GEOTHERMAL RESOURCES COUNCIL

Bulletin

Vol. 48, No. 2 | March/April 2019

Frontier Observatory for Research in Geothermal

-Roadmap Released

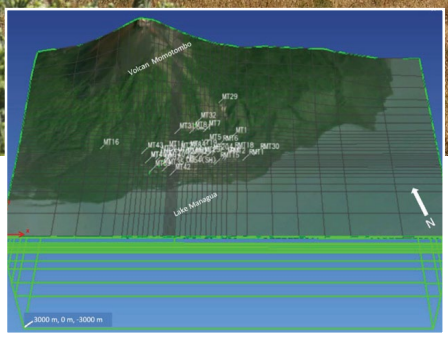
-Results of Drilling and Geoscientific Surveys

Geothermal Resource Group

TAPPING THE EARTH'S ENERGY

Smarter Subterranean Strategies

Employing a fully integrated approach to resource exploration, development and operational management, providing geosciences, reservoir modeling and expert drilling engineering.



- Drilling Engineering, Supervision & Management
- Reservoir Engineering & Resource Management
- Numerical Simulation & Wellbore Modeling
- Geology, Geophysics & Geochemistry
- Well Testing & Resource Assessment
- Scale and Corrosion Control

77530 Enfield Lane, Building E, Palm Desert, California 92211

+1 760.341.0186

www.geothermalresourcegroup.com

Geothermal Resource Group
TAPPING THE EARTH'S ENERGY


RENEW YOUR
MEMBERSHIP
STAY
connected
RENEW TODAY
Geothermal Resources Council
GRC
RENEWAL IS EASY!
www.geothermal.org/membership.html

INNOVATION FOR ENERGY

THERMOCHEM provides a comprehensive range of testing services, consulting engineering and geoscience services, specialized instrumentation and equipment to all major geothermal energy projects worldwide for over 30 years.

THERMOCHEM
Empowering Energy Industries since 1985

- Geothermal Exploration
- Laboratory Testing
- Resource Assessment
- Well Flow Testing Equipment
- Wellbore Logging Equipment
- Reservoir Tracer Testing
- Power Plant Process Optimization
- Corrosion + Scale Control Systems
- Steam Purity, Quality + Flowrate Instrumentation

USA **+1.707.575.1310** | Indonesia **+62.22.686.8110** | **thermochem**.com

Coiled & Straight Length Tubing for Geothermal Applications

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

Commonly Stocked Sizes

- .250" O.D. x .035" or 049" wall
- .375" O.D. x .035" or .049" wall
- Other sizes stocked or available by request.

Commonly Stocked Grades

- Nickel Alloy 625
- Nickel Alloy 825
- 2205 Duplex
- 316L Stainless
- Other alloys available upon request

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

Webco maintains an extensive inventory of coiled and straight length tubing. International shipping is available. Email Laserline@webcotube.com or call 918-245-2211.

WEBCO INDUSTRIES

STRENGTH • AGILITY • INNOVATION

www.webcotube.com

LaserLine® Coiled Tubing

Bulletin

Vol. 48, No.2
March/April 2019

Geothermal Resources Council

P.O. Box 1350
Davis, CA 95617-1350

Phone: 530-758-2360
Fax: 530-758-2839

www.geothermal.org

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.

COVER: *The Stillness of Winter, by* **Hreinn Hjartarson**, *Borehole testing at Theistareykir, Iceland, March 31, 2016. GRC Geothermal Photo Contest 2018*

President's Message

by Andrew Sabin

John Wesley Powell: A Quick Retrospective

One hundred and fifty years ago this May, "Major" John Wesley Powell led an unlikely mix of nine men down the Green and Colorado Rivers into the Grand Canyon on boats of his own design. Three months later Powell and five of these men made it out to the other side. They were the first people ever to complete and record this feat. Most may know of Powell, if they've heard the name at all, for the massive reservoir ironically named for him behind the Colorado River's Glen Canyon dam. He was much more.

Powell was a practical young man of strong convictions with a deep desire for knowledge of all subjects. To the chagrin of his itinerant preacher/part-time farmer father, the young Powell was drawn not to theology but to the natural sciences. After several semesters at three different colleges, Powell's education never included a degree but was complete. He enlisted in the Union Army at the onset of the Civil War, was identified as a leader and engineer (all self-taught skills), and served with U.S. Grant among others until the war's end. Four years later and despite having lost most of his right arm at the Battle of Shiloh, Powell convinced Grant and others of the merits of a scientific mapping expedition by river through the unchartered Grand Canyon. By the time Powell's team passed the Virgin River confluence of the Colorado River on August 30, 1969, four of his men had quit (three never to be seen again) and almost all of their food and scientific equipment had been lost or destroyed as their wooden boats and white water river skills were little match for the powerful rapids. Powell considered the summer a failure because they didn't complete the planned scientific surveys. He raised more money and repeated this journey in 1872 to finish compiling topographic and geologic maps of the region. During this period Powell also developed an interest in the language and culture of the local Native Americans. How this work is perceived today by scholars is unclear but Powell wrote volumes on the language and cultural heritage of local Native Americans and founded the Smithsonian's Bureau of Ethnology in the process.

The money and political support needed to fund Powell's as well as similar west-looking mapping and geologic exploration expeditions was largely from the federal government and always hard-won. People like Wheeler, King and Hayden were Powell's contemporaries and were often fighting over a finite pot of money. Not unlike today, elected officials and government leaders could be persuaded to support an expedition based more on the lobbying success of its leader and his friends than on performance or outcomes. This resulted in uninformed decisions and some mediocre to bad science. Part of Powell's success in this area in addition to being strident about proper field methods, many of which he developed, was that his work was almost always performed on a shoestring budget, at least compared to his peers. And he only denigrated the work of others when he knew he was right, regardless of whether it was politically astute or not. He was instrumental in the creation of the U.S. Geological Survey and supported Clarence King to be the first Director. Powell was King's relatively quick and logical

successor. His tenure was much longer and far more productive than King's. During his time in D.C, he also founded the Cosmos Club – as an undergraduate attending the occasional talk, it was not unusual to hear funny, mocking and often viscous Q&A sessions after a geology presentation; unclear if the beer keg at every meeting contributed to this or not – and had a hand in the creation of National Geographic.

Most who have read about Major Powell acknowledge that he was fearless and tireless and a curious earth scientist, ethnologist, explorer, writer/lecturer who had a hand in the creation of many vital organizations that thrive to this day. He lived in pain every day as surgeries could never correct the nerve damage inflicted by the miniball that smashed his arm during the Civil War. But if he were to pen his own legacy today, it might be for his prescient scientific writings concerning water in the western United States and the larger role that the federal government has played in funding scientific work. Powell concluded that water west of the 100th meridian was in short supply and that only judicious and federally-controlled irrigation, probably mimicking what the Mormons were doing in the Utah desert, would be needed to allow small portions, but not all, of the west to be farmed and settled. Powell didn't contemplate and likely would not have supported the massive, earth-modifying dam projects that began a few decades after his death even though he did actively lecture on the need for the federal government's central role in western irrigation. He would have noted the irony of the largely anti-government stance that many western states now maintain despite the fact that their major cities, and hence commerce, exist only because of federally-funded projects that provide them water and cheap electricity. He would be an active fan, supporter and participant in the geothermal industry, especially in contrast to the behemoth, privately owned and (still) federally subsidized oil and gas industry. Good news for our geothermal community, especially for the young and future practitioners, is that there are lessons to be learned in the drive, the practicality, the attention to detail and the integrity of people like John Wesley Powell. Make sure to read your history. ■

Executive Director's Message

by Will Pettitt, PhD

A Strategy for Our Geothermal Community

This month's GRC *Bulletin* is the longest and most action-packed edition ever with four main articles. The technical content is led by a summary of the FORGE R&D roadmap recently released by the Department of Energy, and then followed by a summary of the Utah FORGE project by Dr. Joe Moore. Our magazine format has continued to experience increased interest from the geothermal community with featured content being a combination of invited and unsolicited articles. In the *Bulletin* this year we are showcasing one article per edition derived from our 2018 Annual Meeting *Transactions* with authors invited to submit a copy specially formatted for the magazine.

Our *Global Geothermal News*, summarized in this publication, is an unbiased accumulation of all the key current affairs and can also be experienced on social media, by email, and internet blog. The broad range of activity mapped out through these pages illustrates the large amounts of energy that people are committing to the future of our industry. The *Bulletin* is also an excellent way to connect, for individuals and organizations to summarize their projects and technologies, and companies to promote their brands. Thanks to everybody inside and outside our industry that contributes to that success, and to our staff that assemble this industry-leading magazine.

Over the past six months I've been leading a strategic review for the GRC. The resulting 2019 *Strategic Plan* is published in the following pages and is updated from one assembled by the Board in 2016. The plan is a result of a comprehensive review of GRC documents put together over the past few years, a review of our budget for this financial year, and brainstorming sessions and reviews by the GRC Staff and Board Members. The plan was approved by the Board at our most recent meeting in Palo Alto ahead of the Stanford Geothermal Workshop. It includes a number of strategic elements, from our high-level core vision through to a set of ambitious strategic objectives and measurable tasks for 2019. Our goal is to maintain this plan regularly with a review and update at the end of each year, so please feel free to contact me with any opinions you have for the next review.

Our 2019 Strategic Objectives are summarized in Figure 1 and map together into the GRC's mission of *being a prestigious, dynamic, and diverse professional association that advances the global geothermal industry and educates through transfer of robust research, knowledge and guidance.* Some of the specific activities that we are planning this year include, amongst others:

- Expanding our Local GRC Sections;
- Establishing a program of mid-year webinars and workshops;
- Building donations and increasing distributions for our Foundation Funds;
- Introducing new industry reports and white papers;
- Redeveloping our website and online tools;
- Establishing a comprehensive marketing plan for geothermal energy; and,
- Moving forward policy and regulatory improvements at State, Federal and International levels.

The *Strategic Plan* contributes to a longer-term vision for the organization (Figure 2). For the GRC

to attain the greatest value proposition for our members, the "Penthouse Suite", we must be built on a solid foundation and robust structure. One beauty of the GRC is that many of these things are already in place. That greatest value proposition, in my view, is being able to deliver effective public relations and government advocacy that promotes the development of geothermal resources and our industry. To be effective the GRC must be able to maintain and enhance its credibility and legitimacy as provider of *robust research, knowledge and guidance*. Our solid foundation is thus our educational resources we have. One enhancement this year is that we will be working with a scientific journal to include a special edition of technical papers invited from our Annual

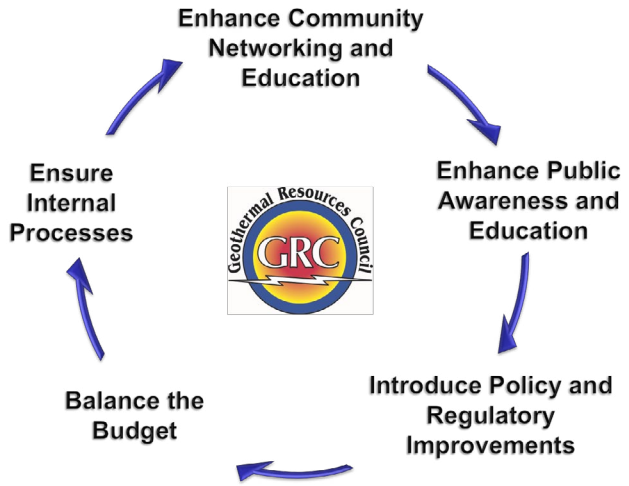


Figure 1: Strategic Objectives for GRC in 2019; developed through a review and assimilation of information produced by the organization through 2016-18.

Meeting *Transactions*, so that we build a spectrum of publications that include: this *Bulletin* magazine; annual meeting proceedings; and; scholarly peer-reviewed papers.

The support structure to get to our value proposition is then the quality and diversity by which we serve people with these resources, including both those people directly inside our community, as well as those outside. One example is the 2019 Annual Meeting and Expo, which is shaping up to be another exciting event under the direction of the Organizing Committee. We have popular and informative workshops and fieldtrips being finalized, a full technical program including the traditional format of sessions as well as round-table and panel discussions, an Expo with sites both inside and outside the conference center for showcasing products and services, and a host of opportunities for networking and socializing with colleagues and clients. Look out for more information on the event as it is released. With the help of our members we will provide the support that the geothermal community needs to develop and grow the industry.

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. ■

Figure 2: Building the Vision of the GRC: An open exchange of information to raise the recognition and acceptance of geothermal energy across society to meet the world's energy demand in a manner that is environmentally responsible.

Strategic Plan 2019

25th February 2019

Published by the Geothermal Resources Council (GRC)
Executive Director, President, and Board of Directors

Introduction

The 2019 GRC Strategic Plan has been assembled through a comprehensive assessment of planning documents drafted by the organization since 2016.

The 2019 plan updates and replaces the previous Strategic Plan published in October 2016 and has been authorized by a Motion of the Board of Directors at the February 10, 2019, meeting, Stanford University, California, USA.

The plan provides a framework by which the staff of the GRC will execute operations, provides guidance on how the GRC will be managed, and provides a vision for the future direction of the organization.

Our Strategic Plan is a living document and will be reviewed and updated at the end of 2019. Any of our members can provide input to the direction of the organization by contacting a Board Member, the Executive Director, or a member of Staff.

We also welcome and appreciate all offers of help from volunteers. Our volunteers are the backbone of our organization and enable the GRC and our geothermal community to be a success. Please contact us.

Sincerely,

Dr. Will Pettitt
Executive Director

Dr. Andy Sabin
President of the Board

Elements of the Strategic Plan

- Vision = What we want for the world.
- Mission = How we will achieve our vision.
- Goals = Our general long-term aspirations for the organization.
- Core Values = Principles for decision-making.
- Objectives = How we will achieve our goals in the given time frame.
- Tasks = Measurable actions to accomplish our objectives

Vision

An open exchange of information to raise the recognition and acceptance of geothermal energy across society to meet the world's energy demand in a manner that is environmentally responsible.

Mission

Be a prestigious, dynamic, and diverse professional association that advances the global geothermal industry and educates through transfer of robust research, knowledge and guidance.

Goals

1. Increase the importance of geothermal resources in helping meet global energy demands.
2. Serve as a source and venue for geothermal knowledge exchange.
3. Build a strong membership.
4. Be fiscally responsible.
5. Produce professional quality products and services.

Core Values

- Financially fit and sustainable
- Member focused
- High professional and technical quality
- Faithful to Scientific Principals
- Serve as a Public Forum
- Collaborative and Cooperative

Objectives

1. Enhance Community Networking and Education – bring people together in our community, provide materials and venues for education and debate, and define our key global messages that enable growth of the geothermal industry;
2. Enhance Public Awareness and Education – improve public relations for the geothermal energy community by developing and executing a marketing and communications plan;
3. Introduce Policy and Regulatory Improvements – work with government and regulatory agencies to incentivize demand and adoption of geothermal energy;
4. Balance the Budget – to operate with a budget surplus by providing self-supporting activities;
5. Ensure Internal Processes – improve professional quality and enhance coordination and communication within the GRC.

Tasks

A detailed set of Strategic Tasks for 2019 have been assembled to help plan GRC operations that include measurable metrics for success. The full task list can be obtained upon request from Ian Crawford, Director of Communications (icrawford@geothermal.org).

Communication from the GRC

by Ian Crawford
Director of Communications

Passing of the Gavel

At the February 10 meeting of the GRC Board of Directors at Stanford University, **Andy Sabin** became President of the Geothermal Resources Council. He thanked the out-going President **Maria Richards** and presented her with a plaque in recognition of her exceptional service.

Andy Sabin with Maria Richards

GRC Announces President-Elect

Jon Trujillo has been elected by his peers on the Board of Directors as the next President-Elect. He will become the 27th President of the global geothermal energy organization in January 2021 after the term of current President **Andy Sabin** ends.

Jon has served on the Geothermal Resource Council's board of directors for the last three years. He is currently on the GRC's executive committee and leads the membership committee.

As CalEnergy's (Berkshire Hathaway Energy) geothermal resource manager, Jon oversees drilling operations, resource management and the facilities' non-hazardous landfill at the Salton Sea geothermal resource in Southern California. Jon has worked in the geothermal industry and with CalEnergy for ten years. His professional experience also includes mineral exploration in Latin America and geologic modeling.

Jon obtained a B.S. in Geology & Geophysics from the University of Missouri – Rolla (currently Missouri University of Science and Technology) in 2002 and spent two years focusing on isotope geochemistry and igneous tectonics at Virginia Tech's geosciences graduate program. He has also completed business courses at the Harvard University Extension School.

Jon commented on his election: "The GRC membership has a broad range of experience, which we can leverage to continue learning from each other. As well, the U.S. energy market has changed, which makes the next five years critical to the long-term growth of our community. We can make the difference and I'm excited to help lead that change. The addition of Will Pettitt and the Policy Committee are great improvements to our organization and leaders in this transformation. Being appointed President-Elect is a huge honor, and I'm excited to continue supporting our amazing community."

GRC Scholarships Now Available

A total of USD 14,000 in educational awards is available for eight students in the global geothermal energy community.

Three (3) GRC Undergraduate Scholarship Awards of USD 500 each are for a third or fourth year undergraduate at an accredited academic institution at the time of the award (Fall 2019).

There are also Five (5) Marcelo Lippmann Graduate Scholarship Awards of USD 2500 each. The GRC Board of Directors decided to rename the graduate awards in memory of our dear colleague **Marcelo Lippmann** who passed on September 10, 2018.

Marcelo was tireless in his support of the Geothermal Resources Council, having served as a board member from 1999-2000 and 2004-2009, and was a member of the Education, Honors and Awards, and International committees. The GRC recognized his extensive scientific achievements

and contributions to the geothermal community in 2010 with the Joseph W. Aidlin award, the highest award bestowed by the Council. A more complete *In Memoriam* can be found in the September/October *Bulletin*.

Applications for the GRC Scholarships must be received by May 24, 2019 to be considered. More information can be found on page 34 of this Bulletin.

2019 GRC Annual Meeting & Expo

Geothermal: Green Energy for the Long Run

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.**

The **discounted rate is available for stays between 12 and 22 September, but you must book by 21 August.**

A guestroom suite at the Renaissance 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: www.geothermal.org/meet-new.html.

The pool bar at the Hilton Palm Springs.

Book Your Booth

Registration for exhibitors is now open!

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 is also be available on the GRC Annual Meeting website at: www.geothermal.org/meet-new.html.

The Palm Springs Convention Center.

Get Exposure!

Sponsorships for the GRC Annual Meeting & Expo are now available. These are great opportunities for companies to get more exposure at the largest annual geothermal gathering in the world.

Make the geothermal community take notice, become a sponsor now!

Download the Sponsorship flyer.....

Communication from the GRC

~~~~~~~

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.....

~~~~~~~

Nominations Open for IGA Board

The **International Geothermal Association (IGA)**, recently removed to **Bonn, Germany**, has announced the opening of nominations for the IGA Board.

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.

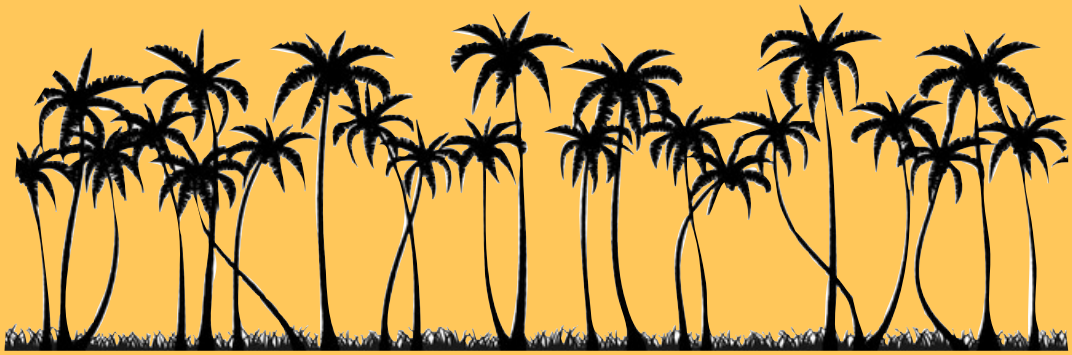
BoD Nomination Guidelines (PDF) ■

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.

Geothermal Resources Council

GRC



PALM SPRINGS

CONVENTION CENTER

PALM SPRINGS, CALIFORNIA

GRC ANNUAL MEETING

SEPTEMBER 15-18, 2019

Inside Geothermal

Global Investment in Geothermal Up 10% in 2018

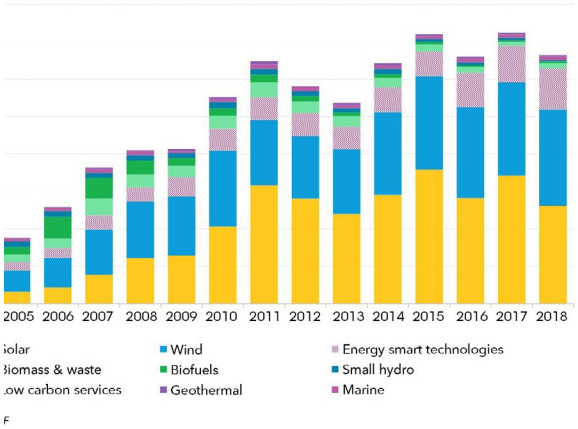
Global clean energy investment totaled **USD 332.1 billion** in 2018, **down 8%** on 2017. However, last year was the fifth in a row in which investment exceeded the USD 300 billion mark, according to authoritative figures from research company **Bloomberg NEF (BNEF).**

Wind investment rose 3% to USD 128.6 billion but overall investment in **solar dropped 24%** to USD 130.8 billion partly due to sharply declining capital costs.

Among other renewable energy sectors, investment in biomass and waste-to-energy rose 18% to USD 6.3 billion, while that in biofuels rallied 47% to USD 3 billion. **Geothermal was up 10% at USD 1.8 billion,** small hydro down 50% at USD 1.7 billion and marine up 16% at USD 180 million.

The U.S. was the second-biggest investing country, at **USD 64.2 billion, up 12%**. According to Bloomberg, developers have been rushing to finance wind and solar projects in order to take advantage of tax credit incentives, before these expire early next decade. There has also been a boom, in both the U.S. and Europe, in the construction of projects benefiting from *Power Purchase Agreement* (PPA)'s signed by big corporations such as **Facebook** and **Google**. *Global Geothermal News.....*

Global new investment in clean energy



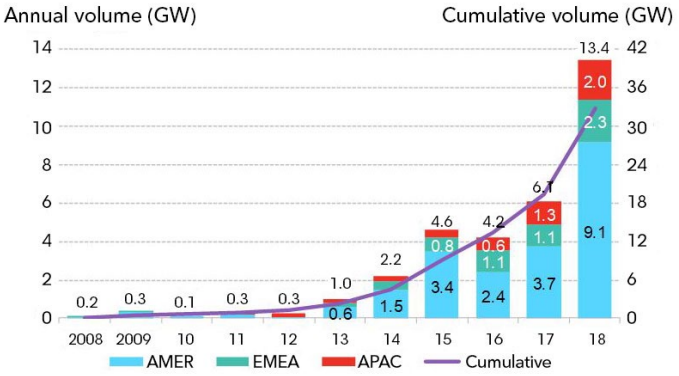
Courtesy Bloomberg

More Private Companies Buying Renewable Energy

BloombergNEF (BNEF) finds in its *1H 2019 Corporate Energy Market Outlook* that **13.4 GW of clean energy contracts were signed by 121 corporations in 21 different countries in 2018.** This was up from 6.1GW in 2017, and positions companies alongside utilities as the biggest buyers of clean energy **globally**.

More than 60% of the global activity in 2018 occurred in the U.S., where companies signed PPAs to purchase 8.5 GW of clean energy, nearly triple the amount signed in 2017. **Facebook** spearheaded a contingent of experienced U.S. corporate energy buyers, purchasing over 2.6 GW of renewables globally in 2018, primarily with utilities in regulated U.S. markets through programs known as green tariffs. This was three times that of the next biggest corporate energy buyer, **AT&T**. *Global Geothermal News.....*

Figure 1: Global corporate PPA volumes



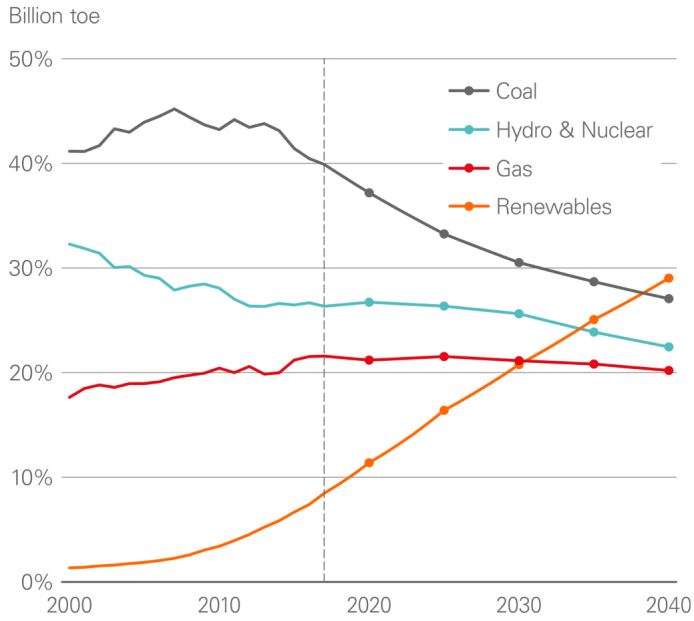
Source: BloombergNEF. Note: Data in this report is through 2018. Onsite PPAs not included. Australia sleeved PPAs are not included. APAC number is an estimate. Pre-market reform Mexico PPAs are not included. These figures are subject to change and may be updated as more information is made available.

Renewables Will Provide Most Power in 2040 - BP Report

The *Energy Outlook* report by Oil & Gas company **BP** explores the forces shaping the global energy transition out to 2040 and the key uncertainties surrounding that transition. It determines that **rising prosperity will drive an increase in global energy demand and that demand** will be met over the coming decades through **a diverse range of supplies including oil, gas, coal and renewables.**

The report states that the mix of fuels in global power generation shifts materially, with **renewables gaining share** at the expense of coal, nuclear and hydro. **The share of natural gas will remain broadly flat at around 20%.**

The report's authors seem to accept that **renewables will account for around two-thirds of the increase in power generation**, with their share in the global power sector increasing to around 30%. In contrast, the share of coal declines significantly, such that by 2040 it is surpassed by renewables as the primary source of energy in the global power sector. *Global Geothermal News.....*



NORTH AMERICA

Bill Would Provide a 30% Investment Tax Credit to Geothermal Projects

The U.S. **Senate Finance Committee** leadership have offered a bill to renew a host of tax breaks that expired at the end of 2017 and 2018, including a long-lapsed tax-break for geothermal energy projects.

The bi-partisan legislation comes from Finance Committee Chairman **Chuck Grassley** (Republican -Iowa) and ranking member **Ron Wyden** (Democrat -Oregon).

According to **Paul Thomsen**, chair of the GRC Policy Committee, the bill would provide a 30% investment tax credit (ITC) to geothermal projects that have commenced construction by December 31, 2019. *Global Geothermal News.....*

FORGE Roadmap

The **Geothermal Technologies Office (GTO)** has announced the release of the Frontier Observatory for Research in Geothermal Energy (FORGE) Roadmap**.**

FORGE is GTO's first-of-its-kind field laboratory located in Utah that is dedicated to research on **enhanced geothermal systems (EGS).** The Roadmap provides recommendations for the critical research that could occur at the FORGE site in **Milford, Utah.** The **Science and Technology Policy Institute (STPI)** developed the Roadmap using GTO funding and in conjunction with the geothermal community.

More information can be found in a special article "*FORGE Ahead - Roadmap Released for DOE's Frontier Observatory for Research in Geothermal Energy*" by **Alexis M.W. McKittrick, Ph.D.**, IDA Science & Technology Policy Institute, on page 36.

In addition, a technical paper from the most recent *Transactions* is included in this issue on page 40: "*The Utah Frontier Observatory for Geothermal Research (FORGE): Results of Recent Drilling and Geoscienti.c Surveys*" by **Joseph Moore**, et al.

U.S. Geothermal Steam Generating Capacity is 3,850 MW

Even though natural gas dominated new electrical generating capacity in 2018, renewable energy sources seem poised to swamp fossil fuels as new generating capacity is added over the next three years, according to data from the **Federal Energy Regulatory Commission (FERC).**

Total Available Installed Generating Capacity

	Installed Capacity (GW)	% of Total Capacity
Coal	265.96	22.23%
Natural Gas	527.69	44.11%
Nuclear	107.98	9.02%
Oil	41.68	3.48%
Water	100.21	8.38%
Wind	94.95	7.94%
Biomass	16.16	1.35%
Geothermal Steam	3.85	0.32%
Solar	35.82	2.99%
Waste Heat	1.36	0.11%
Other*	0.78	0.06%
Total	1,196.42	100.00%

FERC's *Energy Infrastructure Update* report (with data through Dec. 31, 2018) notes that new natural gas generation placed in service in 2018 totaled 20,048 MW, or 64.9% of the total (30,881 MW).

Renewable sources (biomass, geothermal, hydropower, solar and wind) accounted for 10,392 MW, or 33.7%. The balance (1.4%) was provided by nuclear (350 MW), waste heat (51 MW), oil (25 MW), coal (10 MW) and "other" (5 MW).

New geothermal steam generation in 2018 amounted to **an additional 82 MW from 4 units.** Most of this came from **ORNI (Ormat) 41 LLC**'s 61.8 MW **McGinness Hills Geothermal Project** in Lander County, Nevada going online.

The total available **installed geothermal steam generating capacity** is now **3.85 GW** which represents 0.32% of total capacity.

FERC reports that an **additional 943 MW** of geothermal steam capacity **from 19 units** will be **added by 2022**. *Global Geothermal News.....*

U.S. Energy Information Agency Projects Over 8,000 MW Geothermal Energy by 2050

The **U.S. Energy Information Administration (EIA)**'s *Annual Energy Outlook 2019* (AEO2019) provides modeled projections of domestic energy markets through 2050, including cases with different assumptions about macroeconomic growth, world oil prices, and technological progress.

The **AEO2019 Reference case** represents EIA's best assessment of how U.S. and world energy markets will operate through 2050, based on many key assumptions. For instance, the Reference case projection assumes improvement in known energy production, delivery, and consumption technology trends.

The report suggests that **natural gas prices remain comparatively low** based on historical prices during the projection period, leading to increased use of this fuel across end-use sectors and increased liquefied natural gas exports.

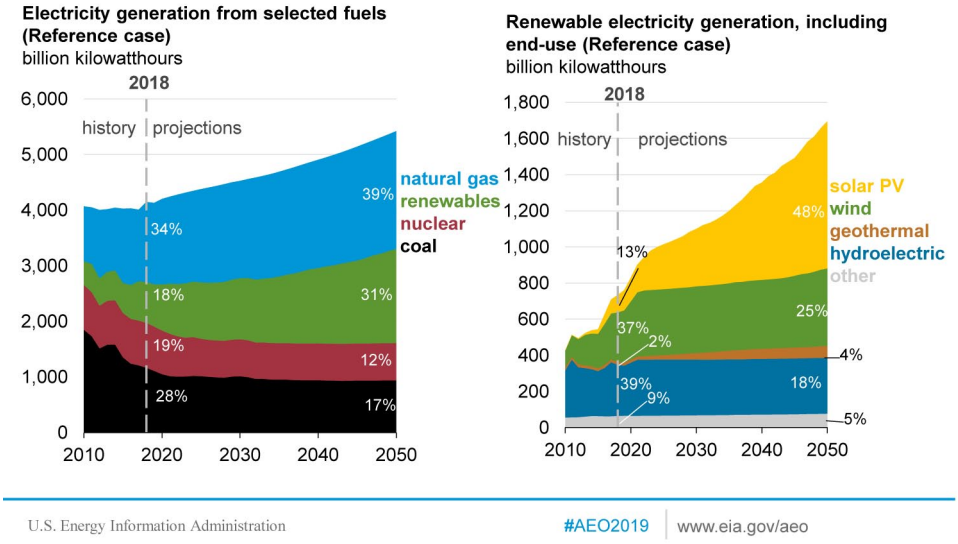
The power sector experiences a notable shift in fuels used to generate electricity, driven in part by historically low natural gas prices. Increased natural gas-fired electricity generation; **larger shares of intermittent renewables**; and additional retirements of less economic coal and nuclear plants occur during the projection period.

In projecting generation from **geothermal energy** the report estimates an average **annual 3.9% increase in capacity from 2018-2050**:

- 2018 - 2.46 GW
- 2019 - 2.49 GW
- 2020 - 2.61 GW
- 2030 - 4.86 GW
- 2040 - 7.29 GW
- 2050 - 8.37 GW

Global Geothermal News.....

Electricity generation from natural gas and renewables increases, and the shares of nuclear and coal generation decrease—



Another Community Choice Aggregator Launches - Opportunity for Geothermal Energy Suppliers

Starting February 2019, **San José Clean Energy (SJCE)** is the city's official electricity provider, bringing homes and businesses cleaner electricity at lower rates than PG&E. Per California law, SJCE will become the default energy generation provider for San José residents and businesses.

Customers will be enrolled in **GreenSource**, SJCE's default power service, that provides **45% renewable energy** from solar, wind and **geothermal** and 35% carbon-free hydropower, and is 80% carbon-free overall. *Global Geothermal News.....*

San Francisco Community Choice Aggregator Contracts for Geothermal Energy from The Geysers

Supporters of **San Francisco**'s renewable energy program **CleanPowerSF** are calling for a "local version of a green new deal" that includes an aggressive build out of local renewable energy projects.

Renewable energy projects and installation of energy efficiencies were long envisioned as part of CleanPowerSF. But the effort has taken longer to materialize than some would hope and now they are worried PG&E's troubles and the bid for a public power system could cause further delays. Those, plans, however, may come into sharper focus next year.

CleanPowerSF officials have reportedly said they have made some investments in renewable energy, including **contracts for geothermal from The Geysers in Sonoma county.** *Global Geothermal News.....*

Non-Hydro Geothermal Power Plant Project Expects to Provide Power by June 2020

GeoGenCo, LLC, of Las Vegas, Nevada, has completed their semi-final designs for their next generation **True Geothermal 20 MW power plant** to be located in **Imperial Valley**, California. GeoGenCo has a 15 MW *Power Purchase Agreement* with **Imperial Irrigation District (IID)** in place and expects to be **providing power by June of 2020.**

GRC Member **Jim McIntosh (Mac)**, GeoGenCo's CEO and COO states, "The project is identified as True Geothermal because all current geothermal projects require substantial amounts of water or steam as part of their power generation process, and are therefore, more appropriately known as hydro-geothermal since water is a mandatory part of the geothermal process (either in the form of brine or steam) for both the extraction of heat and for the disposal of the residual brine."

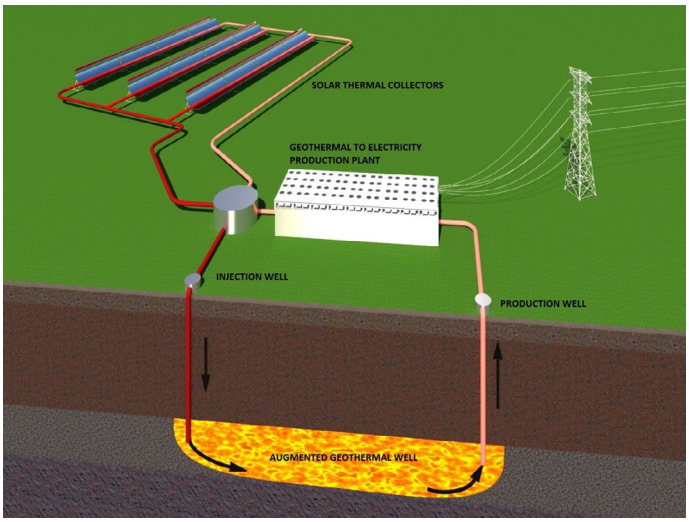
True Geothermal does not utilize any water in their power generation process. Rather than extracting the geothermal fluids, a high-performance heat exchanger is inserted into an existing (but non-performing) geothermal well where **only heat is extracted from the geothermal formation**, not from water, brine or steam. While a permit application for approximately six acre-feet of water has been filed, about one third of this water will be utilized for dust control and the other two thirds reserved for emergency fire-fighting purposes. **Zero water will be utilized for the power generation process.** *Global Geothermal News.....*

Solar Augmented Geothermal Energy Project to Be Tested on Existing Wells in Nevada

Company **UC Won** of **Reno, Nevada,** has announced that it has secured leases on existing geothermal production wells in northern Nevada to begin testing to deploy **RenewGeo** technology.

RenewGeo is the branding for the proprietary process called **Solar Augmented Geothermal Energy**, where solar heat is stored in the ground to create 24/7 sustainable geothermally produced electrical power.

Testing is expected to start during the second quarter of 2019 pending final funding arrangements. *Global Geothermal News.....*



The RenewGeo technology process. Courtesy UC Won.

New Report Documents Significant Benefits of Geothermal Energy Development in Rural Nevada

The Western Way, in partnership with the **Carson Valley Chamber of Commerce**, has released *The Economic Benefits of Nevada Rural Renewable Energy Facilities*. The economic impact study, conducted by **Development Research Partners**, found that 29 rural renewable projects constructed in Nevada from 2006 to 2017 resulted in **significant economic benefits to rural Nevada**.

The study also tested the economic and fiscal benefits of adding new geothermal and solar facilities in Nevada. The model test case was **a new 75 MW-geothermal facility** in Lyon County and a **100 MW solar PV facility** in Nye County.

The report showed the model geothermal project would result in **a total economic output of USD 14.9 million** for construction and **USD 8.9 million** direct and indirect benefits annually. The potential

solar project would yield USD 2.5 million in total economic output and annual operations would generate USD 1.9 million.

The geothermal energy plant would provide almost USD 5.8 Million more in economic benefits than the solar-PV facility. *Global Geothermal News.....*

Table 10: Direct Economic and Fiscal Benefit of Annual Operations of a 75 MW-Geothermal Facility in Lyon County

	Estimated Lyon County
Direct Economic Benefits	
Materials and Equipment	$3,961,100
Lease Payments	$12,100
Wages and Salaries	$2,160,400
Employee Benefits	$925,900
Total Operations Benefits	**$7,059,500**
Employees (FTE)	21
Direct Fiscal Benefits	
Property Tax*	$293,700
Sales and Use Tax	
County Option	$9,900
Basic City-County Relief	$19,500
Total	$29,400
Total Fiscal Benefits	**$323,100**
Total Economic and Fiscal Benefits	**$7,382,600**

**Represents average over first 10 years of operations based on depreciation.*

New Legislation Would Allow More Direct Use of Geothermal Heat from Wells in Idaho

New legislation that would allow a well driller who hits geothermal water in some situations **to use that water for uses other than its heat value** has cleared the House in **Idaho.** The unanimous 68-0 vote sends the legislation to the Senate.

Republican **Terry Gestrin** of Donnelly, in **Valley County, Idaho**, told lawmakers that if a well driller hits water higher than 85°F at the bottom, then the well falls into a geothermal category and must be sealed if not used for its heat.

The legislation would allow the director of the Idaho Department of Water Resources to allow an exemption in some instances. *Global Geothermal News.....*

Power Engineers Wins Engineering Excellence Award for Turkish Geothermal Power Plant

The **American Council of Engineering Companies of Idaho** recently awarded **POWER Engineers Inc.** a first-place *Engineering Excellence Award* for its **Kizildere-3 Geothermal Power Plant** in Turkey.

Owned and operated by **Zorlu Energy**, Kizildere-3, Turkey's largest geothermal power plant at **165 MW capacity**, is one of the world's only **triple-flash plus combined-cycle configuration geothermal plants** — an arrangement that combines two well-known types of technology to increase efficiency. *Global Geothermal News.....*

Kizildere-3 C, by **Matt Fishman**, *POWER Engineers, Inc. 65 MW Kizildere-3 Unit 1 Geothermal Power Plant, Turkey, August 18, 2017. GRC Photo Contest 2017.*

New Mexico Legislation Would Target 100% Carbon-Free Energy by 2045

New Mexico's legislature has set a target of **100% carbon-free energy by 2045** in a new bill. *The Energy Transition Act* (SB 489), sponsored by Democratic Senators **Mimi Stewart** and **Jacob Candelaria** and Representative **Nathan Small**, adds to the *Renewable Portfolio Standards* already on the table.

Gov. Michelle Lujan Grisham championed legislation introduced February 1 that set a timeline for moving the state's electricity supply from coal to solar, wind and **geothermal power** to 50% by 2030 and 80% by 2040. This bill lists those timelines as well, and sets the mark to 100% carbon-free power by 2045. It ranks among the fastest timelines in the nation, tying with California but mandating what that state set as an aspiration.

In 2018 New Mexico generated 9 GWh of geothermal energy from 1.6 MW capacity. *Global Geothermal News.....*

Puna Geothermal Venture Will be Ready for Operation by Year End - Ormat CEO

Ormat Technologies, Inc., the parent company of **Puna Geothermal Venture (PGV)**, has painted a picture of the efforts to resume power production following the eruption of Kīlauea Volcano. **CEO Isaac Angel** gave the update during a conference call on the company's Q4 2018 results.

Mr. Angel commented, "With regards to Puna, work is underway to resume operation of the plant. We have **constructed a new access road** to the power plant, drilled a new fresh water well and **started to open a production well.** Initial tests from the geothermal injection wells indicate **higher temperatures at the reservoir** with **no sign of any negative impact on pressure.** In light of that, we currently estimate that **we will be ready for operation by year end 2019.**

Now, PGV is working on "**removing the plugs from the production wells**", put in place during the eruption to prevent a blowout from lava inundation, and "**mobilizing a large rig to the island to enable drilling additional wells if required**." *Global Geothermal News.....*

Startup Geothermal Energy Developer Aims For Over 10 GW of Renewable Energy Infrastructure Over the Next 30-years

Eden GeoPower Inc. of Massachusetts, USA wants to revolutionize the energy industry by combining renewable energy and **blockchain technology** to develop off-grid geothermal resources. The value created will be in the form of **a security token** built, designed, and distributed by Eden.

The company's goal is to be directly involved with the development of **over 10 GW of renewable energy infrastructure over the next 30-years**. Each geothermal power plant they develop will be capable of producing **up to 50 MW** of geothermal energy, for up to 30 years, and **at a levelized cost of electricity (LCOE) below 5c/kWh.**

In order to avoid transmission costs, Eden GeoPower aims to consume electricity on-site by targeting off-grid power consumers such as **cryptocurrency mining**. Future use cases for the off-grid power-plants will include **hydrogen production** via electrolysis, and powering **off-grid data centers.**

To carry out this development, Eden GeoPower will be financing each of its power plants' capital investment through the digital issuance of a **Special Purpose Vehicle (SPV)**. This digital SPV will take the form of a token which will grant its holder (investor) ownership of a project, as well as recurrent dividends from that project's net earnings. **Eden GeoPower has set up a Title III - Regulation Crowd-funding Campaign and is actively accepting investments.** *Global Geothermal News.....*

Exploration Survey by Drone Carried Out at British Columbia Geothermal Project

Global UAV Technologies Ltd. of **Vancouver, British Columbia** (BC), **Canada**, a diversified and vertically integrated drone technology company, recently completed a drone-based geothermal energy exploration survey for **Borealis GeoPower** Inc. The survey is the first of its kind for Global UAV utilizing both geophysical and thermal imaging sensors at the **Lakelse Geothermal Project** in **Terrace, BC.**

Global UAV's wholly owned subsidiary, **Pioneer Aerial Surveys Ltd.**, collaborated with **Hummingbird Drones Inc.** to collect and analyze high resolution **magnetometer and thermal data** over the 2200 Ha survey area. The survey was conducted using both day and night flight operations to maximize efficiency and data quality. The combination of UAV-MAG™ and drone-based thermal imagery produced high-resolution deliverables on the geological and geothermal features of the survey area for Borealis GeoPower Inc. *Global Geothermal News.....*

(Courtesy Global UAV Technologies Ltd)

Inside Geothermal

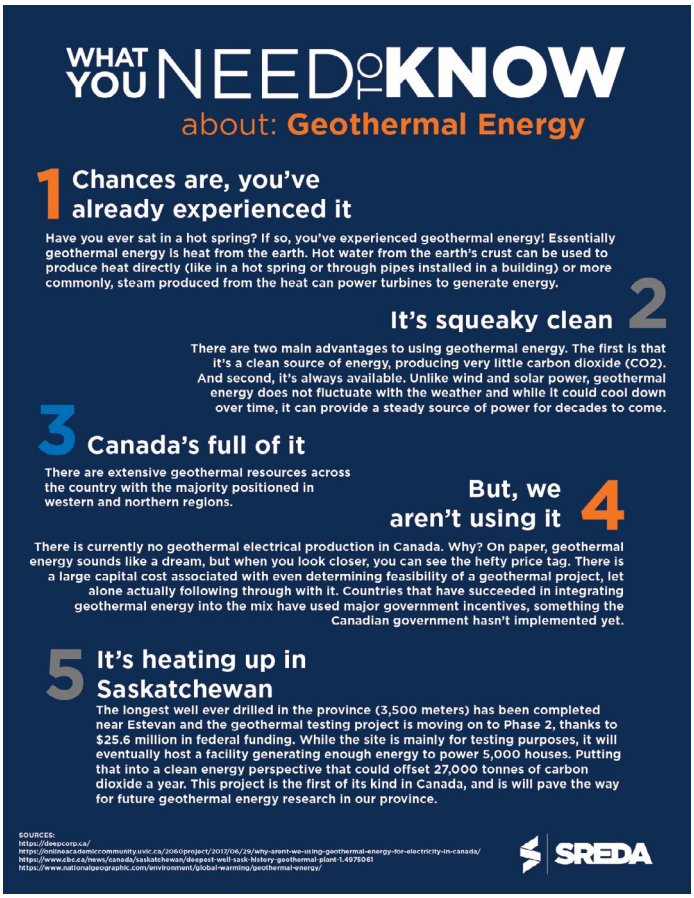
Drilling at 10 MW St. Vincent Geothermal Power Project to Start Soon

St Vincent and the Grenadines Prime Minister **Dr Ralph Gonsalves** has announced that **a drilling rig is on its way** to the eastern Caribbean island and by April 2, over 100 containers of equipment will have arrived.

Drilling for the geothermal power project is expected to begin in April, and by June, the government will have an idea of the full extent and quality of the geothermal resource. *Global Geothermal News.....*

Nice Graphic Boosting Geothermal Energy from Saskatoon Regional Economic Development Authority

To demonstrate their love for the new geothermal power project in their neighborhood, the **Estevan Chamber of Commerce** has produced a great graphic explaining geothermal energy to the folk of Saskatchewan, Canada.



More Funding for Dominica Geothermal Power Project

The island state of **Dominica** says it has held successful negotiations with the **World Bank** on financial assistance for the development of its geothermal sector.

Coordinator of the island's geothermal energy development project, **Ambassador Vince Henderson**, said that a significant amount of the financial package will be in the form of "grant financing."

"What we were essentially negotiating with the World Bank is the **USD 10 million** grant from the **United Kingdom's Department for International Development** which is being administered by the World Bank". *Global Geothermal News.....*

Dominica's energy minister, **Ian Douglas**, stated the geothermal power plant will **begin construction in the third quarter of 2019**. In addition to the World Bank financing mentioned above, some funding was made through Dominica's **Citizenship By Investment (CBI)** program whereby each eligible person that applies to become a citizen of Dominica has to add at least **USD 100,000** to the **Economic Diversification Fund (EDF).** *Global Geothermal News.....*

CENTRAL & SOUTH AMERICA

Costa Rican Geothermal Project to be Completed by Mid-Year

The **55 MW Las Pailas II Geothermal Project** in **Liberia, Guanacaste** Province in north-west **Costa Rica,** is undergoing rigorous testing and on schedule to begin generation and connect to the National Electric System before the middle of the year. *Global Geothermal News.....*

Funds Provided for the Laguna Colorada Geothermal Project

Laguna Colorada geothermal facility (Courtesy ENDE)

The **Central Bank of Bolivia** has transferred **41.9 million Bolivianos** (USD 6 million) to the **National Electricity Company (ENDE)** for the USD 28 million, 5 MW pilot plant at the **100 MW Laguna Colorada geothermal power project.**

In addition, **ENDE** has awarded the contract for the construction of the plant to a joint venture of **Ormat Technologies** and Spanish construction company **Sacyr**. *Global Geothermal News.....*

AUSTRALASIA

MT Survey Reveals a Large, Untapped Geothermal Resource between Rotorua and Taupō

GNS Science geophysicist **Dr Ted Bertrand** has announced the possibility of a large, untapped geothermal resource between **Rotorua** and **Taupō** on the North Island of **New Zealand**.

Bertrand is among a team of three scientists and at least four technicians who have modeled rock types, depths, and temperatures in 366 sites across the Rotorua and Okataina calderas, since 2015, building on previous research started near Taupō in 2009. They used a technique called **magnetotellurics, or MT**, in which sensors and cables are placed on the ground and left for two days.

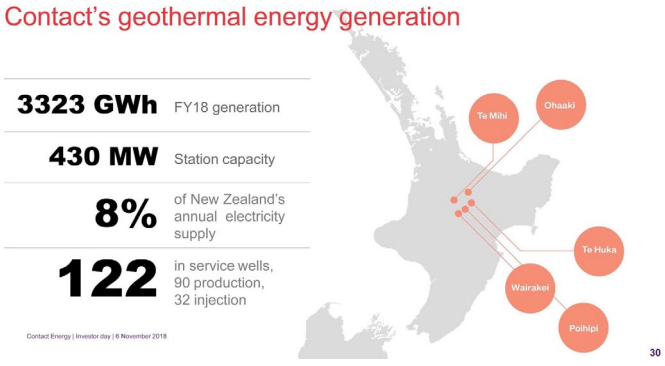
Bertrand said the findings, which have not yet been published, will affect sustainable management of existing geothermal fields, future exploration for new geothermal resources for energy generation, and management of volcanic hazards.

In short, the results show **the association between geothermal and volcanic processes is closer and shallower** than previously thought. *Global Geothermal News.....*

Record Geothermal Energy Generation Helps Contact to Healthy Profit

New Zealand utility **Contact Energy** has posted a net profit of **NZD 276 million** for the six months ended December 2018, well up from NZD 58m a year ago, as reported in the latest half-year profit report. **Much of the increase is due to geothermal energy assets.**

Contact Energy reported record generation of **1,726 GWh from their geothermal power stations,**



11% higher than the prior comparative period, as the company obtained a favorable variation to the **Wairakei** mass take consent and did not repeat the 1H17 planned outage at the **Te Mihi geothermal power station.** *Global Geothermal News.....*

Geothermal Powered Milk Plant on North Island to Open Soon

New Zealand's second Māori-owned dairy plant project is on track to start producing in July. Located at the foot of **Pūtauaki**, a volcanic cone in the **Te Moana o Toi** region of the North Island, the plant will be **powered by a nearby geothermal power facility.**

The plant will be developed on land owned by the **Putauaki Trust** with its principal energy supply sourced from the **Ngati Tuwharetoa Geothermal Assets**-owned geothermal network. Export grade products like organic whole milk powder, milk protein concentrates and butter will be produced at the plant. *Global Geothermal News.....*

Kawerau industrial site (Courtesy Ngati Tuwharetoa Geothermal Assets)

ASIA

Icelandic Company to Help Establish Geothermal Power Plants in China

Reykjavík-based **Arctic Green Energy** and the **Beijing Research Institute of Uranium Geology (BRIUG)** have signed a *Memorandum of Understanding* on cooperation in the field of geothermal exploration and utilization.

The cooperation will be focused on high-temperature geothermal fields in China with the goal of **developing electric power generation projects**. *Global Geothermal News.....*

Filipino Geothermal Energy Companies Join Forces

Two geothermal energy developers in the Philippines have confirmed consolidation

AC Energy, Inc. has taken control of **Phinma Energy Corp.** through a "mutually strategic agreement" that gives the Ayala-led company a 51.48% stake in the listed energy firm for P3.42 billion.

Phinma Energy holds interests in **Phinma Power Generation Corp.** (100%); **Phinma Renewable Energy Corp.** (100%); and **Maibarara Geothermal, Inc.** (25%).

In early 2017, AC Energy and its partners acquired **Chevron's geothermal assets** and operations in Indonesia through **Star Energy Geothermal (**Salak-Darajat) B.V. *Global Geothermal News.....*

In addition, the **Asian Development Bank (ADB)** has invested **USD 20 million** in AC Energy's maiden **climate bond** issuance.

ADB is an anchor investor in the **10-year tranche**, contributing to a total issue volume of **USD 410 million.** Proceeds of the bonds will finance renewable energy projects in the Asia and Pacific region, including Vietnam, the Philippines, and Indonesia.

AC Energy, a wholly-owned subsidiary of Ayala Corporation in the Philippines, has a target of 5 GW of attributable renewable energy capacity by 2025 across the region. *Global Geothermal News.....*

Kalinga Geothermal Power Project Certified as Energy Project of National Significance

The Philippines **Department of Energy (DOE)** has certified the **120 MW Kalinga geothermal power project** of **Aragorn Power and Energy Corp. (APEC)** as an energy project of national significance (EPNS).

Location of Kalinga in North Luzon.

The issuance of EPNS certificates is stipulated under Executive Order 30, which states that concerned government agencies shall **act upon applications for permits not exceeding within a 30-day period.** If no decision is made within the specified processing timeframe, the application is deemed approved by the concerned agency. *Global Geothermal News.....*

In addition, the DOE has allowed APEC to **conduct a grid impact** study for the Kalinga geothermal power project located in **Pasil, Kalinga** province.

APEC and partner **Guidance Management Corp.** estimate the geothermal resource to have a total power generation potential of between 120 MW and 200 MW. *Global Geothermal News.....*

Aboitiz to Supply Geothermal Power to Local Business

Aboitiz Power Corp. has secured a deal with The **Net Group (TNG)** to supply seven office buildings in **Bonifacio Global City** in the Philippines, with **13.5 MW of geothermal energy.**

The power supply will be sourced from **Aboitiz Power**'s geothermal plants under the subsidiary **AP Renewables Inc. (APRI)**, which has facilities in **Tiwi, Albay; Bay** and **Calauan, Laguna**; and **Sto. Tomas, Batangas** province. *Global Geothermal News.....*

Aboitiz Power Corp. has also announced plans to supply electricity **to a planned iron and steel plant** in **Misamis Oriental** province. *Global Geothermal News.....*

Maibarara Geothermal Plants Given Certificate of Compliance for Operation Until 2023

The **Philippines Energy Regulatory Commission** (ERC) has renewed **Maibarara**

Geothermal, Inc.'s (MGI) *certificate of compliance* (COC) to operate its two geothermal facilities in Sto. Tomas town, **Batangas** province.

Developer **PetroEnergy Resources Corp.** identified the facilities as the **20 MW Maibarara-1** and **12 MW Maibarara-2.**

MGI is a joint venture between PetroEnergy renewable-energy unit **PetroGreen Energy Corp.** (65%), **PHINMA Energy Corp.** (25%) and state-owned **PNOC Renewables Corp.** (10%). *Global Geothermal News.....*

Green Climate Fund Approves USD 100 Million Finance for Geothermal Development in Indonesia

The **Green Climate Fund (GCF)** Board has approved the first tranche of **USD 100 million** out of the USD 185 million requested, to finance public and private sector geothermal development in Indonesia.

These funds will help facilitate a total multi-year support facility of **USD 410 million** with contributions from the **World Bank**, the **Government of Indonesia** and private sector developers. The project aims to develop **an additional 600 MW to 900 MW of geothermal capacity.** *Global Geothermal News.....*

Consortium Formed to Develop Geothermal Energy on Flores Island

A consortium of Indonesian, Icelandic, Turkish and Italian companies has been formed to develop geothermal power projects on the Indonesian island of Flores.

The **Eastern Indonesia Geothermal Consortium** includes **North Tech Energy** (Iceland), **Turboden SpA** (Italy) and **SATE Ltd** (Turkey). *Global Geothermal News.....*

Malaysian Geothermal Power Project Approval Revoked - Appeal Fails

Tawau Green Energy Sdn Bhd (TGE) has failed in its appeal against the Malaysian government's decison to revoke its feed-in approval for a 37 MW geothermal power project in **Tawau**.

TGE said it had received requisite approvals to develop the geothermal power plant at **Apas Kiri**. However, at the end of last year, the Energy, Green Technology, Science, Climate Change and Environment Minister **Yeo Bee Yin** scrapped the project due to the firm's failure to carry out the project. *Global Geothermal News.....*

AFRICA

USD 250 Million For Renewable Energy Projects Across Sub-Saharan Africa

The Board of Directors of the **African Development Bank Group (AfDB)** has approved an equity investment of up to USD 25 million in **ARCH Africa Renewable Power Fund (ARPF)**, a private equity fund for renewable energy projects across Sub-Saharan Africa.

ARPF will provide equity for the development and construction of 10 to 15 greenfield renewable energy projects in Sub-Saharan Africa, **adding approximately 533 MW** of installed energy generation capacity from renewable sources in the region. This will provide both **baseload** and peak load power in underserved markets.

ARPF projects will focus on mature technologies including **geothermal**. These would include grid-connected independent power producers, and decentralized energy projects. The Fund's strategy is to prioritize projects with a clear timeline to financial close, with emphasis on de-risking early stage greenfield projects. *Global Geothermal News.....*

AFRICAN DEVELOPMENT BANK GROUP

Drilling Services Awarded for Aluto Langano Geothermal Expansion Project

State utility firm **Ethiopian Electric Power (EEP)** has signed an agreement with two Chinese firms and **Kenya Electricity Generating Company (KenGen)** for drilling services at **the 70 MW Aluto Langano geothermal expansion project.**

The two Chinese firms are part of the **Shandong Kerui Oilfield Service Group.** The agreement is to supply drilling materials and drilling services for an initial 22 wells. *Global Geothermal News.....*

Additional Geothermal Energy Could be Partly Funded by Green Bond - KenGen CEO

Kenya's state-owned power producer, **KenGen**, has announced plans to raise funds from the market later this year and it may opt to issue **the country's first green bond**.

Rebecca Miano, KenGen's CEO, said the company would go to the market once it redeems its 10-year, 25 billion shillings (USD 250 million) bond in October. The bond was heavily oversubscribed when it was issued in 2009.

"Our geothermal-led strategy is bearing fruit," she said, adding the company was developing capacity for an **extra 720 MW in the next four years to 2022**. *Global Geothermal News.....*

Naivasha Flower Grower Uses Geothermal Heat to Win International Accolade

Naivasha based **Oserian Development Company Limited** has won the top prize in the cut flower & bulbs category at this year's **International Grower of the Year** awards held in Germany.

The company utilizes the "**world's largest geothermal heating project**" for maintaining a constant temperature in its greenhouses and for injecting vast amounts of carbon dioxide (CO2) needed to stimulate healthy, strong plant growth. *Global Geothermal News.....*

New Power Line Distributes Cheap Geothermal Power from Olkaria

Kenya Power will construct an 85-kilometre power line between **Narok** and **Bomet** to connect western Kenya to cheap power produced at the **Olkaria geothermal fields.**

Kenya Power said the Bomet line would complete a redundancy ring and ensure that western Kenya has access to more stable power. Currently, power utilities rely on costly thermal power plants and imports from Uganda to power the region.

Kenya Power General Manager in charge of Infrastructure Development and Network Management **David Mwaniki** said there was a **lot of cheap power at Olkaria**, but the company could not transmit it to western Kenya due to lack of infrastructure. *Global Geothermal News.....*

Drilling to Resume at 70 MW Akiira One Geothermal Project

Centum Investment Company Plc and its partners plan to resume exploration for the **70 MW Akiira One Geothermal Project** in **Naivasha** by March after drilling two uncommercial wells.

The **Akiira Geothermal Ltd** consortium reports that the first two wells, started in 2015, encountered insufficient steam pressure to support power generation.

Centum chief executive **James Mworia** said: "We are in advanced discussions with strategic partners to do a joint development of the field and we expect to conclude that in the first quarter and to carry on with the drilling activities."

"The field is rich in geothermal. It's just next to KenGen's Olkaria field. So, I have no doubt it's going to be a successful operation. It's just that it has taken us a long time," he added. *Global Geothermal News.....*

Construction of Quantum Menengai Geothermal Power Plant to Begin Soon

Geothermal Development Company (GDC) General Manager for Resource Development **Cornel Ofwona** said **Quantum East Africa Power Limited** - one of the three independent power producers (IPPs) at the **Menengai** field - has secured funding from the **African Development Bank** allowing the project to move forward.

"We expect Quantum to **start construction** of their 50 MW power plant either in **March or April this year**," Ofwona said. *Global Geothermal News.....*

Tanzanian Government Helps Fund 200 MW Geothermal Power Project

The government of Tanzania has set aside **USD 8.7 million** in the 2018/ 2019 fiscal year for the **Lake Ngozi geothermal project** in Mbeya region, to help offset the projected **total cost of USD 821 million.**

Beatus Segeja, the chairman of the **Tanzania Geothermal Development Company (TGDC),** said the government was collaborating with the country's electric supply company to oversee the construction.

Location of the Lake Ngozi geothermal project in south-western Tanzania.

The first geothermal project in the country is **expected to produce 200 MW** of power from geothermal energy resources **by 2025**. Eventually, the resource is expected to produce up to 600 MW.

According to Mr. Segeja, the **resource temperature is not less than 230°C** with a **chloride concentration of PPM 1450**. TGDC will **drill three wells** at the Lake Ngozi site. *Global Geothermal News.....*

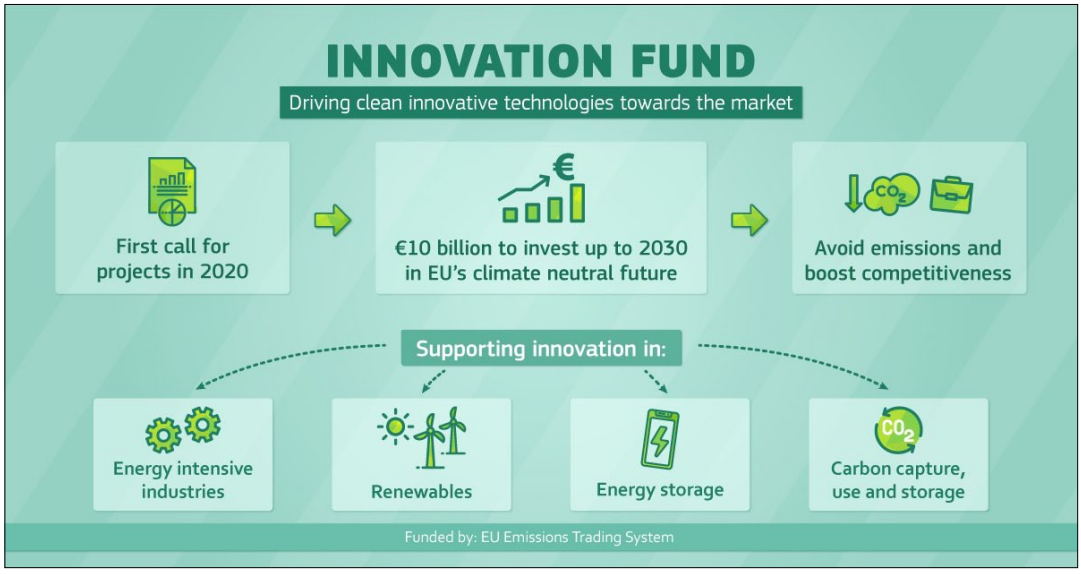
EUROPE

EU Announces Innovation Fund for Low-Carbon Technologies

The **European Commission** has announced an investment program worth over **EUR 10 billion** to boost the global competitiveness of low-carbon technologies in several sectors.

The Commission aims to launch the **first call for proposals** under **the Innovation Fund in 2020**, followed by regular calls until 2030.

The Innovation Fund will pool together resources amounting to around EUR 10 billion, depending on the carbon price. At least 450 million allowances from the **EU Emissions Trading System (EU ETS)** Directive will be sold on the carbon market in the period 2020-2030. The revenues of these sales **depend on the carbon price**, which is currently around EUR 20. *Global Geothermal News.....*



Swiss Company Wins Ruggero Bertani European Geothermal Innovation Award

The **European Geothermal Energy Council (EGEC)** has announced that The **Ruggero Bertani European Geothermal Innovation Award 2019** has been awarded to the Swiss company **Jansen AG**, for their **Jansen HIPRESS borehole heat exchanger**, a novel technology for applications in depths of 300+ meters that allows for exploitation of high temperatures at greater depths so improving the efficiency of the heat pump.

The other four final candidates were:

- **Climeon** (Sweden), for the Fludaorka geothermal plant, Iceland, where a HeatPower module of 2x2x2 m and 150 kW can produce electricity from low temperature geothermal resources (80–130°C).
- **Geofluid** (France), for their anti-corrosion well concept implemented at the district heating grid of Bonneuil-sur-Marne, France.
- **GPC Instrumentation Process** (France), for the validation of the sub-horizontal doublet and reservoir evaluation concept at the district heating system in Cachan, Paris.
- **Turboden** (Italy), for the first 5 stages large axial ORC turbine, as installed on the Velika Ciglena geothermal power plant, Croatia.

Global Geothermal News.....

New Partnership to Develop Geoscience and Geothermal Energy in Europe

Pole AVENIA and 6 out of its 7 partners in the Geo-Energy Europe project have signed a *Partnership Agreement* in Dublin to formalize the creation of the **Geo-Energy Europe** metacluster and sustain its life beyond the end of the ongoing project timeframe (2018-2019).

Inside Geothermal

The Geo-Energy Europe metacluster is an open and voluntary alliance of complementary innovation cluster organizations or equivalent business network organizations from across Europe, involved in geoscience, geo-energy and/or geothermal energy that are committed to working together on a common vision.

That vision is to gather and brand most key players in the field of sustainable geo-energy in Europe under a common "Geo-Energy Europe" banner, and represent European know-how & technologies in this field in world markets, with a focus on the skills and services offered by its Small & Medium Enterprises (SMEs). *Global Geothermal News.....*

Drilling the Deepest Ever Hole in Finland

USA company **Numa**, a leading drilling technology provider, has achieved great success in **Otaniemi, Espoo, Finland** by drilling to **15,092 feet (4,600 meters)** - the deepest hole ever drilled in Finland.

It is estimated the resulting **geothermal heat plant will produce up to 40 MWth** and supply up to 10% of Espoo's heating demand.

The geothermal project utilized multi-stage, telescopic drilling methods to reach the desired depths.

The first stage used Numa's **Patriot 185 hammer** and 26" (660 mm) retained bits with **PCD carbide** to drill down to 900 feet (274 meters).

The second stage used a 17.638" (448 mm) PCD bit to drill down to 9,600 feet (2,900 meters) where the hole was cemented.

The third stage used a Numa **Patriot 125 hammer** specially fitted with fully retained PCD drill bits to ensure strict hole diameter was maintained throughout drilling. Bit sizes from 12" to 12.500" (305 to 318 mm) were used in stage three until a depth of 15,092 feet (4,600 meters) was achieved. *Global Geothermal News.....*

Geothermal Included in Next UK Contract for Difference Auction for Renewable Energy Projects

The UK government has set **May 29, 2019** as the prospective start date for the country's third **contract for difference (CfD) auction** for renewable energy projects with **a proposed cap of 6 GW**.

The **Department for Business, Energy and Industrial Strategy (BEIS)** said the planned **CfD3** round will be open to all so-called Pot 2 less-established technologies such as advanced conversion technologies, anaerobic digestion (AD) of over 5 MW, biomass and combined heat and power (CHP), offshore wind, **geothermal**, remote island wind above 5 MW, tidal and wave power. **All projects have to be delivered in 2023-2024** and **2024-2025.** *Global Geothermal News.....*

First Well at United Downs Deep Geothermal Power Project to be Production Well

Geothermal Engineering Ltd has provided an update on the **United Downs deep geothermal project** in Cornwall, England:

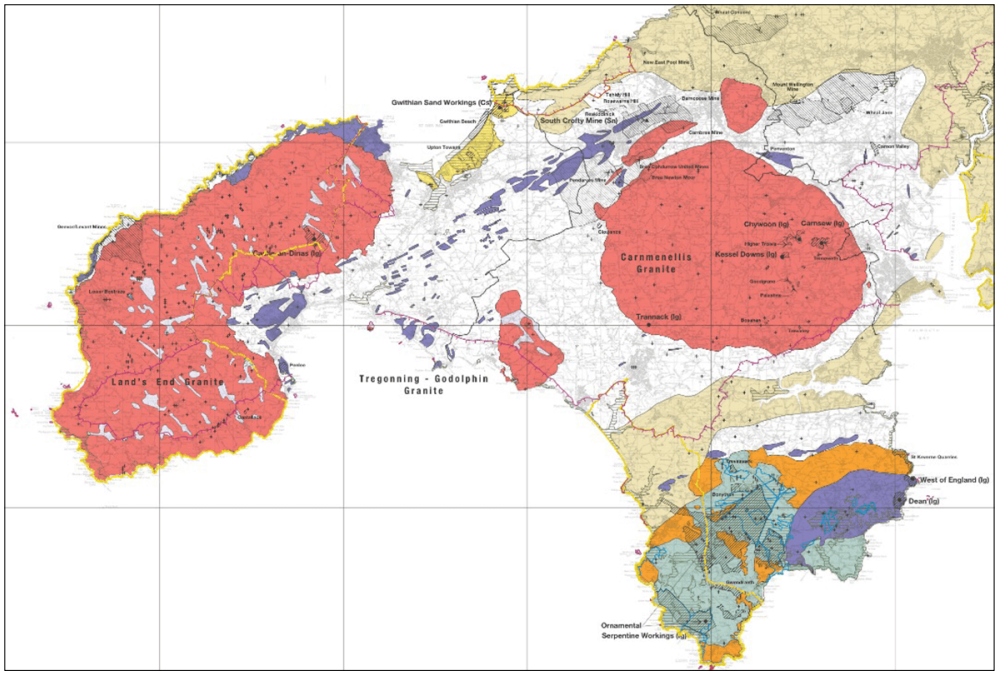
"As of 28th February, drilling continues on **UD-1**. The well was kicked-off (steered) at 3,390 meters and has built up to a **5 degree inclination**. The depth of drilling is now 3,492 meters and today we are tripping out to change the drill bit (121/4"). On the 2nd February at 6.45am, UD-1 became the deepest onshore hole in Cornwall

Having reviewed the drilling performance to date, and the geological information from cuttings, we have decided that **the first well will now be the production well.** This is the more important well of the two as it will provide crucial information about the geology and temperature at our target depth, and it is imperative that we complete it as soon as possible.

We will continue drilling UD-1 at a diameter of 12¼" to a depth of about 4,000m and then run the last of the three casing strings. Then we will finish the hole at a diameter of 8½" before running geophysical logs and carrying out a short period of testing. This should be completed **by the end of March, after which we will skid the rig and begin drilling UD-2.**" *Global Geothermal News.....*

More Funding for Project to Explore for Lithium from Geothermal Brine in Cornwall

Cornish Lithium Ltd. has announced that it has successfully raised a further **GBP 1 million** from its existing investors allowing the company to **continue its exploration for lithium resources in Cornwall.**



Colored in red, the granites of Cornwall are a possible source of geothermal energy and lithium. (Courtesy British Geological Survey)

The company intends to drill extraction boreholes targeting permeable geological features which host the lithium-enriched brines. These brines are believed to be derived from the interaction of geothermal waters with lithium-enriched granite deep beneath Cornwall.

Jeremy Wrathall, chief executive of Cornish Lithium, has stated that extraction of lithium is very clean and environmentally friendly, while **also offering the prospect of generating power through geothermal energy.** *Global Geothermal News.....*

Bath Abbey Geothermal Heating Project Gets Underway

The Roman Baths with Bath Abbey in the background. Photo by **Ian Crawford** *(2017)*

Work to install geothermal heating in **Bath Abbey, in Somerset, England**, using hot water from the city's **Roman baths** has begun.

Every day, 1.1 million liters (250,000 gallons) of hot water flow through the Roman baths from the thermal spring located at the heart of the site. A large quantity of this hot water eventually ends up in the River Avon via the great Roman drain.

When harnessed and converted, the abbey says it could potentially produce **1.5 MWth** of continuous energy to support a **200 kW ground-source heat pump** system. *Global Geothermal News.....*

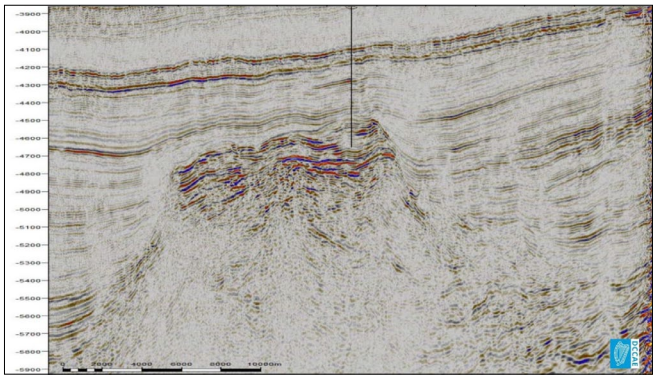
Irish Offshore Basin "a Potentially Significant Geothermal Resource"

In the January/February GRC *Bulletin* we reported on the discovery of a possible new geothermal resource off the south-west coast of Ireland. The reservoir has been located 3,000 meters below the sea bed in a geological feature called the **Porcupine Basin.**

John O'Sullivan, Technical Director at **Providence Resources PLC**, an Irish based oil and gas exploration company, has provided more insight on the find:

"**The reservoir is both massive and porous** with the potential to contain in excess of one trillion litres of 'boiling' water and therefore comprises **a potentially significant geothermal resource.**

The Lower Cretaceous **Dunquin North** carbonate build-up lies buried c. 3,000 metres beneath the seabed in c. 1,600 metres water depth and is c. 170 km off the SW coast of Ireland. This feature comprises the **remnants of a tropical coral island atoll** which existed in the Porcupine Basin some c. 100 million years ago.



Imagery of the Dunquin North carbonate build-up (Courtesy Providence Resources PLC)

Climate Change associated with the Late Cretaceous green-house climatic crisis caused global sea-level rise which quickly buried this feature leaving it 'frozen in time'.

Today Dunquin North hosts **a vast high pressure hot water reservoir system**. Drilling results from the recent **44/23-1 well** in 2013 confirmed reservoir temperatures of c. **250°F (c. 120°C)** in c. 800 atmospheres of pressure (c. 11,000 psi).

Harnessing the potential of Dunquin North poses great challenges for scientists, engineers and policy makers but surely that's what any great endeavour takes." *Global Geothermal News.....*

More Geothermal District Heating Projects in the Netherlands

A geothermal district heating project has been announced for the town of **Zwolle**, the capital of **Overijssel** province in northeastern **Netherlands**.

A feasibility study was completed in December, reporting that such a project was technically, organizationally and economically possible. A location should be chosen by the end of the year along with a design of the network. If everything runs smoothly, **the first heat supply from the geothermal source is expected at the earliest in 2022 or 2023.** *Global Geothermal News.....*

In addition, waste and energy company **HVC** has gotten permission to search for geothermal resources in the so-called **IJmond** municipalities of **Beverwijk**, **Heemskerk** and **Velsen** in the province of **North-Holland**. *Global Geothermal News.....*

Also, farmers from the **Noukoop-Balijade** region and the municipality of **Pijnacker-Nootdorp** (near The Hague) have signed an agreement of intent to improve the geothermal supply to the existing heating network of **Ypenburg, the greenhouse horticulture area of Noukoop -Balijade** and to investigate supplying other urban areas in Nootdorp. *Global Geothermal News.....*

New Geothermal District Heating Project in Berlin Suburbs

The local utility in **Potsdam**, a suburb of **Berlin** in Germany, is researching the use of geothermal energy for heating purposes. **Energie und Wasser Potsdam (EWP)** wants to explore the possibilities of deep geothermal energy at several locations in the city. **A pilot project** that could heat 750 apartments **could be completed by 2022**. *Global Geothermal News.....*

Good Progress at Munich Geothermal District Heating Project

Munich's publicly-owned utility company, **Stadtwerke München**, has completed the drilling of **a second well** for the city's geothermal heating plant.

The completed well reached a depth of **3,044 meters** and tapped into an unexpectedly high temperature resource.

"At **108°C, the temperature is significantly higher than expected**," said Stadtwerke München's Technical Director **Helge-Uve Braun**.

Braun is certain that the site on the River Isar will ultimately play host to the "most powerful and largest geothermal plant in Germany". It was estimated that the plant could deliver **up to 50 MW of thermal energy**. *Global Geothermal News.....*

Ducks at the Schäftlarnstraße Drill Site in Munich, Germany, by David Lentsch. Photo taken on 23rd May 2018. The site is located next to the River Isar and often receives feathered visitors. GRC Photo Contest 2018

Geysir Europe Increases Share in Landau Geothermal Power Plant

Geysir Europe GmbH, a subsidiary of **Daldrup & Söhne AG**, has increased its stake in the operating company **geox GmbH**. Geysir Europe GmbH now holds 100% of the shares in the operating company of the **Landau geothermal power plant,** located in the **southern Rhineland**-Palatinate in western **Germany**. At group level, Daldrup & Söhne AG now holds 75.01% (previously 67.51%) of the power plant. *Global Geothermal News.....*

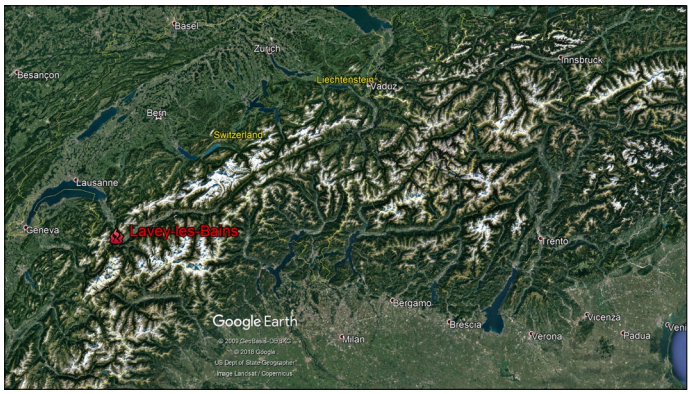
Suburban Basel Geothermal District Heating Plant to be Expanded

A geothermal district heating network in the **Basel** suburb of **Riehen** in northern **Switzerland**, which has been warming the homes of 7,700 inhabitants since 1994, is to be expanded with the addition of **a new borehole to a depth of 2,000 meters.** This will provide geothermal energy for **another 4,000 inhabitants**. *Global Geothermal News.....*

Swiss Geothermal Energy Project to Break Ground This Year

The **Lavey deep geothermal project** was publicly announced in January by the municipalities of **Lavey-Morcles** in the canton of Vaud, and **St-Maurice** in the canton of Valais. Construction is scheduled **to begin by the end of the year. CSD Engineers** is leading the project for the **AGEPP SA consortium.**

The project will make optimum use of the potential of the country's largest known hydrothermal resource to supply electricity and heat to 900 households as well as to the famous spa in **Lavey-les-Bains**. *Global Geothermal News.....*



Location of Lavey-les-Bains is south-western Switzerland

City in Northern Romania to Explore for Geothermal Resources

The National Agency for Mineral Resources (ANMR) in **Romania** has granted **Oradea**, a city in the north-western of the country, an exploration license to search for a geothermal source for the city's heat requirements, the first local administration in the country to own such a permit. *Global Geothermal News.....*

Denizli Geothermal Power Plant to Provide Heat for Greenhouses

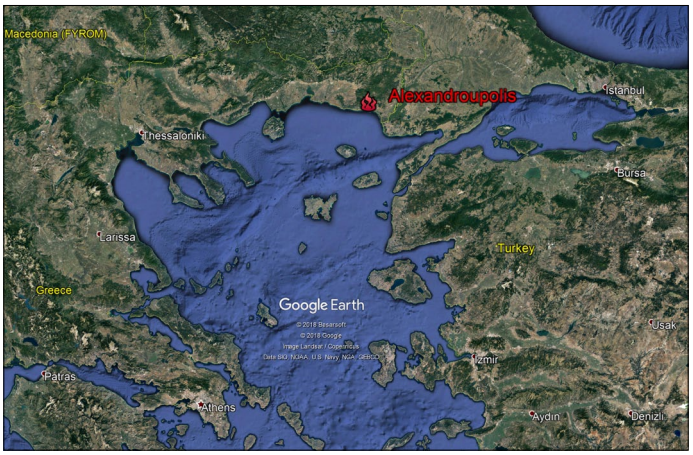
Ali Kindap, head of the the **Turkish Geothermal Power Plant Investors Association (JESDER)** has announced that 165 hectares of greenhouse fields will be built in **Manisa, Aydin** and **Denizli** in western Turkey, heated by the waste water from **Zorlu Energy**'s geothermal power plant in **Saraykoy, Denizli.** *Global Geothermal News.....*

New Geothermal Resource Exploration in Western Turkey

Aytemiz Electricity Production Inc. has announced it will search for geothermal resources in 4 locations in **Salihli, Manisa Province** in the Aegean region of Turkey. *Global Geothermal News.....*

Greek Geothermal District Heating Project Launches

A geothermal district heating project in the far north-east of Greece has been launched. Located in the Traianoupolis neighborhood of **Alexandroupolis**, near the border with Turkey, the system will heat public buildings and boost production of agricultural crops in greenhouses, a first for the country. *Global Geothermal News.....*



Location of Alexandroupolis in Thrace, Greece.

SCIENCE & TECHNOLOGY

Using Titanium to Control Excessive Corrosion in Extreme Geothermal Conditions

According to **NACE International** (National Association of Corrosion Engineers) members **W.D. MacDonald** and **J.S. Grauman** with **Titanium Metals Corp.** (Exton, Pennsylvania, USA), tapping the energy potential in high-power geothermal wells can be restricted by the ability to specify materials that will withstand the extreme environmental conditions.

Geothermal brine reservoirs typically pose severe corrosion problems for operators—due to the combination of steam, water, and brine at elevated temperatures; the presence of **hydrogen sulfide (H_2S), carbon dioxide (CO_2)** and high chloride content—yet these resources can also yield high-enthalpy steam that produces higher power outputs, so they have become **very desirable fields to develop.**

Since the early 1990s, titanium has been used in the **Salton Sea KGRA** (Southern California) to control the excessive corrosion experienced in production wells. Early corrosion testing in the geothermal brine, however, showed that **unalloyed titanium was prone to localized attack** under the most severe conditions in these brines.

TABLE 1. SIMULATED GEOTHERMAL BRINE COMPOSITION

Temperature	Phase	Component	Amount	Duration
304 °C	Gas	CO_2	205 psi_a	30 days
		H_2S	16.6 psi_a	
		N_2	15.9 psi_a	
		Water vapor	776.4 psi_a	
	Liquid	NaCl	4 molar (233.8 g/L)	
		KCl	0.45 molar (33.5 g/L)	
		$CaCl_2 \cdot 4H_2O$	20,000 ppm Ca^{2+} (73.4 g/L)	
		$MnCl_2 \cdot 4H_2O$	2,000 ppm Mn^{2+} (7.2 g/L)	
		$FeCl_2 \cdot 4H_2O$	2,000 ppm Fe^{2+} (7.1 g/L)	
		$NaHCO_3$	3.01 g/L	
		Total Cl^-	198,270 ppm Cl^-	
		pH	5.51 @ RT 4.41 at 580 °F predicted	

A thermodynamic modeling software package was used to predict the concentrations of H2S and CO2 required to achieve the target partial pressures and pH at the test temperature (304°C).

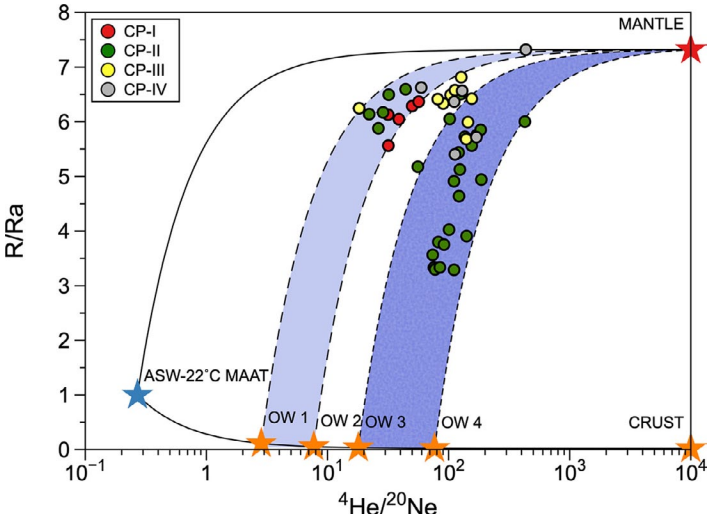
According to MacDonald and Grauman, **titanium's resistance to hot reducing chloride environments** makes it an appropriate material for use in geothermal service, and they foresee the continued use of titanium as the Salton Sea KGRA is further utilized as a geothermal energy source.

Future use of titanium also could possibly be seen in l**ow-chloride geothermal steam** and water service where corrosion occurs from condensed acid or non-condensable acid gases.

Titanium is also being considered and tested for use in more typical steam generating wells where **HCl condensation** has proven to be a corrosion issue, as well as in **enhanced geothermal systems (EGS)** where recirculated water from surface-injected fluid becomes increasingly more corrosive over time. *Global Geothermal News.....*

New Research Suggests Cerro Prieto Geothermal Field is a Fossil System

A recent study of the **Cerro Prieto Geothermal Field** in Baja California, Mexico suggests that the reservoir is a fossil system. By surveying the emission of noble gases, water stable isotopes, and chlorine and bromine contents, the researchers found the following:

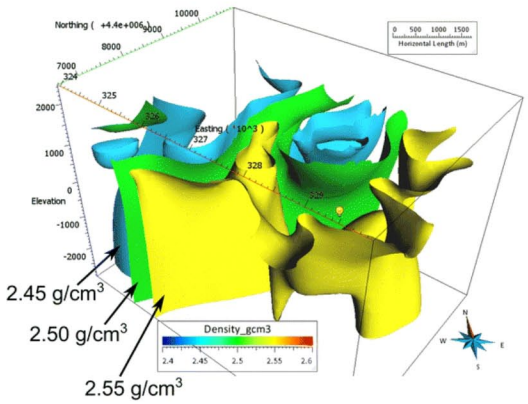


He/ Ne versus He/ He ratios (R/Ra) showing that Cerro Prieto fluids are mixtures of connate waters and magmatic fluids, with little modern recharge.

- $^3He/^4He$ indicates magmatic and old sedimentary fluids, with little recharge.
- Cl, Br, and U-Th/He fluid ages suggest that old fluids are connate seawater.
- Stable isotopes and halogens indicate a third old groundwater from shallower aquifers.
- Active modern recharge is limited, indicating Cerro Prieto is a fossil geothermal system.

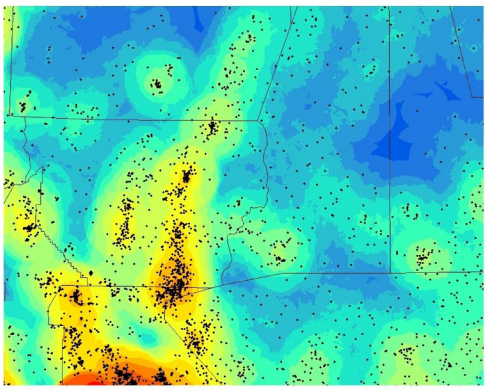
Global Geothermal News.....

National Geothermal Academy 2019



nga

National Geothermal Academy
University of Nevada, Reno



Geoscience focused geothermal training

GEOL 457/657: Module 1: Geothermal Geostatistics

10-14th June 2019 (Monday to Friday, 8:00 - 5:00pm)

Instructors: Dr. Cary Lindsey and Dr. Whitney Trainor-Guitton

GEOL 457/657: Module 2: Geothermal Geophysics

17-21st June 2019 (Monday to Friday, 8:00 - 5:00pm)

Instructors: Dr. Joe Batir, Dr. David Blackwell, Karen Christopherson and Dr. Jeff Witter

- Open to outstanding undergraduate and graduate students, and professionals. International applicants welcomed.
- Each module offered to students for 2 academic credits at either the graduate or undergraduate level.
- All classes to be held at the University of Nevada, Reno, Redfield Campus.

- Course cost: **USD$1000 per module**
- Student applications due by **May 24th 2019**
- Professional applications due by **June 3rd 2019**

For course outlines and application forms, see: https://gbcge.org/education/
or email geothermal@unr.edu

GREAT BASIN CENTER FOR Geothermal Energy

U.S. DEPARTMENT OF ENERGY

University of Nevada, Reno

Cerro Prieto Geothermal Field (Baja California, Mexico) – A fossil system? Insights from a noble gas study, by Daniele L. Pinti, et al. Journal of Volcanology and Geothermal Research, https://doi.org/10.1016/j.jvolgeores.2018.12.010

EDUCATION

GRC Announces Scholarships

Total of $14,000 in educational awards to be given to eight students in the global geothermal energy community

The Geothermal Resources Council (GRC) is pleased to announce the availability of the **2019** GRC Scholarship Awards.

To qualify for any of these awards a student **must be a GRC member** (student memberships are only $20 per year). Selection of recipients will be based upon a variety of factors, including the individual's academic record, student activities, geothermal industry experience, and career goals.

The following awards are available:

- **Five (5) Marcelo Lippmann Graduate Scholarship Awards of $2500** – to be eligible for one of these awards, the candidate must be enrolled in a graduate-level program at an accredited academic institution at the time of the award (Fall 2019). If selected, each recipient is required to submit a paper on his/her research (or research progress) to be published in the GRC *Transactions* and deliver results at the meeting as either a poster or oral presentation. If the recipient presents in the year of the award then the full $2500 is awarded at that time; if the recipient defers to present/publish the following year then $750 is withheld until the following year when the recipient presents.
- **Three (3) GRC Undergraduate Scholarship Awards of $500** – to be eligible for one of these awards, the candidate must be a third or fourth year undergraduate at an accredited academic institution at the time of the award (Fall 2019).

Applications must be received by May 24, 2019 to be considered.

For application instructions and other details see the announcement on the GRC website at: www.geothermal.org/students.html

Please direct questions regarding the scholarship awards to: **Brian Schmidt**, bschmidt@geothermal.org or 530-758-2360, ext. 104

United Nations University Geothermal Training Programme Fellowships Announced

The United Nations University Geothermal Training Programme (UNU-GTP) has announced 6 Fellowships for MSc and PhD studies in Iceland. The awardees are offered a **UNU-GTP fellowship** to start their studies in late July/August 2019:

MSc Fellowship:

- **Birhan Abera Kebede**, Ethiopia, in Geothermal Geology
- **Yerko Figueroa Penarrieta**, Bolivia, in Chemistry of Thermal Fluids
- **John Joseph Lubuva**, Tanzania, Sustainable Energy Engineering
- **Patrick Muanza Kant**, D.R. Congo, in Geothermal Geology
- **Idil Souleiman Bouraleh**, Djibouti, Chemistry of Thermal Fluids

PhD Fellowship:

- **Makoye Mabula Didas**, Tanzania, in Geophysical Exploration

Global Geothermal News.....

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/. ■

FORGE Ahead - Roadmap Released for DOE's Frontier Observatory for Research in Geothermal Energy

by Alexis M.W. McKittrick, Ph.D., IDA Science & Technology Policy Institute

FRONTIER OBSERVATORY FOR RESEARCH IN GEOTHERMAL ENERGY: A ROADMAP

IDA SCIENCE AND TECHNOLOGY POLICY INSTITUTE

Author's Note: This article is a summary of key aspects of the FORGE Roadmap, developed and published by the IDA Science and Technology Policy Institute. The complete roadmap document can be found at https://www.ida.org/idamedia/Corporate/Files/Publications/STPIPubs/2019/D-10474.pdf.

FORGE Background

The Frontier Observatory for Research in Geothermal Energy (FORGE) is a Department of Energy (DOE) effort to accelerate research and development (R&D) within the field of Enhanced Geothermal Systems (EGS) over the next 5 years at the a field site near Milford, Utah, operated by a team led by the University of Utah. FORGE's mission is to enable cutting-edge research, drilling, and technology testing, underpinned by a comprehensive instrumentation and characterization effort and open data policy. Through this project, DOE endeavors to facilitate and spur transformative EGS research across the domestic and international geothermal community, with FORGE at the center, culminating in a set of rigorous and reproducible EGS technical solutions and a commercial pathway to successful EGS development.

The desired outcomes of the FORGE initiative are to:

- Allow the subsurface research community to develop, test, and improve new EGS technologies
- Gain fundamental understanding of key mechanisms controlling fracture generation, fluid flow, heat transfer, and sustainability of EGS reservoirs
- Enable rapid dissemination of technical data to the research community, developers, and other stakeholders
- Enable a pathway towards a rigorous and reproducible EGS development approach
- Reduce uncertainty and risk for industry

More information on the FORGE initiative, including previous phases of development and competition, can be found at https://www.energy.gov/eere/forge/. The 5-year implementation phase of the FORGE initiative will run from approximately mid-2019 to mid-2024. The research recommendations in this roadmap cover this 5-year implementation phase of FORGE at the Utah site.

Scope and Purpose of FORGE Roadmap

DOE's Geothermal Technologies Office (GTO) tasked the IDA Science and Technology Policy Institute (STPI) to research, design, and develop a roadmap for the FORGE initiative. The objective of this roadmap is to provide technical research recommendations to DOE GTO, FORGE's Science and Technology Analysis Team (STAT), and the broader research community for the 5 years of FORGE's operation as an EGS research site operated by the Utah FORGE team at the Milford, Utah site. While the roadmap's components are focused primarily on FORGE's 5-year timeline and are appropriate for the geology of the FORGE test site, these activities will also contribute to the knowledge and understanding of how to build future large-scale, economically sustainable EGS systems beyond the FORGE site.

This roadmap is intended for an audience knowledgeable about geothermal technology and research, and EGS topics specifically. The roadmap focuses on describing high-priority research that can advance EGS technology development at FORGE. Non-technical challenges related to EGS commercialization, such as economic, social, and regulatory barriers are not included in the scope of the roadmap.

Roadmap Development Methods

STPI used several methods to generate the data and information needed to inform the FORGE Roadmap. This information collection focused on the following:

- The current state of EGS research, including recent successes, failures, and developments;
- The remaining technical challenges and research needs of the field, including unmet needs related to tools, data collection methods, specific data or information, modeling and predictive algorithms, and techniques for drilling and measurement; and
- How these needs and challenges could be addressed by research at the FORGE site, including furthering research in specific areas of EGS and special considerations for the FORGE site in Milford, Utah.

To ensure meaningful and relevant information was gathered on the topics above, STPI created an elicitation strategy that included stakeholder groups with subject matter expertise. This strategy was executed in stages (shown in Figure 1) that built off each other, so outputs from one stage could be used to inform the next stage. There were also reflective processing steps in between each stage to ensure the strategy was on-track towards procuring the data and information needed for roadmap development. The elicitation steps included:

1. Conducting a literature review of relevant EGS strategic planning documents and EGS technology review documents;
2. Holding a series of semi-structured, topical interviews with staff from DOE GTO;
3. Holding a series of semi-structured, topical interviews with a diverse selection of members of the EGS research community; and
4. Organizing and convening a facilitated workshop hosted by STPI in August 2018 that included EGS subject-matter experts from the research community.

The technical information derived from the elicitation process was provided to DOE GTO, which reviewed the research activities and identified those that represented core research to accomplish the objectives of FORGE. DOE GTO also determined which activities represented other supporting or enabling research. Clear focus areas emerged from DOE's review of the research activities generated by the elicitation process, and those critical research areas are used to frame the FORGE research recommendations included in this roadmap. STPI then conducted a peer review of the roadmap prior to publication.

Figure 1: STPI's step-by-step methodology for developing this roadmap

Key FORGE Roadmap Components

The FORGE Roadmap describes discrete actions that could be carried out at FORGE to overcome key technical challenges necessary for EGS to be reliable and reproducible. These actions are organized in the roadmap in three sections: critical research areas, enabling R&D, and implementation principles. Each section supports the research described in the previous section(s). See Figure 2 for a visual representation of the components of the roadmap.

The critical research areas represent the recommended primary foci of research in the FORGE Roadmap. They are:

- **Stimulation planning and design:** research that supports efforts to design and optimally stimulate a well in accordance with natural subsurface characteristics
- **Fracture control:** research that supports efforts to develop an optimal fracture network as well as increase understanding of the resulting fracture systems
- **Reservoir management:** research that supports efforts to sustain the long-term heat exchange in the system

Within each of these critical research areas, the roadmap describes 1) core research actions that are essential in furthering EGS development and 2) additional research that could play a supportive role in furthering EGS development. Core research actions aim to address ongoing technical challenges where there is no known technical solution in the current EGS research landscape or research that must be successfully addressed for FORGE to show progress towards a set of technical solutions that will enable a rigorous and reproducible EGS methodology (Figure 2). Core R&D actions are considered the highest priority research actions within this roadmap and are emphasized over the supporting R&D actions and other roadmap components.

In addition to the three critical research areas that are the central objective of this FORGE Roadmap, the roadmap contains a section titled "Enabling R&D," which describes additional research areas that would facilitate the translation of FORGE's research and results to other sites and contribute to increased EGS efficiency. While these areas are high impact research needs, the underlying tools and techniques are already more technologically advanced than those of the critical research areas and are therefore not central to this roadmap's research priorities for FORGE. The Enabling R&D areas include subsurface characterization, drilling, well completions, and induced seismicity management.

While the roadmap focuses on recommending specific research actions that could be conducted at FORGE, it also recommends implementation principles that were emphasized by the research community as critical to the success of FORGE research endeavors. These principles provide an implementation framework for conducting and managing research at FORGE to facilitate advancement in the critical research areas. They include cross-cutting research recommendations that should underlie the technical foundations of all research conducted at FORGE as well as broad operational considerations for the management of the FORGE facility that are born from lessons learned in previous EGS research efforts. ■

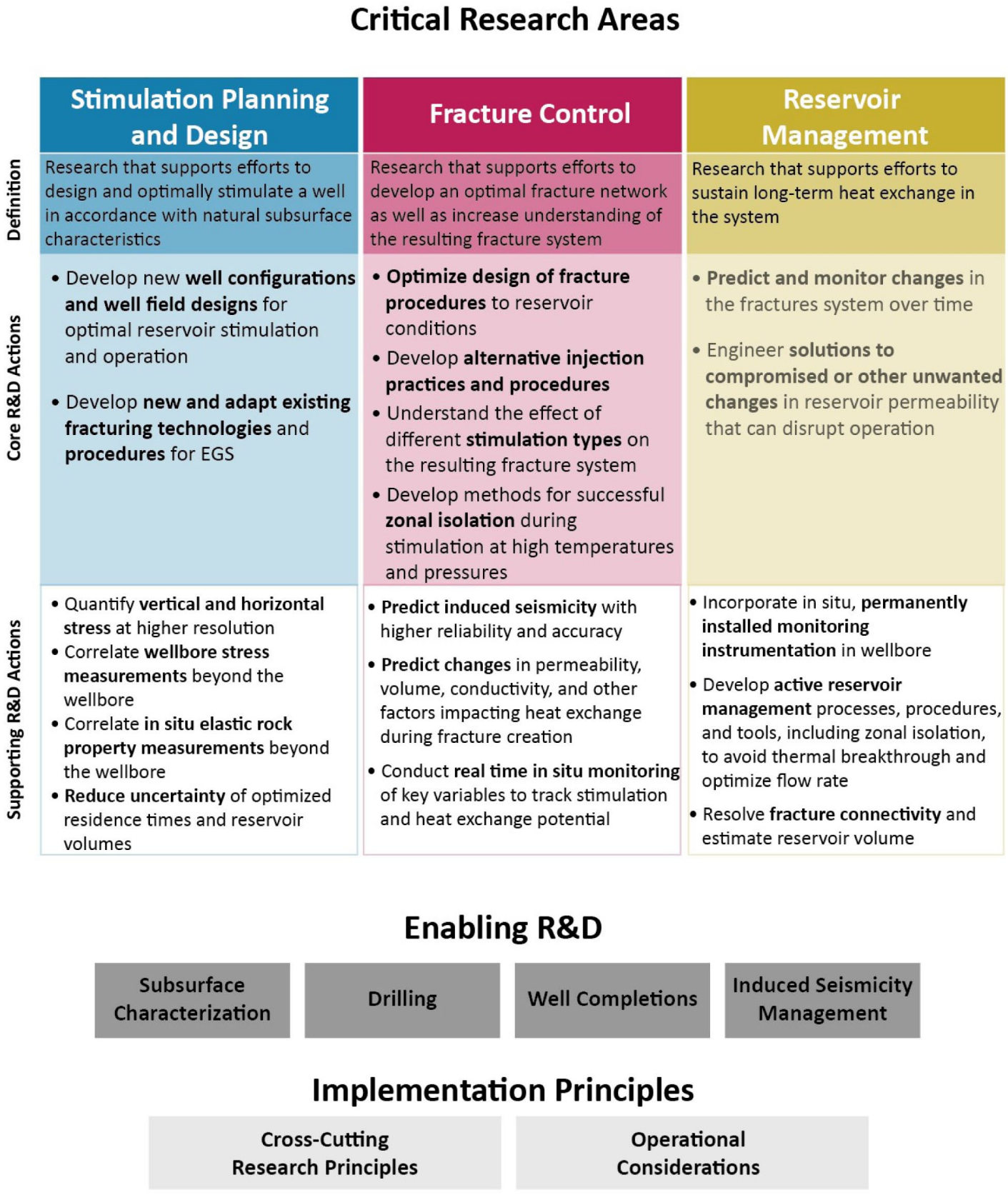


Figure 2: Visual summary of the key components of the FORGE Roadmap, including the Critical Research Areas, the areas of Enabling R&D, and the categories of Implementation Principles.

Over the next few pages we re-publish one of the most note-worthy technical papers on the Utah FORGE Project, from last years GRC Annual Meeting.

As part of an ongoing series of articles, we present the Technical Papers associated with the best presentations made at the last GRC Annual Meeting. This paper is from the session on FORGE Research.

The Utah Frontier Observatory for Geothermal Research (FORGE): Results of Recent Drilling and Geoscientific Surveys

Joseph Moore[1], John McLennan[1], Rick Allis[2], Kristine Pankow[3], Stuart Simmons[1], Robert Podgorney[4], Philip Wannamaker[1], William Rickard[5]
[1]Energy and Geoscience Institute, University of Utah, Salt Lake City, Utah
[2]Utah Geological Survey, Salt Lake City, Utah
[3]University of Utah Seismograph Stations, University of Utah, UT 84112
[4]Idaho National Laboratory, Idaho Falls, Idaho
[5]Geothermal Research Group, Palm Desert, California
jmoore@egi.utah.edu

Keywords
- FORGE
- Milford
- Utah
- Enhanced Geothermal Systems

The U.S. Department of Energy's FORGE (Frontier Observatory for Research in Geothermal Energy) initiative will make Enhanced Geothermal System (EGS) development viable and cost effective by creating a controlled environment where EGS technologies can be developed and tested.

The Utah FORGE site is located in central Utah, 350 km south of Salt Lake City. The region has been extensively explored in support of geothermal development at Roosevelt Hot Springs. Since the 1970s, more than 100 wells, the deepest to 3.8 km, have been drilled in the vicinity of the site. Well 58-32 was drilled to a depth of 2296 m (7536 ft) on the FORGE site in 2017 to characterize the underlying reservoir rocks. Additional supporting data was provided by new geologic mapping and 3-D seismic reflection, gravity, hydrologic and soil gas surveys. The well encountered a bottom hole temperature of 197°C in Tertiary granitic rocks. Although the well encountered more than 2000 natural fractures, measured permeabilities are low, less than 30 microdarcies. Induced fractures indicate the maximum horizontal stress trends NNE-SSW. Stress gradients based on analysis of microhydraulic and Diagnostic Fracture Injection Tests range from 0.58 – 0.63 psi/ft for σ_{Hmin} and 0.68 - 0.82 psi/ft for σ_{Hmax}. A gradient of 1.13 psi/ft was calculated for σ_V. Enhancement and growth of the induced fractures are clearly apparent when pre- and post-injection Formation Microscanner Image logs are compared. These changes demonstrate the suitability of the FORGE reservoir rocks for Enhanced Geothermal System development.

1. Introduction

Enhanced Geothermal Systems (EGS) offer the potential to bring low-cost geothermal energy to locations that lack natural permeability. Since the late 1970's, close to a dozen EGS demonstration projects have been conducted. The results have been disappointing and none of the projects have achieved large-scale commercial levels of production. The goal of the U.S. Department

of Energy's Frontier Observatory for Research in Geothermal Energy (FORGE) program is to develop the techniques required for creating, sustaining and monitoring EGS reservoirs for commercial development.

The FORGE program consists of three phases. Phase 1 involved desktop studies of existing data at five sites. At the conclusion of Phase 1 two sites were selected; the Milford, Utah site and the Fallon, Nevada site. During Phase 2, well 58-32 was drilled into the granitic reservoir beneath the Utah FORGE site to obtain direct measurements on the temperature, rock type, permeability, and stress within the FORGE reservoir. Compliance with the National Environmental Policy Act (NEPA) was demonstrated and an Induced Seismic Mitigation Plan was prepared. The ultimate goal of the FORGE project is to demonstrate to the public, stakeholders and the energy industry that EGS technologies have the potential to contribute significantly to future power generation.

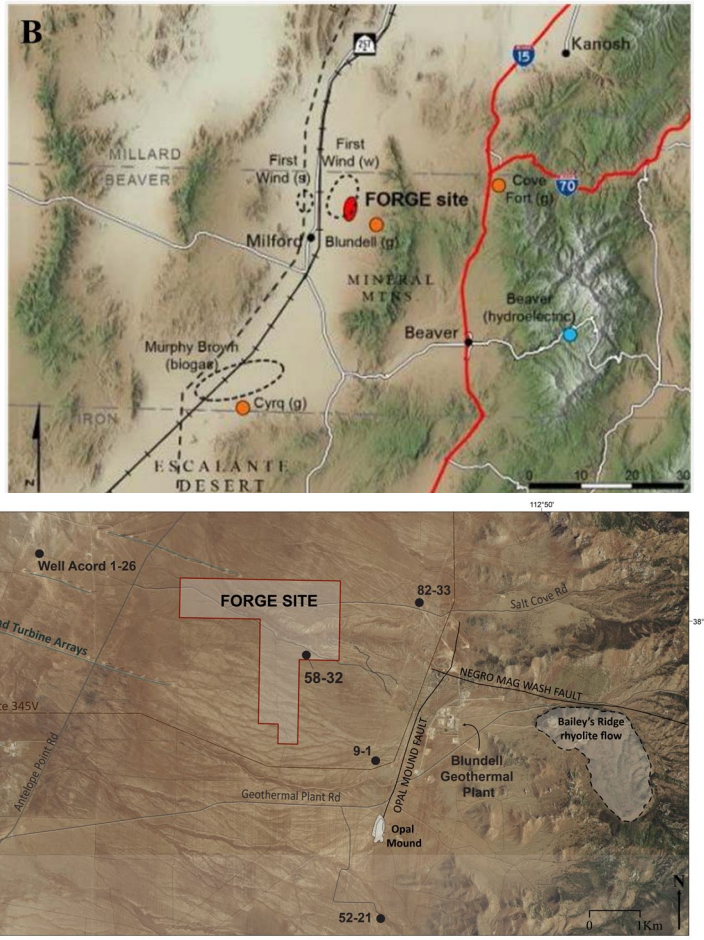
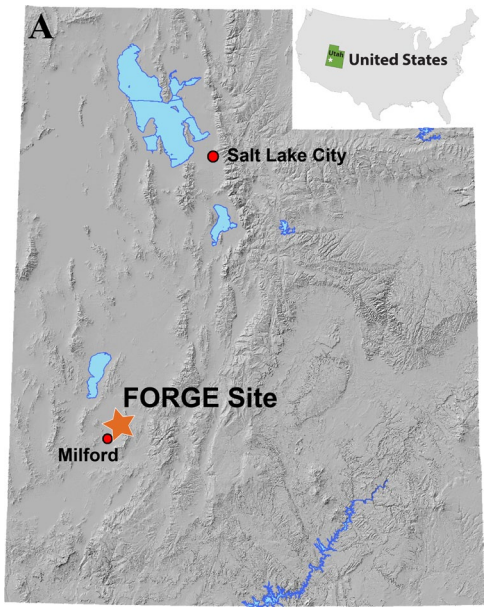


Figure 1. A) Location of the FORGE site. B) Distribution of renewable energy projects within Utah's Renewable Energy Corridor. The town of Milford is centrally located within the corridor, 16 km south of the FORGE site. C) Location of the FORGE site, key wells and energy projects. The Blundell power plant and production wells are located east of the Opal Mound fault. Milford.

2. The Utah FORGE Site

The Utah FORGE site is located 350 km south of Salt Lake City and 16 km north of Milford, a small community with a population of 1400 (Figure 1). The FORGE site is unpopulated and covers an area of about 5 km^2. It is situated within Utah's Renewable Energy Corridor adjacent to a 306 MWe wind farm, a 240 MWe solar field and PacifiCorp Energy's 38 MWe Blundell geothermal plant at Roosevelt Hot Springs. Cyrq Energy's 10.5 MWe geothermal field at Thermo and a biogas facility currently producing 1.5 MWe are located approximately the same distance south of Milford.



Considerable supporting infrastructure exists near the site. Milford has motel accommodations, a supermarket, hardware store, and a hospital. Beaver, a larger population center, is located 56 km from Milford adjacent to I-15, a major interstate. The Union Pacific Railroad passes through Milford, offering the possibility of shipping heavy equipment by rail and then by truck to the FORGE site. The Milford Municipal Airport, located a few kilometers north of Milford, has a 1524 m long sealed runway that can accommodate piston or turboprop, single- or twin-engine planes.

The area around the FORGE site has been the focus of numerous geoscientific studies over the last 40 years, starting with intensive geothermal exploration during the late 1970s. More than 80 shallow (<500 m) and 20 deep (>500 m) wells were drilled and logged, providing a very complete picture of the thermal structure of the region (Figure 2). The deepest well, Acord-1, reached a

depth of 3.8 km (Welsh, 1980). In support of the FORGE project, new geological mapping, 2 and 3-D seismic reflection, gravity and geochemical surveys were conducted, and well 58-32 was drilled, logged and tested (Allis et al., 2018; Gwynn at al., 2018; Hardwick et al., 2018; Jones et al., 2018; Kirby et al., 2018a, b; Miller et al., 2018). The well reached a depth of 2296 m (7536 ft) and a bottom hole temperature of 197°C.

3. Geology

The FORGE site is located on the gently sloping alluvial plane west of the Mineral Mountains. The geology of the central Mineral Mountains east of the site is dominated by a composite Tertiary pluton composed of diorite, granodiorite, quartz monzonite, syenite, and granite (Nielson et al., 1986) (Figure 2). Paleozoic and Mesozoic sedimentary sequences are exposed in the northern and southern parts of the Mineral Mountains. These sedimentary rocks are major components of the regional stratigraphy but were not encountered in any of the deep wells.

U-Pb zircon dating indicates development of the plutonic complex began with the intrusion of hornblende diorite at 25.4 Ma (Aleinikoff et al., 1987), followed by the emplacement of younger plutonic rocks at ~18 Ma and 11 to 8 Ma (Nielson et al., 1986; Coleman and Walker, 1992; Walker et al., 1997). Precambrian gneiss, with a metamorphic age of ~1720 Ma (Aleinikoff et al., 1987), forms a narrow belt on the west side of the range. Both the Tertiary and Precambrian rocks are partially covered by Quaternary (<1 My) rhyolite lava flows originating from domes along the crest of the range. Temperatures of 250°C in the Roosevelt Hot Springs reservoir suggest the presence of a still cooling magma chamber in the shallow crust.

Well 58-32 was drilled to a depth of 2296 m (7536 ft) on the eastern side of the FORGE site (Figure 3). Chip samples were collected at 3 m intervals and a complete suite of geophysical and image logs were run from the 9 5/8 inch casing shoe at 662 m (2172 ft) to the base of the well. The well penetrated 1323 m of plutonic rocks.

Based on thin section and X-ray diffraction analyses, plagioclase, K-feldspar, and quartz are the dominant minerals within the plutonic rocks (Jones et al., 2018). These minerals are accompanied by minor amounts of biotite, hornblende, clinopyroxene, apatite, titanite, zircon, and magnetite-ilmenite. The minerals are intergrown and commonly coarse grained, forming a strong low porosity reservoir, dominated by granite, quartz monzonite and monzonite. Illite and chlorite are the major clay minerals, but they constitute <5% of the rock. Trace amounts of other secondary minerals include carbonate and anhydrite. Fractures in the cored intervals (2073-2076 m and 2268-2271 m) are locally lined with chlorite or epidote. These hydrothermal minerals are products of paleo-hydrothermal activity; there is no evidence of modern hydrothermal fluid flow.

Acord-1 is the only deep well west of the FORGE site and the only well to penetrate deep into the basin fill of Milford Valley (Figure 2). The well encountered nearly 3.1 km (10,175 ft) of basin

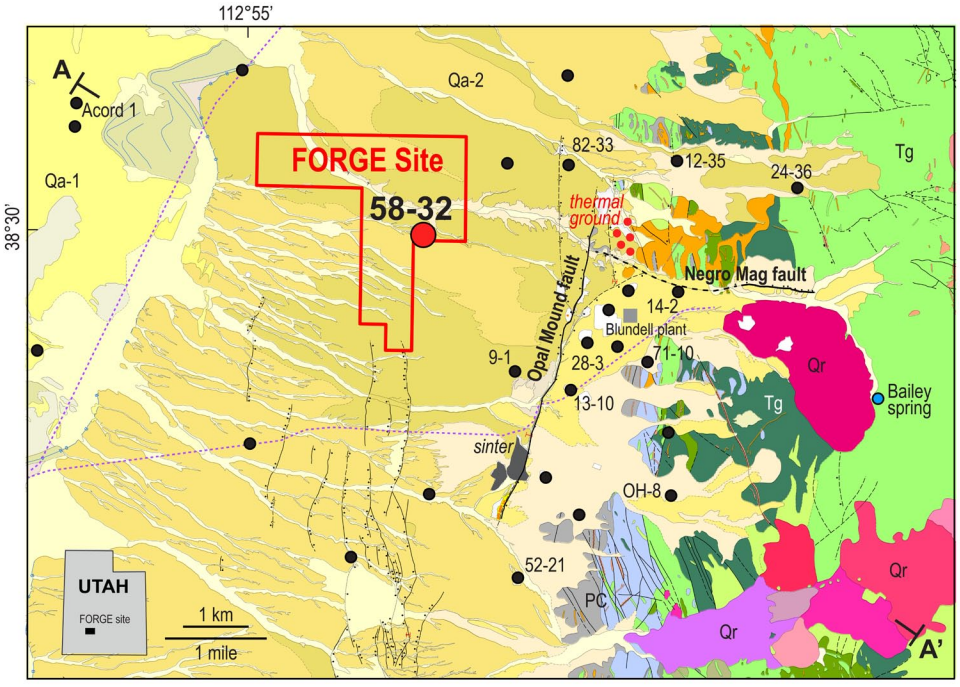


Figure 2. Geologic map of the FORGE site and surrounding area (modified from Nielson et al. 1986 and Kirby et al., 2018), For clarity, only a few of the many wells are shown. See Figure 3 for cross section A-A'. Abbreviations: Qa-1=Lake Bonneville silts and sands; Qa-2=alluvial fan deposits; Qr=Quaternary rhyolite lava and pyroclastic deposits; Tg=Tertiary granitoid; PC=Precambrian gneiss; black filled circles=wells. Arrows show the direction of σ_{Hmax}. Stress data from 52-21 and 14-2 compiled by Davatzes (2016, written comm.)

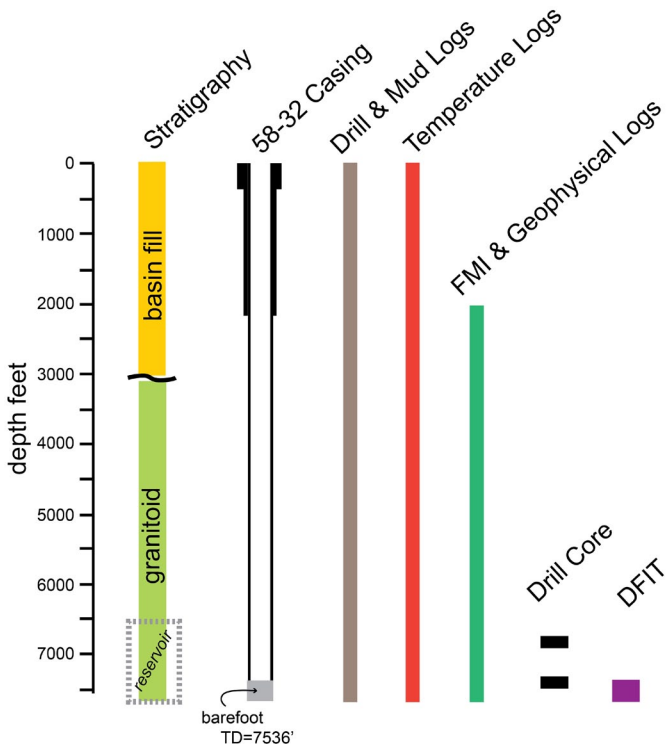


Figure 3. Summary of major activities conducted in well 58-32. A Schlumberger Formation Microscanner Image log, Dipole Sonic Shear Imager log, Isolation Scanner (CBL), Compensated Neutron log, Caliper log, Compressional and Shear Sonic log, Induction log, Triple Combo log (Gamma Ray, Induction, and Neutron Porosity log), and a SlimXtreme Sonic log (CBL) were run in the hole from 662 m to total depth.

fill above the crystalline basement rocks. Poorly consolidated lacustrine and evaporite deposits characterize the basin sequence above about 1310 m (4298 ft) per Jones et al. (2018). At greater depths, Tertiary(?) tuffaceous and volcaniclastic deposits, interbedded with minor ash-flow tuffs and andesite lava flows characterize the stratigraphy. Well 58-32 encountered only 968 m (3176 ft) of undeformed, and poorly sorted alluvial deposits derived from the plutonic rocks in the Mineral Mountains. Few fractures cut these alluvial deposits, which dip to the west at 30° or less. No evidence of volcanic deposits like those found in Acord-1 were observed.

The structural setting of the FORGE site reflects the effects of two distinct tectonic events; late Mesozoic to early Cenozoic compression during the Sevier orogeny and middle Tertiary to Recent extension. The Sevier orogeny produced large-scale low-angle thrust faults found in the surrounding mountain ranges (e.g., Hintze and Davis, 2003), but the effects of this orogeny near the FORGE site are poorly understood.

The younger faulting episode is related to ongoing east-west Basin and Range extension, which dates back to at least ~17 Ma. This extension has produced predominantly north-south trending fault zones throughout the Basin and Range (e.g., Hintze and Davis, 2003; Dickinson, 2006).

Within the FORGE area, the earliest of these structures is represented by the contact between the basin fill and underlying plutonic rocks. In contrast to the steeply dipping range front faults characteristic of the Basin and Range Province, the contact between the granite and valley fill deposits dips approximately 20° to the west (Hardwick et al., 2016; Allis and Miller, 2017, unpub. data) (Figure 4). This contact is marked by an intensely sheared rhyolite, possibly a dike emplaced prior to the formation of the detachment surface. Professor John Bartley (University of Utah, pers. comm. 2017) interprets the alluvial basement contact as a rotated and eroded Basin and Range fault. The contact can be imaged across the FORGE site without evidence of major disruptions. The seismic reflection image shown in Figure 4 illustrates the geometry of the contact where it passes through well 58-32.

The most prominent of the younger Basin and Range structures is the Opal Mound Fault (Figure 2), which dips steeply to the east and offsets surficial deposits of alluvium and silica sinter, with a total down-dip displacement of at least 15 m (Nielson et al., 1986). Temperature and pressure data discussed below demonstrates the Opal Mound forms a hydraulic barrier separating the permeable Roosevelt Hot Springs geothermal system from the low permeability thermal regime to the west, beneath the FORGE site. South of the Opal Mound Fault, north-south trending faults form a series of short, narrow grabens and horsts (Nielson et al., 1986; Kleber et al. 2017). These faults die out to the north as the FORGE site is approached. New 2- and 3-D seismic reflection surveys indicate these faults are shallow features that do not offset the contact between the basement and overlying basin fill deposits (Miller et al., 2018).

The Negro Mag fault is another major steeply dipping fault, but it trends east-west (Figure 2). The fault cuts across the Mineral Mountains for ~6 km; however, the direction and amount of displacement are unknown due to the absence of markers within the plutonic rocks (Nielson et al., 1986). An east-

west trending structure, 2 km south of Negro Mag fault, was the site of seismicity in the late 1970's (Zandt et al., 1982; Nielson et al., 1986). Both the Negro Mag and Opal Mound faults appear to terminate at their intersection. These east-west faults may reflect regional arc-parallel structures, formed as Eocene-Oligocene magmatism migrate southward migrating and/or Proterozoic structures in the deep-seated basement (e.g., Dickinson, 2006; Wannamaker et al., 2015).

4. Temperature and Pressure Relationships

Two distinct hydraulic regimes can be identified in the region surrounding the FORGE site, based on well data (Allis et al., 2016). Wells located east of the Opal Mound fault are characterized by convective thermal gradients indicative of hydrothermal upflow. Many of the shallow temperature profiles exhibit boiling-point-for-depth relationships. A typical temperature profile for Roosevelt Hot Springs wells is shown in Figure 5. In contrast, temperature profiles from wells west of the Opal Mound fault, including well 58-32 and the surrounding wells 9-1, 82-33 and Acord-1 are characterized by conductive gradients. These wells define a large region of low permeability rocks appropriate for EGS development. Integration of all temperature gradient data shows that the potential volume of the reservoir rock immediately adjacent and beneath the FORGE site with temperatures >175°C at <4 km depth is more than 100 km^3. Thus, the region holds potential for large-scale EGS development.

Temperatures in well 58-32 were measured 37 days after drilling (Figure 5). The top of the reservoir, defined by a temperature of 175°C, was encountered at 1990 m. A temperature of 197°C was recorded at the base of the well.

Prior to the start of production at Roosevelt Hot Springs in 1984, deep wells east of the Opal Mound fault had a uniform pressure profile consistent with hot water having a density of 800 kg/m^3 (Allis and Larsen, 2012; Figure 6). Well 82-33, a deep well west of the Opal Mound fault had a pressure profile consistent with cold water with a density of 1000 kg/m^3, about 30 bars lower than wells on the east side of the Opal Mound fault in the Roosevelt Hot Springs geothermal system (Faulder, 1994). Other wells west of the Opal Mound fault plot on the same pressure gradient as 82-33. Well 9-1 is located on the boundary between the two regimes. It is unproductive and used as a monitoring well. Thus, the Opal Mound fault forms a major pressure barrier between the low permeability, conductive regime surrounding the FORGE site to the west and the high permeability convective regime in Roosevelt Hot Springs geothermal system to the east (Allis, et al., 2016).

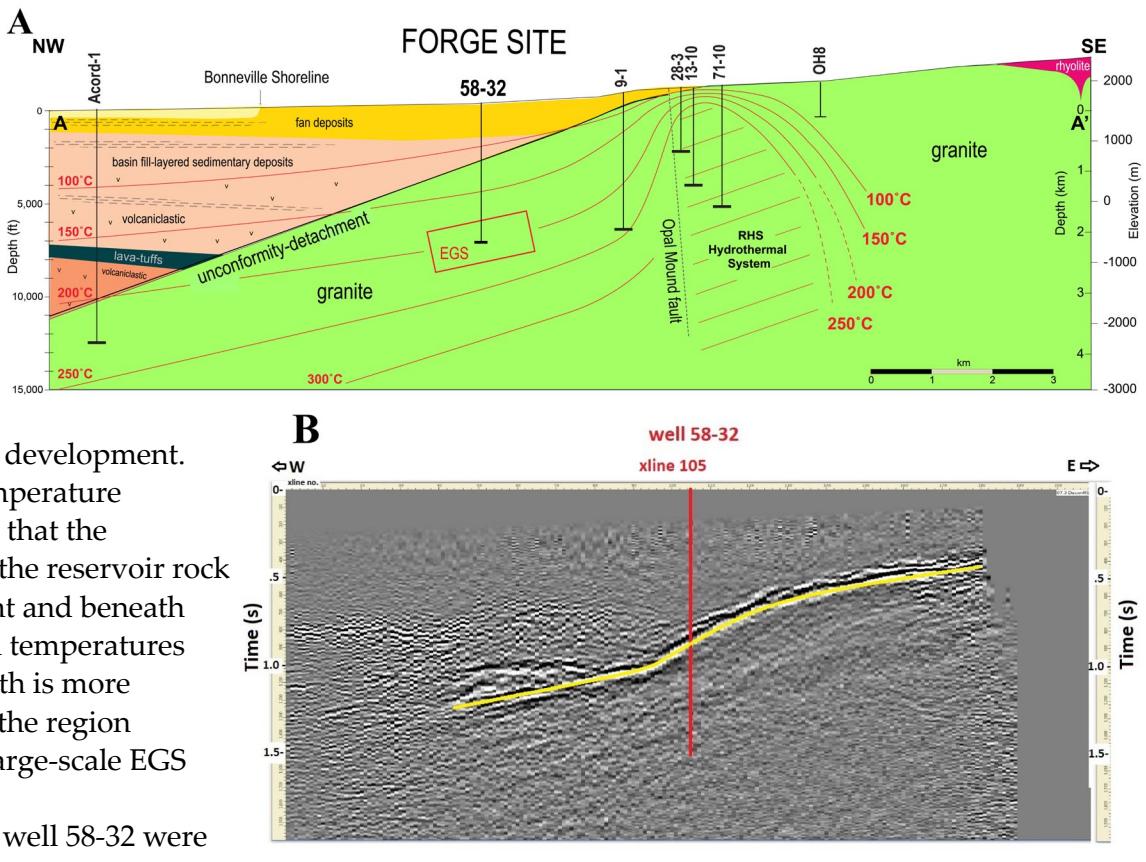


Figure 4. Cross sections through well 58-32 (Kirby et al., 2018). A) Cross section A-A' from Figure 2, showing the top of the crystalline basement rocks in the vicinity of the FORGE site. The Roosevelt Hot Springs hydrothermal system lies east of the Opal Mound fault. Isotherms are interpreted from well measurements. The red box represents the approximate position of the FORGE EGS reservoir. B) East-west profile on Inline 95, which runs through well 58-32. The basement contact is highlighted with a dashed yellow line and the reservoir by the dashed red box.

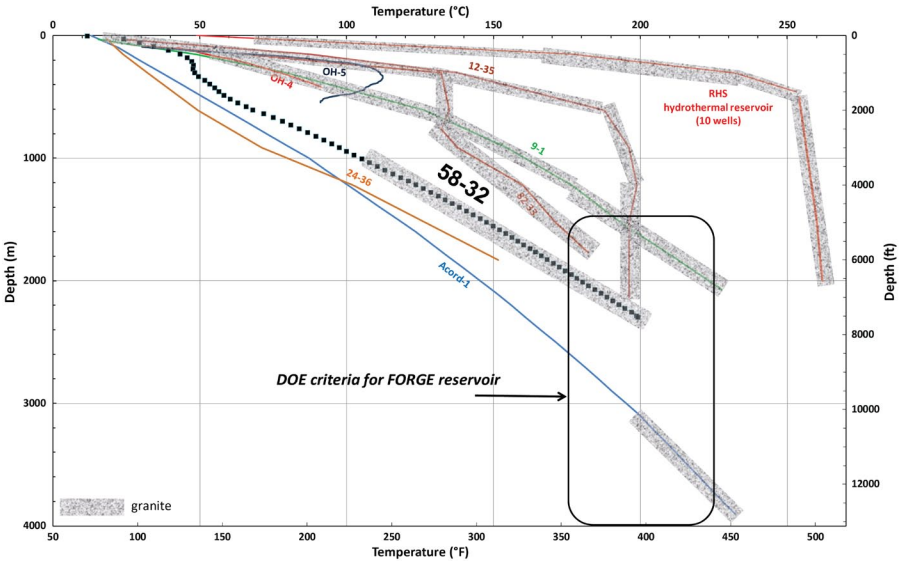


Figure 5. Temperature profiles in wells surrounding the FORGE site. The dashed rectangle shows conditions established by the U.S. DOE for a FORGE reservoir. See Figure 2 for well locations. Productive wells tapping the Roosevelt Hot Springs geothermal system display convective thermal gradients. These wells lie east of the Opal Mound fault. The three deep wells surrounding the FORGE site, Acord-1, 82-33 and 9-1, display conductive gradients. Well 58-32 reached a temperature of 197°C at its base.

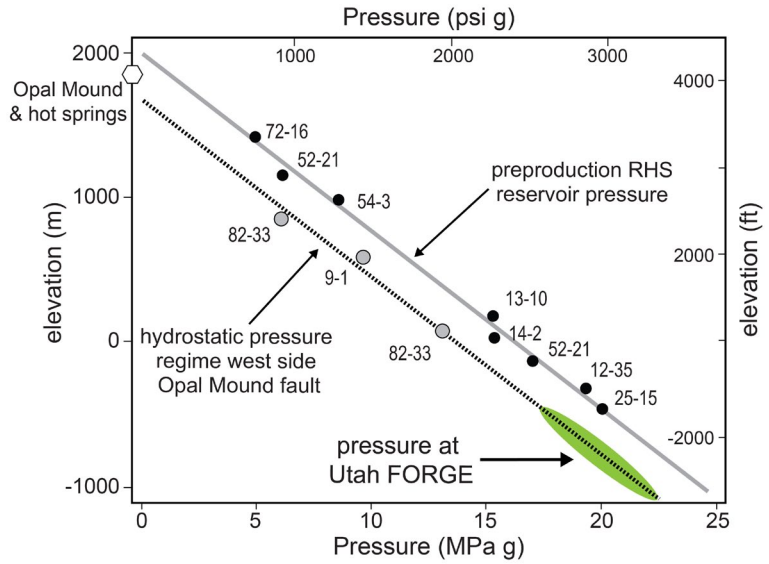


Figure 6. Pressure data for wells east (red trend; RHS = Roosevelt Hot Springs) and west (blue trend) of the Opal Mound fault. These data imply the presence of two distinct pressure regimes separated by the fault (Allis et al., 2016). The FORGE site lies to the west of this barrier.

5. Stress Characteristics

Understanding the stress directions and magnitudes is one of the essential lessons learned from past EGS projects. At the FORGE site, the orientation of the maximum total horizontal stress, σ_{Hmax}, was inferred from the well 58-32 Formation Microscanner Image (FMI) log. More than 2000 natural fractures and 356 induced fractures were identified. Azimuths of the induced fractures indicate the orientation of σ_{Hmax} trends NNE-SSW (Figure 7). A similar orientation was obtained from televiewer logs run in wells 14-2 and 52-21 (Keys, 1979; Davatzes, 2016, written comm.) (refer to Figure 2), indicating that stress directions are consistent across the region.

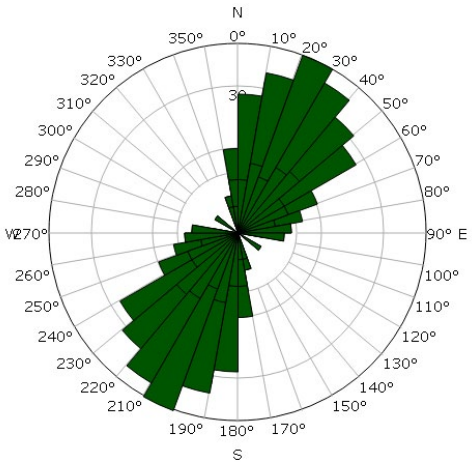


Figure 7. Azimuths of induced fractures in well 58-32. The orientation of the fractures indicates σ_{Hmax} trends NNE-SSW.

Forty-five meters at the base of well 58-32 were left uncased to conduct microhydraulic fracturing and Diagnostic Fracture Injection Tests (DFIT) for the determination of the stress magnitudes and permeability. After logging and casing the well, a packer with a stinger was set just inside the casing to isolate the openhole section of the well. A temperature-pressure tool was placed below the packer allowing for reliable bottomhole measurements. This tool was hung below a burst disk that was ruptured after pressure testing the drill string. Figure 8A shows surface and bottomhole pressure data for the five injection cycles conducted on September 22, 2017. Details of the injection program are shown in Table 1. The testing consisted of a short injection/falloff test to assess permeability, three low-rate microhydraulic fracturing cycles for stress determination and a DFIT at ~6 BPM with an extended shut-in. The testing continued on September 23 (Figure 8B). Following a low rate injection cycle and a step rate test (SRT), 200-mesh calcium carbonate was pumped during a second DFIT. The purpose was to slightly prop the fractures taking fluid and to enhance differentiation between fractures identified in pre- and post- FMI logs.

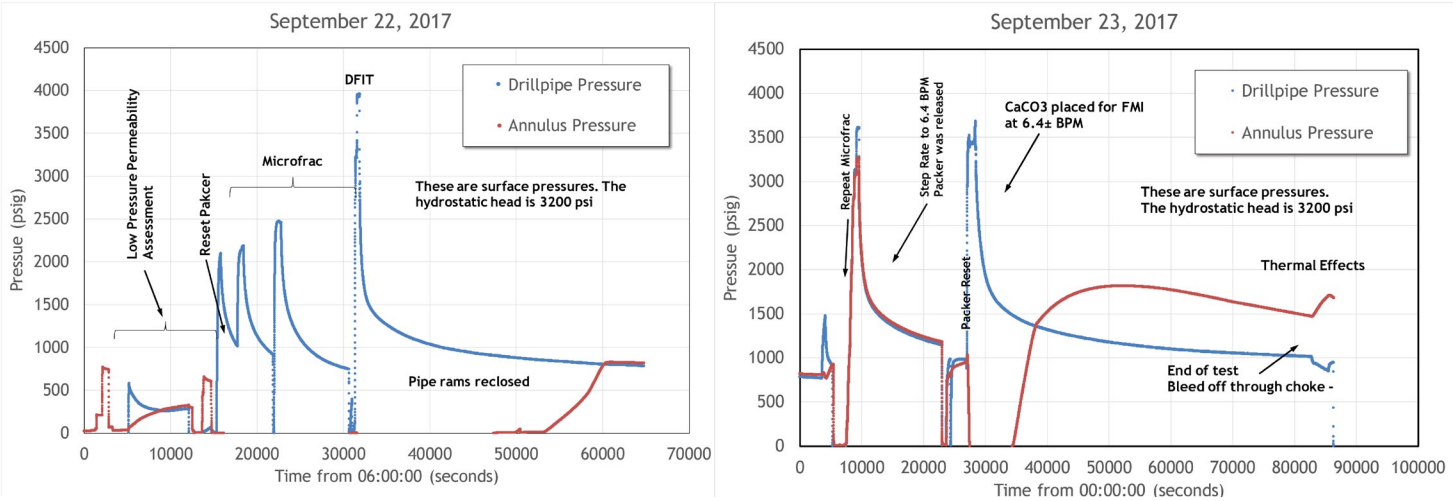


Figure 8. Surface pressures during the injection campaign. A) Injection program conducted on September 22, 2017. B) Injection program conducted on September 23, 2017. DFIT = Diagnostic Fracture Injection Test.

Table 1. Details of the injection testing program.

Cycle	Description	Purpose
1	Injection falloff: Pressure was increased to below the pressure required to hydraulically fracture the formation. Well shut-in and pressure decay monitored	Assessment of native permeability before hydraulic fracturing testing
2	Micro-hydraulic fracture: 2.8 bbl were pumped at 0.4 bpm	Stress measurement
3	Micro-hydraulic fracture: 4.2 bbl were pumped at 0.4 bpm	Stress measurement
4	Micro-hydraulic fracture: 10.0 bbl were pumped at 0.8 bpm	Stress measurement
5	DFIT pumped initially at 5.8 bpm and increased to 8.7 bpm for 5 minutes (67.2 barrels pumped). Prolonged shut-in.	Stress and permeability measurements
6	Repeat micro-hydraulic fracture test. 0.4 bpm and 3.8 bbl pumped	Stress measurement
7	76.9 bbl were pumped in a Step Rate Test (SRT) where rate progressively increased • 0.4 bpm, 2.7 bbl pumped • 0.8 bpm, 4.1 bbl pumped • 1.6 bpm, 9.8 bbl pumped • 3.2 bpm, 16.1 bbl pumped • 6.3 bpm, 44.2 bbl pumped	SRT is alternative method for evaluating minimum in-situ stress as a function of injection rate. Furthermore shut-in pressure decline at the end of the SRT can be used to pick fracture closure with classic techniques
8	Another DFIT: This injection sequence also contained an 8 bbl slug of viscosified fluid carrying 200-mesh calcium carbonate proppant. 28.8 bbl of water at 6.4 bpm, followed by 8 bbl of viscosified xanthan with $CaCO_3$ at 6.4 bpm, displaced with 3 bbl of water at 6.4 bpm, and 8 bbl of water at 3 bpm to encourage screen out and fracture packing for subsequent logging.	Stress measurement

Figure 9 summarizes the results of the stress analyses for determining the total maximum and minimum horizontal stresses. This figure shows inferences based on slopes determined from diagnostic plots (log-log plots of pressure drop and time since shut-in). A half-slope is indicative of linear flow and a quarter slope may suggest bilinear flow into orthogonal fractures. The transition from either of these regimes could indicate fracture closure and suggest the magnitude of one of the horizontal principal stresses. These analyses were supplemented with and were consistent with two different interpretations of the G-function (see for example, Economides and Nolte, 2000; McClure et al., 2014). Gradients based on G-function analyses (measurements using the tangent and the compliance techniques for closure stress assessment) also fell in these ranges. The composite analyses yielded stress gradients of 0.58 – 0.63 psi/ft (most likely value is 0.62 psi/ft) for σ_{Hmin}, and 0.68 - 0.82 psi/ft (most likely value is 0.77 psi/ft) for σ_{Hmax}. The gradient of the total vertical stress, σ_V was estimated to be 1.13 psi/ft by integration of the density log from depth to the surface. These stress relationships are indicative of a normal faulting regime.

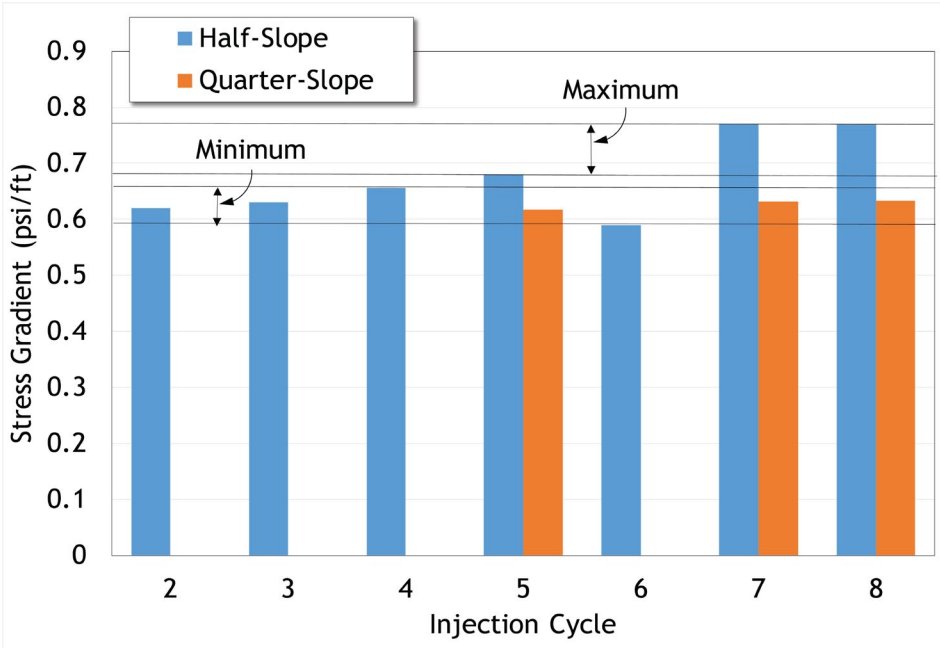


Figure 9. Summary of minimum and maximum stress gradients determined from the evaluation of diagnostic plots of post-shut-in data.

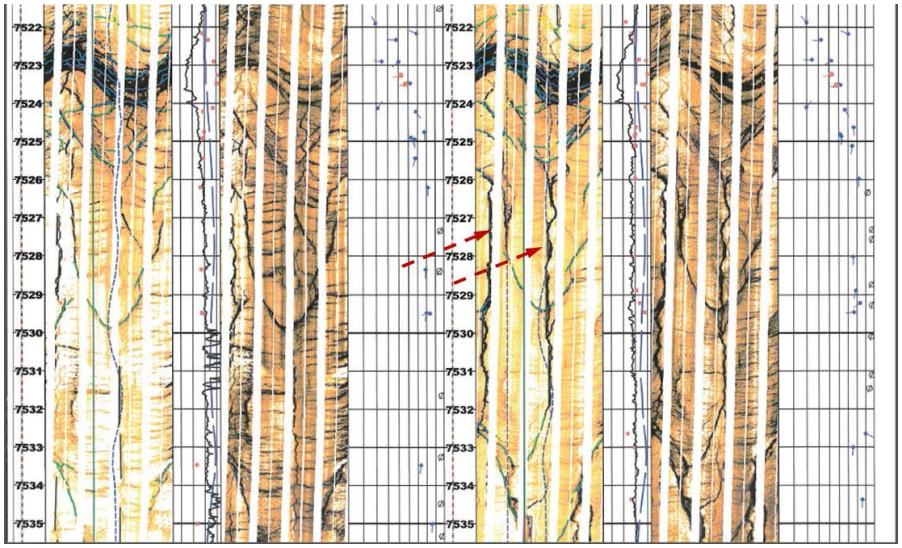


Figure 10. Comparison of FMI logs before (left two tracks) and after (right two tracks) injection. Induced fractures are near-vertical and are shown by circles with azimuth trends to the right of the tracks. Blue tadpole symbols show the direction and dip of natural fractures. The arrows point to induced fractures that display significant enhancement and growth after injection.

Comparison of the pre- and post- stimulation FMI logs demonstrates that significant enhancement and growth of the induced fractures occurred during the injection testing (Figure 10). The orientations of these enhanced fractures confirms the NNE direction of σ_{Hmax}. The low pressures applied during the injection tests provide prima facies evidence that reservoir conditions are appropriate for EGS development.

Permeability within the reservoir rocks is controlled by fractures. Transmissibility was determined from the first DFIT measurement to be 4.5 md-ft, suggesting a permeability about 30 microdarcies.

6. Microseismicity

Seismicity in the area has been monitored since 1981 (Figure 11). There is no record of any events beneath the FORGE site. Analysis of the seismic catalogue for the time period 1 January 2000 to 30 June 2003 found an M_{comp} = 1.5 for the Utah FORGE site (Pankow et al., 2004). In late 2016, broadband seismometers were installed at sites FORU, FORU 2, 3, and 4 to improve detection of seismic events beneath the FORGE footprint. We currently

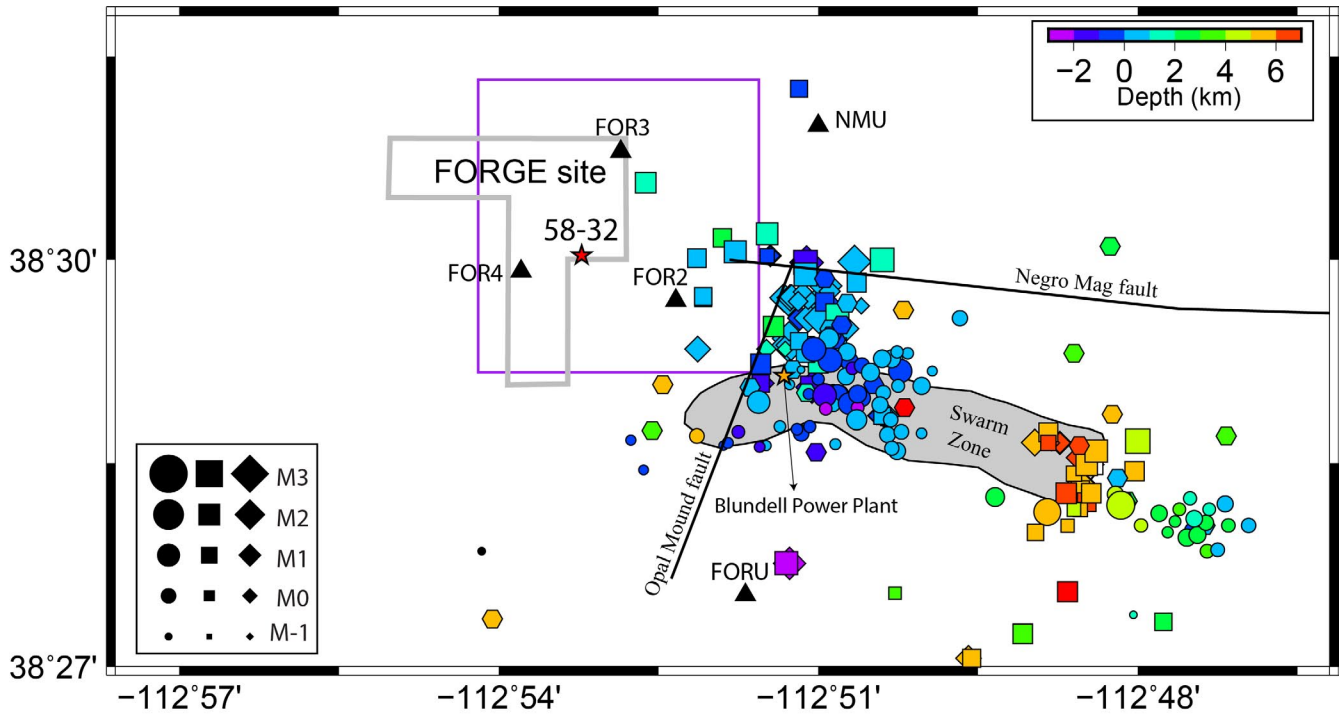


Figure 11. Locations of seismic events in the vicinity of the FORGE site (Pankow et al., 2017). Triangles mark the locations of seismometers. The size of the symbols is proportional to the magnitude of the seismic events. Circles = University of Utah Seismic Stations (UUSS) catalog from November 2016 through February 2018 after the deployment of stations FORU and FOR 2-4; Squares = UUSS catalog from August 1981 through October 2016; Diamonds = detected earthquake catalog created by Potter (2017) using the software Detex (Chambers et al., 2015); Hexagons = catalog of earthquakes detected on the Nodal arrays. The purple rectangle indicates the boundaries for the dense Nodal array. Many of the events occur along a fault zone defined by a seismic swarm recorded by Zandt et al. (1982).

estimate M_{comp} to be close to zero. Small events have occurred to the east but none have been observed beneath the FORGE site. Analysis of the seismic data and faults surrounding the FORGE site suggests the risk of induced seismicity and seismic hazards is low (Pankow et al., 2017).

Many of the events near the Opal Mound fault are relatively shallow and located in the vicinity of the Blundell power plant borefield. This spatial association with the borefield suggests seismicity is related to injection and/or production. However, the magnitude of the events displays no relationship to the volume of the injected fluid (Potter et al., 2017). Events to the east are deeper, and appear to lie along the northwest trending fault zone (swarm zone in Figure 11) defined by Zandt et al. (1982).

7. Conclusions

The Milford FORGE site is ideally suited for the development and testing of technologies that can be used to create and sustain EGS reservoirs. The site is located on the alluvial plane adjacent to the Mineral Mountains. Data from nearly 100 deep and shallow wells, integrated with the results of new geologic mapping, results from 58-32, and 2- and 3-D seismic reflection, gravity, and geochemical surveys has provided a detailed picture of the geological, thermal and stress characteristics of the FORGE reservoir.

The FORGE site is separated from the nearby Roosevelt Hot Springs geothermal system to the east by the north-south trending Opal Mound fault that formed in response to ongoing east-west Basin and Range extension. Wells east of the Opal Mound fault are characterized by convective thermal gradients and preproduction pressures 30 bars higher than wells to the west of the fault, which display conductive thermal gradients. This pressure difference requires the presence of two distinct pressure regimes, with high-permeability rock associated with the hydrothermal system to the east, and relatively impermeable rock to the west beneath the FORGE site.

Well 58-32 was drilled to a depth of 2296 m (7536 ft) on the FORGE site. The well penetrated 1329 m of plutonic rocks, primarily granite, quartz monzonite and monzonite beneath the overlying gently dipping and undeformed alluvial deposits. The basement contact dips approximately 20° to the west across the FORGE site. A temperature of 197°C

(continued on page 50)

DELIVERING MORE GEOTHERMAL EXPERTISE

ORMAT

Development | Exploration | Drilling | Engineering | Manufacturing | Construction | Operation

ORMAT offers geothermal clients more of everything that matters when it comes to developing geothermal resources.

We've built more than 2,900 MW of capacity in approximately 180 power plants worldwide. We're experts at using more technologies, including conventional steam, binary, combined cycle and integrated two-level unit technologies. We've developed more facilities, in more sizes, from a few kilowatts to hundreds of megawatts. We're involved in more of the essential steps needed to take a facility from concept to reality; whether it is exploring, developing, designing, engineering, manufacturing, constructing or operating geothermal power plants.

Doing more also means we offer clients more of our in-depth experience as an operator. We've learned more about geothermal by operating a global network of geothermal facilities efficiently and profitably; and it is that deeper knowledge we share with our clients. We do more to add value to existing facilities, year after year, by expanding and integrating new technologies to boost efficiency and power output.

More is what ORMAT is all about. Give us a call, we've got more to share to make your project excel.

Learn more at www.ormat.com and contact us at +1-775-356-9029 or info@ormat.com

(continued from page 48)
was measured at the base of the well. The top of the FORGE reservoir, defined by a temperature of 175°C, was encountered at a depth of 1990 m.

Induced fractures identified in the Formation Microscanner Image log of the well trend NNE-SSW, the direction of σ_{Hmax}. Stress gradients were determined from microhydraulic and Diagnostic Fracture Injection Tests conducted in the open hole section of the well close to its base. The results of the injection testing yielded stress gradients of 0.58 – 0.63 psi/ft) for σ_{Hmin} and 0.68 - 0.82 psi/ft for σ_{Hmax}. A gradient of 1.13 psi/ft was calculated for σ_V. Comparison of pre and post injection FMI logs document enhancement and growth of the induced fractures, providing evidence the stress field is appropriate for EGS development.

ACKNOWLEDGEMENTS

Funding for this work was provided by U.S. DOE under grant DE-EE0007080 "Enhanced Geothermal System Concept Testing and Development at the Milford City, Utah FORGE Site". We thank the many stakeholders who are supporting this project, including Smithfield, Utah School and Institutional Trust Lands Administration, and Beaver County. A grant from the Utah Governor's Office of Energy Development has provided support for educational outreach activities. The Bureau of Land Management and the Utah State Engineer's Office have been very helpful in guiding the project through the permitting processes. Gosia Skowron assisted in the preparation of the figures and manuscript. Her help is greatly appreciated.

REFERENCES

Allis R.G. and Larsen, G., 2012, Roosevelt Hot Springs Geothermal field, Utah – reservoir response after more than 25 years of power production. Proceedings 37th Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, CA.

Allis, R.G., Moore, J.N., Davatzes, N., Gwynn, M., Hardwick, C., Kirby, S., Pankow, K., Potter, S., and Simmons, S.F., 2016, EGS Concept Testing and Development at the Milford, Utah FORGE Site: Proceedings, 41st Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, CA.

Allis, R.G., Gwynn, M., Hardwick, C., Hurlbut, W., and Moore, J., 2018, Thermal characteristics of the FORGE site, Milford Utah: Transactions, Geothermal Resources Council Transactions, v. 42.

Aleinikoff, J.N., Nielson, D.L., Hedge, C.E., and Evans, S.H., 1987, Geochronology of Precambrian and Tertiary rocks in the Mineral Mountains, south-central Utah: US Geological Survey Bulletin, v. 1622, p. 1-12.

Chambers, D., Koper, K.D., Pankow, K.L, and McCarter, M.K., 2015. Detecting and characterizing coal mine related seismicity in the Western U.S. using subspace methods: Geophysical Journal International, v. 203, p. 1388-1399.

Coleman, D.S., Bartley, J.M., Walker, J.D., Price, D.E., and Friedrich, A.M., 1997, Extensional faulting, footwall deformation and plutonism in the Mineral Mountains, southern Sevier Desert, in Link, P.K., and Kowallis, B.J., editors, Mesozoic to recent geology of Utah: Brigham Young University Geology Studies, v. 42, part 2, p. 203–233.

Dickinson, W.R., 2006, Geotectonic evolutions of the Great Basin: Geosphere, v. 2, p. 353-368.

Economides, M.J. and Nolte, K.G. 2000. Reservoir Stimulation, 3rd Edition: John Wiley & Sons Ltd, West Sussex, England, 2000.

Faulder, D.D., 1994, Long-term flow test #1, Roosevelt Hot Springs, Utah: Transactions, Transactions Geothermal Resources Council, v. 18, p. 583-590.

Gwynn, M., Allis, R., Hardwick, C., Jones, C., Nielsen, P., Hurbut, W., 2018, Rock properties of FORGE well 58-32, Milford, Utah: Transactions Geothermal Resources Council, v. 42.

Hardwick, C.L., Hurlbut, W., Gwynn, M., Allis, R., Wannamaker, P., and Moore, J., 2018, Geophysical surveys of the Milford, Utah FORGE Site: Gravity and TEM: Transactions Geothermal Resources Council, v. 42.

Hardwick, C.L., Gwynn, M., Allis, R., Wannamaker, P., and Moore, J., 2016, Geophysical Signatures of the Milford, Utah FORGE Site: Proceedings, 41st Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, CA.

Hintze, L.F., and Davis, F.D., 2003, Geology of Millard County, Utah: UGS Bulletin, 133, pp. 305.

Keys, W. S., 1979, Borehole geophysics in igneous and metamorphic rocks, in Society of Professional Well Log Analysts Annual Logging Symposium, 20th, Tulsa, Okla., 1979, Tulsa, Okla., Transactions: Houston, Society of Professional Well Log Analysts, p. 001-0026.

Kirby, S.M., Knudsen, T.R., Kleber, E., and Hiscock, A., 2018a, Geologic Map of the Utah FORGE Area: Utah Geological Survey Contract Deliverable for DOE project number DE-EE0007080, scale 1:24,000, 2 plates, 13 p.

Kirby, S.M., Knudsen, T.R., Kleber, E., and Hiscock, A., 2018b, Geologic setting of the Utah FORGE site, based on new and revised geologic mapping: Transactions Geothermal Resources Council, v. 42.

Kleber, E., Hiscock, A., Kirby, S., Allis, R., Quirk, B., 2017, Assessment of Quaternary faulting near the Utah FORGE site from high resolution topographic data: Transactions Geothermal Resources Council, v. 41.

Jones, C.G., and Moore, J.N., and Simmons, S.F., 2018. Lithology and Mineralogy of the Utah FORGE EGS Reservoir: Beaver County, Utah: Transactions Geothermal Resources Council, v. 42.

Miller, J., Allis, R., and Hardwick, C., 2018, Seismic reflection profiling at the FORGE Utah EGS site: Transactions Geothermal Resources Council, v. 42.

McClure, M.W., Blyton, C.A.J., Sharma, M.M., and Jung H., 2014. The Effect of Changing Fracture Compliance on Pressure Transient Behavior During Diagnostic Fracture Injection Tests, SPE 170956, SPE ATCE, Amsterdam, The Netherlands, October 27-29, 2014.

Nielson, D.L., Evans, S.H., and Sibbett, B.S., 1986, Magmatic, structural, and hydrothermal evolution of the Mineral Mountains intrusive complex, Utah: Geological Society of America Bulletin 97, p. 765-777.

Pankow, K.L., Arabasz W.J., Nava, S.J., and Pechmann, J.C., 2004. Triggered seismicity in Utah from the 3 November 2002 Denali fault earthquake, Bulletin Seismological Society of America, v. 94, p. S332-S347.

Pankow, K.L. Potter, S., Zhang, H. and Moore, J., 2017, Local seismic monitoring at the Milford, Utah FORGE site: Transactions Geothermal Resources Council, v. 41.

Potter, S., Pankow, K., Moore, J., Allis, R., 2017, Seismicity in the Mineral Mountains, Utah and the Possible Association with the Roosevelt Hot Springs Geothermal System: Seismological Society of America poster presentation.

Wannamaker, P.E., Moore, J.N., Pankow, K.L., Simmons, S.F., Nash, G.D., Maris, V., Batchelor, C., and Hardwick, C.L., 2015. Play fairway analysis of the eastern Great Basin extensional regime, Utah: Preliminary indications: Transactions Geothermal Resources Council v. 39, p. 793-804.

Welsh, J. E., 1980, McCulloch Acord 1-26, Roosevelt Hot Springs Area, Beaver Co., Utah. Unpublished petrography.

Zandt, G., McPherson, L., Schaff, S., and Olsen, S., 1982, Seismic baseline and induction studies: Roosevelt Hot Springs, Utah, and Raft River, Idaho. U.S. Dept. of Energy Report DOE 01821-T1, 58 p. ■

First Field Scale Test of Closed Loop Geothermal to be Conducted at Coso California

by John R. Muir, Sr. VP Business Development of GreenFire Energy Inc.

Despite its potential, geothermal power generation has always been a tough business. Finding the three components necessary for conventional geothermal projects – heat, water, and subsurface permeability – in the right proportions at the same site is comparatively rare. But even then, developing a project has involved high risk, long lead times, a lot of money, and dogged patience. The heart of the problem is the unpredictable nature of subsurface rock formations that resist easy characterization or modification. Consequently, every project, and every well, is a custom effort.

To address this complexity, geothermal developers have tried three general strategies. First, they have tried to reduce risk and improve production through continuous improvements in geophysical analytical tools. Second, they have tried to alter the resource itself by creating engineered fracture systems, a process known as EGS. While improvements in tools and EGS are still ongoing, the third approach, frequently referred to as "closed loop" well systems, has yet to be investigated at field scale.

The conceptual simplicity of closed loop systems is inherently appealing because a sealed downhole heat exchanger obviates the need to deal with the full complexity of subsurface formations. Drilling risk is reduced because intersecting natural fractures with flowing water is not essential. Indeed, the problems associated with maintaining water circulation through rock are avoided. Finally, having a "closed loop" system to circulate the working fluid also reduces the problems of corrosion, non-condensable gases, other chemical reactions, and dealing with particulates. But, as has been asserted for a long time, closed loop systems have a major drawback – with limited surface area they can't absorb enough heat to be economically viable. Or can they?

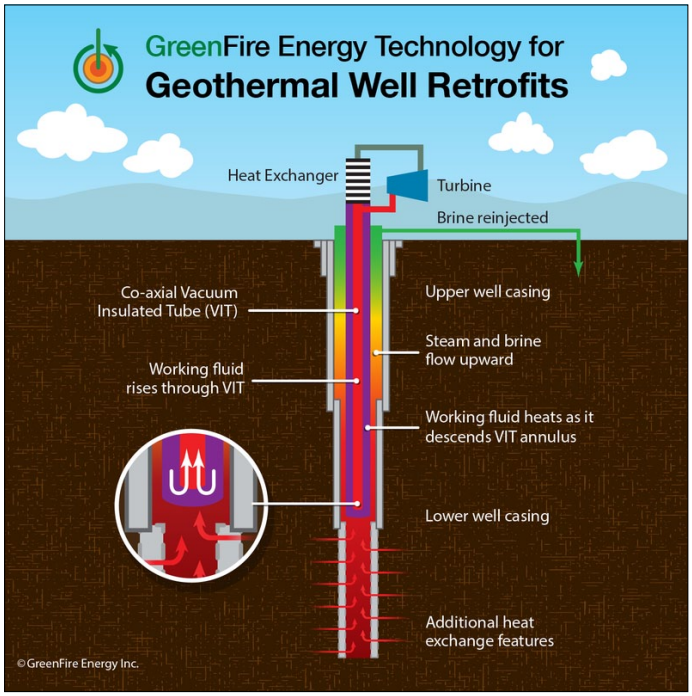
GreenFire Energy (GFE) has performed extensive modeling of the thermodynamics and costs of closed loop systems. This research suggests that closed loop geothermal production can be both technically viable and commercially attractive, particularly in two environments:

- Where very hot geothermal resources are available for greenfield projects and drilling can go "hot and deep," such as at many locations around the Ring of Fire; in these cases, power is principally generated from conduction of heat from the resource (Full Scale ECO2G™), and
- Where conventional hydrothermal wells have become unproductive despite hot bottom hole temperatures. Many of these wells can be retrofit with appropriate technologies (typically involving a closed loop system but with proprietary enhancements) to make such wells productive. Substantial power is generated by heat transfer from, and coproduction of, geothermal brine (Retrofit ECO2G™).

In April 2019 GreenFire Energy will conduct the first field-scale test of a closed loop system using an idle well in the Coso geothermal field. First phase testing will compare the performance of water and

supercritical CO_2 (sCO_2) as the production fluid in a closed loop system. Test results will be compared with the models that GreenFire has developed as a result of four years of research with the US DOE, national laboratories, and a variety of expert consulting firms. GreenFire will test at various flow rates of fluid in the closed loop, while also varying the brine flow conditions (including non-flowing conditions). This will be used to support and verify both Full Scale ECO2G and Retrofit ECO2G modeling.

The physical aspect of the project is conceptually straightforward. GreenFire will insert a tube-in-tube assembly into the well to a depth of 1000 feet. For testing with water, the water will flow down the outer tube to collect heat and then rise to the surface through the inner, vacuum insulated tube (VIT). For sCO_2 the flow path will be reversed. Additional testing will involve the coproduction of brine to the surface to assess the potential for additional energy to be extracted. Careful measurements will be taken to determine the amount of power that could be generated using the conventional steam turbine equipment in operation at the site, or that could be generated by a wellhead generator designed for use of sCO_2. Importantly, a thermosiphon will be created and measured in the system with both water and sCO_2.



Conceptual diagram of GreenFire's closed loop technology for well retrofits. Note that two separate flows may be involved. Production fluid flows through the closed loop assembly while brine can be coproduced around the outside of the assembly to bring additional heat to the surface.

The GFE project involves a series of technical challenges relating to testing both water and supercritical CO_2 in the same apparatus, particularly because of the high pressure involved with sCO_2. The design also needed to include pumps and makeup tanks suitable for both types of fluids. Engineering for the project was provided by Veizades & Associates working closely with GreenFire and Coso Operating Company.

The Coso project was made possible via a major grant from the California Energy Commission from the GRDA fund. Additional funding was obtained from the Shell Oil "GameChanger" program and from the Electric Power Research Institute and its member J-Power, a major Japanese utility that operates its own geothermal fields. Even with this level of funding, the project could not have been successfully completed without the extraordinary cooperation, expertise, and support of Coso Energy, operator of the site.

All major equipment and materials have been delivered to the site and construction is in process. It is anticipated that active testing for the first phase will begin in late April of this year and will be completed in May. A final report of testing results will be made available to the California Energy Commission and project participants later this year. ■

The vacuum insulated tube (VIT) is inserted into the well. Courtesy Chris Ellis

Courtesy GreenFire Energy Inc

GeoCoat – High Performance Coatings For Aggressive Geothermal Environments

By Geo-Coat consortium

GEO-COAT

Geothermal energy, the thermal energy sourced from the earth, is one of the natural sources of the energy that has been in use since pre-historic times. Despite its natural abundance and potential as the next-generation low-carbon energy technology, the exploitation of geothermal resources continue to remain a challenge – the deployment of geothermal energy in renewable electricity generation is largely eclipsed by solar and wind power.

Geothermal resources are naturally aggressive environments with the integrity of geothermal power plant components more often compromised due to inherent high temperatures, pressure and predominance of the corrosive species in geofluids. The threat is increased as wells move to deeper geothermal resources – geofluids become all the more antagonistic, multiplying the corrosion, erosion, and scaling effects.

Geo-Coat (http://www.geo-coat.eu/) is a collaborative initiative aimed at providing an integrated framework to develop novel corrosion- and erosion- resistant coating systems specifically tailored to meet the differing needs of specific geothermal environments. The project builds on the experiences of materials science and flow assurance technologies in the oil and gas sector – transfer the lessons learnt to the geothermal arena. "Our target is to design new high-performance coatings to resist specific issues, or combinations of issues as experimentally derived at key failure points within geothermal power plants", says the team of experts in Geo-Coat.

Geo-Coat innovations

Geothermal sources exhibit a wide range and combination of degradation mechanisms, resulting from high temperatures and the aggressive chemical make-up of the brines, coupled with the pressure drops and chemistry changes that occur at different points in the process and equipment. As such, there is a clear need for improved surface resistance in geothermal applications.

The Geo-Coat project develops specialized corrosion- and erosion- resistant coatings, based on selected High Entropy Alloys (HEAs) and Ceramic/Metal mixtures (Cermets), to be applied through thermal powder coating techniques (primarily high velocity forms of HVOF / Laser cladding) specially

developed to provide the required bond strength, hardness and density for these challenging applications. Given that there is no single material or coating solution possible, Geo-Coat targets to design these new high performance coatings to resist each of the specified threats or combinations of threats, as experimentally derived at key failure points within geothermal runs, and to apply them only to the affected components. The project, thus builds a knowledge-based matrix of key problems and solutions that can be modeled and applied more widely, allowing the design of highly resistant systems with minimized costs.

Flow assurance modeling is a relatively new area and is rapidly becoming widely used in the oil & gas industry where it is considered to be one of the most important key technologies for efficient, economical and safe oil & gas production[1]. The Geo-Coat flow assurance simulator comprising various geofluid models will provide information on pressure, flow velocities, temperatures, and geofluid compositions in the whole system, thereby setting the performance requirements for the coating methodology selection at each process point. Additionally, the Geo-Coat Decision Support System (DSS) with the relevant information from the models and database will help produce reliable lifecycle estimates for performance, operational costs, environmental impacts and risk.

Geo-Coat consortium

The Geo-Coat consortium consists of 11 members[2] including research institutes, SMEs and end users. The project is led by TWI, a foremost independent research and technology organization in the UK[3].

Acknowledgement

The project has received funding from European Commission H2020 program, grant agreement number 764086. ■

[1] Multiphase technology – the best Norwegian invention since 1980, https://www.ife.no/en/ife/ife_news/2012/flerfaseteknologien-beste-norske-oppfinnelse-siden-1980

[2] http://www.geo-coat.eu/consortium/

[3] https://www.twi-global.com/who-we-are

Sampling for steam. Photo courtesy Orkuveita Reykjavikur SF.

Sampling for water. Photo courtesy Orkuveita Reykjavikur SF.

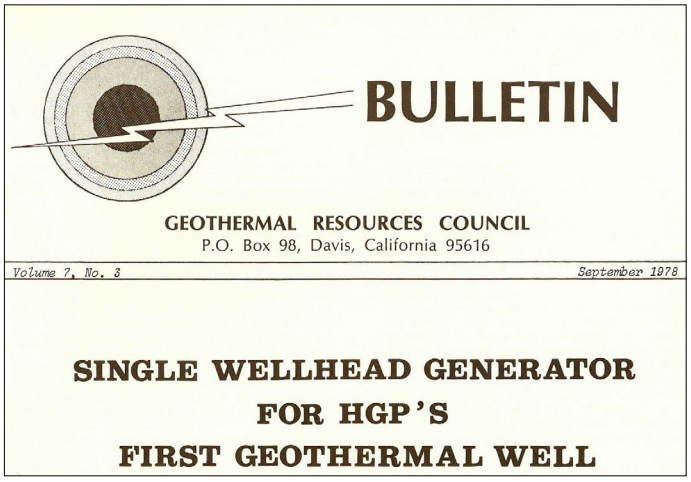
Geothermal History in the Making

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 more than 40 years to 1978 and an early geothermal power project on the Big Island of Hawaii.

~~~~~~~


BULLETIN

GEOTHERMAL RESOURCES COUNCIL
P.O. Box 98, Davis, California 95616

Volume 7, No. 3 September 1978

SINGLE WELLHEAD GENERATOR
FOR HGP'S
FIRST GEOTHERMAL WELL

The GRC Bulletin cover from September 1978.

James T. Kuwada, Vice President of Rogers Engineering Co., Inc. of San Francisco, California, announced that a contract was executed on September 14, 1978, between Rogers and the Research Corporation of the University of Hawaii (RCUH) to design, engineer and manage construction of a 5 MW (nominal) geothermal flash steam power plant.

This project is part of Hawaii Geothermal Project's (HGP) proof-of-feasibility program at well site HGP-A located at Pohoaki in the Puna District of Hawaii, approximately 25 miles southeast of Hilo.

Proposed facilities will include: the steam gathering and waste water disposal systems; complete geothermal power plant and switchyard facilities; plant support facilities (offices, maintenance shops and laboratory), and a visitor's exhibition center. The plant will feature a condensing turbine and will incorporate environmental control facilities to comply with regulatory requirements.

The Hawaii Geothermal Project Development Group (HGP/DG) represented by State of Hawaii Department of Planning and Economic Development (DPED), the University of Hawaii Geothermal Project Group (HGP), and the County of Hawaii selected RCUH as the legal, administrative and fiscal agent to oversee the project to its successful conclusion. This project, scheduled for completion and start-up in August 1980, will be operated by Hawaii Electric Light Company (HELCO) of Hilo.
~~~~~~~

~~~~~~~

UPDATE: The Hawai'i Groundwater and Geothermal Resources Center (HGGRC) at the University of Hawai'i has an excellent website at https://www.higp.hawaii.edu/hggrc/; among the many pages of useful information is an extensive history of geothermal on the islands, including this update on the Hawaii Geothermal Project:

"Hawaii Geothermal Project-A was drilled with a rotary rig, and it was completed in 1976 at a depth of 6,450 feet. It recorded a maximum temperature of 676°F (358°C) and a total mass flow of approximately 100,000 pounds per hour, with nearly equal amounts of both liquid and steam at a surface temperature of 365°F (186°C). Well HGP-A powered a 2.8 MW demonstration plant from 1981 to 1989 without any significant change in flowing pressure or steam fraction. The plant was shut down in 1989, and the well was subsequently plugged and abandoned.

In 1989, Ormat Technologies, Inc. acquired the 500-acre Puna Geothermal Venture lease located adjacent to the HGP-A site and in 1993 started operations of a 30 MW geothermal power plant."

(Courtesy Hawaiian Fire Dept.)

Last year the eruption of the Kilauea Volcano threatened the Puna Geothermal Venture site but the damage from lava was restricted to a few buildings on the outskirts including an old warehouse that was indeed part of the former Hawaii Geothermal Project-A. ■
~~~~~~~

Publications, Websites, Videos & Maps

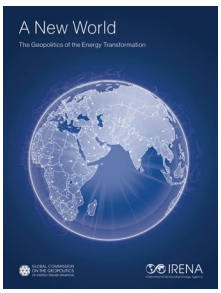
by Ian Crawford

Decarbonising the Electricity System: Time to Act Now (Nuclear Energy Agency)

The **Organization for Economic Co operation and Development (OECD) Nuclear Energy Agency (NEA)** sets out an argument for reducing the emissions of carbon from the electricity system in a new report. Of course the study sets out to demonstrate how nuclear power still remains the economically optimal choice to satisfy stringent carbon constraints despite the economic challenges it faces during the changeover between different reactor generations. However, **the report does recommend an increase in the uptake of renewable energy, including geothermal.**

The Costs of Decarbonisation: System Costs with High Shares of Nuclear and Renewables highlights that the increased share of variable energy sources has resulted in large inefficiencies imposed on the entire electricity system. These system costs are not properly recognized by current market structures and are currently borne by the overall electricity system in a manner that makes it difficult—if not impossible—to make well-informed decisions and investments. Download the report.....

Global Commission Describes New Geopolitical Power Dynamics Created by Renewables (IRENA)



Political and business leaders from around the world have outlined the far-reaching geopolitical implications of an energy transformation driven by the rapid growth of renewable energy. In a new report launched at the **Assembly of the International Renewable Energy Agency (IRENA)**, the **Global Commission on the Geopolitics of Energy Transformation** says the geopolitical and socio-economic consequences of a new energy age may be as profound as those which accompanied the shift from biomass to fossil fuels two centuries ago. These include changes in the relative position of states, the emergence of new energy leaders, more diverse energy actors, changed trade relationships and the emergence of new alliances.

The Commission's report *'A New World'* suggests that the energy transformation will change energy statecraft as we know it. Unlike fossil fuels, renewable energy sources are available in one form or another in most geographic locations. **This abundance will strengthen energy security and promote greater energy independence** for most states. At the same time, as countries develop renewables and increasingly integrate their electricity grids with neighboring countries, new interdependencies and trade patterns will emerge. The analysis finds oil and gas-related conflict may decline, as will the strategic importance of some maritime chokepoints. Download the Report (PDF).....

Table 2. **Cost assumptions for generating plants and storage capacities**

Technology	Discount rate (%)	Size (MWe)	Electrical efficiency (%)	Load factor (%)	Construction time (years)	Lifetime (years)	Overnight cost (incl. contingency) (USD/kW)	Annualised investment costs (USD/MW/year)	Fuel costs (USD/MWh)	O&M costs	
										Fixed (USD/MW/year)	Variable (USD/MWh)
Gas – OCGT	7%	300	38.0%	85%	2	30	700	58 380	80.81	20 000	15.30
Gas – CCGT	7%	500	58.0%	85%	2	30	1 050	87 580	52.94	26 000	3.50
Coal	7%	845	45.0%	85%	4	40	2 200	183 170	21.84	37 000	5.00
Nuclear	7%	1 000	33.0%	85%	7	60	4 700	413 880	10.00	100 000	1.50
Onshore Wind	7%	50		30%	1	25	2 000	171 620	0.00	62 000	0.00
Offshore Wind	7%	250		40%	1	25	5 000	429 050	0.00	175 000	0.00
Solar PV	7%	1		15%	1	25	1 600	137 300	0.00	36 000	0.00
Hydro – run-of-the-river	7%	10		50%	5	80	4 300	347 750	0.00	65 000	0.00
Hydro – reservoir	7%	10		20%	5	80	3 250	262 830	0.00	50 000	0.00
Hydro – pump storage	7%	10		NA	5	80	4 450	359 890	0.00	65 000	0.00
Battery storage	7%	1	90.0%	NA	1	10	1 146	163 164	NA	17 190	0.00
Onshore Wind – low-cost scenario	7%	50		30%	1	25	1 333	114 410	0.00	41 333	0.00
Offshore Wind – low-cost scenario	7%	250		40%	1	25	2 500	214 530	0.00	87 500	0.00
Solar PV – low-cost scenario	7%	50		30%	1	25	640	54 920	0.00	14 400	0.00

The report used average investment costs of generation technologies, including geothermal energy.

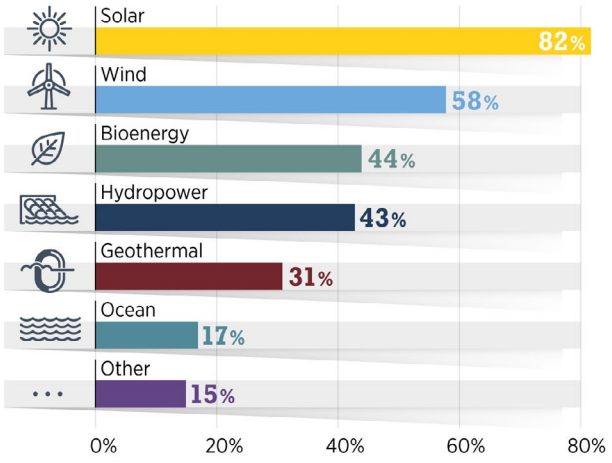
Renewable Energy: A Gender Perspective (IRENA)

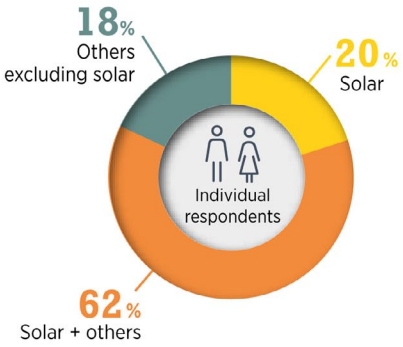
Renewable Energy: A Gender Perspective provides new insights on women's role in renewable energy employment and decision-making globally.

This report by the **International Renewable Energy Agency (IRENA)** aims to help fill the knowledge gap in this field. Based on a ground-breaking, first-of-its-kind online survey combined with in-depth research, the study highlights the importance of women's contributions in the energy transformation, the barriers and challenges they face, and measures that governments and companies can take to address these.

The study finds that **women represent 32% of the renewable energy workforce.** This compares favorably to the broader, conventional energy sector. **For those in the geothermal sector the share is 31%** (see figure below).

Types of renewable energy technology relevant to the work of individuals responding to the survey

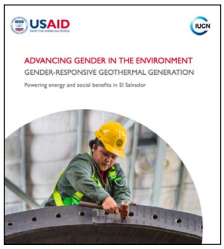




Source: IRENA online gender survey, 2018.

Still significant imbalances remain, both in highly developed markets and in communities where renewables are only now extending energy access. The decentralized nature of renewable applications, however, brings energy choices to the household and community level, where women tend to have a greater voice. Download the report.....

Gender-Responsive Geothermal Generation: Powering Energy and Social Benefits in El Salvador (International Union for Conservation of Nature)



This case study highlights the various ways in which **LaGeo**—a geothermal energy utility in **El Salvador**—developed strategies throughout its corporate mission and operations to adhere to national laws on gender equality and national development goals, resulting in environmental, social, and women's empowerment outcomes, as well as positive impacts on business outcomes.

This case study shows how utilities can increase gender equality and promote women's empowerment through institutional policies, examining management structures, and utilizing **corporate social responsibility (CSR)**. It also highlights how LaGeo used CSR initiatives across numerous impact areas, such as livelihood activities, reforestation and mitigation efforts, social infrastructure development, conservation work, education, and health initiatives to demonstrate the benefits of geothermal energy in delivering environmental sustainability and employment. In turn, these efforts build strong community relations to help mitigate and prevent vandalism. The case provides recommendations and selected resources for further reading that other companies, across sectors, might consider. Download the report.....

Accelerating Geothermal Heat Adoption in The Agri-Food Sector: Key Lessons and Recommendations (IRENA)

Predominantly known for power generation and district heating, geothermal energy can also be used in its primary form (i.e. heat) in the agri-food sector – for instance in greenhouses or for food drying and processing.

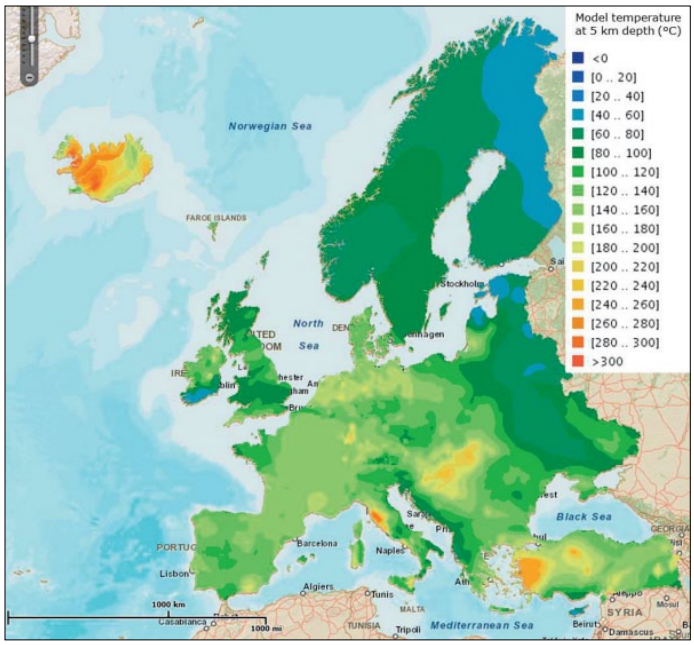
Using it for such purposes can help increase food availability, reduce dependency on fossil fuels, protect against price volatility and diminish harmful emissions from the sector. Furthermore, it can significantly reduce food waste. Download the report.....

CHPM2030 Brochure Now Available in 14 Languages

The brochure for the "**Combined Heat, Power and Metal extraction" (CHPM)** project is now available in 14 languages:

English Download | Czech Download | Dutch Download | Finnish Download | French Download | German Download | Greek Download | Hungarian Download | Italian Download | Polish Download | Portuguese Download | Serbian Download | Slovenian Download | Spanish Download

CHPM2030 aims to develop a novel and potentially disruptive technology solution that can help satisfy the European needs for energy and strategic metals in a single interlinked process. Working at the frontiers of geothermal resources development, minerals extraction and electro-metallurgy the project aims at converting ultra-deep metallic mineral formations into an "**orebody-Enhanced Geothermal Systems (EGS)**" that will serve as a basis for the development of a new type of facility for CHPM.



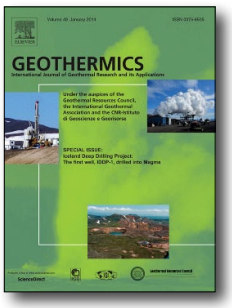
Earth's Geothermal Hotspots: New Dataset Launched (European Commission)

A global geothermal energy dataset which the **Joint Research Centre (JRC)** of the **European Commission** has been updating since 2014, has been made publicly available, with a wealth of information for assessing the global market for geothermal power.

The dataset covers all **366 geothermal power plants** that exist across the world. It shows how the cumulative capacity of geothermal power has increased steadily and almost linearly since 1985, reaching about 10.4 GW in 2017.

Beyond capacity, there's also a wealth of technical and market information about geothermal power plants, including turbine type, reservoir information and turbine manufacturer. Go to the Dataset webpage.....

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 ■

Calendar of Events

International Geothermal Workshop (IEA Geothermal and Geoplat)
8-9 April, Gran Canaria, Spain
http://iea-gia.org/gran-canaria-geothermal-workshop/

SoCal Section of the Geothermal Resources Council - Meeting
9 April, 3:30 pm, Stockmen's Club, Brawley, California
https://geothermalresourcescouncil.blogspot.com/2019/03/usa-california.html

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

XXVI Mexican Geothermal Association (AGM) Annual Congress
10-12 April 10, Morelia, Michoacán, Mexico
http://geotermia.org.mx/congreso-agm/

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

12th Imperial Valley Renewable Energy Summit (Imperial Valley Economic Development Corporation)
24-26 April, Imperial, California, USA
www.ivedc.com/events/imperial-valley-renewable-energy-summit-2019/

39th Euroheat & Power Congress
6-8 May, Nantes, France
https://www.ehpcongress.org/

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

National Geothermal Academy 2019
10-21 June, Reno, Nevada, USA
https://gbcge.org/education/

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

GeoEnergy Days (Pole Avenia)
25-27 June, Pau, France
http://www.geoenergydays.com/

6th Geothermal Congress for Latin America and the Caribbean (GEOLAC)
16-18 July, Santiago, Chile
http://newenergyevents.com/geolac/

2019 ARMA-CUPB International Geothermal Conference
5-8 August, Beijing, China
http://www.arma-cupb.com/homePage/cupb/index.html

7th Indonesia International Geothermal Convention and Exhibition (IIGCE)
13-15 August, Jakarta Convention Center, Indonesia
http://www.iigce.com/

3rd International Geothermal Conference GEOHEAT
3-6 September, Petropavlovsk-Kamchatsky, Russian Federation
http://www.igc-geoheat.com/

1st Conference on Geophysics for Geothermal and Renewable Energy Storage
8-12 September, The Hague, Netherlands
https://events.eage.org/en/2019/near-surface-2019/conferences/1st-conference-on-geophysics-for-geothermal-and-renewable-energy-storage

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

European Geothermal Workshop 2019 - Characterization of Deep Geothermal Systems
9-10 October, Karlsruhe Institute of Technology, Germany
http://www.agw.kit.edu/EGW2019.php

Geothermal Resources in Sedimentary Basins Conference
14-18 October, Edmonton, Alberta, Canada
http://gssb2019.com/

1st Canadian Geothermal Students Day
November, Québec City, Québec, Canada
https://canadiangeothermal.wixsite.com/cgsd

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 ■

The GRC Membership Directory At Your Fingertips

www.my.geothermal.org

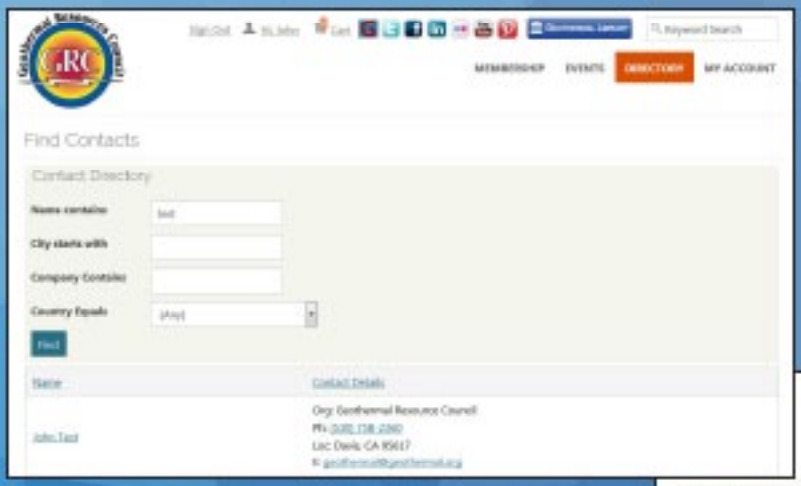
The online membership directory provides the most up to date contact information for all GRC members at your fingertips.

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)

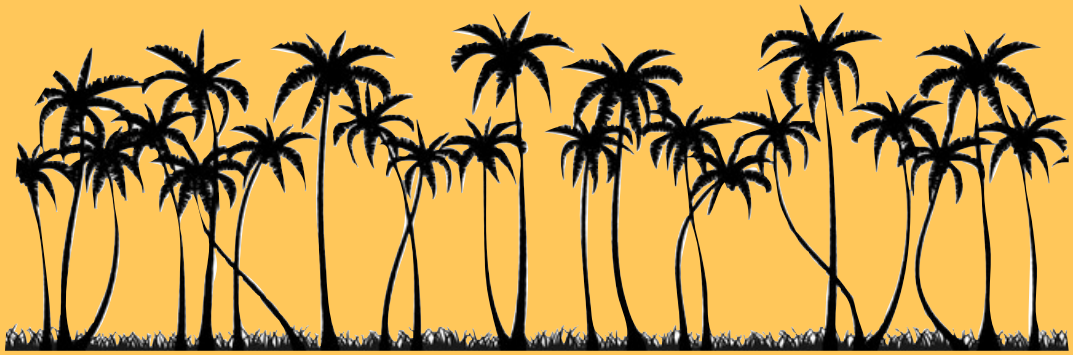
Step 4

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 Resources Council

GRC



PALM SPRINGS

CONVENTION CENTER

PALM SPRINGS, CALIFORNIA

GRC ANNUAL MEETING

SEPTEMBER 15-18, 2019