approved acceptance of further financing under the **Sustainable Energy Facility (SEF)** for the Eastern Caribbean from IDB, with resources coming from the **Green Climate Fund (GCF)** and the **Government of Italy.**

SEF is part of CDB's **GeoSmart Initiative**, which aims to reduce the financial, technical and institutional barriers to geothermal energy development in five Eastern Caribbean states – **Dominica, Grenada, St. Kitts and Nevis, Saint Lucia** and **St. Vincent and the Grenadines**. The program also helps governments build capacity and strengthen institutions so they can be better equipped to implement and manage geothermal energy initiatives. *Global Geothermal News.....*

The GeoSmart Initiative.

Drilling Contract Signed for Four Wells at St. Vincent Geothermal Power Project

St. Vincent Geothermal Company Limited (SVGCL) and **Jardboranir hf. (Icelandic Drilling Company)** have signed a drilling contract to drill four wells for the **10 MW St. Vincent geothermal power project.** The commissioning of the plant is expected in approximately 2 years time. *Global Geothermal News.....*

Power Engineers to Help on Nevis Geothermal Power Project

NRE International, Inc. (NREI), the developer of the **10 MW Nevis Geothermal Project**, in cooperation with the **Nevis Island Administration (NIA)**, has announced that USA-based **Power Engineers** has joined the Nevis project team to provide design review, inspection and owner's representative services for the construction of the Nevis Geothermal Project.

NREI and NIA have completed extensive investigations to define the geothermal reservoir beneath the island, completed the well testing necessary and are **now in the final design stages prior to construction start.**

NREI is a subsidiary of **Thermal Energy Partners, LLC**, a geothermal energy development firm based in Austin, Texas. *Global Geothermal News.....*

Construction of Dominica Geothermal Power Plant to Begin by Fall

The Dominica Government says it intends to **start construction** of a geothermal energy power plant **by the third quarter of 2019**.

Energy Minister **Ian Douglas** said that the plant to be constructed in the **Roseau Valley**, on the outskirts of the capital, is proceeding "on track", and

that a local company has already been established to ensure the continued success of the project.

Last year, the **World Bank** announced that it would be providing more than USD 17 million in funds towards the development of the geothermal plant. *Global Geothermal News.....*

CENTRAL & SOUTH AMERICA

All Recently Drilled Wells Successfully Connected at 65 MW San Jacinto Geothermal Project

Polaris Infrastructure Inc. of Toronto, Ontario, Canada, reports on progress at the **San Jacinto-Tizate Power Plant** in **Nicaragua**.

The company's wholly-owned operating subsidiary, **Polaris Energy Nicaragua S.A.,** which owns and operates the San Jacinto project, successfully connected all recently drilled wells during the second quarter of 2018. Along with the commissioning of a new separator station on pad 12, HPS3, steam production has been sufficient to bring the San Jacinto plant close to its **77 MW (gross) nameplate capacity**. At this time the plant is operating in the 70-72 MW (gross) range. *Global Geothermal News.....*

Borinquen 1 Geothermal Power Project Postponed for Two Years

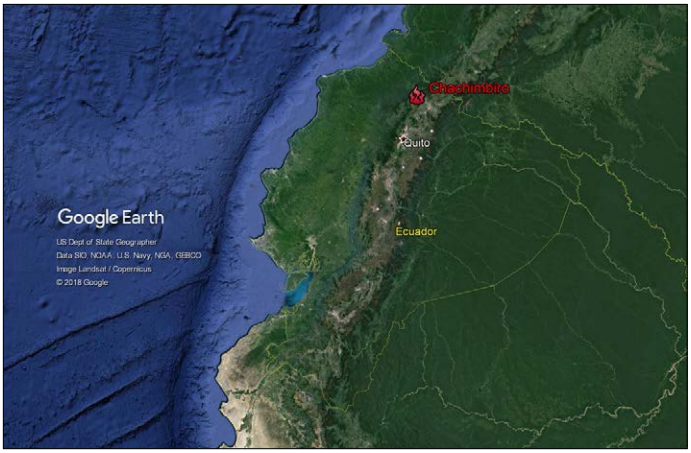
The president of the state-run **Costa Rican Electricity Institute (ICE), Irene Cañas**, has announced that the **55 MW Borinquen 1 geothermal power project**, initially scheduled to enter into operation in 2024, will now be commissioned in 2026.

Cañas indicated that **Costa Rica's electricity demand has been decreasing** in recent years due to factors such as the incorporation of new technologies, the change in consumption patterns, energy efficiency policies, the migration of the manufacturing process industry to services, and the economic contraction. *Global Geothermal News.....*

Exploration Continues at Ecuador Geothermal Power Project

Corporación Eléctrica del Ecuador (CELEC) has announced that it has started feasibility studies at the **Chachimbiro geothermal power project** in **Imbabura province** in the north of Ecuador.

Six additional wells will be drilled to establish the size of the geothermal reservoir and the capacity of the planned power plant. The work will be financed by the government of Japan through **the Japan International Cooperation Agency (JICA)** program. *Global Geothermal News.....*



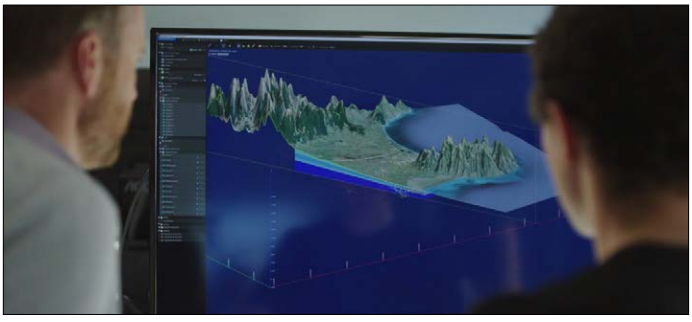
Location of the Chachimbiro geothermal power project in Imbabura province in the north of Ecuador.

AUSTRALASIA

Geosoft is Acquired by Seequent

Seequent of Christchurch, New Zealand, has announced it has signed an agreement to acquire **Geosoft**, a Canadian geoscience software company headquartered in Toronto but with offices around the world.

The acquisition brings together Seequent's **Leapfrog 3D** geological modeling software suite, including **Leapfrog Geothermal**, with Geosoft's subsurface geoscience and exploration dataset technology – to create a subsurface offering for the mining, civil engineering, energy and environmental sectors. *Global Geothermal News.....*



Seequent staff look at a 3D model.

Research to Test Hypothesis that Surface Gases from Rotorua Geothermal Field Actually Come from Deep Underground

A research project at **GNS Science** that will investigate the emission of greenhouse gases from volcanic areas in the North Island of New Zealand has won funding in this year's round of the prestigious **Marsden Fund**.

This project has been awarded **NZD 958,000** over three years to test a hypothesis that **geothermal gases**, which comprise many gases but mainly carbon dioxide, **originate from eight or more kilometers below the ground** and find their way to the surface via weaknesses in the Earth's crust.

Such a finding would overturn the view that these gases come from much shallower geological features.

It is well established that about 1000 tonnes of carbon dioxide is released into the atmosphere from the **Rotorua geothermal field** every day. But there is little understanding of where the gas comes from or the pathways used to get to the surface.

Project leader Isabelle Chambefor

Project leader **Isabelle Chambefort** said her team will use a combination of isotope analysis of gases and measurements of gas flows at the surface to trace the origin, transport, and interaction of gases in the **Taupo Volcanic Zone.** *Global Geothermal News.....*

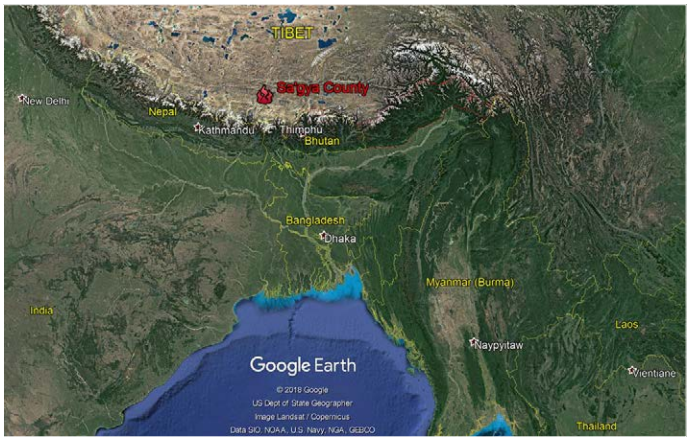
ASIA

Tibetan Geothermal Field has Estimated 80 MW Capacity

According to a survey prepared by the **Bureau of Geologic Exploration and Mineral Development** of the **Tibet Autonomous Region** of the People's Republic of China, the **Kawu geothermal field** has an **estimated power generation potential of up to approximately 80 MW.**

The exploration right of the **Kawu geothermal field** in **Sa'gya County** covers an area of approximately 105 square kilometers. The surface water temperature in the hot spring area ranges from 62°C to 86°C and there are more than 100 springs surrounded by rich sulphur, salt frost and large travertine.

Based on the geological structure and geochemistry preliminary analysis, it is estimated that the geothermal reservoir of the Kawu Geothermal Field might be at **1,500 to 2,000 meters depth** with a possible temperature range of approximately **170°C to 240°C**, making it one of the best geothermal energy resources in the Tibet Autonomous Region. *Global Geothermal News.....*



Location of Sa'gya County, in the "Tibet Autonomous Region" of China.

More Geothermal Heat Power Modules for Japan

Swedish company **Climeon** has received an order from **Iwana Power GK** for geothermal "Heat Power" modules to be deployed as a geothermal power plant in the **Gifu Prefecture** in central **Japan**. *Global Geothermal News.....*

Taiwan Geothermal Power Project Begins

State-run **Taiwan Power Co. (Taipower)** and oil refiner **CPC Corp., Taiwan** have launched a joint plan to explore geothermal energy in **Yilan County**, northeastern **Taiwan**.

A ceremony was held in early November at the site of the planned **Renze No. 3 Geothermal Well** in Yilan to mark the beginning of the exploration phase to drill a total of **six exploratory wells** in **Renze** and neighboring **Tuchang** before June 2021.

Location of Renze Hot Springs in Yilan County in north-eastern Taiwan.

CPC Chairman **Tai Chein** said the exploration project, estimated to produce an **installed capacity totaling 8 MW of electricity** if successful, is being carried out in three stages, with the first stage involving the drilling of two **1,500 meter-deep wells** at a cost of NTD 130 million (USD 4.23 million). *Global Geothermal News.....*

BacMan Geothermal Power Plant to Supply Power to Local Companies

Energy Development Corp. (EDC) has signed a two-year contract to power the manufacturing operations of **Citizen Machinery Philippines Inc. (CMP)** in **Tanuan**, **Batangas**, near Manila, with **2.5 MW of geothermal power** from EDC's **BacMan geothermal power Plant.**

"As a manufacturing company, Citizen Machinery Philippines desires to be supplied by **stable and low-cost electricity**, especially since our foundry consumes much power," CMP president **Akihide Kanaya** said. "EDC's BacMan geothermal project meets these criteria," he said. *Global Geothermal News.....*

In addition, EDC has also signed a two-year contract with automotive parts company **Continental Temic Electronics Philippines** to supply **2.7 MW of geothermal power** from BacMan geothermal power plant for its facilities in **Calamba, Laguna**. *Global Geothermal News.....*

PSALM to look Again at Privatization of Unified Leyte and Mindanao 1 and 2 Geothermal Power Plants

State-run **Power Sector Assets and Liabilities Management Corporation (PSALM)** has announced it will rework divestment packages for its remaining *energy conversation agreements* (ECAs) or *supply contracts* with independent power producers (IPP).

The assets to be covered by the consultancy work will include proposed privatization packages for the **Unified Leyte geothermal plant** and the **Mindanao 1 and 2 geothermal power plants.** *Global Geothermal News.....*

Shares of Geothermal Energy Developer Delisted from the Philippine Stock Exchange

Shares of **Energy Development Corp. (EDC)** have been purposely delisted from the Philippine Stock Exchange. The trading of EDC shares was suspended due to the company's failure to comply with the **10-percent minimum public ownership** requirement.

Instead EDC raised funds for investment through a tender offer of **2.01 billion EDC shares at P7.25 apiece**. The company said this will help them pursue a long-term corporate strategy that requires greater flexibility over factors such as its dividend policy and leverage. *Global Geothermal News.....*

Indonesian Government to Allow More Foreign Direct Investment in Geothermal Energy Sectors

As part of its 16th economic package, the Government of Indonesia has announced that in order to attract further foreign investment, it intends to **relax the restrictions on foreign direct investment (FDI)** in certain business sectors, **including the geothermal energy sector.**

There is **no change** in respect of geothermal power generation of up to **10 MW (maximum of 67 percent FDI)**. Reportedly, **100 percent FDI** will be allowed in 54 business sectors currently included in the 2016 negative list that up until now were closed or restricted for FDI including **Geothermal drilling services (95%), Geothermal operating and maintenance services (90%)**, and **Geothermal surveying services (95%).** *Global Geothermal News.....*

Approval for Malaysian Geothermal Power Project Revoked

The approval given to **Tawau Green Energy Sdn Bhd** to build what would have been the **first geothermal power plant in Malaysia** has been revoked.

Malaysian Energy, Green Technology, Science, Climate Change and Environment Minister **Yeo Bee Yin** said the government decided to scrap the project due to the firm's failure to carry out the project.

"There was no project progress and the drilling operations have ceased since the third quarter of 2016. "It seemed that the company has ceased its operation and affairs at the site."

Initial surveys at the **Apas Kiri** site had indicated a geothermal reservoir with a temperature of **above 200°C**, suggesting a **potential capacity of 37 MW**. *Global Geothermal News.....*

Location of Tawau, Malaysia on the island of Borneo.

The Potential for Geothermal Energy in India

A recent study by the **Indian Institute of Technology (IIT)** Bombay's **Professor Trupti Chandrashekhar** suggests good potential for geothermal power in **Maharashtra State**.

The study was conducted along the coastline of Maharashtra, one of the seven geothermal areas of India. There are more than **60 hot water springs** in 18 locations in the west coast geothermal province, with surface water temperatures **between 40°C and 72°C.**

If tapped efficiently, this energy could be used to generate geothermal electricity. Professor Chandrashekar said, "The mid- and long-term development plan [for the region] could be centered on the **use of geothermal energy for generating cheap, clean and base power generation systems,** beginning with the drilling of 10-to-15-metre-deep exploration [wells] along the identified locations." *Global Geothermal News.....*

Puga Geothermal Field Ladakh, by **Dr. Ritesh Arya**, *Chandigarh, India. GRC Photo Contest 2017.*

In addition, a new analysis of available data has shown that the **Puga geothermal field** in **Ladakh Province** in **Kashmir**, northern India could be a good site for further exploration.

A team of researchers from **Birla Institute of Technology and Science (BITS)** Pilani used thermo-hydro-geological data to conceptualize geothermal reservoirs and then used simulation software to assess a key parameter called the '**Useful Resource Base' (URB)** of reservoirs.

URB denotes extraction temperature of a reservoir for an operation period of 20 years which is the typical lifetime for a geothermal field. The researchers differentiated the sites based on a cumulative score computed on nine criteria like a cumulative discharge of thermal springs, minimum and maximum electrical resistivity, representative reservoir temperature and other factors. *Global Geothermal News.....*

Discussions Held on Geothermal Energy Cooperation Between India and Iceland

India and **Iceland** have discussed cooperation in geothermal energy among other areas during a bilateral meeting between External Affairs Minister **Sushma Swaraj** and Icelandic Foreign Minister **Gudlaugur Thor Thordarson**. *Global Geothermal News.....*

Good Progress at Geothermal Power Plant in Iran

The **Iranian Geothermal Energy Association (IGEA)** reports good progress at what would be the first geothermal power plant in the country.

According to the website of **Petro Tech Sun (PTS)**, the **5 MWe Sabalan Geothermal Power Plant**, near **Ardabil** in the far north of Iran, **is 40% complete**. *Global Geothermal News.....*

Site of the Sabalan Geothermal Power Plant, near Ardabil in the far north of Iran. (Courtesy Petro Tech Sun)

South Korea to Help Map Geothermal Resources in Kazakhstan

The **Republic of Kazakhstan** and the **Republic of Korea** have signed a *Memorandum of Cooperation* in the field of information technology and communications, including data gathering on geothermal energy.

Rapil Zhoshybayev, Chairman of the International Center for Green Technology and Investment Projects, said they are creating a unified energy efficiency map of the country including geothermal energy resources. *Global Geothermal News.....*

AFRICA

UK Government Announces Funding for Renewable Energy Projects

The UK **Department for Business, Energy & Industrial Strategy** has announced an additional **GBP 100 Million** in funding for renewable energy in sub-Saharan Africa.

The new investment triples funds for the **Renewable Energy Performance Platform (REPP)** to support up to 40 more renewable energy projects over the next 5 years. The new funding could unlock an **extra GBP 156 million of private finance** for renewable energy markets in Africa by 2023.

Developers of small-scale solar, wind, hydro and **geothermal projects** will be supported to harness each country's natural resources, and the electricity generated is expected to provide 2.4 million people a year with new or improved access to clean energy. Power produced from new projects funded is expected to save around 3 million tonnes of carbon over their lifetime, compared with fossil fuel generation. *Global Geothermal News.....*

Draft Legislation Lays out Royalties Schedule for Geothermal Energy in Kenya

A new **Energy Bill** – which completed its public consultation phase in February 2018 – may result in a significant shake-up of Kenya's geothermal segment. Significantly, the draft legislation lays out a **royalties schedule.**

The bill will see **geothermal firms pay fees of between 1% and 2.5% of the revenues** generated from the energy source **during their first decade** of operation and **5% thereafter.**

The proposed royalty on profits is a standard model in the international geothermal market. For example, the US has deployed a similar framework for decades, applying a modest rate of 1.75% for the first 10 years of production, before moving companies to a royalty rate of 3.5% thereafter. *Global Geothermal News.....*

KenGen Breaks Ground on 83 MW Olkaria 1 Unit 6 Geothermal Power Plant

Kenya Electricity Generating Company (KenGen) has broken ground for the **83 MW Olkaria 1 Unit 6 Geothermal power plant** in **Naivasha.** The project to projected to be completed by 2021. *Global Geothermal News.....*

Cyrq Energy Requests Approval for 75 MW Suswa Geothermal Power Project

Cyrq Energy, of **Salt Lake City**, Utah, USA has asked for approval from the Kenyan government to proceed with the plans to ultimately build a **300 MW geothermal power plant** in **Suswa, Narok County**, in south-western **Kenya**.

GRC Member **Nicholas Goodman,** President and CEO of Cyrq Energy, confirmed the reports and said that a feasibility study has already been carried out on the site and regulatory approval request has been sent to the competent authorities.

"The first phase of the project will be financed internally, with a mix of equity and debt, while long-term debt will be guaranteed for the other phases of the project," said Nicholas Goodman.

The CEO further added that **the company plans to start producing 75 MW within two years** of the Kenyan authorities' approval. The overall project is set to **take 3 to 4 years before completion**, after which electricity is first sold to the utility firm **Kenya Power** under a long-term **25-year power purchase agreement.** *Global Geothermal News.....*

EUROPE

EU Clean Energy Package Sets 32% Binding Target for Renewables in 2030

The **European Parliament** has adopted the *Renewable Energy Directive*, the *Energy Efficiency Directive* and the *Governance Regulation*, a **Clean Energy Package** that will be the basis for the European climate and energy regulatory framework after 2020.

Commenting on the news the **European Geothermal Energy Council (EGEC)** said the legislation is not ambitious enough, but it does lay out a framework that **allows for the accelerated development of geothermal energy.**

The EU Clean Energy Package sets a **32% binding target for renewables in 2030**, and a target of 32.5% energy efficiency improvements. The new legislation also includes an obligation for nations to **increase the share of renewables in heating and cooling by 1.3% annually.**

Philippe Dumas, EGEC Secretary General commented "The introduction of a sectorial obligation to increase the penetration of renewable heating and cooling is a positive signal for geothermal and lets us expect that strong policies will be implemented to decarbonize a sector which represents nearly half of the EU's energy demand". *Global Geothermal News.....*

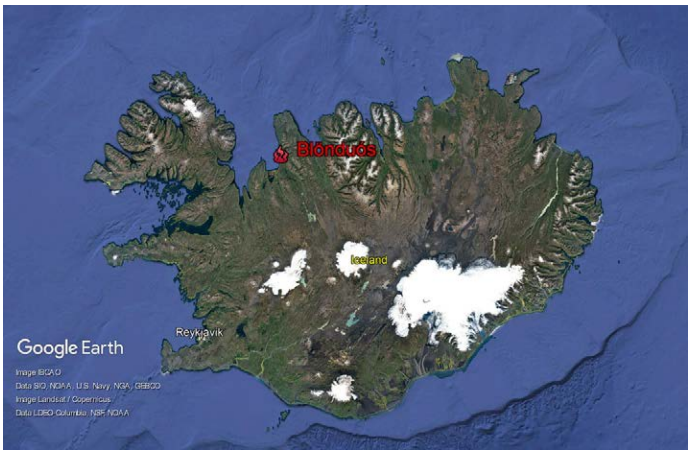
Another Icelandic Data Center to be Powered by Geothermal Energy

Landsvirkjun and **Etix Everywhere Iceland**, a subsidiary of **Etix Everywhere Borealis**, have signed a power contract for the supply of **25 MW** to the company's new **data center** in the **Blönduós** municipality in the north of Iceland.

Operations have already begun in Blönduós and construction work to expand the data center is currently underway. The center will be the first energy-intensive industrial operation to connect to Landsnet's transmission network in the area.

A combination of renewable energy resources, competitive terms and the Icelandic climate contribute to creating favorable conditions for data centers in Iceland.

The energy covered by the agreement will be delivered from Landsvirkjun's current power station network. Landsvirkjun has recently opened a new geothermal station nearby, in **Þeistareykir** in the north of Iceland. *Global Geothermal News.....*



Location of Blönduós in north Iceland.

First Electricity at Climeon Geothermal "Heat-power" Plant in Fludir

Christopher Engman, CRO/CMO of Swedish company **Climeon**, has announced that electricity has been produced at **Varmaorka**'s geothermal heat-power plant in **Fludir** in Iceland. He says this is the first step to **a target of 29 MW**. *Global Geothermal News.....*

A Climeon heat-power module.

Geothermal District Heating Network to be Built in Finland

Finnish drilling company **Robit Finland Oy** is to cooperate with **TEGS Finland Oy** on new technology for drilling of deep geothermal wells. The cooperation will focus on **improving the performance of drill bits** intended for deep well drilling to enable significant cost savings.

Location of Nekala, Tampere in Finland.

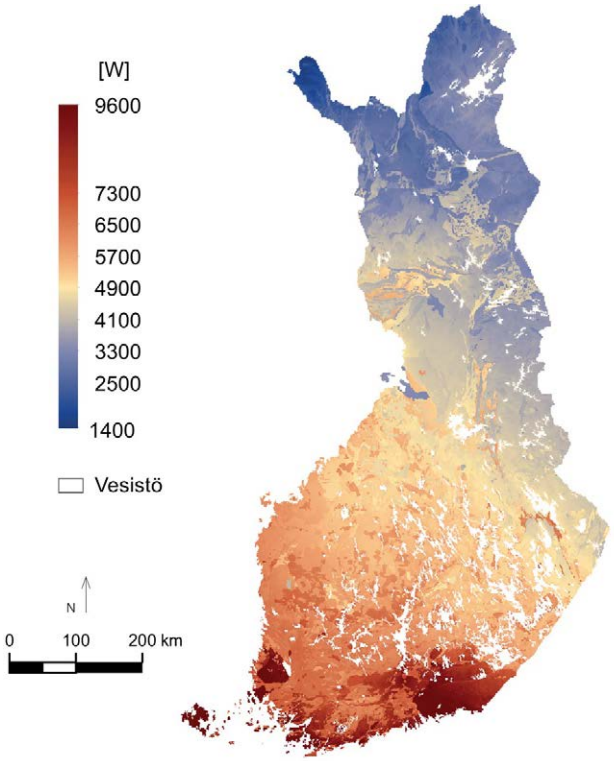
Inside Geothermal

The Finnish Ministry of Economic Affairs and Employment has awarded TEGS Finland a grant of over **EUR 2 million** for the construction of a geothermal heat plant at **Nekala, Tampere in Finland.** A **7-8 kilometers deep well** will supply geothermal waters for a district heating network. Construction of the production plant, which will generate 29,050 MWh of heat per year was slated to start in January. *Global Geothermal News.....*

Artificial Intelligence Survey Shows Big Potential for Geothermal Energy in Finland

New research by the **Geological Survey of Finland (GTK)** using artificial intelligence has indicated that the potential capacity for geothermal energy in Finland is about a thousand times the country's total energy production.

The total theoretical geothermal energy potential from the top 300 meters of the Finnish sub-strata is about **300 million GWh**. The most promising area for geothermal energy is in **southern and southwest Finland**. *Global Geothermal News.....*



Map showing distribution of geothermal heat in Finland. (Courtesy Geological Survey of Finland)

Irish Offshore Basin Could be a Source of Geothermal Energy

Irish oil and gas explorer **Providence Resources** is evaluating a possible new geothermal resource off the coast of south-western Ireland.

The geothermal reservoir is located 3,000 meters below the sea bed in a geological feature called the **Porcupine Basin**. *Global Geothermal News.....*

Location of the Porcupine Basin off the coast of south-west Ireland.

First Borehole Underway at UK Geoenergy Observatory in Glasgow

Marking the beginning of the 15-year research investment, a 7.2-meter high drilling rig broke ground on the first borehole for the British Geological Survey **UK Geoenergy Observatory** in **Glasgow, Scotland.**

Over the next year, the drilling team will drill 12 boreholes of various depths, which will enable research into Glasgow's geology, its underground water systems and the **potential for heat from the water in the city's disused coal mines.** One of the biggest aims of the project is to find out whether there is a long-term sustainable mine water resource that could provide a **low-cost, low-carbon heat source** for homes and businesses. *Global Geothermal News.....*

Update from the United Downs Geothermal Power Project

As of January 28th, the United Downs geothermal power project in Cornwall, England has reached a **depth of 2,173 meters**, drilling with a 12 1/4" bit at a rate of around 3.2 meters per hour. The team has also run the **13 3/8" casing** and cemented it in place, installed the surface well control equipment and drilled out the cement and casing shoe and new formation using a 12 1/4" rotary drilling assembly.

Geothermal Engineering Ltd (GEL) project manager **Peter Ledingham** *and geologist* **Lucy Cotton** *in front of the drilling rig at United Downs.* (Courtesy GEL)

Penzance Geothermal Lido to Open by Summer

The UK's first geothermal heated lido in **Penzance, Cornwall** is due to **open at the end of May** and the pool is going to be even hotter than first expected. The **Jubilee Pool** geothermal spa will reach **temperatures of up to 30°C.**

Geothermal Engineering Ltd (GEL) has finished drilling and has reached **a warm water 'geothermal vein' at 410 meters** depth below Penzance's iconic sea-water open-air Lido. The company said the hot water will now be tapped to heat a section of the Jubilee Pool all year round.

GEL managing director **Ryan Law** said hitting the warmer than expected hot water vein **was like 'striking gold'.**

He said: "We are delighted that we have hit the hot water vein," said. "It is warmer than expected and capable of yielding much more geothermal energy than planned. *Global Geothermal News.....*

Progress in Realizing a Geothermal Well on TU Delft Campus

The Board of the University at **TU Delft** has made a decision-in-principle to proceed towards realizing a geothermal research well on the campus.

TU Delft is doing research on new materials and innovative ways of monitoring subsurface processes and was recently awarded more than EUR 5 million by the Netherlands Organization for Scientific Research (NWO) (EPOS-NL project) for geothermal research. *Global Geothermal News.....*

Trial Operations Begin at Holzkirchen Geothermal Power Plant

Trial operations have commenced at the **Holzkirchen geothermal power plant** in **Bavaria**, southern **Germany**. As a first step, the submersible centrifugal pump is supplying heat to the local district heating network. In the spring, the power plant will also commence trial operations which are expected to continue throughout the year.

Holzkirchen is currently the southernmost and deepest hydrothermal geothermal project in Germany. The two wells drilled in 2016 and 2017 reached **final depths of approx. 5,100 meters** (vertical) with a drilling distance of up to 6,084 m. The drilling component of the project was completed in 2017. The geothermal resource at the surface has a temperature of **approximately 155°C** and has a production rate of **approx. 55 liters per second.** *Global Geothermal News.....*

Second Well Successfully Drilled at Munich Geothermal District Heating Project

The pump tests for the second well of the **SWM geothermal project** in **Schäftlarnstraße, Munich** have been successfully completed.

The second well reached a final depth of more than 3,000 meters with a total drilling distance of more than 4,000 meters. The rig has now been moved to the third well location, and drilling has re-commenced. A total of six wells is planned. *Global Geothermal News.....*

Good Progress at Garching Geothermal Project

Silenos Energy GmbH reports that the **Garching geothermal district heating project** located just to the north of **Munich** in southern Germany, is on track.

The deflected drill path of 5,025 meters has reached the **target depth of 3,827 meters**. Subsequent tests showed that the temperature of the deep groundwater at **125°C** is quite satisfactory and the **flow of 105 liters per second** meets all expectations. *Global Geothermal News.....*

Geothermal Well in Budapest Reaches 72 Degrees Celsius Resource at 1300 Meters Depth

Arpad Lorberer, Geoscientist and Consultant Hydrogeologist has reported successful drilling at a site in the Hungarian capital of **Budapest**.

Two geothermal wells have been drilled reaching the geothermal aquifer at around **1,300 meters**. The production well produced hot water at **about 72°C** flowing at a rate of **23 liters per second**. The second, re-injection well reached a "huge karst cavern" at a depth of about **1250 meters**. *Global Geothermal News.....*

Spain Plans to Source 70 Percent of Electricity from Renewables by 2030

Spain has set out plans to switch **entirely to renewable electricity by 2050**, with goals that go further than current European Union plans. Under the new strategy, **greenhouse gas emissions from Spain would be cut by 90%** compared to 1990 levels, by the middle of the century.

The nation intends to invest massively in renewable power over the next decade, while banning new licenses for fossil fuel drilling and fracking wells.

It is also planning to source **70 percent of electricity from renewables by 2030**, and 100 percent by 2050. In 2017, Spain got roughly a third of its power from renewable sources such as sunlight, wind, rain, tides, waves, **and geothermal heat.** *Global Geothermal News.....*

Croatian Geothermal Plant is Commissioned

Turboden has announced the commissioning of the **17.5 MWe Velika Ciglena geothermal power plant** in **Croatia** in December 2018, the largest ORC system in Europe, for Turkish customer **Geoen - MB Holding.**

The Velika Ciglena project sources steam and hot water at **170°C** to produce electricity to feed the local power grid. Turboden designed and manufactured a unique single turbine to **generate 16 MWe**. The ORC turbogenerator with a 5-stage axial turbine, optimizes the performance with a rotation speed of 1,500 rpm. *Global Geothermal News.....*

Greek Government Plans for Nearly 2000 GWh of Geothermal Energy by 2040

The **Greek Ministry of Energy** has published a **National Energy Strategic Plan** outlining targets for energy production over the next 24 years.

The government is planning for production of **631 GWh of geothermal energy by 2030, 1,301 GWh by 2035 and 1,971 GWh by 2040.** *Global Geothermal News.....*

First Locally-Made Generator to be Installed on Turkish Geothermal Power Plant

Italian companies **Exergy** and **Nidec ASI** have recently finalized a collaboration allowing Exergy to attain the Turkish Certification for **local manufacturing** of generators.

The **first made-in-Turkey generator** ever supplied in the Turkish market, designed by Nidec ASI, will be installed on a 10 MWe geothermal power plant for Exergy's customer **Kiper Elektrik Üretim A.Ş.**, part of Kipaş Holding group. *Global Geothermal News.....*

SCIENCE & TECHNOLOGY

GRC Member Conducts Rock Fracturing Experiment to Demonstrate Potential of EGS

Researchers at the **University of Oklahoma (OU)** recently conducted an unprecedented rock fracturing experiment that showcased the potential for **enhanced geothermal systems (EGS)** as a viable power source for the United States.

Supported by funding from the Department of Energy's **Geothermal Technologies Office (GTO), Dr. Ahmad Ghassemi - a GRC member** - and his research team of graduate students successfully fractured and stimulated a series of 13-cubic-inch blocks of granite and other igneous rocks found in EGS reservoirs.

The OU team was able to **extract more than 50 watts of power production from the small rocks**,

which is equivalent to a household light-bulb, showing promise that field-scale fractures and a properly engineered EGS can produce considerable amounts of power. *Global Geothermal News.....*

A Magnetotelluric Study of the Tulu Moye Geothermal Field

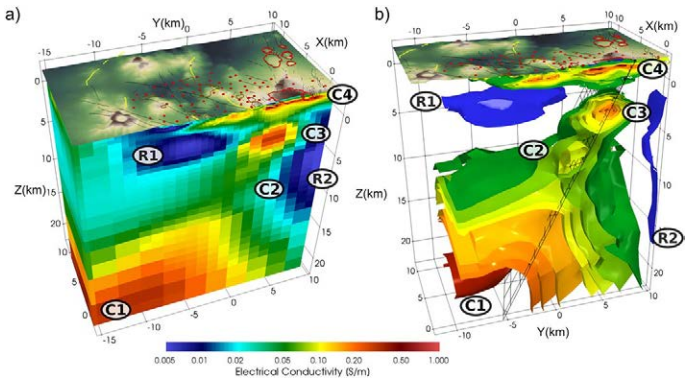
Authors of a recent paper describe using magnetotelluric methods to provide new insights into rift-associated volcanism, risk assessment, and geothermal energy production in the east-African Rift Valley.

The Earth's continental plates can be broken apart by tectonic forces to form rift systems that may extend over thousands of kilometers. Continental rifts are often associated with numerous volcanoes that are fed by magma, which forms deep in the Earth's mantle and rises up along pathways of the fractured tectonic plate. A detailed understanding of the volcanic systems is important for hazard assessment and for geothermal energy production.

The authors analyzed geophysical data that were measured at a volcanic field at the **Tulu Moye geothermal field** in the **Ethiopian Rift Valley**. The data consist of time series of the natural electric and magnetic fields. These fields are sensitive to the electrical conductivity structure of the Earth and can be used to image the subsurface electrical properties down to depths of many kilometers. Magma, for example, has typically very high electrical conductivities, which is why this method is ideal to detect melt reservoirs in the Earth's crust.

The obtained model shows, in great detail, **how magma is transported through the crust and how it is stored below the volcanic system.** Therefore, it provides new insights into rift-associated volcanism, risk assessment, **and geothermal energy production.** *Global Geothermal News.....*

Magnetotelluric Image of Transcrustal Magmatic System Beneath the Tulu Moye Geothermal Prospect in the Ethiopian Rift (American Geophysical Union)



by Friedemann Samrock, Alexander V. Grayver, Hjalmar Eysteinsson, Martin O. Saar. First published: 28 November 2018 *Geophysical Research Letters*, https://doi.org/10.1029/2018GL080333

LIDAR Provides Insights Into Possible Geothermal Resources

Under the direction of **Nevada Bureau of Mines and Geology** Director **Jim Faulds** - a **GRC Member** - and spearheaded by faculty member and Geologic Mapping Specialist **Seth Dee**, a project utilized airborne **light detection and ranging (lidar)** technology to produce high-resolution topographic maps of the **Reno-Sparks-Carson City** area, including major geothermal fields.

The data will benefit a number of in-progress Nevada Bureau of Mines and Geology studies to understand earthquake and flood hazards, as well as natural resources. The project received initial funding through the United States Geological Survey (USGS) and Research & Innovation at the **University of Nevada, Reno.**

Using lidar, the project collected data by bouncing light pulses off the surface of the earth. The result is a high-resolution, three-dimensional topographic map that allows improved identification of geologic features such as flood plains, glacial deposits and earthquake faults. This can also support the assessment of ecological systems, infrastructure planning and **the identification of geothermal reserves to support clean-energy production.**

The Nevada Bureau of Mines and Geology has created an outstanding online story map, titled *Reno's Bare Earth: Below the Neon*, to document the project and share examples of lidar images. Visit the story map at unr.edu/nbmg/bare-earth. *Global Geothermal News.....*

Galena fault scarp located near Steamboat Springs south of Reno. (Courtesy Nevada Bureau of Mines and Geology)

EDUCATION

Geothermal Design Challenge: Data Visualization for Students

The U.S. **Department of Energy (DOE)** in coordination with **Utah FORGE and the Idaho National laboratory**, has announced a competition for students interested in geothermal energy.

The DOE will award **USD 11,000 in cash prizes** to teams of currently enrolled students in **high school, undergrad or graduate school.** The Challenge asks students to research datasets, interpret information and create a data visualization portfolio that tells a compelling story about the search for clean, renewable geothermal energy.

The top 3 winning teams will be awarded as follows: **USD 5,000 for 1st place team / USD 3,500 for 2nd place team / USD 2,500 for 3rd place team.**

The **deadline to submit portfolios is April 10.** Interested parties can register or learn more at https://utahforge.com/studentcomp/. ■

The GRC Membership Directory At Your Fingertips

www.my.geothermal.org

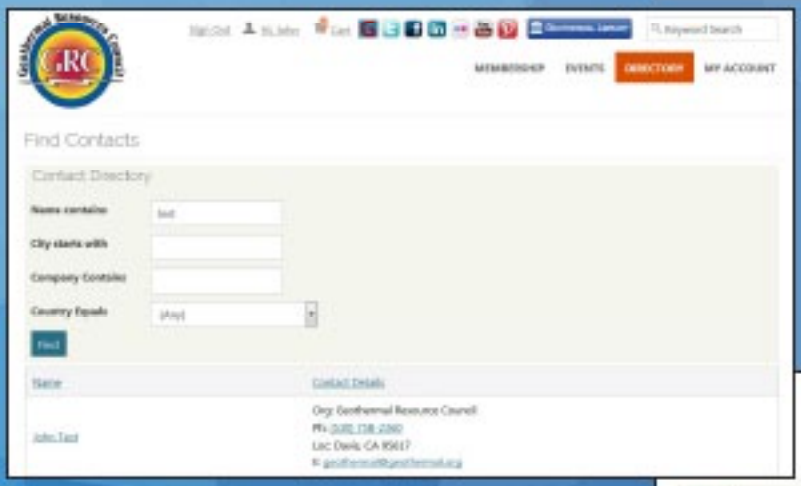
The online membership directory provides the most up to date contact information for all GRC members at your fingertips.

Step 1

Login to the GRC Membership website: my.geothermal.org
(Tip: Bookmark this webpage on your smart phone 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.

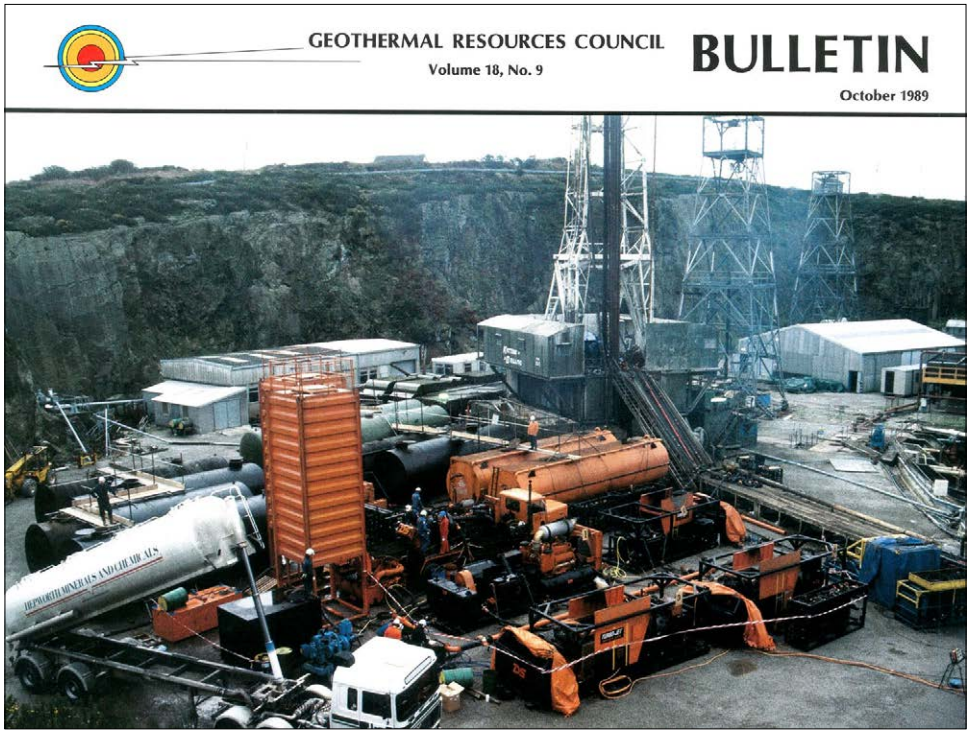
This feature is only available to current GRC members. If you have not renewed, please contact Anh Lay at alay@geothermal.org to renew your membership and update your profile!

Geothermal History in the Making

by Ian Crawford, Director of Communications

In 2022, the Geothermal Resources Council, the GRC, will be celebrating its 50-year anniversary. Our association was established in 1972 "to encourage development of geothermal resources worldwide." To mark our golden anniversary, we are running a series of articles looking back on the history of geothermal energy around the world over these past decades.

In this issue we look back 30 years ago to 1989 and an early hot dry rock (HDR) research project in the United Kingdom.



The cover of the October 1989 GRC Bulletin displaying a proppant placement experiment in Rosemanowes Quarry, near Penryn in Cornwall, England, February 1989. (Photo by Camborne School of Mines).

Hot Dry Rock Geothermal Energy Research at the Camborne School of Mines

by **Roger Parker**, Project Director**, Camborne School of Mines** Geothermal Energy Project, Rosemanowes Quarry, Herniss, Penryn, Cornwall, UK.

GRC *Bulletin*, Volume 18, No. 9, October 1989

The Camborne School of Mines (CSM) Hot Dry Rock Geothermal Energy project in the period of 1977-89 has been concerned mainly with the technology of the development and characterisation of Hot Dry Rock (HDR) reservoirs in a jointed granite. There has been no attempt to demonstrate the exploitation of the energy extracted. The UK Department of Energy has been responsible for providing most of the funding, but the Commission of the European Communities provided significant support until 1986.

In Phase I (1977-1980), boreholes 300m deep were drilled in the Carnmenellis granite at Rosemanowes Quarry, near Penryn in

Cornwall. It was demonstrated that it was possible to connect the boreholes by hydraulic stimulation of natural joints in the granite, and to circulate water through these joints (Batchelor, 1982).

Phase 2 (1980-1988) was carried out in three parts at Rosemanowes, with the aim of investigating reservoir development at a depth of about 2 km, which was considered to provide conditions reasonably representative of those expected at the greater depths required for commercial exploitation. Hydraulic stimulations using water and a medium viscosity gel were used to create the reservoir, and long periods of circulation of the reservoir were used to establish its hydraulic and thermal characteristics.

Phase 3 began in 1988, having as its main objective the development in Cornwall of a prototype of a commercial system for generating electricity. For an acceptable lifetime, this prototype would require a reservoir 6 km deep occupying a rock volume of 300 million m3 producing water at 200°C, at a rate of 75 1/ s.

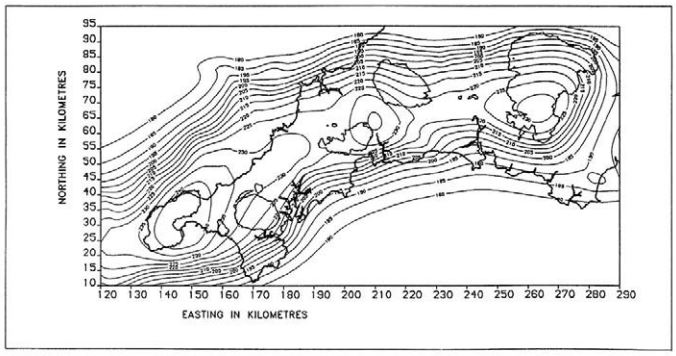


Figure 3. Model calculated temperature at 6 kms depth for Cornwall, England.

After twelve years of work at Rosemanowes, the CSM project has demonstrated that it is possible to create a large hot dry rock geothermal reservoir occupying a rock volume of 5 to 10 million m^3 in granite, at a depth which allows a significant understanding of the engineering problems associated with the creation, development and circulation of the reservoir. This understanding is vital for the next stage of the project, which it is hoped will apply the lessons learned to the development of a new reservoir at a depth representative of the requirements of a commercial system. The area which still requires considerably more experience than has been possible on this single site is the stimulation of the rock mass to create the reservoir. Modelling and design studies can only support practical experience in this field; they can never replace it. Once an experimental reservoir has been created, it is important to devote adequate effort to characterising it, otherwise the lessons to be learned for the future will be incomplete.

We believe that at Camborne School of Mines we have laid a firm foundation for future development of HDR technology, and look forward to a significant growth in experimental activity in this field. We have valued the cooperation and support we have received from HDR research teams in the USA, in France and Germany, in Japan and in Sweden. Cooperation is so essential to the development of a significant research effort in a field of this nature.

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Update

The research at Rosemanowes Quarry ultimately proved to be successful, and showed that Cornish hot granite could be fractured to create a geothermal reservoir at depth. Though the wells yielded substantial quantities of hot water, to reach a temperature to generate steam hot enough to drive a turbine would have required drilling a further kilometer or more into the granite, an option which proved to be too expensive to pursue at that time. The development of a new reservoir at a depth representative of the requirements of a commercial system at Rosemanowes was never achieved.

However, the research findings and experience has provided important data for other hot dry rock projects over the years, including the European HDR project at Soultz-sous-Forêts in France and the current United Downs Deep Geothermal Power Project located just over 4 miles away from the Rosemanowes Quarry. ■
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CAPTION: View from the Top, by Diego Mena. Borinquen Geothermal Project, Costa Rica, Drilling Well PGB 05, on March 15, 2008. GRC Geothermal Photo Contest 2018.

Can Geothermal Well Costs be Sufficiently Reduced to Drive Industry Growth?

By John P de Wardt, CEng, FIMechE; De Wardt and Company Inc., Steamboat Springs, Colorado, USA

Abstract

Well costs have a major impact on petroleum and geothermal projects. These costs manifest themselves as capital expenditure (Capex) during a project's well construction phase and as operating expenditure (Opex) during its well production phase. Drilling petroleum and geothermal wells have many aspects in common as well as some specific distinctions. As a result of massive swings in product (oil and gas) prices, petroleum drilling has faced significant well cost challenges. Natural gas prices in the U.S. fell some years ago, which drove producers, initially to meet the challenge to profit in this environment, to quickly create low-cost (not cheap) wells. Today, the oil industry continues on this path and as a result, compared with earlier this decade, half the number of drilling rigs are producing more oil, which is significantly reducing the cost per barrel.

Introduction

Petroleum drilling has continued to deliver throughout a highly volatile product price environment in which deep, low product prices have followed sustained, high product prices. Drilling efficiency has risen to the challenge created by this volatility to enable producers to survive in low product-price environments. Geothermal drilling has similarly narrow price margins that could benefit from efficiency cost improvements.

Petroleum drilling and geothermal drilling operate in different business worlds that have some, although not significant, connectivity. Petroleum drilling is far higher volume than is geothermal drilling; in U.S. land drilling alone some 1,000 rigs are now drilling almost continuously through the year for petroleum, while geothermal drilling accounts for some 6 to 12 rigs with frequent stops and starts in activity.

First, petroleum drilling is primarily, although not always, in sedimentary basins that usually include softer formations than those of the hard-rock reservoirs of geothermal drilling. However, because many petroleum operations drill into fractured, basement reservoirs, there is an overlap.

Additionally, temperatures are much different as petroleum target reservoirs are typically in normal geothermal gradients while geothermal drilling targets reservoirs with higher gradients. In recent years, petroleum drilling has pushed into higher pressure and temperature reservoirs while mastering high-pressure/high-temperature (HTHP) drilling operations and creating another area of limited overlap with geothermal operations.

Recognizing distinctions, however, is no reason to deny the similarities between the two industries and the lessons that can be translated from one to the other. For example, one major geothermal well drilled for supercritical steam overran the budget in the upper-hole section, which is characterized by normal geothermal and pressure gradients.[1] The overrun was the result of major non-productive time (NPT) events, which may have been avoided using more effective drilling processes and procedures.

Recent Improvements in Petroleum Drilling

Well Architecture

Horizontal drilling has become as quick as vertical drilling and today includes very long horizontal sections completed economically even in a challenging oil-price environment. In 2015, record-length, extended-reach drilling (ERD) wells were drilled and completed to 13,500 m (44,280 ft) MD with 12,033 m (39,480 ft) displacement in 156 days. Since that time, drilling times have been reduced, and measured depths increased to 15,000 m (49,210 ft) MD with up to 14,129 m (46,354 ft) displacement (Figure 1).

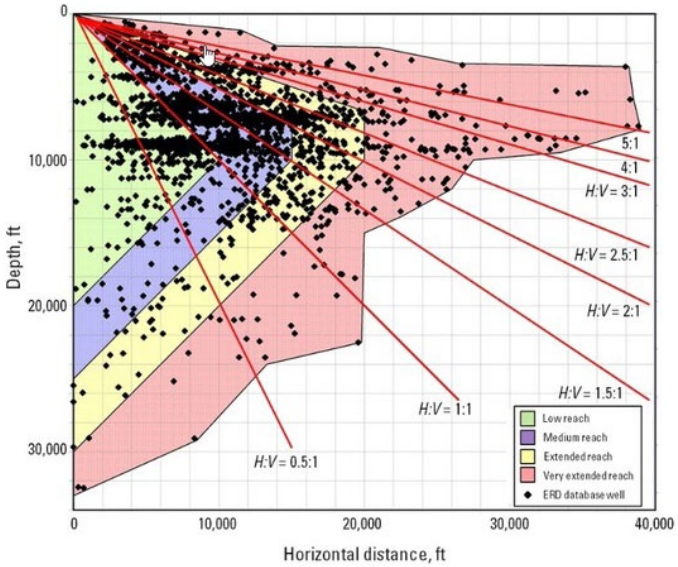

Figure 1. Extended Reach Drilling Envelope for Global Petroleum Wells – source Schlumberger

Drilling Performance

Currently U.S. natural-gas drillers are supplying market demand at gas sales price that are some 20% of their all-time high while using just a quarter of the number of drilling rigs that were employed during those high commodity price years. In the U.S., oil production has grown significantly from low-productivity shale wells while the number of drilling rigs operating was half the last peak rig count. A significant step up in drilling performance has been a major contributor to this success.

Bits and Sensors

This outer extreme of the petroleum drilling envelope demonstrates a range of accomplishments. Petroleum drill-bit design has significantly advanced both rate of penetration and duration of drilling. Bit technology, combined with drilling dysfunction management, is enabling harder formations to be drilled for longer durations, which reduces the number of trips for bit replacement. Petroleum drilling downhole sensor technology is improving in both data sensing accuracy and ruggedness of the sensor and processor systems. Numerous downhole systems have achieved increased temperature ratings.

Each of these is discussed in more detail below.

Architecting Wells

Today, petroleum drillers can deliver complex well shapes and multiple parallel path wells. Processes and technologies measure the position and orientation of these wellbores with a known uncertainty, increase the value of geological mapping and steering to best zones of interest, and manage the impact of hydraulic fracturing.

- The development of shale formations has driven the routine requirement to drill multiple parallel wells. These wells must have known relative positions and allow

fracture lengths to cover the intermediate space without going beyond it. Child wells, infill parallel wells, are now being drilled positionally to accesses remaining reserves.

- Steam-assisted gravity drainage (SAGD) wells are drilled with two parallel bore holes, one above the other; steam injected into the upper well heats the oil, allowing it to flow through the formation to the lower production well.
- Operators are reentering mature oilfields using coiled tubing drilling to drill multiple sidetracked boreholes into zones that were not earlier produced. This has been a significant contributor to the continued production on Alaska's North Slope. For example, one well in the Kuparuk Field has eight sidetracked boreholes from the master wellbore, earning it the nickname, "Octowell." The practice has created complex and tortuous well paths from the master wellbore to small disconnected reserves for continuous addition of production.

Many of these designs resemble those proposed for enhanced geothermal system (EGS) reservoir designs. These petroleum techniques and technologies could potentially be applied.

Performance Drilling Growth

Driven by the culmination of need and opportunity, especially in North America, the growth of performance drilling has escalated significantly in recent years. The need was driven by another oil price reduction (crash) and realization that shale drilling can be profitable. However, shale wells must be long and must be drilled quickly with a significant focus on cost control. Slow, expensive wells cannot be tolerated financially with lower oil price, low production rates, or rapid depletion that characterize oil production from shale formations.

Rigs

The opportunity to improve performance was created by numerous surface and subsurface technology adoptions. Drilling rigs changed from original mechanical-drive mechanism, through DC (SCR) drive mechanisms, to AC variable frequency drive (VFD) mechanisms. Electric (VFD) rigs can be "dialed in" to specific values to optimize drilling operational parameters. Significant control systems and thence automation can be applied to VFD mechanisms. Drilling rigs also added power in electrical generation, in hydraulics from the drilling fluid pumps, and in drill string rotation from the top drives. More power with greater control has enabled significant improvements in the operational characteristics of petroleum drilling.

Surface and Subsurface Systems

Subsurface systems, combined with surface control systems, have enabled improved well borehole steering at far higher immediate and overall drilling rates than was possible using predecessor technologies. A combination of automated steering, automated MWD, and robust data communications has enabled directional drillers to move from the rig site to the office, simultaneously moving directional drillers up a level in the decision process. This, along with the aforementioned growth in power, has delivered the mile-a-day (MAD) boreholes measured from the vertical through the inclination build (kick-off) into the horizontal section. A recent record is 2,035 m (6,680 ft) in 24 hours (an *average* ROP of 85 m (278 ft) per hour, or more than nine drill pipe connections per hour!).

Focus on Performance

The supplier industry has shifted its mindset from a focus on revenues to a focus on performance for the client, while the customer-base shifted from low-cost services to impact on well costs. Drilling performance is now a price-competitive advantage for suppliers who achieve and demonstrate it. These suppliers have been integrated into drilling teams with the operator, drilling contractors, and original equipment manufacturers (OEM's).

Performance Improvements Driven by Soft Issues

Automobile manufacturing has achieved significant performance improvements through technology application. Lean Manufacturing, known as the Toyota Production System (TPS), demonstrated equivalent improvements through reorganization of work systems and processes. This has been a very important lesson for all industries;

technology improvements alone leave about 50% of the potential savings unrealized.

Lean Drilling™, the original bespoke program adopting the lessons from Lean Manufacturing / TPS into petroleum drilling, has repeatedly created significant time and cost reductions, which have resulted in best-in-class performance in many global locations.[2] Key drivers for these soft solutions include:

- Organization Architecture: alignment to objectives through aligned delivery systems across breadth and depth of the involved organizations
  - o Involvement: everyone (all competencies) participates
- Culture change / team building: vision, values, equal players, common objective
  - o Financial return: need to see return to make investment
- Performance gap recognition: team owned stretch goal using Maximum Theoretical Performance (MTP) which reaches beyond Technical Limit (TL), Best in Class (BIC), Best of the Best (BOB)[3]
  - o Commitment: We are going to do this no matter what.
- Project services systems: professional detailed scheduling, cost estimation / control, risk management[4]
  - o Detailed process focus: The devil is in the details.

Bits and Sensors

Both surface and downhole data is very important for monitoring, analyzing and thence improving drilling performance. Some years ago, petroleum drilling commenced an increase in the acquisition and use of data for drilling performance improvement, along with the implementation of real-time operations centers (RTOCs). Simultaneously, data quality (accuracy) was identified as a major issue in some key drilling measurements.

Efforts are underway to classify sensor accuracy in situ and apply contractual specifications to ensure correct maintenance and calibration is carried out. Rig data errors from a low of 1% to a high of 40% have been measured across multiple land rigs.[5] State engines to automatically acquire and analyze operations in far greater detail than is possible in manual reports are now being employed for routine drilling operations. State engines have identified significant wasted time in simple repetitive operations, such as making a connection during drilling; these durations are often thought to be a matter of a couple of minutes but have been repeatedly measured at 20 minutes or more because of onsite procedures that were found to be unnecessary.

The concept of Mechanical Specific Energy (MSE), originally used effectively in lab environments to evaluate the drilling efficiency of bits, has been brought to the field as a powerful means to discern when energy input to the drill string is being wasted as dynamic dysfunction. The subsequent drilling parameter adjustments have led to significant increases in rates of penetration with the same bit, BHA, mud parameters and drilling rig. This methodology has gained widespread adoption following its initial introduction in the early 2000s.[5]

Drilling Systems Automation

Drilling automation is a fast-growth systems and technology change currently underway in the petroleum industry. When very high frequency adjustments are required to set drilling operational parameters for maximum performance, automated systems have proven their ability to outperform drillers. Systems can initiate the drilling process at each connection in the desired manner repetitively and far more consistently than can humans operating the rig controls. This leads to longer bit life.

Automated Managed Pressure drilling (MPD) has become the norm for closed loop drilling applications. And MAD wells have been achieved when the directional driller was able to transition to a supervisory role through the automation of data acquisition, processing, and steering.

Petroleum versus Geothermal Drilling

Not unlike Geothermal operations, petroleum drilling costs command a high percentage, typically some 50% to 70%, of project costs, including the well completions. This demonstrates that both industries have a similar incentive to speed up drilling and reduce well costs. Petroleum drilling

operates on a significantly larger scale and global footprint than does geothermal drilling, which provides greater opportunity for funding of technology and process developments. The lessons learned from these developments provide fertile ground for geothermal drilling adoption, especially lessons from the independent petroleum drillers actively developing large plays with multiple wells in the U.S.

One study identified that six major issues commonly found in geothermal drilling operations have been identified and compared to similar situations in petroleum drilling operations.[6] These problems include lost circulation, rig and equipment selection, cementing, rate-of-penetration (ROP), efficient and consistent drilling program, and effective time management. Because of these issues, geothermal drilling operations analyzed in this report averaged 56.4 more drilling days than comparable petroleum wells (Figure 2). The petroleum wells reached an average depth of 3,810 m (12,500 ft) faster than any geothermal well reached depths of less than 3,048 m (10,000 ft). While it is understood that there are differences in drilling environments, a thirteen-to-one time ratio would seem to be excessive.

Petroleum Drills Hard Rock – Across the Globe

Unbeknownst to many, drilling fractured basement for petroleum production has been undertaken at multiple locations across the globe. The challenges addressed include rotary drilling of very high compressive strength rock, managing drill string dynamics, managing fluid losses while drilling, minimizing production impairment during the drilling process, and steering the wells in high inclination laterals. Progress has been made in rates of penetrations in these metamorphic rocks as new rig designs with fast, sometimes continuous, drill pipe tripping operations offer a new time reduction mechanism even when multiple drill bits are required to drill through the hard rock reservoir section.

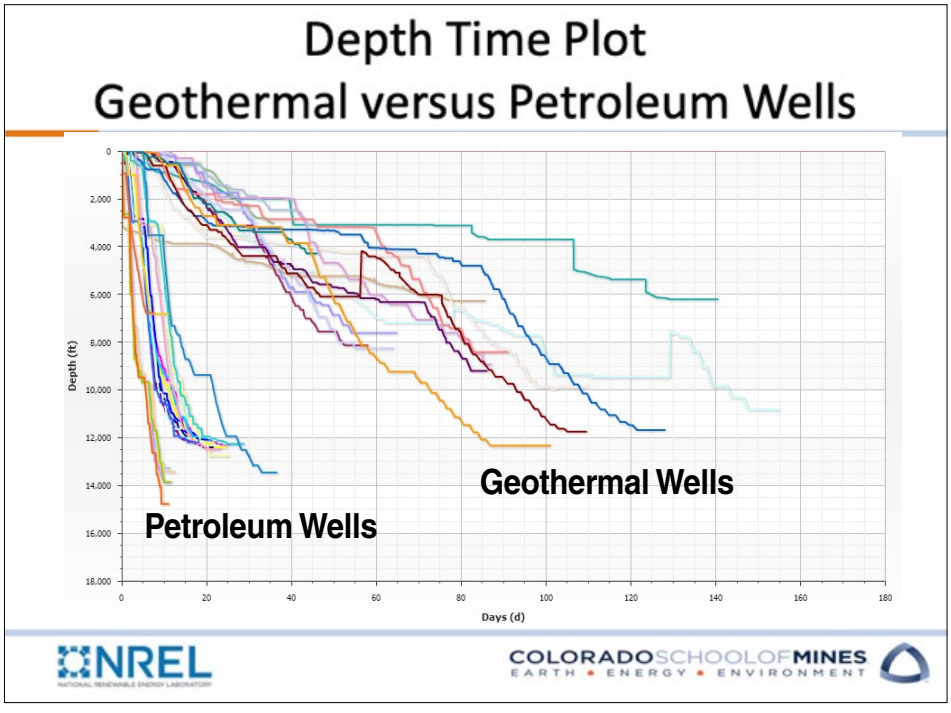

Figure 2. US Land Petroleum versus Geothermal Wells - Depth / Time Plots

Observations

Petroleum has shown huge drilling performance improvements when the need arose to drill multiple long reach horizontal wells in shale developments. Overall drilling rates (spud to TD) have risen from 185 m (600 ft) to 610 m (2,000 ft) per day. This vast gain was achieved through a combination of technology and work process improvements. A similar relative performance improvement in geothermal drilling must be available to those who are willing to redesign their work processes and apply the most suited technologies.

A first step in that process would be to identify a development prospect where significantly faster and lower cost wells may drive development expansion. The front-end loading of design and planning for a chosen well with the right catalysts for change may prove that lower well costs can be achieved through elevated drilling performance. This will be the proven basis on which to project lower, and potentially declining, well costs for more expansive developments.

Conclusions

The recent petroleum drilling performance improvements highlighted above provide a strong case that geothermal

drilling operations can be undertaken in less time and at lower costs than they typically require today. Adoption of relevant petroleum best practices provides a fast means to achieve time and cost reductions in drilling geothermal wells. Significantly shorter drilling times and lower well costs can open the door to economic development of multiple well projects enabling the scaling up of the delivery of geothermal energy.

Acknowledgements

Katherine R Young; Geothermal Program Manager, National Renewable Energy Laboratory

Alfred W. Eustes III, PhD, PE; Colorado School of Mines

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Lean Drilling™ is a trademark of De Wardt and Company Inc. ■
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Corporate Focus

The GRC would like to highlight our partners in the industry with a regular series of articles featuring our company colleagues. We thank our friends in the corporate sector for their ongoing support.

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THERMOCHEM®
Empowering Energy Industries since 1985

Thermochem (TCI) is the world leader in testing, engineering, consulting services, specialty instrumentation and equipment supply for the geothermal power industry. This includes chemical engineering, laboratory analysis, geochemistry, field testing services and products. From base operations in the Western USA and South-East Asia, Thermochem has served geothermal energy companies for more than 30 years. The Thermochem brand is known for strong technical competence, global experience, innovation and quality. Thermochem is the only vertically-integrated geothermal service company.

Thermochem, Inc. (USA) was founded in 1983 by Paul von Hirtz as a geothermal laboratory and consulting company, primarily serving The Geysers geothermal projects in Northern California (the largest geothermal development in the world). Thermochem rapidly grew, serving all geothermal energy projects in the USA, and expanded into The Philippines and Indonesia in 1990. Thermochem, Inc. now provides services in 35 countries and employs over 25 chemists, engineers, geoscientists and technicians. Thermochem designs and builds the equipment and instrumentation they use to provide their testing services, including TFT®, steam purity/quality instruments, PTS and DHS wellbore logging tools, well test mufflers and pilot test units. They also sell this same equipment and instrumentation to its customers, plus pH-mod and acid neutralization systems for wellfields and power plants.

PT. Thermochem Indonesia was founded during the geothermal energy boom in Indonesia in the 1990's when many foreign companies were actively developing projects. Not long after the founding of PT. Thermochem Indonesia the Asian Financial Crisis hit the region and most foreign developers and service companies left Indonesia. PT. Thermochem Indonesia maintained its operations and won the respect of Indonesian governmental agencies and remaining private developers, which solidified their position within the country when the economy strengthened and geothermal development resumed. PT. Thermochem Indonesia provides services to virtually all geothermal projects within Indonesia and helps supports TCI world-wide operations in Malaysia, the Philippines, and Africa. Currently PT. Thermochem Indonesia employs 35 full-time chemists, engineers, geoscientists and technicians.

The Thermochem, Inc. headquarters is the TCI Geothermal Energy Research Center, based in Northern California near The Geysers. The 20,000 ft^2 Research Center houses the state-of-the-art analytical laboratories. This Center provides a base for field testing activities and includes manufacturing, machining, welding and electronic assembly capabilities for chemical process equipment, specialized instrumentation, wellbore logging tools and electronics. Flow calibration loops are used to support testing of flowmeters, new TFT® instruments and wellbore velocity sensors. A high-temperature test loop with 400°C oven provides hot simulated brine and saturated or superheated steam for calibration and testing of wellbore tools, power plant monitors and corrosion and scale inhibitor testing. ■

Elizabeth Easley performing training in Kenya.

CONTACT:
3414 Regional Parkway, Suite A, Santa Rosa, California 95403
+ 1 707 575-1310
marketing@thermochem.com

Paul von Hirtz and Russ Kunzman working on new instrumentation in Thermochem's Santa Rosa, CA, Geothermal Research Facility.
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GRC Annual Meeting & Expo 2018

In the first part of our overview of the 43rd Annual Meeting of the Geothermal Resources Council (GRC) - in the November/December 2018 Bulletin *- we ran a photo essay of the Opening Session, Annual Charity Golf Tournament, Photo Contest and the Poster Session. Also, Sue Hodgson reported on a fieldtrip to Gabbs Valley to see at first hand the application of Play Fairway Analysis to exploration of geothermal resources in central Nevada.*

In this issue of the GRC Bulletin *we report on the GRC Awards, more Fieldtrips, the Mixer - Trivia Night!, and the Expo.*

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The GRC Awards

The Geothermal Resources Council (GRC), presented the prestigious Aidlin, Pioneer, Henry J Ramey Jr., and Geothermal Special Achievement awards at the GRC Annual Meeting in Reno, Nevada, on October 17, 2018.

The 2018 GRC Awards and Membership Meeting lunch was a very popular event.

The recipients of these awards have a lifetime of achievement in the geothermal academic, scientific and commercial communities. The GRC Awards recognizes the contributions of these individuals to educational institutions and the geothermal community around the world.

This year's **AWARDS WINNERS** *are:*

Joseph W. Aidlin Award -

Ron Barr

"For your early and long-standing service to the GRC, your active promotion of the use of geothermal energy, and your participation in the development of numerous projects over more than 40 years."

Ron Barr *(left) receives a plaque in recognition of his award from* **Marcelo DeCamargo** *(center) - GRC Awards Committee Chair, and* **Maria Richards** *(right) President of the GRC.*

Geothermal Pioneer Award -

Zvi Krieger

"For contributions to the development and enhancement of binary plant technology, integration of facilities and reservoir characteristics leading to successful projects, and for leadership in the advancement of geothermal development around the world."
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Zvi Krieger *(left) gives thanks for his award. Looking on are award sponsor* **Patrick Walsh** *(center), and* **Marcelo DeCamargo.**

Henry J. Ramey Jr. Award -

Peter Rose

"For developing and commercializing the high temperature geothermal tracers that now make tracer returns one of the most insightful tools available to reservoir engineers."

Pete Rose *(left) with award sponsor* **Dick Benoit.**

Geothermal Special Achievement Award -

Roy Baria

"For your outstanding work in the worldwide development of Enhanced Geothermal Systems."

Roy Baria *(center) is joined by award sponsor* **Ann Robinson-Tait** *(right) and* **Marcelo DeCamargo.**

Geothermal Special Achievement Award -

Virgil Welch

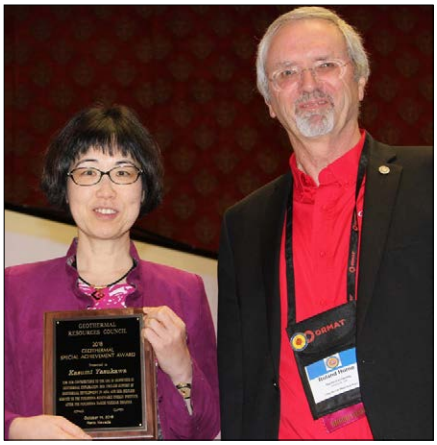
"In recognition of a long and distinguished career in providing project management and drilling solutions to the geothermal industry, dealing effectively with challenging wells, and mentoring a generation of drilling professionals."

Virgil Welch *(right) listens as* **John Tuttle** *makes the introductions.*

Geothermal Special Achievement Award -

Kasumi Yasukawa

"For her contributions to the use of geophysics in geothermal exploration, her tireless support of geothermal development in Asia, and her selfless service to the Fukushima Renewable Energy Institute after the Fukushima Daiichi nuclear disaster."



Kasumi Yasukawa *is presented her award by* **Roland Horne.**

The winners of the 2018 GRC Awards. From left to right: **Ronald Barr, Peter E. Rose, Kasumi Yasukawa, Roy Baria, Zvi Krieger and Virgil Welch.**

Scholarship Winners

The Geothermal Resources Council as a non-profit educational association dedicated to the promotion of geothermal energy and associated technologies around the world, was pleased to recognize the recipients of eight GRC Scholarship Awards at the GRC Annual Meeting.

The selection was based upon a variety of factors, including the individual's academic record, student activities, geothermal industry experience, and career goals.

From left to right: **John Grill, Estefanía Ramírez Restrepo and Yuran Zhang** *are happy GRC Scholarship winners.*

Undergraduate Awards

- **John Grill** (Montana Tech University)
- **Christ Quinicot** (Negros Oriental State University)
- **Estefanía Ramírez Restrepo** (University of Medellin)

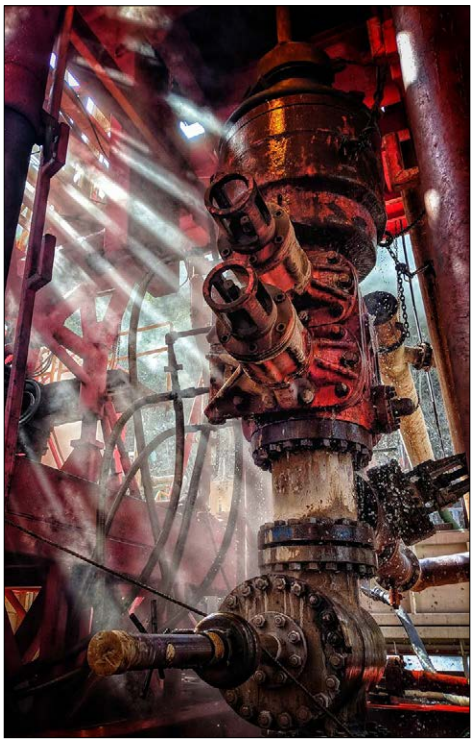
Graduate Awards

- **Estefanny Dávalos-Elizondo** (Oklahoma State University)
- **Jonathan Ogland-Hand** (The Ohio State University)
- **Arna Palsdottir** (Cornell University)
- **Jared Smith** (Cornell University)
- **Yuran Zhang** (Stanford University)

Photo Contest

Piyush Bakane *(right) receives a certificate and $150 for his 1st Place award in the 2018 GRC Geothermal Photo Contest, from GRC Executive Director* **William Pettitt** *(left).*

Estefanía Ramírez Restrepo *receives a certificate recognizing her Undergraduate Scholarship award from* **Dave Boden**, *Chair of the GRC Education Committee.*



"Ray of Steam" by **Piyush Bakane**, *the 1st Place award in the 2018 GRC Geothermal Photo Contest. Taken while well testing at the Zunil geothermal power plant in Guatemala.*

More photos from the GRC Awards Luncheon.....

Fieldtrips

The GRC Fieldtrips have always been a popular attraction at the GRC Annual Meeting. What better way to make new acquaintances, network, learn from experts in the field and experience outstanding scenery!

In 2018 there were four fieldtrip options:

- Long Valley Caldera Field led by **Gene Suemnicht** and **Roy Mink**.
- Steamboat Springs Geothermal Field led by **Matthew Sophy**.
- Geothermal Direct Use Tours of the Peppermill Resort, compliments of the Peppermill Resort & GRC.
- Searching for Blind Geothermal Systems Utilizing Play Fairway Analysis, Western Nevada led by **Jim Faulds, Jason Craig**, and **Nick Hinz** (University of Nevada, Reno).

Jim Faulds *leads an al fresco presentation at the Gabbs Valley geothermal field.* (Photo by Jason Craig)

At the Don Campbell power plant operated by Ormat (Photo by Jim Faulds).

More photos from the Gabbs Valley fieldtrip.....

The GRC Fieldtrip crew at Mammoth! (Photo by Dr Thomas Borrmann)

Gene Suemnicht *explains the geothermal system at Well No. 57-25 at the Casa Diablo Geothermal Field.* (Photo by Dr Thomas Borrmann)

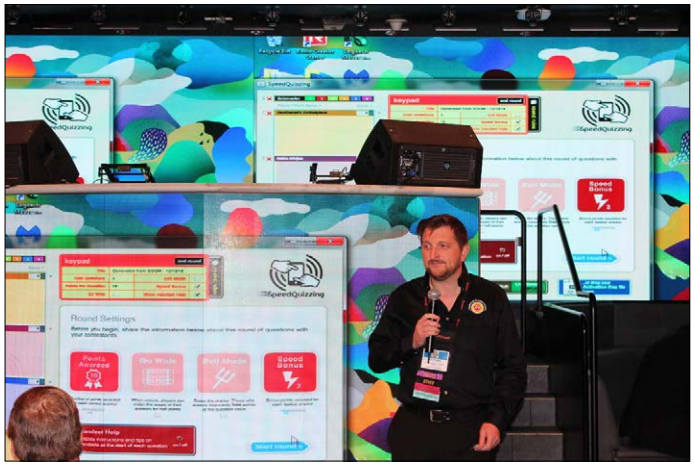
Surface geothermal manifestations on the ground above the Casa Diablo geothermal power plant. (Photo by Dr Thomas Borrmann)

Bodie was a gold-mining boom-town of several thousand souls in the late 1800's. Now it is a well-preserved "ghost town". (Photo by Dr Thomas Borrmann)

More Photos from the Long Valley fieldtrip.....

The Mixer - Trivia Night!

The GRC Student Committee did an outstanding job of organizing the Trivia night mixer. Teams answered questions related to geothermal to win, nothing but bragging rights! The GeothermEx Enthalpians were the victors this time!



GRC Executive Director **William Pettitt** *welcomes the players.*

The evening was a networking success!

Travis Broadhurst *of the GRC Student Committee did a great job guiding contestants.*

More photos from the Trivia Night.....

The Expo

The Expo had more than 70 exhibitors - a great turnout for the geothermal energy industry.

GRC President **Maria Richards** *and GRC Executive Director* **William Pettitt** *celebrate a successful ribbon-cutting opening of the Expo.*

1. The folks at Ormat celebrated their involvement in the Sarulla geothermal power plant in Indonesia.

2. **Brad Ring** *at the Horizon Well Logging Inc. booth.*

3. The GRC Expo is one of the best places in the global geothermal energy industry to discuss business and make deals!

4. There was time to relax and chill with friends and colleagues at the end of the day! From left to right: **Shaun Robinson, Danielle Matthews-Seperas, Maria Richards and Tim Conant.**

More photos from the Opening Reception.....

Cheese & Wine Social - The Farewell Reception

At the Reno meeting we decide to try something new. We thought it might be a good idea to bring all the attendees back together for one last social event to say farewell. Just as the Technical Sessions were winding up we put on a Wine & Cheese networking reception. It was a tremendous success! Look for the same at this year's GRC Annual Meeting & Expo, 14-17 September in Palm Springs, California.

1. **Charlene Wardlow** *(left) of the California Department of Conservation, Division of Oil, Gas, and Geothermal Resources (DOGGR).*

2. **Kevin Kitz** *(left), Senior Consulting Engineer, KitzWorks, LLC.*

3. **Dr. Andy Sabin** *(left), Director of the Navy's Geothermal Program Office and the new President of the GRC, speaks with* **Susan Fox Hodgson** *(right).*

4. **William Pettitt** *(left) is the Executive Director of the GRC.*

More photos from the farewell reception.....

All Photos by Ian Crawford except where mentioned. ■

Publications, Websites, Videos & Maps

by Ian Crawford

World Energy Outlook 2018 (IEA)

Major transformations are underway for the global energy sector, from growing electrification to the expansion of renewables, upheavals in oil production and globalization of natural gas markets. Across all regions and fuels, policy choices made by governments will determine the shape of the energy system of the future.

At a time when geopolitical factors are exerting new and complex influences on energy markets, underscoring the critical importance of energy security, *World Energy Outlook 2018*, the **International Energy Agency (IEA)**'s flagship publication, details global energy trends and what possible impact they will have on supply and demand, carbon emissions, air pollution, and energy access.

In the Renewables 2018 forecasts, the **share of renewables in meeting global energy demand is expected to grow** by one-fifth in the next five years **to reach 12.4% in 2023.**

Renewables will have the fastest growth in the electricity sector, providing almost 30% of power demand in 2023, up from 24% in 2017. During this period, renewables are forecast to meet more than 70% of global electricity generation growth, led by solar PV and followed by wind, hydropower, and bioenergy.

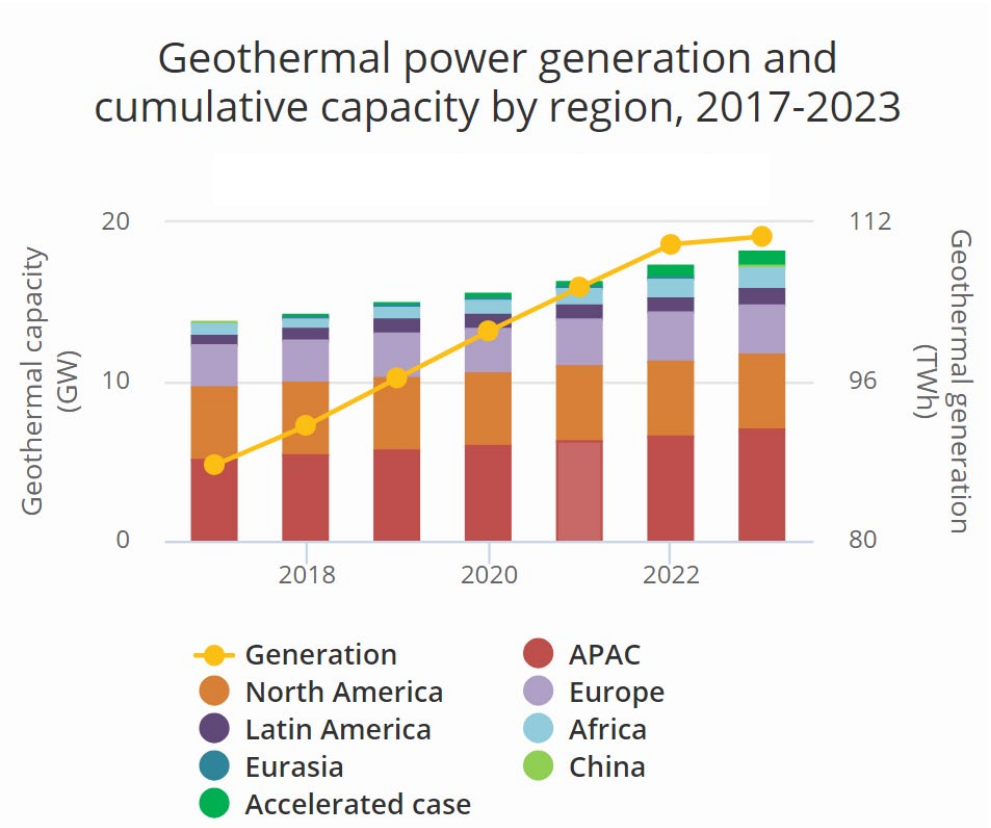
In 2017, global geothermal power generation stood at an estimated 84.8 TWh, while the cumulative capacity reached 14 GW. **Global geothermal power capacity is expected to rise to just over 17 GW by 2023**, with the biggest capacity additions expected in **Indonesia, Kenya, Philippines** and **Turkey**. Download the report.....

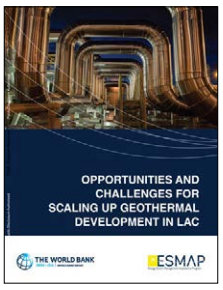
Opportunities and Challenges for Scaling-up Geothermal Development in LAC (World Bank)

Geothermal energy can play a substantial role in meeting the energy needs of many **Latin America and Caribbean Region (LAC)** countries given the region's vast potential.

The majority of geothermal resources in the LAC region remain largely untapped, not only in Central America and Mexico where development is more advanced, but also in the Caribbean and in South America. If further explored and developed in a sustainable fashion, these resources could meet a significant share of the base load power needs of the region, at a competitive cost, resulting in direct economic and environmental benefits.

This report is envisioned to be a decision-makers' guide for assessing key challenges and measures to facilitate expanding geothermal development in LAC. Download the report (PDF).....





Mapas de Ruta Tecnológica de Energías Renovables - *Renewable Energy Technology Route Maps* (Secretario de Energía)

The Secretaría de Energía of Mexico has prepared a series of documents to help the development of geothermal - both direct use and for generating electricity. The purpose of the *Technological Route Maps* is to identify the challenges and barriers that the country faces for the sustainable use of renewable energies by 2030.

The documents pertaing to "Geotermia" (in Spanish only) are listed below:

Geotermia (Geothermal)

- Documento del Mapa de Ruta Tecnológica.
- Diagnóstico Tecnológico del CEMIE.
- Reporte de Inteligencia Tecnológica.
- Cartera de Necesidades de Innovación y Desarrollo Tecnológico.
- Diagrama del MRT.

Usos Directos del Calor Geotérmico (Direct Uses of Geothermal Heat)

- Mapa de Ruta Tecnológica
- Reporte de Inteligencia Tecnológica
- Cartera de Necesidades de Innovación y Desarrollo Tecnológico
- Diagrama del MRT

More information on the documents.....

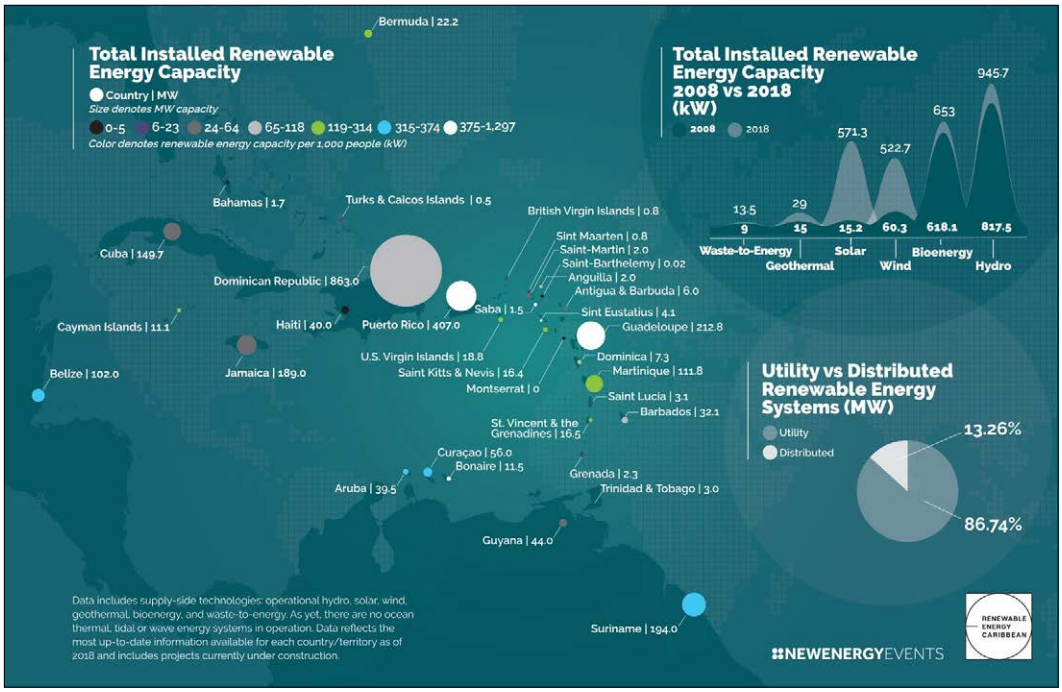
The Status of Renewable Energy in the Caribbean (New Energy Events)

This report by New Energy Events provides a snapshot of renewable energy growth in the Caribbean over the last 10 years – synthesizing data and energy statistics from over 300 projects and encompassing all major supply-side technologies such as solar, wind, **geothermal**, hydro, waste-to-energy, and bio energy.

There is approximately 3.1 GW of installed and operational renewable energy in the Caribbean including hydro, whose legacy is giving way to new technologies.

Geothermal, which shows little progress across the region over the ten-year period, may yet have its day in the sun. Unlike waste-to-energy, geothermal has supporters with significant capital. For instance, the multilaterals, led by the Caribbean Development Bank, the Inter-American Development Bank and The World Bank, have mobilized funding to address inherent issues around geothermal resource and project risk — although this does not necessarily guarantee success. In some of the region's smaller markets, the question is not between geothermal and intermittent renewables, rather it is a question of one or the other. **It is estimated that the Caribbean holds 3,770 MW of potential geothermal energy.**

Which will prevail in the coming years will depend on the new regional algorithm whose key components are economics, reliability — and resilience. That debate is playing out vigorously in the region as we speak. Download the report.....



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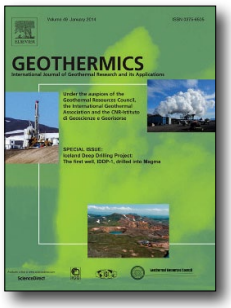
Geothermics



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 2018 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.

Please, follow the steps below in order to get the Geothermics journal for the reduced price:

1. Contact Elsevier Team at emeasocieties@elsevier.com for a proforma invoice and mention the special rate for *Geothermics* journal:
   a. USD 133 – for individual members
   b. USD 305 – for corporate/institutional members
2. Wait for the Elsevier Team to send you the *proforma* invoice.
3. Provide a payment and confirm payment has been sent and applied to your account in order to receive the online registration instructions per email.
4. Wait for the online registration instructions per email. Please note that your e-mail address will be uploaded to the system for access to the journal via Science Direct.

Members can also reach Elsevier Team by phone: (+1) 877 839 7126 or (+44) (0)1865 843434 ■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Calendar of Events

GeoEnergi 2019 (Norwegian Centre for Geothermal Energy Research)
4-5 February, Bergen, Norway
http://cger.no/index.cfm?id=442606

GT'2019 - Geothermal Turkey Congress
6-7 February, Ankara, Turkey
https://geothermalturkey.org/

Stanford Geothermal Workshop
11-13 February, Stanford, California, USA
https://geothermal.stanford.edu/events/workshop

GeoTHERM - Expo & Congress
14-15 February, Offenburg, Germany
www.geotherm-germany.com/

10th European Geothermal PhD Day
25-27 February, Potsdam, Germany
www.geothermalresearch.eu/egpd-2019/

3rd Annual Geothermal Conference - The heat of the future (GEOOP)
27 February 27, Fællessalen, Christiansborg, Denmark
https://geoop.dk/konference-2019/

DAP Symposium 2019 (TU Delft) Urban Heating: Risks & Rewards - Integrating cities with geothermal energy
12 March, Delft, Netherlands
www.dapsymposium.nl/

8th ITB International Geothermal Workshop 2019
20-21 March, Institut Teknologi Bandung, Bandung, Indonesia
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IGC Invest Geothermal
28 March, Frankfurt am Main, Germany
www.investgeothermal.com/

AAPG 3rd Hydrocarbon – Geothermal Cross Over Technology Workshop
9-10 April, Geneva, Switzerland
www.aapg.org/

EAGE/DGMK Joint Workshop on Deep Geothermal Energy - Underground Storage of Hydrogen
24 April, Celle, Germany
https://events.eage.org/en/2019/eage-dgmk-joint-workshop-on-deep-geothermal-energy

IGC Islands Geothermal Conference
15-16 May, Terceira Island, Azores, Portugal
www.igc-islands.com/

EAGE Annual Conference & Exhibition 2019
3-6 June, London, UK
https://events.eage.org/2019/eage-annual-2019

European Geothermal Congress 2019 (EGEC)
11-14 June, The Hague, Netherlands
http://europeangeothermalcongress.eu/

43rd GRC Annual Meeting & Expo
15-18 September, Palm Springs, California, USA
www.geothermal.org/meet-new.html

Praxisforum Geothermie.Bayern
7-9 October, Munich, Germany
www.praxisforum-geothermie.bayern/en

IGC Turkey Geothermal Congress & Expo
6-8 November, Izmir, Turkey
https://www.igc-turkey.com/

Der Geothermiekongress 2019
19-22 November, Munich, Germany
https://www.der-geothermiekongress.de/kongress-2019/der-geothermiekongress.html

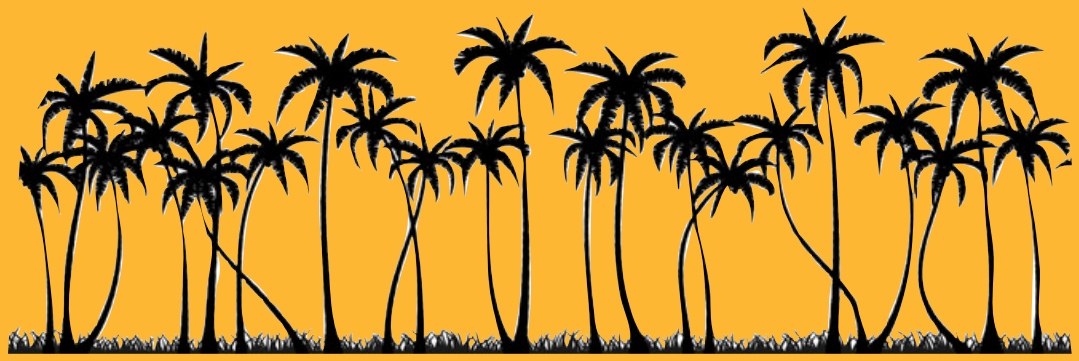
41th New Zealand Geothermal Workshop (NZGW)
25- 27 November, University of Auckland, Auckland, New Zealand
https://nzgeothermal.org.nz/

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

44th GRC Annual Meeting & Expo
18-21 October 2020, Reno, Nevada, USA
www.geothermal.org/meet-new.html ■

Geothermal Resources Council

GRC



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