GEOTHERMAL RESOURCES COUNCIL

Bulletin

Vol. 47, No. 4
July/August 2018

GRC Annual Meeting & Expo - Register NOW!

-Geothermal's Role in Today's Energy Market

Reducing Risk

-Removing Silica from Geothermal Brine

-Protecting a Geothermal Power Plant from Lava

-Increasing Reservoir Capacity with EGS

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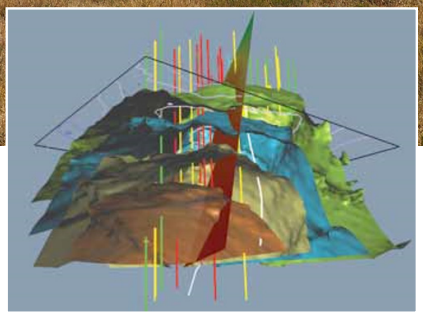

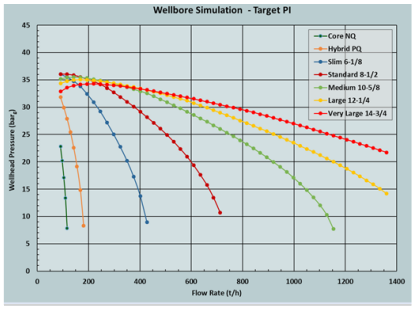

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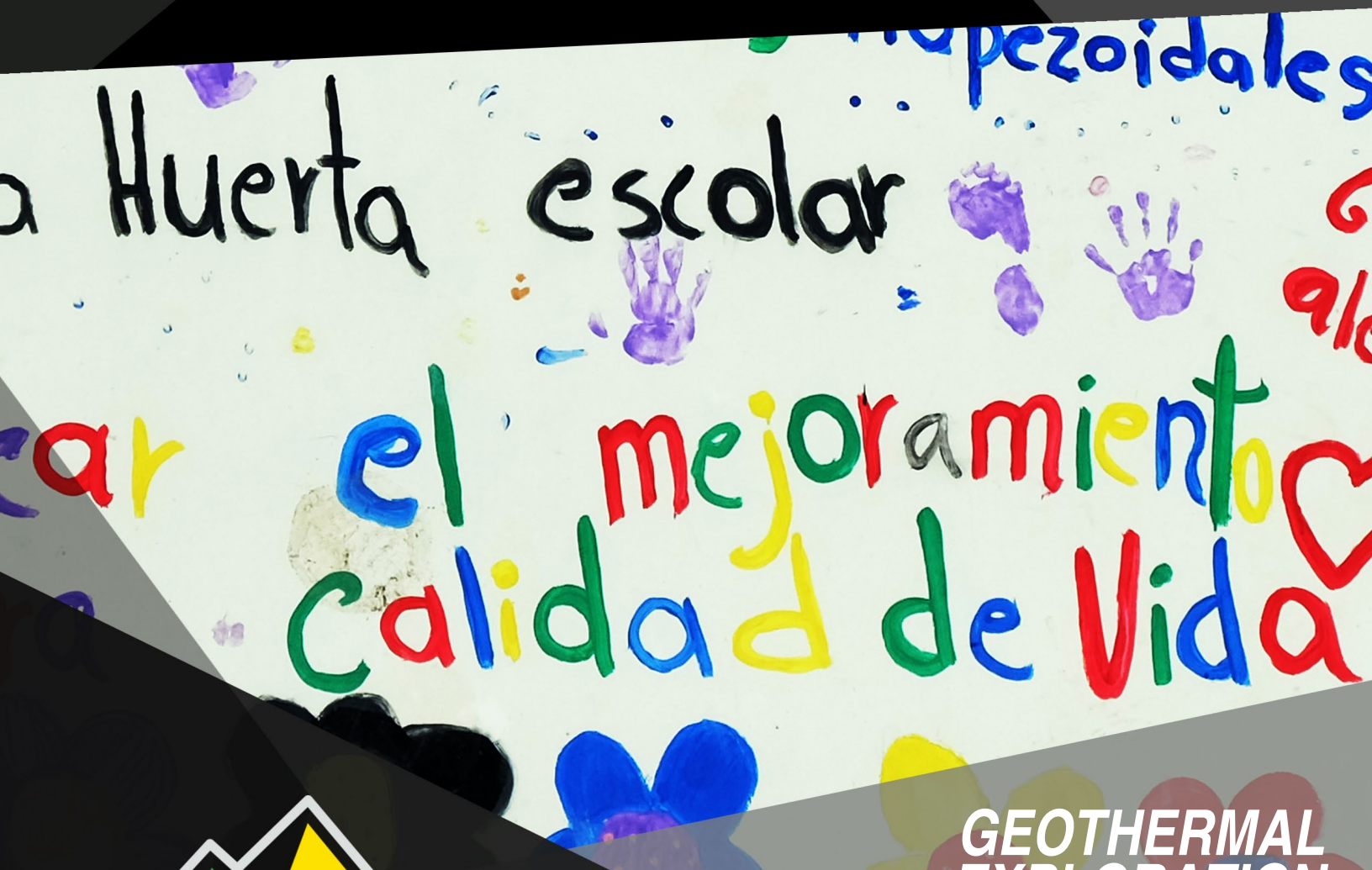

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The Geothermal Resources Council (GRC) *Bulletin* (ISSN No. 01607782) is published as a service to its members and the public, with six issues per annual volume. The GRC is an international, non-profit educational association whose purpose is to encourage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

COVER: *The Power of Thor.* *By **Robert Zierenberg**,* Davis, USA. The lighthouse on the Reykjanes Peninsula, Iceland, showing the way to safe passage at sea, and the drilling rig Thor at the Iceland Deep Drilling Project (IDDP) -2 supercritical drill hole, showing the way to the future of geothermal power. GRC Photo Contest 2017.

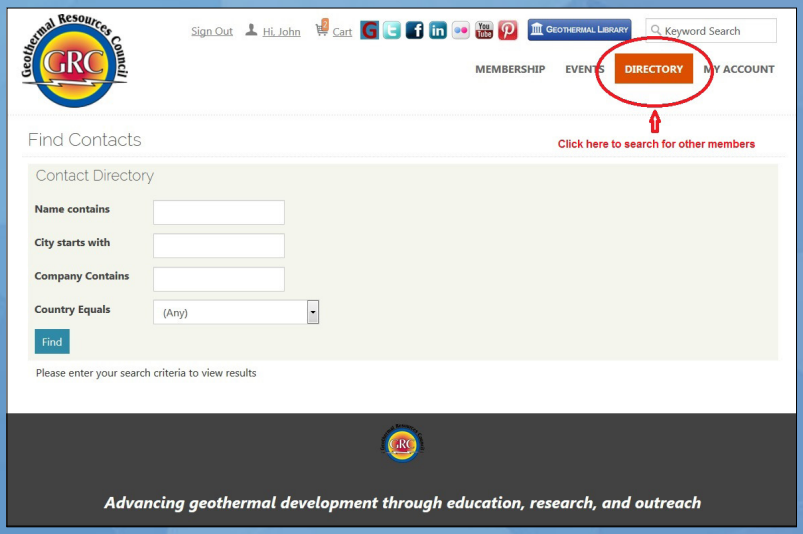
The GRC Membership Directory At Your Fingertips

www.my.geothermal.org

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

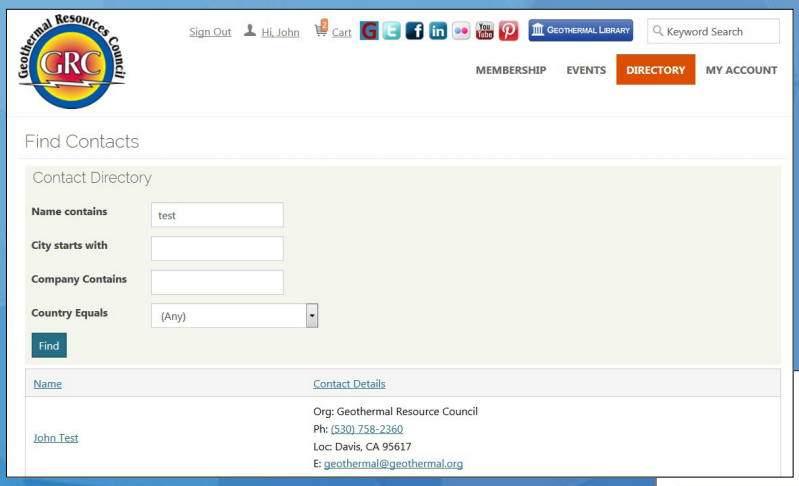
Step 1

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



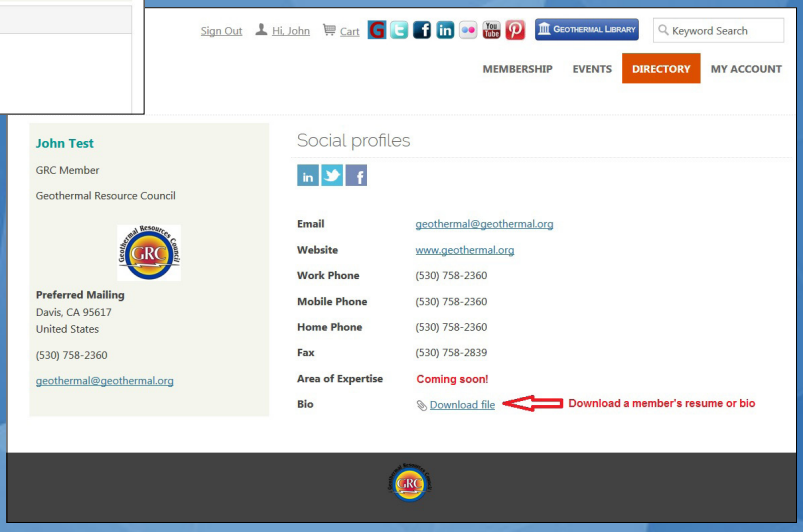
Step 2

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!

President's Message

by Maria Richards

Time to Celebrate!

Wohoo! Celebration time is here! YES, that is how I feel with Will Pettitt as our Executive Director. His ideas, knowledge, energy, and enthusiasm for geothermal resources bring to life my brainstorming ability. I find myself back to daydreaming (not stressing) about possibilities for GRC and the geothermal community. If you want to feel renewed and share your future hopes for GRC, I suggest giving him a call, rather than email, to allow the two of you to build a relationship.

Looking back over the past three years there are many reasons to celebrate as a GRC Member. It's rare when we take time to highlight our successes. Working this past year closely with Estela, Anh, Ian, Brian, and Chi-Meng, we'd discuss weekly the current projects and how to keep improving them, advancing programs, working around set-backs, etc., thus only briefly celebrating their accomplishments. The GRC Board is also focused on future activities, rather than reflecting on what we've accomplished.

I am a believer in 'high fiving' incremental accomplishments and celebrating big successes. Acknowledging the larger number of small successes creates the true meaning of synergy when a final goal is met. As July is the beginning of our GRC budget year, this seems like a perfect time to share and highlight our GRC milestones from the past few years, so you as a Member can cheer too.

List of GRC Successes for Fall 2016 - June 2018

- Strategic Plan completion (October 2016)
- Email address GRCPres@geothermal.org established so members can easily connect with the President (January 2017)
- Society of Petroleum Engineers and GRC host combined workshop: High Temperature and Corrosion in Drilling & Production (Spring 2017)
- Put on two workshops in Indonesia on "Integrated Subsurface Analysis to Optimize Decisions in Geothermal Exploration" and "Project Development Strategy and Economic and Investment Evaluations" (Summer 2017 & 2018)
- Online Membership Directory through my.geothermal.org (Fall 2017)
- GRC Members raise funds for colleagues impacted by The Geysers area wildfires (Fall 2017)
- New Annual Meeting venue a success in Salt Lake City, Utah - SLC was a new venue for many of us (Fall 2017)
- Largest 'Meeting of the Members' on record held in SLC (Fall 2017)
- New GRC Policy Committee (Fall 2017)
- Unification voted on by members of Geothermal Energy Association and Geothermal Resources Council (December 2017)
- Board of Directors fills all 30 seats again to increase diversity and knowledge on board (2017-18)
- Ambassador Program and related materials (see the website for more details) (Fall 2017 and ongoing)
- Initiation of first International Satellite office located in Bogota, Columbia (December 2017)
- Transition to digital *Bulletin* and *Roster* (Spring 2018)
- Society of Exploration Geophysicists and GRC sign an MOU for enhancing member benefits and activities (Summer 2018)
- Positive cash-flow for budget year-ending in June 2018 (Summer 2018)
- $45,000 of GRC Student Scholarships given to 15 US, and 3 International students in the past three years
- Field trips from the GRC Annual Meeting to The Geysers, the California Independent System Operator (CAISO), Yellowstone, Southern Utah Geology & Geothermal Power Plants, Northern Nevada Geology and Geothermal Power Plants, Steamboat Springs Geothermal Field, the Peppermill Resort Direct Use Geothermal Heating System and to Fly Ranch Geyser and San Emidio Geothermal Power Plant. ■

Executive Director's Message

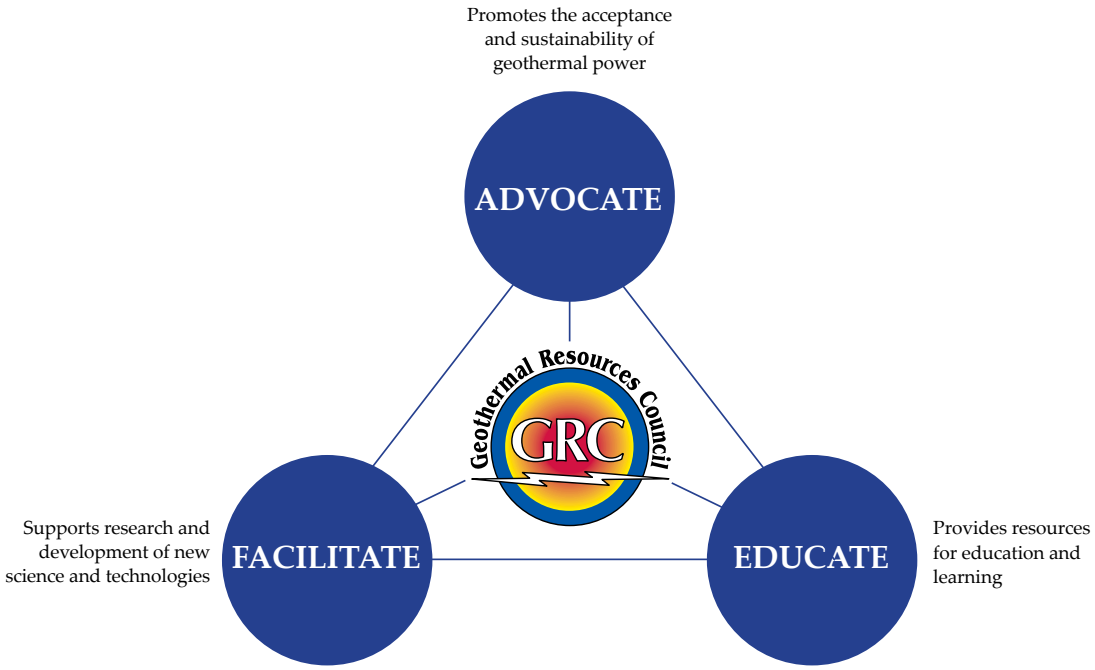
by Will Pettitt, PhD

The GRC at once Advocates, Facilitates and Educates

It's been with great pleasure that I've begun my new role with the GRC as Executive Director and I'm now writing the first of my articles in the *Bulletin*. In the first few weeks I've been impressed with the commitment, talent and professionalism of everybody involved in the organization. In that sense the GRC epitomizes the geothermal community, our wider membership, and our national and international collaborators. The geothermal industry is going through a period of resurgence and new growth, with new science, technologies, projects and opportunities. I believe our membership will look towards the GRC to lead our community, and speak on behalf of the industry, through this next phase.

Our organization's mission is to help elevate the whole industry by raising the recognition and acceptance of geothermal energy across the spectrum of society in government, industry, academia and the general public, both at home and abroad. Geothermal energy should be synonymous with renewable energy and should be the first word that is uttered when government leaders give speeches that reference renewable energy; it should not be missing from the list of alternatives or from the discussion. Similarly, the first thought in the public conscience about renewable energy should be geothermal energy and the reasons why our power is the future of renewables should be clear and obvious to all. We should be outward facing and actively collaborating with other renewable industries to be a vibrant partner within this sector. I believe that working towards these goals, by taking all the small, practical, steps to get there, will help us achieve our mission.

Those practical steps rely on the strategic direction of the GRC as an organization. One of my first activities is to review that strategy with our Board of Directors and understand their direction in terms of specific initiatives and priorities. The GRC staff are also knowledgeable and experienced and have their own views, enthusiasm and passions for our focus moving forward. You, our membership, can provide input and encouragement to



all of us through your communications with the Board and our staff, and through your involvement in our activities, outreach and balloting. I see the motivation of GRC as being summed up by three words: Advocate; Facilitate; Educate.

- Be a strong, sustainable and robust professional society that advocates on behalf of our membership to increase recognition of the geothermal industry in a collaborative environment with our partners;
- To facilitate research and development of science and technologies for geothermal power to help drive its implementation and efficiency;
- To educate our membership, community and society by providing resources and activities that network, inform and provide assistance to our members in their own work.

As brief examples, here are three ongoing initiatives that I encourage you to learn more about from our website and feedback ideas for what could be further achieved:

1. The Policy Committee has been set up as part of the merger between GEA and GRC to be our advocacy group with government and to support legislation at all levels;
2. Our Annual Meeting in Reno looks to be the most successful and thriving in many years and we hope to welcome many of you there starting Friday October 12 with our pre-conference workshops;
3. The Ambassador Program aims to inform and educate through a network of volunteers in industry and academia to expand awareness of geothermal energy across all parts of society.

There is much work to do, and a lot to be accomplished, for the GRC to fulfill our mission for our industry and community in partnership with our membership and collaborators. On behalf of all the staff and board, we look forward to working with you on these initiatives and helping support you in your own endeavors. ■

Communication from the GRC

by Ian Crawford
Director of Communications

William Pettitt is the New Executive Director of the GRC

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

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

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

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

Successful First Meeting of the GRC Policy Committee

The GRC recently unified with the Geothermal Energy Association (GEA), the US trade association for commercial interests in geothermal electricity production, to strengthen our ability in advancing the science, education, and development of renewable geothermal energy resources.

The GRC Policy Committee has been set up as a separate part of the GRC, independently funded by interested organizations, to advocate on behalf of the geothermal community. It has successfully held its first meeting with a well-attended conference call that touched on some current federal and state legislative affairs affecting the industry.

The Policy Committee discussed the active Renewable Portfolio Standard and Energy Choice initiatives in Nevada, legislative activity in California, and federal efforts to streamline geothermal drilling.

Discussions will continue to determine the GRC's role in these issues. If you would like to join the next meeting of the Policy Committee, or learn more about their initiatives, then please contact **Josh Nordquist** (Chairman), **Will Pettitt** (Executive Director), or **Anh Lay** (Membership Services).

More Information about the GRC Policy Committee.....

Registration is Now Open

The biggest geothermal energy event of the year is just a few months away. Make your arrangements now!

Preparations are almost complete for the 2018 GRC Annual Meeting and Expo. The latest information is available on the GRC website at: www.geothermal.org/meet-new.html.

A *Program* is available to view, download and print-out if you wish. However, we strongly urge you to view all the information on your computer or mobile device.

Early birds who register **before September 30** pay only **$880** as Geothermal Resources Council (GRC) members for a three-day registration or $1080 as non-members. **The non-member registration includes GRC membership through 2019.** The cost includes lunches on all three days and a USB stick containing all the Technical Papers.

Students with a current identification card from an accredited institution **pay just $150** for a three-day registration which also includes GRC membership through 2019.

In addition to the expansive Technical Program the three-day registration to the GRC Annual Meeting includes an Opening Reception on Sunday evening, the Opening Session on Monday morning, a Networking Reception on Tuesday **and entry to the Expo.**

Register Online at: http://my.geothermal.org/
OR

Register now using the GRC Annual Meeting *Registration Form* available on the GRC website at: www.geothermal.org/meet-new.html

Early bird discount ends September 30.

Reserve your Room for the Geothermal Event of the Year

https://aws.passkey.com/event/49537648/owner/7268/home

Reservations can now be made for hotel rooms for the GRC Annual Meeting & Expo in Reno, Nevada, USA, October 14-17, 2018

All the events and accommodation are in one location, the luxurious **Peppermill Resort Spa Casino.**

There is a choice of three room styles at discounted rates. In the **Peppermill North and West Wings** the room rates start at an affordable **$89 a night**. The award winning luxurious **Tower Rooms** offer panoramic views of the majestic Sierra Nevada mountains and are available from **$109 a night.** Top of the line are the lavish accommodations in the **Tuscan Tower** at **$149 a night.**

The discount ends September 19.

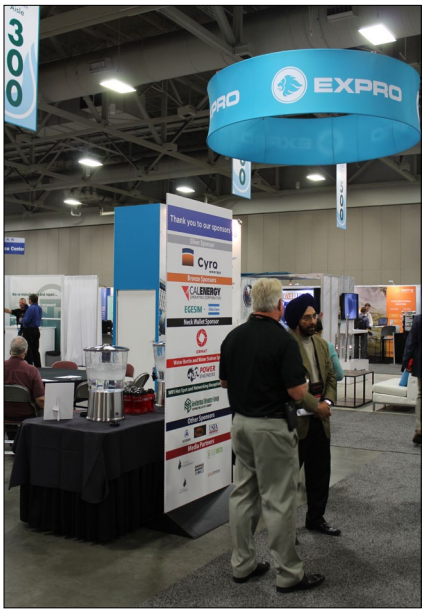
Attendees can make their reservations on a secure website prepared specially for the GRC. The links are available from the GRC Annual Meeting website at: www.geothermal.org/meet-new.html.

The Edge patio overlooking the geothermally-heated swimming pools at the Peppermill. Courtesy The Peppermill.

Exhibitors - Reserve a Booth

The **3-day expo** held in conjunction with the Annual Meeting will provide ample opportunities for networking. The GRC Expo presents exhibitors with the opportunity to maximize their exposure at the largest annual geothermal energy gathering in the world.

All the essential information is available on a new website hosted by the GRC at http://my.geothermal.org/GRC/Exhibitor/GRC/Exhibitor_Portal/Exhibitor_Portal.aspx



The Expo hall in 2017. Photo by Ian Crawford.

Last year, the Expo hosted 78 Exhibitors. In 2018, we anticipate an even larger number.

Exhibitors who desire a booth at the Expo should contact the GRC. Contact Anh Lay at alay@geothermal.org or (530) 758-2360 for more information.

Geothermal Event? We've got an app for that!

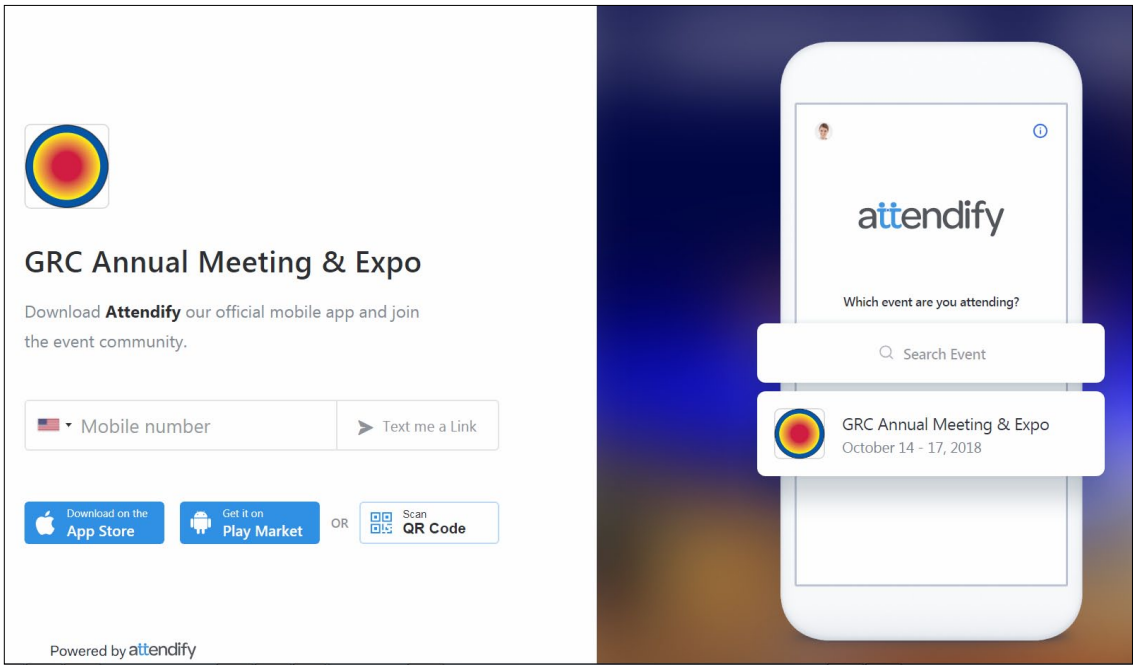
Due to popular demand we are again providing **a mobile app** for the GRC Annual Meeting & Expo for use on a **Smartphone, tablet or desktop.** This is the best way to keep up-to date with news and information at your favorite geothermal energy event. Are you going to Reno to network? The app will help you find old friends and connect with new ones.

The app can be downloaded from a dedicated website at https://attendify.com/app/o2gnls/ - the instructions are a little different to last year - **you have to first download a "container app".**

1. Download the "**Attendify - Network at Events**" app from the **App Store** or **Google Play.**
2. Open the app and sign up by tapping the corresponding button at the top or bottom of the page, or log in if you already have a profile. To create an account, we recommend using the email address you registered for the event with.
3. Search for "**GRC Annual Meeting**".
4. If you already joined an event, it will be visible on the home screen of the Attendify App under "**Your Events**" section, or you can quickly open the list of all events you joined from the side menu.
5. On the event card, you can find the GRC Annual Meeting's date, location, and description. **Tap join to access the event**, see the full, up-to-date information and start interacting with other users.

You are in now! Here is what you can do with the Attendify App:

- Share photos, post messages, comment & like other users' posts
- @mention other attendees in your post and they will receive a notification about it
- Cross-post to other social networks (Twitter, LinkedIn)
- Connect & network with other attendees
- Send private messages
- Save participants' profiles as VCards to your phone
- Take notes (you can #tag other attendees to document something about them)
- Bookmark sessions, speakers, sponsors, exhibitors, and attendees
- Rate speakers and sessions, provide feedback & comments
- Set scheduled reminders for sessions & create a personal schedule
- Receive push notifications from the event organizer
- Vote in polls & view voting statistics
- Access all event information (schedule, documents, maps, speaker bios)
- Search attendees by "Interests"



Download the app at https://attendify.com/app/o2gnls/

Inside Geothermal

Preparing For The Future – The IGA Is Implementing Far Reaching Changes

The **International Geothermal Association (IGA)** has published a manifesto for change that sets forth a vision for the European-based organization.

The Geothermal Resources Council (GRC) is an affiliate of the International Geothermal Association (IGA).

Upon concluding a tremendous amount of work on a strategic alignment program, the International Geothermal Association is implementing a series of changes. These improvements will help prepare the geothermal sector for the future and emphasize the IGA's role in the representation of the global geothermal energy sector.

To focus and strengthen its role, the International Geothermal Association (IGA) is proud to announce a series of reforms following the recent decisions made during the IGA Board of Directors meeting in Reykjavik, Iceland.

IGA has made strides toward a more sustainable, independent structure that reflects the international nature of the representing body of the global geothermal sector through the association. This effort will transition IGA to an independent structure and position itself for growth by changing its funding model and modus operandi.

IGA understands the need to sharpen its value proposition for members and has taken steps to redefine elements of its membership model. Henceforth, IGA will increase its emphasis on the industry with different corporate membership levels and engagement. At the same time, the association will sharpen its profile towards value proposition for our affiliated members, national associations, and institutions.

Alongside many ongoing and planned initiatives, the IGA is striving to create value for the geothermal sector and expand its collective voice on behalf of global geothermal development. These initiatives are already well underway with the deployment of UNFC *Specifications for Geothermal Energy Resources*, and engagement on the *Geothermal Sustainability Assessment Protocol.* IGA is planning to establish an Advisory Council to support IGA and its initiatives.

IGA is actively taking steps for a deeper engagement with industry on activities and alignment that supports and strengthens our scientific and academic roots.

Furthermore, IGA has decided to change the frequency of the World Geothermal Congress from every five to three years. Following the World Geothermal Congress 2020, which will be held from April 27 to May 1, 2020 in Reykjavik, Iceland, the next congress will take place in 2023. The aim of this decision is to engage more frequently with our global members and emphasize the importance of promoting geothermal energy and its benefits for other industries.

IGA is preparing a new communications strategy with the goal of increasing engagement with its membership, affiliated organizations, partners and the wider international geothermal community. IGA is also proud to present and launch their new website: www.geothermal-energy.org and www.lovegeothermal.org. More Information.....

The current IGA Board includes a number of GRC Members.

Over 90,000 Employed in the Worldwide Geothermal Sector

TABLE 1. ESTIMATED DIRECT AND INDIRECT JOBS IN RENEWABLE ENERGY WORLDWIDE, BY INDUSTRY, 2016-17

	World	China	Brazil	United States	India	Germany	Japan	Total European Union[k]
Solar Photovoltaic	3 365	2 216	10	233	164	36	272	100
Liquid Biofuels	1 931	51	795[g]	299[h]	35	24	3	200
Wind Power	1 148	510	34	106	61	160	5	344
Solar Heating/ Cooling	807	670	42	13	17	8.9	0.7	34
Solid Biomass[a,b]	780	180		80[i]	58	41		389
Biogas	344	145		7	85	41		71
Hydropower (Small)[c]	290	95	12	9.3	12	7.3[j]		74[l]
Geothermal Energy[a,d]	93	1.5		35		6.5	2	25
CSP	34	11		5.2		0.6		6
Total (excluding Large Hydropower)	8 829[f]	3 880	893	786	432	332	283	1 268
Hydropower (Large)[c,e]	1 514	312	184	26	289	7.3[j]	20	74[l]
Total (including Large Hydropower)	10 343	4 192	1 076	812	721	332[j]	303	1 268[l]

The figures include geothermal power, heat and ground-based heat pumps for EU countries.

The renewable energy industry created more than 500,000 new jobs globally in 2017, a 5.3 per cent increase from 2016, according to the latest figures released by the International Renewable Energy Agency (IRENA). According to the fifth edition of *Renewable Energy and Jobs – Annual Review*, the total number of people employed in the sector (including large hydropower) now stands at 10.3 million globally, surpassing the 10 million figure for the first time.

The figures for geothermal include power, heat and ground-based heat pumps for EU countries. IRENA estimates employment in the **United States' geothermal sector at 35,000 jobs** followed by the European Union at 25,000 including Germany with 6,500, Japan - 2,000, and China - 1,500. A total of 93,000 are employed in the geothermal sector worldwide. *Global Geothermal News.....*

NORTH AMERICA

Utah Site Selected for Location of the Frontier Observatory for Research in Geothermal Energy

The U.S. **Department of Energy (DOE)** has announced that the **University of Utah** will receive up to **USD 140 million** in continued funding **over the next five years** for cutting-edge geothermal research and development.

After three years of planning, site characterization, and competition, the proposed site outside of **Milford, Utah** has been selected as the location of the **Frontier Observatory for Research** in **Geothermal Energy (FORGE) field laboratory**.

This new FORGE site is dedicated to research on enhanced geothermal systems (EGS), or man-made geothermal reservoirs. *Global Geothermal News.....*

See the special article *Frontier for Research in Geothermal Energy Awarded to University of Utah* on page 36 for more information on this news.

Just Under 8,000 Employed in the U.S. Geothermal Power Generation Industry

Produced by the **Energy Futures Initiative (EFI),** in partnership with the **National Association of State Energy Officials (NASEO)**, the *U.S. Energy and Employment Report* (USEER) finds that the Traditional Energy and Energy Efficiency sectors today employ approximately 6.5 million Americans. These sectors increased in 2017 by about 2 percent, adding 133,000 net new jobs, roughly 7% of all those created in the country.

According to the report, **the geothermal power generation industry employed 7,927 in 2017**, up from 5,768 in 2016 and 7,645 in 2015. An additional **27,239 were employed in the combined heat and power plants (CHP) sector.** *Global Geothermal News.....*

USD 3.6 Million Available for Projects Involving Machine Learning for Geothermal Energy

The U.S. **Energy Department (DOE)** has announced up to **USD 3.6 million** for 4-6 projects that will focus on early-stage **R&D applications** in **machine learning** to develop technology improvements in exploration and operational improvements for geothermal resources. The rapidly advancing field of machine learning offers substantial opportunities for technology

advancement and cost reduction throughout the geothermal project lifecycle, from resource exploration to power plant operations.

Through this *funding opportunity announcement* (FOA), DOE's **Office of Energy Efficiency and Renewable Energy (EERE) Geothermal Technologies Office (GTO)** will fund projects to support new analytical tools for finding and developing geothermal resources, to establish the practice of machine learning in the geothermal industry, and maximize the value of the rich datasets utilized in the geosciences.

GTO will provide funding in two areas:

1. **Machine Learning for Geothermal Exploration**
2. **Advanced Analytics for Efficiency and Automation in Geothermal Operations**

For consideration of full application, applicants must submit their concept paper **by 5 p.m. ET on Aug. 23, 2018** to be eligible to submit a full application. *Global Geothermal News.....*

DOE Announces USD 4.3 Million Funding to Advance Waterless Stimulation Technologies

The Department of Energy's **Geothermal Technologies Office (GTO)** has announced the selection of three projects to receive up to **USD 4.3 million** in funding via a Lab Call to conduct early-stage research and development to advance state-of-the-art **waterless stimulation technologies** applied to geothermal wellbores.

The selected projects include:

- **Oak Ridge National Laboratory** – *Foam Fracturing Study for Stimulation Development of Enhanced Geothermal Systems*
- **Pacific Northwest National Laboratory** – *Responsive Fracturing Fluids for Enhanced Geothermal Systems*
- **Sandia National Laboratories** – POT *(Pressure, Orientation, & Timing) for Anhydrous Energetic Stimulation*

The most commonly applied wellbore stimulation technology, **hydraulic fracturing**, relies heavily on water-based fracturing fluids due to the general availability and low cost of water as well as its capability for proppant transport. DOE is interested in developing **stimulation methods that require little to no water** – reducing the usage needed for geothermal progress and easing constraints on water consumption. In addition, there are crosscutting applications with oil and gas, where there is growing concern with the amount of water disposed after similar operations have been completed. *Global Geothermal News.....*

Loan Guarantees Available for Tribal Renewable Energy Projects

The U.S. **Department of Energy (DOE)** has issued the first loan guarantee solicitation for the **Tribal Energy Loan Guarantee Program (TELGP)** under DOE's **Loan Programs Office**. This solicitation provides as much as USD 2 billion in partial loan guarantees to support economic opportunities for **Native American** and **Alaska Native** communities through energy development projects and activities.

Authorized by the **Energy Policy Act of 2005,** TELGP would provide partial loan guarantees to leverage private sector lending and help increase the availability of commercial debt financing in **tribal energy markets,** rather than replace existing debt markets, for commercial technologies. This partial loan guarantee model is based on the successful **Financial Institution Partnership Program (FIPP)** which DOE has used to help projects leverage public and private lending for energy infrastructure projects. *Global Geothermal News.....*

NREL Releases Updated Annual Technology Baseline for Electricity Generation

The DOE's **National Renewable Energy Laboratory (NREL)** has released the ***2018 Annual Technology Baseline (ATB)***, updating a key source of reliable electricity generation technology cost and performance data used to support and inform electricity sector analysis in the United States.

Now in its fourth year, the ATB documents technology-specific information on a broad spectrum of electricity-generation technologies,

including wind, solar, **geothermal,** hydropower, biopower, coal, natural gas, and nuclear.

Geothermal technology cost and performance projections will be more extensively updated upon completion of the **Geothermal Vision Study.** Until then, the projections are based on those documented in **2017 ATB - Geothermal,** with the following changes:

- The dollar year was updated from 2015 to 2016 with 1.3% inflation.
- Technology-specific financial assumptions are included, as for other technologies in 2018 ATB, using data from Wall 2017 (*Geothermal Costs of Capital: Relating Market Valuation to Project Risk and Technology,* Wall, Anna M.; Dobson, Patrick F.; Thomas, Holly Geothermal Resources Council *Transactions*, v. 41).

Global Geothermal News.....

Annual Technology Baseline

National Renewable Energy Laboratory

Over USD 600,000 for Geothermal Technologies in Small Business Innovation Research Funding

SBIR·STTR America's Seed Fund

Nearly **USD 13 million** in funding has been announced for **Small Business Innovation Research (SBIR)** and Small Business Technology Transfer (STTR) research and development projects under the auspices of the **Office of Energy Efficiency and Renewable Energy (EERE).** The money will fund 87 new projects across 34 states including four geothermal energy projects:

- **Porifera Inc.,** San Leandro, California
  USD 149,916.79 - SBIR
  An Efficient PFO-SPS System for Concentration of Brines and Wastewater
- **Mainstream Engineering Corporation,** Rockledge, Florida
  USD 149,955.11- SBIR
  Thermal Energy Storage for Dispatchable Geothermal Power
- **Tech4Imaging LLC**, Columbus, Ohio
  USD 155,000.00 - SBIR
  Non-Invasive Operations Tool for Dispatchable Geothermal Wells
- **TerraCOH Inc.,** Hopkins, Minnesota
  USD 149,999.69 - SBIR
  CO2 Plume Geothermal (CPG) and the Earth Battery - Innovative Geothermal Power Production Using Non-water Working Fluids

Global Geothermal News.....

U.S. Geothermal Steam to Provide 4,960 MW Generating Capacity by 2021 - FERC

Proposed Generation Additions and Retirements by March 2021

	Additions		Retirements	
Primary Fuel Type	No. of Units	Installed Capacity (MW)	No. of Units	Installed Capacity (MW)
Coal	5	1,827	70	17,008
Natural Gas	366	92,965	136	15,544
Nuclear	6	6,363	5	4,532
Oil	29	754	39	523
Water	262	12,545	25	706
Wind	474	84,392	2	68
Biomass	61	680	18	70
Geothermal Steam	24	1,130	0	0
Solar	1,761	48,816	5	2
Waste Heat	8	176	0	0
Other *	49	680	1	0
Total	3,045	250,328	301	38,453

Sources: Data derived from Velocity Suite, ABB Inc. and The C Three Group LLC. The data may be subject to update.

* "Other" includes purchased steam, tires, and miscellaneous technology such as batteries, fuel cells, energy storage, and fly wheel.

The U.S. **Federal Energy Regulatory Commission (FERC)**'s latest *Energy Infrastructure Update* also reveals that the total installed capacity of **renewable energy sources now provides over one-fifth (20.39%)** of total available U.S. generating capacity.

Combined, wind and solar alone exceed one-tenth (10.18%) of installed capacity–a share greater than either nuclear power (9.11%), hydropower (8.49%) or oil (3.64%). **Geothermal steam provides 0.32% of total generating capacity with 3,830 MW.**

The report also estimates proposed Generation Additions and Retirements by March 2021. **Geothermal Steam is proposed to add 24 units for an additional 1,130 MW of capacity.** *Global Geothermal News.....*

New Zealand to Collaborate With U.S. DOE on Geothermal Energy Technologies

The U.S. **Department of Energy (DOE)** has announced an agreement with New Zealand's **Ministry of Business, Innovation and Employment (MBIE)** to collaborate on the advancement of geothermal technologies.

The overarching goal between DOE's **Office of Energy Efficiency and Renewable Energy (EERE)** and MBIE's **Labour, Science and Enterprise Group** is to establish a framework for cooperation in the development of advanced, cost-effective geothermal energy technologies; accelerate the availability of

geothermal technologies worldwide; and identify and address wider issues relating to geothermal energy, such as induced seismicity and mineral recovery. The proposed areas for collaboration include the joint development and improvement of modeling tools, mineral recovery, direct use applications, and supercritical geothermal systems. *Global Geothermal News.....*

Geothermal Scientists Get Berkeley Lab Support for EGS Startup

Fellowship program **Cyclotron Road** has announced the next cohort of fellows. These 13 scientists and engineers will spend the next two years embedded at **Berkeley Lab**, advancing their technology innovations from promising concepts to first products. **Two winning scientists are from the geothermal energy sector.**

Tim Latimer and Jack Norbeck will further develop their project: **Fervo Energy—Empowering Geothermal Energy.**

Fervo Energy is developing technology for power generation from **Enhanced Geothermal Systems (EGS)** incorporating proven, cost-effective technologies from other fields, such as horizontal drilling, to unlock the potential of geothermal energy. *Global Geothermal News.....*

Jack Norbeck *(left) and* **Tim Latimer** *(right)*

EnergySource Lithium from Geothermal Brine Project Begins Design Phase

EnergySource, the developers of the **55 MW John L. Featherstone geothermal power plant** in Southern California, has been awarded a **USD 2.5 million state grant to study lithium extraction from geothermal brine.**

The project, at the **Hudson Ranch** site next to the Salton Sea, started its design phase in May and will be ready to **break ground in about a year**. *Global Geothermal News.....*

Endangered Toad May Affect Nevada Geothermal Power Project

U.S. wildlife officials have agreed to consider **Endangered Species Act** protection for a rare toad in northern Nevada's high desert where **Ormat** wants to build a geothermal power plant.

The U.S. **Fish and Wildlife Service** said that conservationists presented substantial scientific information suggesting the **Dixie Valley toad** could be at risk of extinction. Its 12-month review will include examining the extent to which any conservation efforts have reduced the threats.

The 2-inch-long (5-centimeters) toad with flecks of gold on its olive-colored body was discovered in 2007 in thick underbrush of a spring-fed marsh in the Dixie Valley, where an ancient lake once covered 190,000 square miles (492,100 sq. kilometers).

It's only found in an area covering less than 3 square miles (7 square kilometers) in the marshy remnant of the lakebed east of Reno, Nevada.

U.S. land managers are considering Ormat Technologies' plans for a geothermal plant there next to the **U.S. Naval Air Station Fallon.**

A federal listing could trigger land-use restrictions, but it's not clear how it might directly impact plans for the geothermal plant in a state with a mandate to procure 25 percent of its energy from renewable sources by 2025.

Dixie Valley toad (Courtesy California Herps)

Officials with the U.S. **Bureau of Land Management** said the wildlife service's determination wouldn't immediately affect their review of the geothermal project. *Global Geothermal News.....*

Ormat Seeks Permission to Build 62 MW McGinness Hills III Geothermal Power Project

Energy company **ORNI 41** — a subsidiary of **Ormat Nevada, Inc.** — has applied to the Nevada **Public Utilities Commission** for permission to build a third unit at **McGinness Hills** in Northern Nevada.

The **McGinness Hills III project** would include a **62 MW** geothermal power plant built next to **two existing 48 MW** generating stations and a **230-kilovolt power line** to connect it to the grid.

The plant, like the first two phases of the McGinness Hills project, would be built on U.S. Department of the Interior's **Bureau of Land Management (BLM)** land. The company has already filed its applications with the federal government and **BLM has previously approved the location for a geothermal facility.**

The new plant will require drilling **five production wells and two injection wells.** The injection wells will be on private property leased to ORNI/Ormat. It will include about 15 acres of land altogether. *Global Geothermal News.....*

Both the U.S. Bureau of Land Management and Ormat Technologies will be exhibiting at the GRC Annual Meeting & Expo from October 14-17 at the Peppermill Resort Spa & Casino, Reno, Nevada, USA.

Private Investor Buys Into Tungsten Mountain Geothermal Power Plant

Ormat Technologies Inc. has announced that one of its wholly-owned subsidiaries that indirectly owns the **26 MW Tungsten Mountain geothermal power plant** entered into a partnership agreement with a private investor.

Under the transaction documents, the private investor acquired membership interests in the project for an initial purchase price of approximately **USD 33.4 million** and for which it will pay additional installments that are expected to amount to approximately **USD 13 million.** Ormat will continue to operate and maintain the power plant and will receive substantially all the distributable cash flow generated by the power plant.

The Tungsten Mountain geothermal power plant, located in Churchill County, Nevada, **began commercial operation on December 1, 2017.** *Global Geothermal News.....*

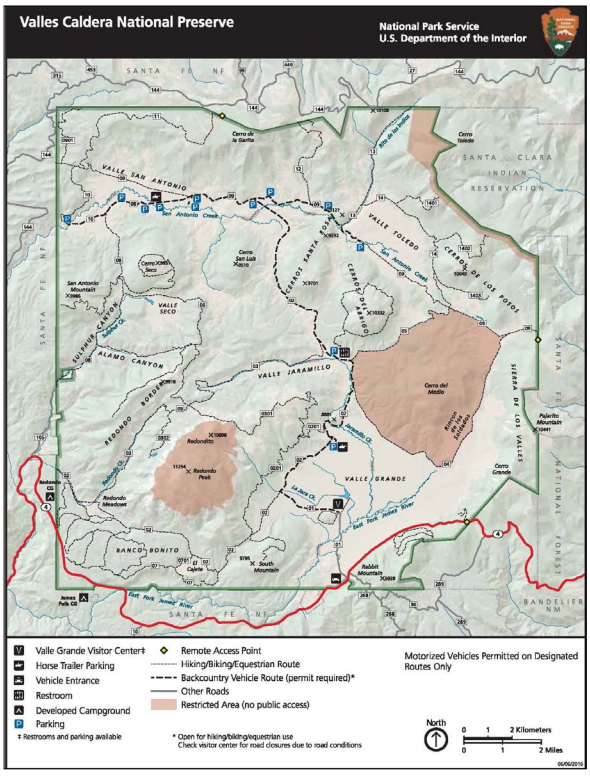
Utah Utility Seeking Cost-Competitive Bids for Geothermal Energy

In response to broad demand from communities and businesses for electric power from renewable energy sources, **Rocky Mountain Power** is seeking cost-competitive bids for solar, wind and geothermal energy projects in Utah to interconnect to the **PacifiCorp** system.

Customers sponsoring the request for *proposal* include **Park City, Salt Lake City, Summit County, Park City Mountain Resort, Deer Valley Resort,** and **Utah Valley University**, which are all working with Rocky Mountain Power to meet their clean air and sustainability goals through renewable energy.

The company is seeking proposals for **308,000 MWh** of power generation, which equates to approximately **40 MW of geothermal capacity** or approximately 100 to 126 MW of wind or solar capacity. This is **enough electricity to power about 34,000 typical homes in Utah.** *Global Geothermal News.....*

New Mexico Geothermal Resources Put Off Limits to Development



Courtesy National Park Service

The **Santa Fe National Forest** finalized a decision to prohibit energy development on 195,000 acres of land adjacent to **Valles Caldera National Preserve** in **New Mexico.** The lands have been under consideration since 2015 to be leased for geothermal development.

Valles Caldera National Preserve is one of the newest units in the U.S. National Park System and contains some of the most extensive geothermal activity in the West, including hot springs, bubbling mudpots and steaming fumaroles. *Global Geothermal News.....*

Statement by Ormat CEO on Puna Geothermal Venture

*In early May **Ormat Technologies**' CEO **Isaac Angel**, commenting on his company's Q1 2018 results, had the following to say about the closure of the **Puna Geothermal Venture (PGV)** due to lava intrusion:*

"On May 3, 2018, the Kilauea volcano located in close proximity to our Puna geothermal power plant in the Puna district of Hawaii's Big Island erupted following a significant increase in seismic activity in the area in the recent weeks. We have taken steps to secure the Puna facilities including, among others, taking electricity generation offline, evacuating nonessential personnel from the power plant and we are in the progress of moving pentane to an off-site location.

We are still assessing the impact of this eruption on our Puna facilities. Any significant physical damage to the plant and extended shutdown of the Puna power plant could have an adverse impact on the electricity generation and availability, which in turn could have a material adverse impact on our revenues. We continue to monitor the condition of the Puna facilities, coordinate with HELCO, the offtaker and without other local authorities and are taking steps to both further secure the power plant and restore its operations as soon as it's safe to do so.

As of today, there is no damage to the power plant; however, we don't know yet the impact of the eruption on our production injection wells. We have a business interruption of property insurance coverage; however, this is an ongoing event and until it stabilizes, we will not know the potential indemnification we can recover from the insurance company or if at all." *Global Geothermal News.....*

See the special article *Lava Eruption Disrupts the Puna Geothermal Venture - The Background* on page 53 **for more information about the closure of the PGV power plant.**

Geothermal Resource Well Authorizations Issued to Canoe Reach Geothermal Project

The **British Columbia Oil and Gas Commission** has issued geothermal resource well authorizations to **Borealis Geopower Inc.** for four thermal gradient wells on its **Canoe Reach Geothermal Project**, south of **Valemount**, British Columbia, Canada.

The well authorizations will allow the company to begin drilling for collection of geotechnical and temperature gradient information.

This is the first time the commission has issued a well authorization under the **Geothermal Resource Act**. The commission was made the provincial regulator of geothermal resources on March 31, 2017.

Borealis started drilling on Monday, June 11. *Global Geothermal News.....*

Courtesy Borealis Geopower Inc.

Saskatchewan DEEP Geothermal Power Project Begins Drilling

The **Government of Saskatchewan** in Canada has announced **CND 175,000** in funding for the **Deep Earth Energy Production Corporation (DEEP)** to establish a geothermal power demonstration plant in the **Estevan** area.

The funds, to be delivered over two years through the **Saskatchewan Advantage Innovation Fund (SAIF),** will be used to purchase equipment and build the infrastructure needed to demonstrate the feasibility of geothermal power generation in the province.

DEEP estimates that the hot geothermal aquifer in the project's selected region near Estevan **may support the generation of up to 500 MW** of power. A *Power Purchase Agreement* with **SaskPower** allows for an initial project to be developed that is expected to deliver **5 MW** to the provincial grid.

The company has completed a prefeasibility study for the project and was reported **to begin drilling the initial production and injection wells in June.**

The **3,400-metre deep wells** will produce hot brine which DEEP will measure and analyze over 90 days, to determine the project's economic feasibility. Construction of the above-ground infrastructure would occur in 2018. *Global Geothermal News.....*

Binary Geothermal Energy Plant Could Power Lithium Extraction Facility in Western Alberta

Calgary-based company **E3 Metals Corp.** has produced a **lithium concentrate** of up to **1,206 milligrams per liter**, a concentration factor of 16 times. The lithium was sourced from the **Leduc Formation** water at the **Exshaw West Project Area** in western **Alberta.**

With high porosity and permeability, the **Leduc Formation** has demonstrated the ability to deliver high volumes of hot (**70 to 100°C/ 158 to 212°F**) brine. With extensive oil and gas infrastructure – including disposal wells, production sites and pipelines – and a mature regulatory regime, **Alberta is an attractive jurisdiction for petro-lithium development**, the company said.

The company states on its website that **the geothermal brine from the Leduc reservoir can be used in a binary geothermal energy plant** to power the production. *Global Geothermal News.....*

Mexican Government Considers Separate Auction to Boost Geothermal

Mexico is considering the introduction next year of a dedicated price support mechanism for geothermal energy outside its technology-neutral auctions dominated by wind and solar.

Secretaría de Energía (Sener)'s European representative **Nelson Mojarro** said it has a "strong preference" for the development of projects outside the "huge concentration" of renewables in the south-east region of **Istmo de Tehuantepec.**

"We understand it is more challenging for certain technologies and we are considering whether there needs to be another auction for other technologies specifically to boost geothermal," he added. *Global Geothermal News.....*

CENTRAL & SOUTH AMERICA

IDB Loan to Help Geothermal Energy Projects in Costa Rica

The President of Costa Rica, **Carlos Alvarado**, and the Minister of Treasury, **Rocio Aguilar,** have signed **Law No.9573** which grants Costa Rica a line of credit of **USD 500 million** from the **Inter-American Development Bank (IDB)** – known as a Conditional Credit Loan for Investment Projects (CCLIP) – for the development of sustainable electric projects.

Some of the projects that will receive financing include, the **Las Pailas II** geothermal power plant and the construction of the **55 MW Borinquen I** and **Borinquen II** geothermal power plants in Liberia. *Global Geothermal News.....*

AUSTRALASIA

Upgrade to Birdsville Geothermal Power Plant Cancelled

Plans to replace what was Australia's only utility-owned and operated geothermal power station in **Birdsville** in central west **Queensland**, have been dumped in favor of a switch to distributed solar and storage.

State government-owned network operator **Ergon Energy** said that it would encourage residents of the frontier town to install rooftop **solar PV and battery storage** as the best option for increasing renewables on the isolated grid.

Ergon said it had "reluctantly decided" not to continue with plans to replace the town's geothermal power station, which at its peak supplied up to 20 per cent of the town's electricity needs.

Those plans, which were very much alive in June last year, would have integrated a new geothermal power station with the existing diesel power station, lifting the share of renewables generation to 70 per cent for the outback, off grid town.

Ergon's manager of isolated networks, **Glenn Dahlenburg**, said the decision to drop the geothermal component was guided by rapidly changing energy market dynamics – in particular, the plummeting cost of solar PV. *Global Geothermal News.....*

Drilling for 25 MW Extension of Ngāwhā Geothermal Power Station to Resume

Drilling at the proposed expansion of the **Ngāwhā Geothermal power station** in **Northland** New Zealand is set to continue.

The drilling, being conducted by **Iceland Drilling** will bring the NZD 176 million project closer to **Top Energy**'s aim to **double the existing geothermal station's 25 MW capacity.** *Global Geothermal News.....*

ASIA

Swedish Company To Provide 4 Geothermal Heat Power Modules to Japan

Swedish company, **Climeon**, has received an order for four geothermal "heat power" modules to be purchased by **Baseload Capital Sweden** on the behalf of a heat power operator in Japan. The order value amounts to just over **EUR 2 million** (USD 2.3 million).

The start-up heat power operator will be jointly owned by a number of Japanese stakeholders and Baseload Capital Sweden.

The modules are to be delivered during 2019 and are expected to be put into operation the same year. Climeon's role in the project is as a supplier, but the company also owns 20 percent of Baseload Capital Sweden, which was formed to finance investments in geothermal heat power.

Japan is one of Climeon's priority markets so the company has **opened an office** in **Nagano**, Japan to explore and evaluate the company's ability to sell geothermal heat power modules in the country. *Global Geothermal News.....*

Deep Well in North-East China Could Tap Geothermal Energy Resources

A scientific drilling program in northeast China's **Heilongjiang Province**, called the **Songke Second Drilling Well**, has just completed an exercise that successfully reached **7,018 meters** underground.

Aside from the technical achievement of the drilling itself, the program has highlighted the potential for the Songliao Basin to be a site for deep shale gas extraction or **geothermal energy** production. *Global Geothermal News.....*

EDC to Use Green Bond to Optimize Output of Geothermal Power Plants

International Finance Corp. (IFC), the investment arm of the **World Bank Group** for the private sector, has launched the **Mabuhay Bond** – the first peso-denominated green bond in the **Philippines** – to bankroll the optimization program of **Energy Development Corp. (EDC)**.

IFC will use proceeds of the bond to finance EDC's capital expenditure program, which is focused on **optimizing the generation output of its geothermal power plants** and improving resiliency to climate impacts. *Global Geothermal News.....*

Philippines Government to Survey Possible Geothermal Energy Resources

The **Philippines Department of Energy** is set to conduct a study on the geothermal energy potential in three communities in **Central Luzon**, north of the capital Manila, in addition to areas further south.

The **Buguias – Tinoc** and **Tuba-Pugo** geothermal fields are part of the DOE's study project along with **Mt. Malindang** in Misamis Occidental; **Mt. Sembrano** in Rizal; **Mati – Lupon Tarragona** and Coron, Palawan geothermal fields.

DE – REMB Geothermal Energy Management Division Chief **Engr. Ariel Fronda** said the study will only include a geological and geochemical survey. *Global Geothermal News.....*

MakBan Geothermal Power Plant to Supply Electricity to Nueva Ecija Province

Electricity producer **Aboitiz Power Corporation** and the **Nueva Ecija Electric Cooperative, Inc. II** are to deliver 33 MW of electricity from the MakBan geothermal power plant to ten towns in **Nueva Ecija** province, north of Manila in the Philippines. *Global Geothermal News.....*

Phinma Withdraws from Leyte Geothermal Power Exploration Project

Phinma Petroleum and Geothermal, Inc. (PPG), formerly Trans-Asia Petroleum Corporation, has withdrawn from a service contract that sought to explore the possibility of geothermal energy in **Leyte.**

The energy exploration company will recognize a loss of **P32.7 million** for the write-off of its share in expenditures incurred so far in Service Contract No. 51 in the **Eastern Visayas, Philippines**. *Global Geothermal News.....*

EDC President Calls for Government Supported Geothermal Exploration Mitigation Fund

Richard B. Tantoco, EDC president and chief operating officer

The Philippines government can support the growth of the country's geothermal industry by helping with the upfront risk that goes with the development of the indigenous energy resource, the president of **Energy Development Corp. (EDC)** has said.

"Globally, geothermal has always grown in government's hands — whether it's Costa Rica, Mexico… because government has an unlimited balance sheet," said **Richard B. Tantoco,** EDC president and chief operating officer.

"So if government could do anything to help, not just us but any of the 13 players that have concession areas, it's to help with that upfront risk," he added.

Mr. Tantoco made the statement in response to a request for comment on the country's standing in global geothermal power generation, which has slipped a notch lower this year after being overtaken by Indonesia for the second spot. The US remains the world's biggest.

"FiT (feed-in-tariff) will always help because you have a PPA (*Power Purchase Agreement*) with the government. But really, if you look at geothermal — historically and worldwide — the biggest issue… is in the upfront risk," he said. *Global Geothermal News.....*

New Tariff Regime for Indonesian Renewable Energies Including Geothermal

SSEK Indonesian Legal Consultants have summarized the new tariff regime for renewable energies in Indonesia including geothermal.

The new regime gives the Indonesian state power company, **PT Perusahaan Listrik Negara (PLN),** greater control over tariffs in the sector through business-to-business negotiations and benchmarking against the applicable **Electricity Generation Basic Cost** (Biaya Pokok Penyediaan Pembangkitan or BPP).

The renewables covered by **MEMR Reg. 50/2017** are solar, wind, hydro, biomass, biogas, waste, **geothermal** and ocean energy.

For hydro, waste and **geothermal** energies, the tariff calculation is as follows: If the local BPP is greater than the national BPP from the previous year, the maximum benchmark tariff is the local BPP. If the local BPP is equal to or less than the national BPP from the previous year, the tariff shall be based on a mutual agreement between the **Independent Power Producers (IPPs)** and PLN.

Exceptions to New Tariff Regime are:

- Entities that have been appointed as winners of capacity quotas for solar projects, have obtained approval for the price of electricity from the MEMR, or have been appointed operators of hydropower, biomass, biogas or waste projects **or been awarded a geothermal working area,** and have signed a Power Purchase Agreement (PPA) with PLN;
- Entities that have been awarded a geothermal working area but have not signed a PPA;
- Any state-owned company that has been mandated with geothermal concession;
- Any holder of a geothermal concession that has signed any steam sale contract and/or PPA which has been verified or is in the process of being verified by the Indonesian Financial and Development Supervisory Board (BPKP). *Global Geothermal News.....*

Star Energy Group Holdings Taken Over by Barito Pacific

Indonesia-based diversified group **PT Barito Pacific Tbk** has finalized its acquisition of a majority stake in local geothermal power producer **Star Energy Group Holdings Pte Ltd.**

Barito Pacific has bought a 66.67% interest in the geothermal energy company for **USD 755 million (EUR 648 million).** *Global Geothermal News.....*

Loan Kick Starts 98.4 MW Rantau Dedap Geothermal Power Project

Marubeni Corporation has announced that **PT. Supreme Energy Rantau Dedap** has signed a loan agreement for limited-recourse project financing, allowing for the start of construction of the **98.4 MW Rantau Dedap Geothermal Independent Power Project** in South Sumatra province in Indonesia.

All generated power will be dispatched to **PT. PLN (Persero)** under a **30-year *Power Purchase Agreement.*** *Global Geothermal News.....*

Exploration Starts at 20 MW Tulehu Geothermal Power Project

Exploration has begun at the **Tulehu geothermal power plant** project in **Tulehu** and **Suli** villages, **Central Maluku District, Maluku Province, Indonesia.**

The **Tulehu Geothermal Working Area** has a **potential of 60 MW**, but in this initial project, PLN will develop **2x10 MW**. *Global Geothermal News.....*

First Phase of Sorik Marapi Geothermal Energy Project Now Producing Power

Eiríkur Bragason, CEO at **KS Orka** reports via *LinkedIn* that the first **15 MW Unit at Sorik Marapi geothermal power plant** in Indonesia has started generating power only 19 months after spud in of the first well. *Global Geothermal News.....*

Nearly 2 GW Geothermal Energy Capacity from 13 Geothermal Power Plants in Indonesia

Based on the latest data from the Indonesian **Directorate of Geothermal, Directorate General of New Energy, Renewable and Energy Conservation,** there is **1,948.5 MW** of geothermal resources being utilized in 2018, from 13 geothermal power plants (PLTP) in 11 geothermal working areas (WKP). *Global Geothermal News.....*

No	PLTP	Developer /Operator	Total Capacity	WKP, Location
1	PLTP Sibayak	PT Pertamina Geothermal Energy	12 MW	Sibayak - Sinabung, North Sumatra
2	PLTP Sarulla	Sarulla Operation Ltd	330 MW	Sibual-buali, North Sumatra
3	PLTP Ulubelu	PT Pertamina Geothermal Energy	220 MW	Waypanas, Lampung
4	PLTP Salak	PT Star Energy Geothermal Salak. Ltd	377 MW	Cibeureum - Parabakti, West Java
5	PLTP Wayang Windu	Star Energy Geothermal Wayang Windu	227 MW	Pangalengan, West Java
6	PLTP Patuha	PT Geo Dipa Energy	55 MW	Pangalengan, West Java
7	PLTP Kamojang	PT Pertamina Geothermal Energy	235 MW	Kamojang - Darajat, West Java
8	PLTP Darajat	Star Energy Geothermal Drajat	270 MW	Kamojang - Darajat, West Java
9	PLTP Dieng	PT Geo Dipa Energy	60 MW	Dieng Plateau, Central Java
10	PLTP Karaha	PT Pertamina Geothermal Energy	30 MW	Karaha Bodas, West Java
11	PLTP Matalako	PT Perusahaan Listrik Negara	2.5 MW	Matalako, NTT
12	PLTP Ulumbu	PT Perusahaan Listrik Negara	10 MW	Ulumbu, NTT
13	PLTP Lahendong	PT Pertamina Geothermal Energy	120 MW	Lahendong - Tompaso, North Sulawesi

Indonesian Government Provides Extension of Exploration for Several Geothermal Working Areas

The Indonesian government, through the Directorate General of Renewable Energy and Energy Conservation (EBTKE) of the Ministry of Energy and Mineral Resources (ESDM), has provided an **extension of exploration** for three geothermal working areas (WKP):

- **WKP Baturaden**, Central Java, **220 MW**, managed by **PT Sejahtera Alam Energy**.
- **WKP Blawan** - Ijen, East Java, **110 MW**, developed by **PT Medco Cahaya Geothermal**.
- **WKP Telaga Ngebel**, East Java, **65 MW**, managed by **PT Bakrie Darma Karya Energy.**

Global Geothermal News.....

AFRICA

More Funding for 10 MW Tendaho Geothermal Power Project

A **EUR 8 million grant** will be provided to the **10 MW Tendaho geothermal development project** in the Afar region of Ethiopia. Funded by the European Union, through the **European Union Africa Infrastructure Trust Fund (EU-AITF)**, this financing will enable completion of the drilling activities, geothermal exploration and subsequent development efforts. *Global Geothermal News.....*

Olkaria III Geothermal Power Plant Expands to 150 MW

Olkaria III flow test, by ***Patrick Walsh****. Active flow test during construction of the 4th addition to Ormat's Olkaria III complex in Kenya. Taken from the top of Olkaria Hill in November 2015. GRC Photo Contest 2016.*

Ormat Technologies Inc. has announced that the **11 MW Plant 1 expansion project** at the **Olkaria III** complex in Kenya has successfully completed tests and **commenced commercial operation** on June 2, 2018.

Since 2000, Ormat has developed and expanded the Olkaria III complex in phases increasing the generating capacity from 13 MW to 139 MW by 2016. With the completion of the 11 MW expansion project, the **total generating capacity of the complex has reached 150 MW.** The scope of the project included drilling of new wells, adding a new **Ormat Energy Converter** unit, and optimizing other existing units.

The electricity generated from the expanded Plant 1 will be sold to **Kenya Power and Lighting Company Limited** under the terms of Plant 1 within the Olkaria III complex *power purchase agreement* (PPA). *Global Geothermal News.....*

Funding Provided for 35 MW Quantum Power Menengai Geothermal Power Project

The **African Development Bank (ADB)** has approved a **senior loan** of **USD 29.5 million** and a **concessional loan** of **USD 20** million from the **Climate Investment Funds (CIF) Clean Technology Fund (CTF)** to **Quantum Power East Africa GT Menengai Ltd.**

The funding will support the development of the **35 MW geothermal power plant** at the Menengai geothermal field in **Nakuru County**, Kenya, one of three modular geothermal plants in the Menengai field planned for **a combined capacity of 105 MW**. *Global Geothermal News.....*

Grant Awarded to Fund Geothermal Exploration in Western Kenya

Kenya renewable energy firm **Capital Power** has secured **USD 720,000** (about Sh72.6 million) from the **African Union Commission (AUC)** for a **140 MW geothermal prospect** in **Homa Bay County**, on the shores of Lake Victoria in western Kenya.

Director **Tony Wanyama** said the funds will be used to conduct a surface study and infrastructure upgrade program at the **Homa Hill** site.

The grant represents 80 percent of the total cost of the surface exploration at USD 1.07 million (about Sh107.9 million). Capital Power has stated it will conduct the studies starting this year, with the **commissioning of the power plant expected by 2023.** *Global Geothermal News.....*

Location of Homa Bay County in Western Kenya

Update On East Africa Geothermal Risk Mitigation Facility

The Chairperson of the Commission of the **Geothermal Risk Mitigation Facility (GRMF)** for Eastern Africa has given an update on the support scheme:

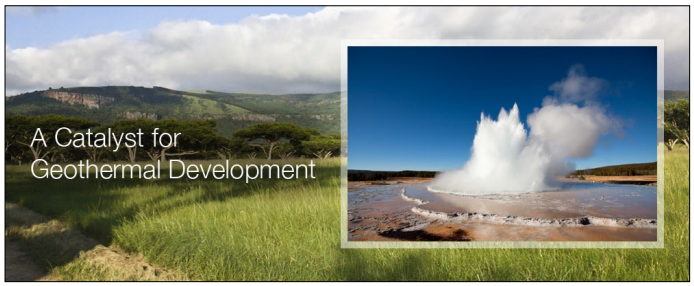
"The main challenges for development of geothermal resources in the East African Rift System include: (i) inadequate policy and regulatory framework to attract investments; (ii) large upfront cost of geothermal resource exploration and development; and (iii) risks in resource "exploration" and "power development".

"I wish to note that the Geothermal Risk Mitigation Facility Program remains one of the successful projects in the [African Union] Commission, despite the challenges mentioned above. Much progress continues to be made by the developers in preparing their GMRF grant applications and in complying with the GRMF requirements."

No	Project	Nature	Country	Applicant
1	North-East Ghoubbet	Surface Study	Djibouti	ODDEG
2	Gisenyi	Surface Study	Rwanda	Energy Development Corporation Limited (EDCL)
3	Emuru-Angogolak	Surface Study	Kenya	Diamond Grip Construction Company Ltd.
4	Buranga	Surface Study	Uganda	GIDS Geothermal
5	Natron	Surface Study	Tanzania	TGDC
6	Panyimur	Surface Study	Uganda	Geothermal Resources Department
7	Dimbil-Dirdir (Goros)	Drilling	Djibouti	ODDEG
8	North West Assal	Drilling	Djibouti	ODDEG
9	Fantale	Drilling	Ethiopia	Cluff Geothermal Ltd
Total possible grants			3. M USD	

The projects that are pre-qualified to submit full application for the Fifth Application Round.

"The Commission will continue to work with development partners to improve the capacity and expertise of interested Member States and mobilize more financial resources to meet the increased interest in geothermal energy development as witnessed by the growing number of projects that are submitted for grant awards. It is critical that Member States put in place the appropriate institutional, legal and regulatory frameworks, in order to attract more private investors and allocate adequate resources to the Commission for the expansion of this Programme to other AU countries." *Global Geothermal News.....*



Better Supply of Geothermal Power from Olkaria to Capital

President Uhuru Kenyatta commissioned an ultra-modern gas-insulated substation and Energy Cabinet Secretary, **Hon. Charles Keter** commissioned a 7km underground 220 kV cable running from **Athi River** to **Embakasi** through **Nairobi National Park** that will improve supply of geothermal energy to the capital.

Maintained by **Kenya Electricity Transmission Company Limited (KETRACO)**, the cable and associated substation will offer an alternative power route and additional capacity to Nairobi from geothermal energy resources in **Olkaria** thus greatly improving the reliability and availability of power in the city. *Global Geothermal News.....*

EUROPE

Miklos Antics is New President of European Geothermal Energy Council

EGEC, the **European Geothermal Energy Council, has appointed Miklos Antics** of **GPC Instrumentation Process (GPC IP)**, as its new President.

The appointment comes after the tragic loss of EGEC president **Ruggero Bertani** last month (see page 62 for obituary). The board meeting unanimously approved the nomination of Miklos Antics, who has been member of the EGEC board since 2004 and has served as EGEC vice-president since 2013.

Commenting on the appointment, the new president said: "I'm looking forward to serving as President, as well as continuing the valuable work, by building on the achievements inherited from my predecessors, in fostering geothermal development and highlighting the important role of geothermal in the energy transition". *Global Geothermal News.....*

Icelandic Company Orders Another 67 Heat Power Modules

Swedish company **Climeon** has signed an agreement with Icelandic company **Varmaorka** to expand upon an existing order for geothermal "heat power" modules.

In August 2017, Climeon won an order for 100 geothermal power plants from Varmaroka. Now Varmaorka has **increased its order to 197 modules** with a total value of about **EUR 65 million**, excluding service costs and software licenses.

"The potential of geothermal energy on Iceland with Climeon's technology is greater than we thought a year ago. During the year we have secured several new sites, and we therefore want to increase the speed of our rollout and secure delivery of modules to us," says **Ingvar Gardarsson,** Chairman of the Board of Varmaorka. *Global Geothermal News.....*

Stimulation Begins at Espoo Geothermal District Heating Project

A project to build Finland's first geothermal district heating network has now progressed to the stimulation stage.

According to **Peter Malin**, adjunct faculty at **Southern Methodist University (SMU)**, stimulation of the **6,400 meter** deep **OTN-III** well at the **St1 Deep Heat project** in **Espoo**, near Helsinki, began on June 4.

There are 5 stages of packed-off, ball-operated hydraulic-stimulation equipment along the uncased bottom 750 meters of the well. About 10,000 cubic meters of drinking-quality water have been injected via 3 of the 5 stages, with pumping currently occurring on stage 4.

The engineering calculations provide a target volume of 18,000 cubic meters of water across the five stages for an economic return. *Global Geothermal News.....*

1,520 Meter Well Drilled for Geothermal District Heating Project at Norwegian Airport

Norway's deepest geothermal borehole is now under construction at **Oslo Gardermoen Airport.** Airport operator **Avinor** is managing the energy project, called **Rock Energy**, in partnership with the company **Båsum Boring** through its joint venture **Norwegian Energy Drilling**.

"We've drilled to a depth of 1,500 meters for both boreholes, and when the project is completed they should be capable of heating the entire area of the engine test site. This has never been achieved before in Norway," says **Thor Erik Musæus**, the project's general manager, who adds that the extracted energy could also be used to heat large buildings. *Global Geothermal News.....*

British Geothermalist Wins Prestigious Applied Geoscience Medal

Dr. Charlotte Adams, Durham Energy Institute fellow, has been awarded the prestigious **Aberconway Medal** by the UK **Geological Society**. This prestigious medal is awarded for excellence in applied geoscience and reflects Dr. Adam's ground breaking work in ultra-low enthalpy geothermal energy, especially how geothermal heat can be extracted from flooded coal mines. *Global Geothermal News.....*

Geothermal Energy Pioneer Receives Prestigious British Engineering Award

Lucien Bronicki

Lucien Bronicki, former Chairman and CTO of **Ormat Industries Ltd,** has received the 2018 **Royal Academy of Engineering Prince Philip Medal** for his outstanding work in developing new technologies to harness the earth's geothermal power.

The Prince Philip Medal is the Academy's most prestigious individual award, made in honor of its Senior Fellow, **Prince Philip Duke of Edinburgh KG KT.** The award is made biennially to an engineer of any nationality who has made an exceptional contribution to engineering.

Lucien Bronicki has made significant contributions to engineering science as a whole, with about 50 scientific publications and 35 authored patents, with another 65 co-authored. He has also supported institutions focusing on geothermal energy production, such as the **Geothermal Resources Council.**

Lucien Bronicki said, "It is a great honor to receive the Prince Philip Medal. At the time, "selling" a completely new type of power unit against well established and proven diesel generators or geothermal steam plants was difficult and it is gratifying that today there are many well established manufacturers and R&D centers promoting ORC systems." *Global Geothermal News.....*

Drilling at British Geothermal Lido to Complete in September

Penzance's Art Deco **Jubilee Pool** will soon become the first in Britain to be heated by geothermal energy. The drilling of a **1,500 meter-deep geothermal well** began in March and, upon its completion in September, a large, semi-circular section of the pool will boast bathing waters as **warm as 35˚C**. It's scheduled to **open to the public in spring 2019.**

Work on the ground-breaking **GBP 1.4 million** project has been carried out by **Geothermal Engineering Ltd (GEL)**. *Global Geothermal News.....*

Inside Geothermal

New Hope for Eden Project Geothermal Power Scheme

Cornwall Council in south-west England has agreed to provide **GBP 1.4 million** towards the **Eden Project geothermal energy scheme.** The project is being led by Cornwall-based **EGS Energy** which has planning permission for a **3-4 MW geothermal power plant** in Bodelva, near St. Austell.

Geothermal Engineering Limited (GEL) has, as part of the package, agreed to fund a Council officer's salary (up to GBP 42,000) to promote and advance the geothermal industry in Cornwall.

Cornish Lithium Ltd will also be involved and will test the geothermal brine for the valuable mineral.

On its website, Eden states: "On a site the size of a football pitch, the geothermal power plant would produce enough power for the Eden Project and around 4,000 houses, plus all the heat we can use, and more." *Global Geothermal News.....*

Drilling Starts at Dutch Geothermal District Heating Project

The **Huisman** company has been awarded a contract for the delivery of a geothermal doublet in **Pijnacker**, in the Dutch province of **South Holland**. Drilling started at the end of April and the installation will heat a large area of greenhouses, a residential area and a local pool. The wells will be drilled directionally to a planned depth of **approximately 2,300 meters.** *Global Geothermal News.....*

149 MW of Dutch Geothermal Projects to Get Renewable Subsidy

Netherlands Enterprise Agency (Rijksdienst voor Ondernemend Nederland – RVO) has announced the second round of its **2017 SDE+** (Stimulering Duurzame Energieproductie) program for large-scale renewable energy power projects.

Overall, around 3,330 MW of renewable energy generation capacity was contracted through the round, **including 149.4 MW of geothermal projects.** Applications for 264 MW of geothermal projects were submitted.

The geothermal projects that will receive the subsidy:

- **Amerlaan Geothermie B.V.**, depth>=500m – installed capacity 31.19 MWth – near Den Haag (The Hague)
- **ECW Geo Andijk B.V.,** 32.19 MWth – near Alkmaar
- **Hoogweg Aardwarmte B.V.**, 29.26 MWth
- **Ennatuurlijk B.V.,** depth >=500m, 20.63 MWth
- **Agriport Warmte B.V.,** 36 MWth

The SDE+ compensates for the difference between the price of renewable energy and the market value of the energy supplied. Subsidies are allocated for periods of 8, 12 or 15 years depending on the maximum number of full load hours for each technology. *Global Geothermal News.....*

Consortium Commissioned to Study Ultra Deep Geothermal Energy and EGS Risks in the Netherlands

Dutch company **Witteveen + Bos** has been commissioned by the Dutch State Supervision of Mines (SSM) to investigate the risks of Ultra Deep Geothermal Energy and Enhanced Geothermal Systems in the Netherlands. Witteveen + Bos will cooperate with the German company **Q-Con**, the Belgian company **Vito, TU Delft, Newell** and **Weisenborn-Linskaill & Associates**. *Global Geothermal News.....*

New Geothermal District Heating Network in Paris Suburb

A new geothermal district heating network was inaugurated on June 2nd in the **Grigny** and **Viry-Châtillon** suburbs of southern **Paris**.

Put into service last winter, the network can already provide **124 GWh of heat per year**, enough for 12,000 homes. The **71°C** geothermal waters are from **a depth of 1,800 meters.** *Global Geothermal News.....*

Successful First Phase of Drilling at Munich Geothermal District Heating Project

Stadtwerke München has announced that after three months of drilling at the **South (HKW Süd) combined heat and power plant** in **Munich** a geothermal resource of **over 100°C** and flowing at more than **120 liters per second** has been reached at a depth of **2,800 meters.** The second phase of drilling starts at the end of July. *Global Geothermal News.....*

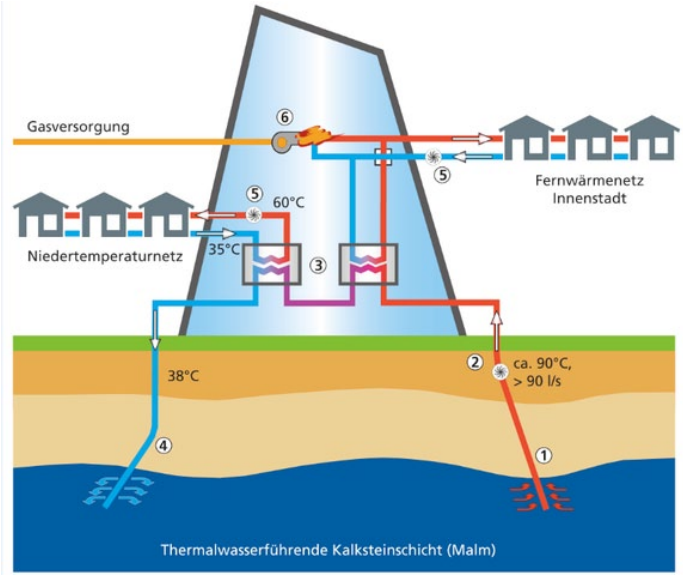
Tests Indicate Bavarian Geothermal Power Project is Not Viable

Finnish company **Taaleri Investments Ltd,** part of the **Taaleri Group**, acquired the majority shareholding in Munich-based **Erdwärme Oberland GmbH** (86.42% of shares and votes) from the Italian energy-company **Enel** on March 12, 2018.

Taaleri intends to invest in geothermal electricity and district heating projects in Bavaria in Germany. However, tests at the **Weilheim geothermal project**, located 45 Kms south-west of Munich, have shown that the project is not commercially viable because of lower than expected flow rates. *Global Geothermal News.....*

Construction Starts on 50 MWth Thalkirchen Geothermal Power Plant

Construction has started on what will be Germany's largest geothermal power plant to date. The **50 MWth** southern heating plant in **Thalkirchen**, a suburb of **Munich** will supply geothermal-heat to 80,000 Munich residents by 2020. Work on the six wells has now begun. *Global Geothermal News.....*



Courtesy Stadtwerke München

Daldrup & Söhne to Provide Drilling Services at North Germany Geothermal District Heating Project

German company **Daldrup & Söhne AG** has received an order for drilling at a geothermal district heating project in **Schwerin-Lankow**, in the northeastern German state of **Mecklenburg-Vorpommern.** The drilling was slated to have started around the end of May 2018 and is projected to go to a **depth of 1,250 meters**. Around 15% of Schwerin's district heating is hoped to be provided by geothermal energy in the future. *Global Geothermal News.....*

Promising Signs at Geneva Geothermal District Heating Project

Drilling at a geothermal district heating project at **Satigny**, a municipality of the **Canton of Geneva, Switzerland**, has yielded promising results.

This water naturally rises to the surface **from 744 meters depth** at a temperature of **33°C** and a flow rate of more than **50 liters per second**. A further six boreholes will be drilled over the next three years. The canton hopes geothermal heat will cut the use of heating oil by 53 percent. *Global Geothermal News.....*

Courtesy GEothermie 2020

Financing Provided to Increase Use of Geothermal Energy in Portugal

The Portuguese government has approved three financing lines totaling **EUR 2.1 million (USD 2.45m)** to support geothermal projects.

Launched and operated by the **Innovation Support Fund (FAI)**, this initiative aims to increase of the use of geothermal energy in the country.

The largest amount, EUR 1.7 million, is intended for development and expansion of **heat distribution networks.**

The other two lines are intended to finance technical or scientific studies to **better understand geothermal resources in Portugal**. A EUR 300,000 support line will assess **hydrothermal exploration** and the potential for geothermal resources at temperatures above 25°C.

The other line of EUR 100,000 is for the expansion of the **National Geothermal Atlas.** *Global Geothermal News.....*

Two Groups Seek to form Partnership on Greek Geothermal Power Projects

Two investment schemes, **Helector SA**, a member of the **Ellaktor group**, as well as a team comprised of **Terna Energy** and sister company **Terna Aioliki Xerovouniou SA**, have submitted binding second-round bids to an international tender staged by **PPC Renewables** for a strategic partner in the installation of power stations at four geothermal fields in **Greece**.

The tender's deadline for second-round offers expired on June 1. A total of six teams had expressed first-round interest.

PPC Renewables plans to establish a joint venture with its prospective strategic partner to develop geothermal power stations of at least 8 MW on **Lesbos** and 5 MW at each of the other locations. The company website lists exploration on **Milos – Kimolos** in the Polyaigos islands group, **Nisyros island, Lesbos** island and on the **Methana** peninsula (on the mainland).

PPC Renewables intends to soon launch exploratory drilling procedures at its own expense. These drilling endeavors are planned to run concurrently with the ongoing selection process for a strategic partner. *Global Geothermal News.....*

SCIENCE & TECHNOLOGY

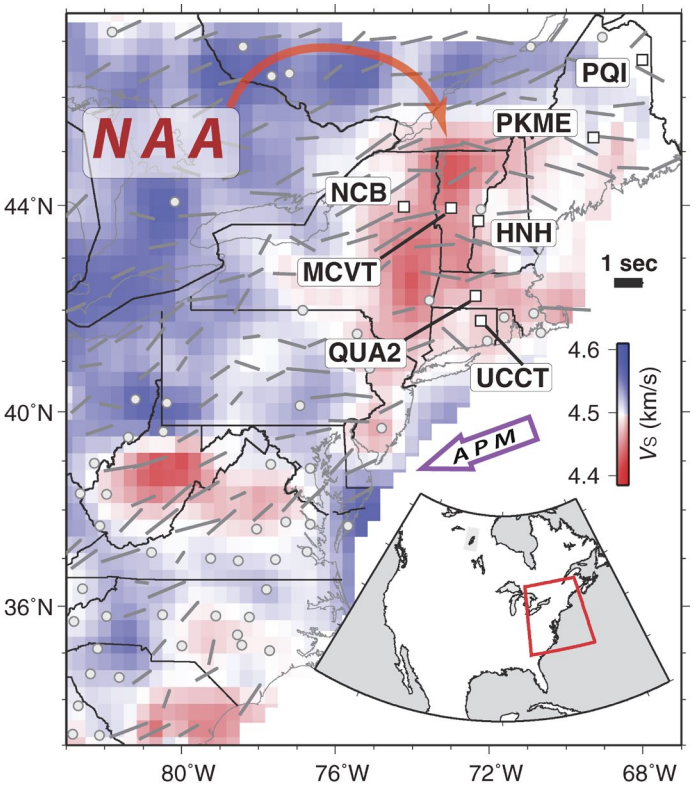
Geothermal Heat Upwelling Detected Under New England

A vast mass of hot rock is welling up underneath **Vermont** and extending into other subterranean regions **below New England**, new research shows.

Scientists used a network of thousands of seismic measurement devices in the largest geological study of its kind, detecting the enormous blob upwelling under Vermont, New Hampshire, and Massachusetts – and possibly elsewhere.

Buried in two years of data, the team zeroed in on New England, having previously identified a thermal anomaly that was **hundreds of degrees Celsius hotter than its surroundings** in the upper mantle about 200 kilometers (124.2 miles) below the surface, and measuring approximately 400 kilometers (248.5 miles) in diameter. *Global Geothermal News.....*

Seismic evidence for a recently formed mantle upwelling beneath New England, by Vadim Levin, Maureen D. Long, Peter Skryzalin; Yiran Li, Ivette López. *Geology* (2017) 46 (1): 87-90. https://doi.org/10.1130/G39641.1



Method for Increasing the Extraction of Rare Earth Elements from Geothermal Brine

Surface mining for rare earth elements used in smart phones and wind turbines is difficult and rarely done in the United States. Scientists wanted to know if they could **pull the metals, present at trace levels, from geothermal brines using magnetic particles.** The particles, wrapped in a molecular framework shell known as a **metal-organic framework, or MOF,** should easily trap the metals and let the rest flow past. However, the team led by **Pete McGrail** at **Pacific Northwest National Laboratory** found the magnetic strength dropped by 70 percent after the MOF shell was formed.

The use of MOFs may allow for the separation of yttrium, scandium, and other elements **from saline water from geothermal sources**, produced waters from oil and gas fields, or wastes such as fly ash.

The team showed that the chromium penetrated into the pores in the iron particles and was reduced by capturing an electron from the iron thus oxidizing it. The magnetic strength of magnetite is strongly determined by the amount of ferrous versus ferric (oxidized) iron in the material. The iron oxidation thus degraded the magnetic properties. These fundamental insights will allow materials science researchers to adjust the MOF chemistry to prevent the unwanted oxidation-reduction reactions and better retain the core-shell material's magnetic properties. *Global Geothermal News.....*

Sameh K. Elsaidi et al. *Reduced Magnetism in Core–Shell Magnetite@MOF Composites,* *Nano Letters* (2017). DOI: 10.1021/acs.nanolett.7b03451

Better Location of Boreholes Helps Geothermal Well Drilling

When constructing geothermal systems for the extraction of heat from underground hot water reservoirs, optimal positioning of the boreholes can considerably reduce seismicity. This is the result of induced seismicity studies by scientists of **Karlsruhe Institute of Technology (KIT).**

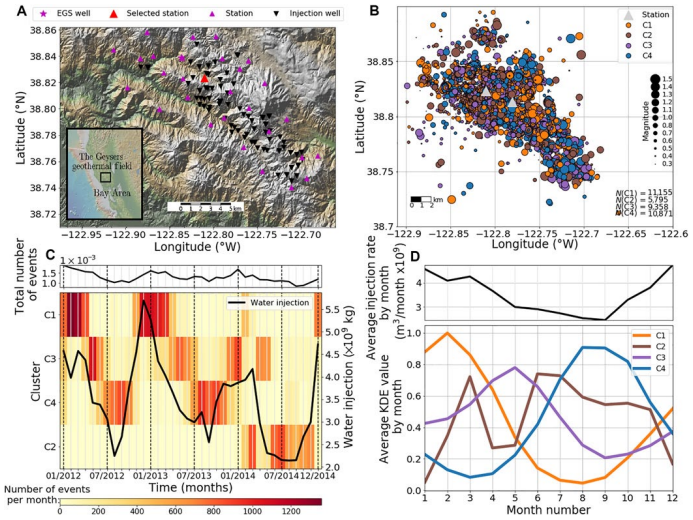
Induced seismicity means shocks caused by human activities. Based on the change of water pressure in the rock (pore pressure) and the mechanical stresses in the rock, the researchers modeled changes of the stress field as a result of the injection and extraction of fluids, e.g. gases or liquids. *Global Geothermal News.....*

Induced Seismicity in Reservoirs: Stress Makes the Difference. B. Müller, F. Schilling, Th. Röckel, and O. Heidbach. *Erdöl Erdgas Kohle,* DOI: 10.19225/180106

Algorithms Pick Out Hidden Signals that Could Boost Geothermal Energy Production

The earthquake rupture process comprises complex interactions of stress, fracture, and frictional properties. New **machine learning methods** demonstrate great potential to reveal patterns in time-dependent spectral properties of seismic signals and enable identification of changes in faulting processes.

Clustering of 46,000 earthquakes of 0.3 < ML < 1.5 from **The Geysers geothermal field** in **Northern California** yields groupings that have **no reservoir-scale spatial patterns** but clear temporal patterns. Events with similar spectral properties repeat on annual cycles within each cluster and track changes in the water injection rates into the Geysers reservoir, indicating that **changes in acoustic**



properties and faulting processes accompany changes in thermomechanical state.

The methods open new means to identify and characterize subtle changes in seismic source properties, with **applications to tectonic and geothermal seismicity.** *Global Geothermal News.....*

Machine learning reveals cyclic changes in seismic source spectra in Geysers geothermal field, by Benjamin K. Holtzman, Arthur Paté, John Paisley, Felix Waldhauser and Douglas Repetto. *Science Advances* 23 May 2018: Vol. 4, no. 5, eaao2929 DOI: 10.1126/sciadv.aao2929

How Heat is Transported to the Earth's Surface from Molten Rock

In the March/April GRC Bulletin we published an interview with Cary Lindsey, a past GRC Scholarship winner. In the article Cary spoke about some research she was undertaking in Yellowstone National Park. She has now published the results.

Researchers at **Washington State University** and the **University of Idaho** have found a new way to estimate how fast magma is recharging beneath the **Yellowstone supervolcano**. While their findings offer no help in predicting if the volcano will erupt, they can now get a better understanding of a key factor—**a pool of basalt magma recharging the system**—in how it works.

With funding from the **National Science Foundation**, the researchers "spiked" several hot springs in **Yellowstone National Park** with **deuterium**, a stable hydrogen isotope. The researchers used the length of time needed for deuterium concentrations to return to background levels and the temperature of the hot springs to calculate the amount of water and heat flowing out of the springs. Using deuterium for estimating heat

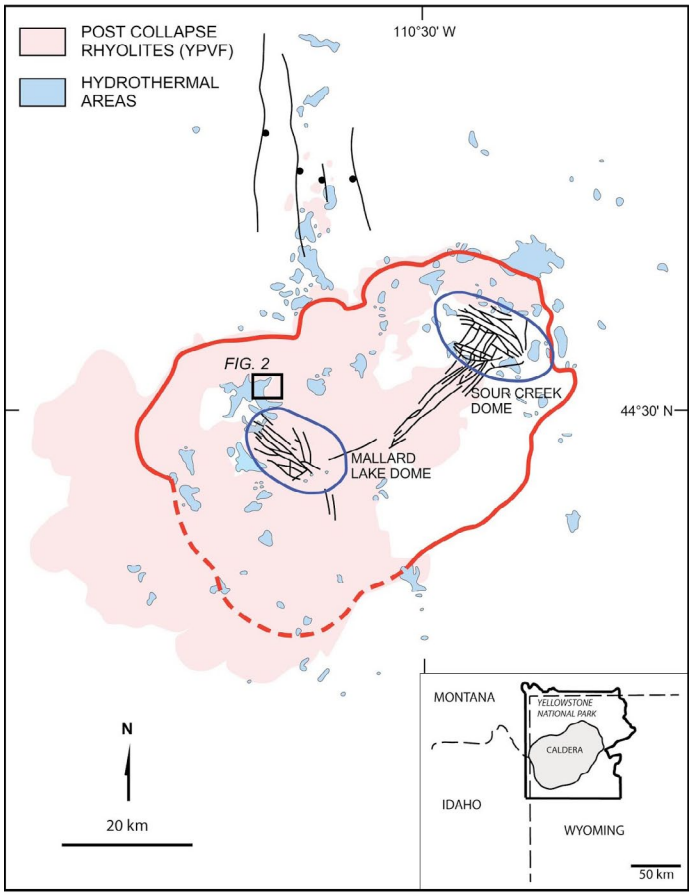


Figure 1. Geologic map of the Yellowstone Caldera, Wyoming and Idaho, USA, showing the topographic caldera wall (red line, dashed where inferred), the two resurgent domes (blue lines), resurgence-related faults within the caldera (black lines), and basin–range faults north of the caldera (black lines with ball on downthrown wall). The area of the post-collapse rhyolites and the locations of both active and extinct hydrothermal features are shown (modified from Christiansen, 2001; Vaughan et al., 2012, 2014). The black box indicates the study-area location in Lower Geyser Basin (Fig. 2). YPVF—Yellowstone Plateau Volcanic Field.

flow is safe for the environment and has no visual impact to distract from the park visitors' experience.

The team found that previous studies **underestimated the amount of water coursing through the springs and the amount of heat leaving the springs.** The data also allowed the team to estimate the amount of magma entering the supervolcano from the mantle.

The study also has **implications for geothermal energy**, helping inform how heat is transported to the earth's surface from molten rock. *Global Geothermal News.....*

Direct measurement of advective heat flux from several Yellowstone hot springs, Wyoming, USA, by Nicholas McMillan, Peter Larson, Jerry Fairley, Joseph Mulvaney-Norris, Cary Lindsey. *Geosphere* (2018). DOI: https://doi.org/10.1130/GES01598.1

New Tool Could Revolutionize Geothermal Exploration

A recent test at the **SIGMA-V experiment** at the **Sanford Underground Research Facility** featured the **SIMFIP (Step-Rate Injection Method for Fracture In-Situ Properties)**, a tool that could revolutionize the way scientists study geothermal energy.

Developed at **Lawrence Berkeley National Laboratory (LBNL)**, the SIMFIP allows precise measurements of displacements in the rock and, most importantly, the aperture, or opening, of a hydro fracture.

The SIMFIP measures fracture openings in hard rock in the **EGS Collab** test site at **Homestake Mine**

The SIGMA-V team were excited with the results. (Courtesy Sanford Underground Research Facility)

in **South Dakota**. The team had drilled eight slightly downward-sloping boreholes in the rib (side) of the West Drift: The injection hole, used for stimulating the rock, and production well, which produces the fluid, run parallel to each other through the rock. Six other boreholes contain equipment to monitor microseismic activity (rock displacement); electrical resistivity tomography (subsurface imaging); temperature; and strain (how rocks move when stimulated).

The SIGMA-V team hoped to see signals as small as a few microns of displacements in the rock. As they watched **data accumulate in real time** over a two-day period, the excitement in the West Drift was palpable. *Global Geothermal News.....*

Update for Leapfrog Geothermal Software

Leapfrog Geothermal 3.6, a purpose-built 3D geothermal modeling solution has been updated. This new release adds more geothermal functionality and further integration with leading reservoir engineering and geophysical software.

- Import and visualize a TETRAD flow simulation model using input "IS" and output "GV" files. Visualization includes time dependent grid attributes such as pressure and temperature.
- Improved TOUGH2 workflow – improved usability with support for unstructured gridding and fault rock types.

Global Geothermal News.....

Seequent, the parent company of the Leapfrog software, will be exhibiting at the *GRC Annual Meeting & Expo* from 14-17 October at the Peppermill Resort Spa and Casino, Reno, Nevada, USA.

EDUCATION

Submit an Abstract to 2020 World Geothermal Congress

WORLD GEOTHERMAL CONGRESS 2020 REYKJAVIK

April 27 - May 1, 2020, Reykjavik, Iceland

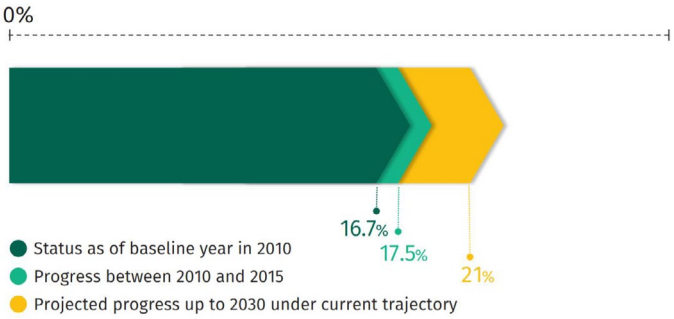
The technical program committee of the 2020 World Geothermal Congress invites you to submit an abstract for the meeting. **Abstract submissions will close on Thursday 31st January 2019.**

- Submit an abstract.....
- Author instructions and a listing of the main themes.....

CLIMATE CHANGE

World is Falling Short of Renewable Energy Targets

FIGURE E7 • Renewable energy share in total final energy consumption (%)



Tracking SDG7: The Energy Progress Report by **IRENA** provides a comprehensive look at the world's progress toward global energy targets for access to electricity, clean cooking, renewable energy and energy efficiency.

As of 2015, the world obtained **17.5% of its total final energy consumption from renewable sources,** of which 9.6% represents modern forms of renewable energy such as **geothermal**, hydropower, solar and wind. The remainder is traditional uses of biomass (such as fuelwood and charcoal).

Based on current policies, **the renewable share is expected to reach just 21% by 2030**, with modern renewables growing to 15%, f**alling short of the substantial increase demanded by the SDG7 target.** *Global Geothermal News.....* ■

Geothermal History in the Making

by Ian Crawford, Director of Communications

In 2021, the Geothermal Resources Council, the GRC, will be celebrating its 50-year anniversary. Our association was established in 1971 "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 have a special treat. We present an excerpt from Geothermal Resources Council - The Early Years, by David N. Anderson, now available as a special paper on the GRC Website.....

Dave Anderson, Executive Director of the GRC for over 26 years reminisces about the early years of the geothermal energy industry in the USA, from the exploration for resources in The Geysers in the early 1950's and a brief history of the GRC from its formation in 1971 through to Dave's retirement in 1997. Judy Fischette, a long-time colleague of Dave's, has collected stories that chart the growth of geothermal energy in the States, including the progress of the GRC as a prominent leader in the international geothermal energy industry.

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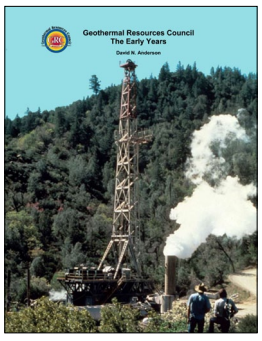
The Creation of the Geothermal Resources Council

The Geothermal Resources Council (GRC) was formed at the meeting in Olympia, Washington in May of 1971. It was a two-day affair, including an evening session, with discussions on what future actions were necessary to bring the resource to the attention of governmental agencies, the public, and the electrical power industry. Joseph Aidlin, chief counsel for the Magma Power Company, chaired the session. He presented a strong case that there was a vital need for an association which would carry out the mission formulated at the meeting. As a representative of the State of California, David Anderson volunteered to work with the steering committee and was appointed the secretary of the committee.



Several other states also voiced an interest in getting involved.

A follow up organizational meeting was convened in Sacramento, California in June 1971. It included several industry members, PG&E, and representatives from California, Washington, and the federal government. The first order of business was to design and incorporate a nonprofit association.

A lively discussion ensued on the merits of forming a Company Trade Association versus a Membership Educational Association. About half of the members wanted a nonprofit trade association, the others a nonprofit educational group. At this juncture the representative from PG&E, Dean Worthington, made a strong appeal for a trade association which he felt would best serve the new industry. His logic was based on the looming environmental movement that was now starting to affect his company and other industries throughout the U.S. Other individuals in attendance disagreed, and it was finally decided that the new association would be a membership association which would be called the Geothermal Resources Council (GRC).

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The Geothermal Resources Council had achieved a position as a prominent leader in the international geothermal industry representing members from forty-two countries when Anderson left in 1997 to serve as the Executive Director of the Association for Efficient Environmental Energy Systems and the Western Geothermal Heat Pump Resource Center. He retired from that association in 2003.

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Get the whole story of geothermal history in the making by reading the full 15 page paper. Download *Geothermal Resources Council - The Early Years*, by David N. Anderson. ■
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REGISTER NOW FOR THE FIRST ANNUAL GRC

TRIVIA?

NIGHT & MIXER!

PRESENTED BY THE GRC STUDENT COMMITTEE

Challenge Your Colleagues In A Game Of Knowledge!

How Much Do You Know About Geothermal Energy?

WHO: You and up to 5 colleagues against teams (plus a student paired by the GRC) from all over the world representing every sector of the industry.

WHAT: An intense game of team trivia, complete with prizes for the top finishing teams.

WHEN: Monday, October 15th 2018 @ 6pm - 9pm

WHERE: The Edge Night Club at the Peppermill Resort Spa Casino, Reno NV, USA

WHY: Enjoy friendly academic competition while contributing to the development of geothermal students across the glove! All proceeds will go to the GRC Student Committee to fund future student events and activities.

HOW: Register TODAY at my.geothermal.org. Cost is $700 for a team of up to five (5) or $140 for an individual (will be placed in a team of 5), and $75 to watch the competition. Student are free wit ha GRC Annual Meeting registration. Registration includes free hors d'oeuvres and up to three (3) drinks.

1. 10x10 booth for the 2019 GRC Annual Meeting, picture in the GRC Bulletin & bragging rights!
2. $50 gift card to each person.
3. 2019 GRC Individual membership for each person.

Frontier Observatory for Research in Geothermal Energy Awarded to University of Utah

By Elisabet Metcalfe, Physical Scientist,
Geothermal Technologies Office's Enhanced Geothermal Systems Program

The Frontier Observatory for Research in Geothermal Energy (FORGE), the flagship initiative of the U.S. Department of Energy's Geothermal Technologies Office (GTO), is envisioned as a dedicated site where the subsurface scientific and engineering community will be able to develop, test, and improve new technologies and techniques in an ideal enhanced geothermal systems (EGS) environment.

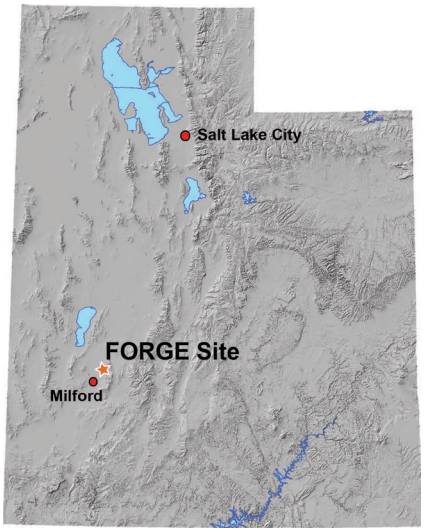
On June 14, the Department of Energy (DOE) announced that the final location of the FORGE initiative will be at the University of Utah's Milford site in Utah. As part of its selection, the University of Utah will receive up to $140 million over the next five years to conduct cutting-edge research and development (R&D) in the first-of-its-kind geothermal field laboratory.

Borne from GTO's vision for longer-term, transformational EGS, the FORGE initiative kicked off with a funding opportunity announcement in July 2014. A year later, five teams and their proposed sites launched into Phase 1 efforts, focused on mission-critical technical and logistical tasks to demonstrate the proposed sites' viability and the teams' commitment to achieving FORGE objectives in later phases. Following the first downselect in the summer of 2016, two teams proceeded into Phase 2: Sandia National Laboratories and their proposed site at Fallon, NV;

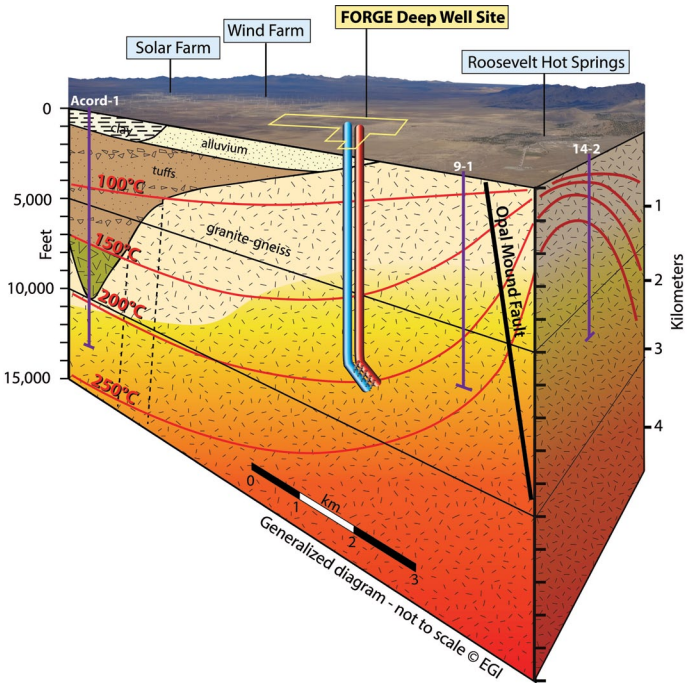
The Utah FORGE site in Milford, Utah. (Courtesy Utah FORGE)

and University of Utah's proposed site in Milford, UT. Phase 2A and 2B activities involved National Environmental Policy Act (NEPA) analyses, preliminary seismic monitoring, further site characterization, and the drilling of a new full-size well.

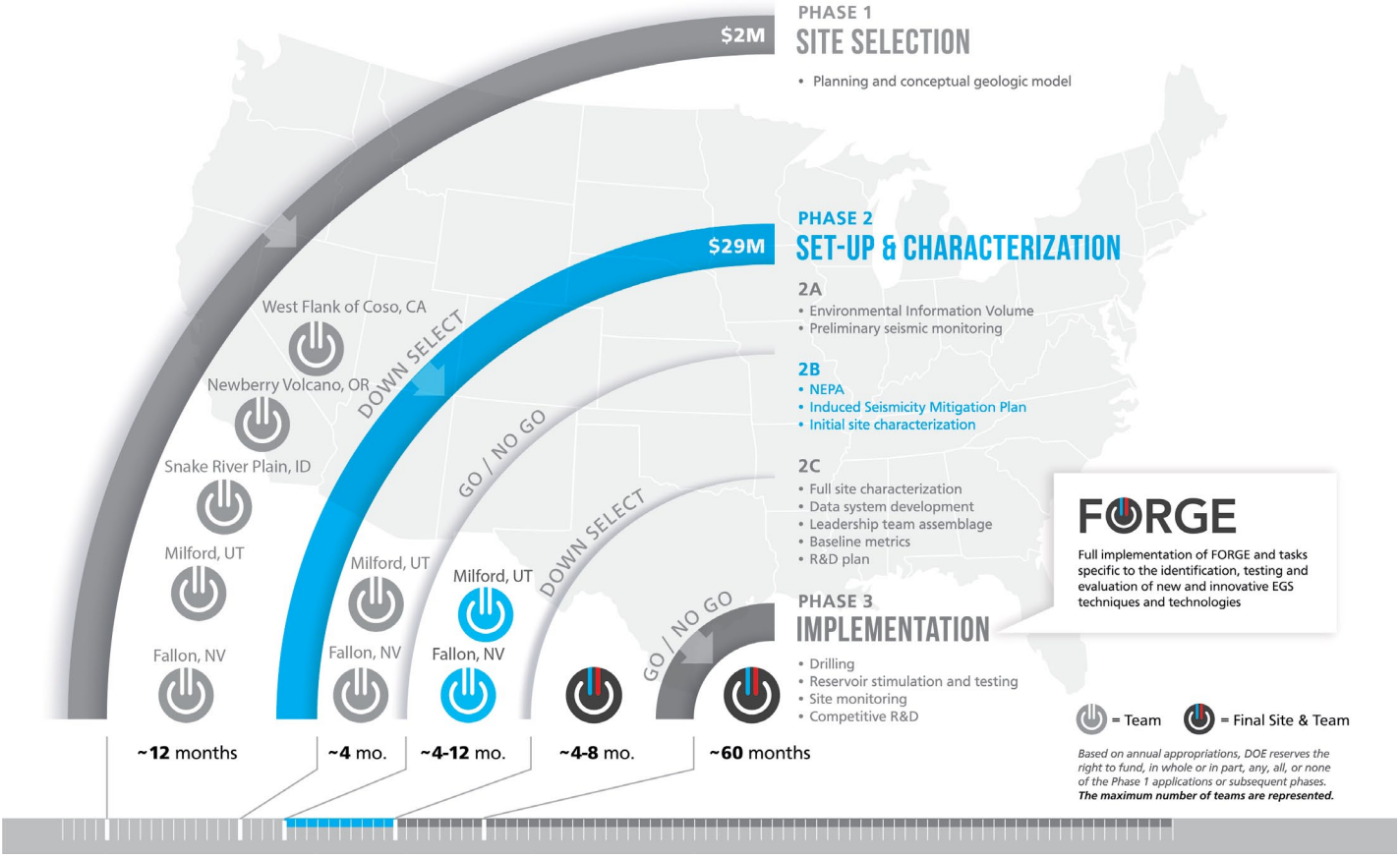
The work performed by both teams – Sandia and the University of Utah – during Phases 1 and 2 was exceptional. Multidisciplinary teams of experts synthesized massive quantities of data. Researchers and scientists employed state-of-the-art technologies and techniques to characterize the subsurface, leading to the consummate understanding of both sites. That knowledge supported the development of pioneering geologic models, both of which are publically available to induce future research efforts and innovation. Both teams planned and drilled new deep wells to constrain their models, and performed the task with research and efficiency in mind. They tested new bits and methods, and both teams drilled their wells in record times, faster than the vast majority of wells drilled in a geothermal environment. Additionally, the FORGE teams developed innovative partnerships, where scientists, practitioners, and researchers from academia, the National Laboratories, government agencies, and industry worked side-by-side in the pursuit of the FORGE mission. Underpinning these remarkable achievements was the shaping and fostering of a community comprised of local stakeholders, environmentalists, students, state and local governments, and the general public.



The Utah FORGE site is located in Southern Utah. (Courtesy Utah FORGE)



Schematic of the Utah FORGE site in Milford. (Courtesy Utah FORGE)



FORGE Phase infographic.

Since Milford's selection as the final FORGE site, Phase 2C activities have been underway by the University of Utah team. Phase 2C activities include full Milford site characterization, assembling a leadership team, and finalization of baseline metrics and R&D plan. Phase 3 activities will include drilling, reservoir stimulation and testing, seismic monitoring, and competitive R&D.

GTO is excited to work with the University of Utah team to further advance the goals and objectives of the FORGE initiative, as well as continuing to collaborate, innovate, and resolve EGS challenges toward achieving the ultimate goal of EGS commercial success. GTO is honored to be part of an initiative that will forge not only a new and bright future for geothermal, but also new relationships and inspiration to accomplish something truly revolutionary.

Q&As:

1. What will the $140 million in continued funding over the next five years be used for primarily?

The $140 million will be used to conduct Phase 2C and 3 activities. Phase 2C activities include full Milford site characterization, leadership team assemblage, and finalization of baseline metrics and research and development (R&D) plan. Phase 3 activities include drilling, reservoir stimulation and testing, seismic monitoring, and competitive R&D. Fifty percent of Phase 3 funding will fund competitive R&D solicitations.

2. Do you intend to update the EGS Roadmap published in 2012?

GTO will be releasing a programmatic roadmap as part of the GeoVision study, to be released later this year. Additionally, GTO is currently developing a FORGE roadmap in collaboration with a cross-section of geothermal experts from industry, universities, and national labs that will be released in December 2018.

3. What goals are in place for the EGS research, and what metrics will be used to measure the success?

The University of Utah will assemble a Science and Technology Analysis Team (STAT) to plot the

R&D activities that will take place during Phases 2C and 3. This entity will consist of a group of best-in-class technical experts to provide overall technical guidance and to ensure that GTO objectives are fully considered and incorporated into the execution of FORGE and associated R&D field projects. The STAT will play a critical role during Phases 2C and 3 of FORGE by assessing R&D needs in accordance with GTO and FORGE roadmaps and goals, establishing technical baseline information and performance specifications, guiding ongoing site characterization and monitoring efforts, developing topics for recurring FORGE R&D solicitations, providing guidance for review and selection of R&D projects, and developing out-year R&D strategies. The STAT will also assess the progress and results of all R&D technology and techniques implemented at FORGE and provide input to the site operator for the development of annual topical reports. GTO will appoint at least 30% of the members on the STAT or other equivalent bodies.

At a high level, the objective of FORGE is to establish and manage the University of Utah location as a dedicated site where the subsurface scientific and engineering community will be eligible to develop, test and improve new technologies and techniques in an ideal EGS environment.

4. Will the research endeavors include undergraduate and graduate students?

Yes. Throughout the initial phases of the FORGE initiative, graduate students supported the University of Utah's efforts in developing a strong understanding of the Milford site. GTO plans to engage students of all levels in the next phases of FORGE. As stated in the original FORGE funding opportunity announcement, the initiative will address workforce development through engaging students and educators (K-12 and higher education) onsite and in the classroom regarding EGS science and technology. DOE is proud to support the development of the next generation of research scientists helping to make success at FORGE, and in turn EGS, a reality.

5. Will GTO oversee the research, and will GTO representatives visit the facilities?

DOE will be substantially involved in the FORGE initiative. DOE will have a significant role in project decision-making, including participation in decisions related to the technical, programmatic, and/or financial aspects of the project and/or operation of the FORGE. Responsibilities will include but are not limited to: collaborating on FORGE activities and recommending alternate approaches; reviewing and concurring with ongoing technical performance; the appointment of members to review teams (in an amount of at least 30% representation); resolving conflict of interest, liaise between other federal programs and/or industry staff.

6. What can the geothermal community expect next?

GTO is currently negotiating the University of Utah's Phase 2C scope. Work should begin sometime this fall. ■

There will be a number of sessions on **FORGE Research – Enabling EGS** at the GRC Annual Meeting & Expo, from October 14-17 at the Peppermill Resort Spa and Casino in Reno, Nevada, USA.

To find out more about the crucial research the GRC invites you to attend the biggest annual geothermal energy event of the year! Registration is now open!

- *Thermal Characteristics of the FORGE site, Milford, Utah,* by Rick Allis, Utah Geological Survey; Mark Gwynn, Utah Geological Survey; Christian Hardwick, Utah Geological Survey; Joe Moore, Univ of Utah; Will Hurlbut, Utah Geological Survey.
- *Seismic Reflection Profiling at the FORGE Utah EGS Laboratory,* by Rick Allis, Utah Geological Survey; John Miller, consultant.
- *Mechanical Specific Energy Analysis of the FORGE Utah Well*, by Ozgur Balamir, Geothermal Resource Group, Inc.; William Rickard, Geothermal Resource Group, Inc.; Ernesto Rivas, Geothermal Resource Group, Inc.; Nasik Islam, Energy & Geoscience Institute, Dept. of Chemical Engineering, University of Utah.

(continued on page 40)

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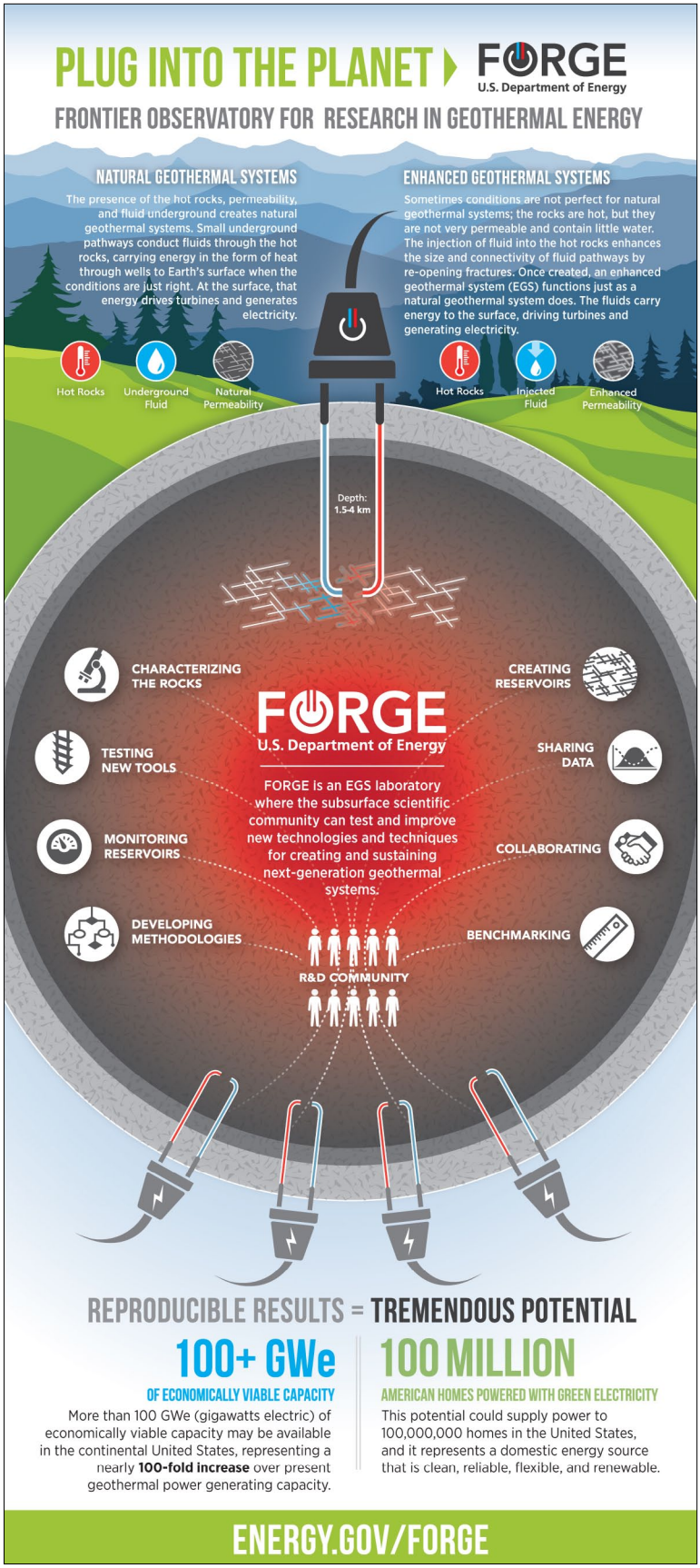
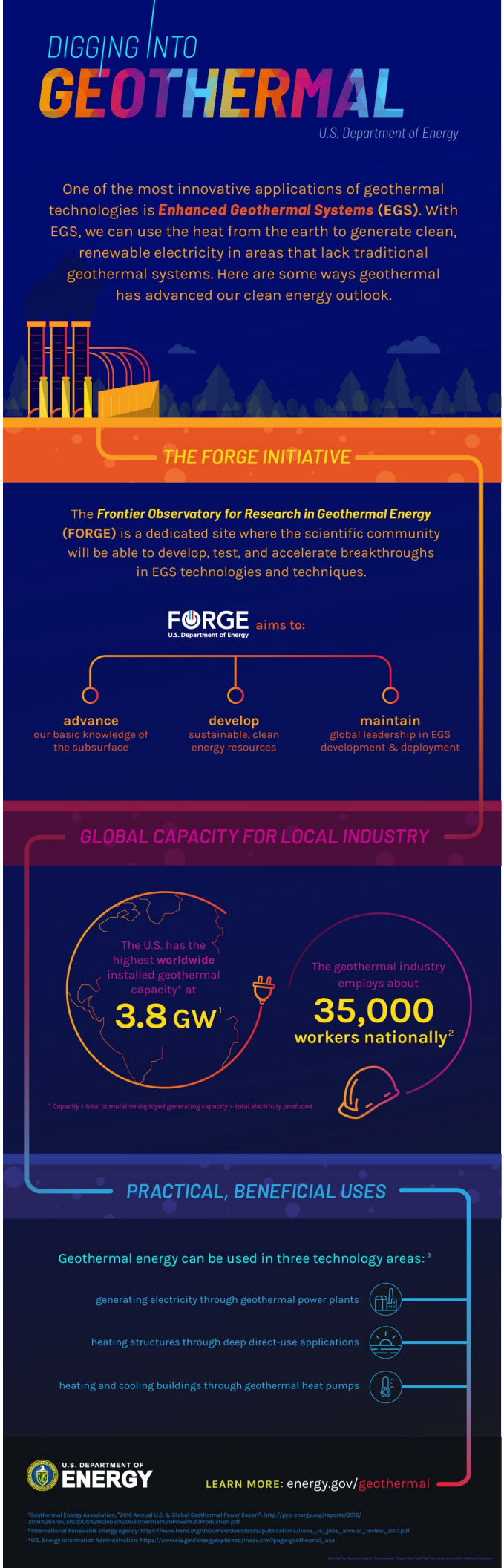
- *Compilation of Rock Properties from Well 58-32, Milford, Utah FORGE Site,* by Mark Gwynn, Utah Geological Survey; Rick Allis, Utah Geologic Survey; Christian Hardwick, Utah Geological Survey; Clay Jones, Energy & Geoscience Institute; Peter Nielsen, Utah Geological Survey; Will Hurlbut, Utah Geological Survey.
- *Earth modeling of the Utah FORGE Site,* by Rob Podgorney, INL; Michael Janis, University of Oklahoma; Stuart Simmons, EGI, University of Utah; Rick Allis, Utah Geologic Survey; Joe Moore, Univ of Utah.
- *An Overview of the Geology, Geochemistry, and Geophysics of the Utah FORGE Site,* by Stuart Simmons, EGI, University of Utah; Joe Moore, Univ of Utah; Rob Podgorney, INL.
- *DFIT and Fracture Modeling of the Utah FORGE Site,* by John McLennan, EGI; Bryan Forbes, EGI; Siavash Nadimi, University of Utah; Aleta Finnila, Golder; Rob Podgorney, INL.
- *Native State and Reservoir Production Modeling of the Utah FORGE Site and Vicinity,* by Rob Podgorney, INL; Hai Huang, Idaho National Laboratory; Yidong Xia, INL; John McLennan, EGI; Bryan Forbes, EGI; Siavash Nadimi, University of Utah; Aleta Finnila, Golder; Joe Moore, Univ of Utah.
- *Geologic Setting of the Utah FORGE Site Based on New and Revised Geologic Mapping,* by Stefan Kirby, Utah Geological Survey; Tyler Knudsen, Utah Geological Survey; Emily Kleber, Utah Geological Survey; Adam Hiscock, Utah Geological Survey.
- *Geology of the Utah FORGE site and environs:* Beaver County, Utah, by Clay Jones, Energy & Geoscience Institute.
- *Geophysical Surveys of the Milford, Utah, FORGE site: Gravity and TEM,* by Christian Hardwick, Utah Geological Survey; Will Hurlbut, Utah Geological Survey; Mark Gwynn, Utah Geological Survey; Rick Allis, Utah Geologic Survey; Philip Wannamaker, University of Utah/EGI; Joe Moore, Univ of Utah.





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 Field Operations / Direct Use.

Transforming Silica into Silicate – Pilot Scale Removal of Problematic Silica from Geothermal Brine

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Keywords
- Scale formation
- Silica scale
- Silica
- Calcium silicate hydrate
- Nano-structured calcium silicate hydrate
- Geothermal energy

ABSTRACT

The condensation of dissolved silica species to form a hard silica scale is a major issue in the generation of electrical energy and heat recovery from geothermal hot water and wet steam resources. In previous publications we have shown that nano-structured calcium silicate hydrate (NCaSilH) forms readily from dissolved silica species in the separated geothermal brine and, therefore, provides an attractive solution to the world-wide problem of the formation of silica scale. NCaSilH is placed into context with silica species and other calcium silicate hydrates to demonstrate why the controlled formation and uses of this material are of interest in geothermal resource operation and management and in various end user applications. The formation and removal of this novel precipitated silicate from the brine is discussed in the early stages of pilot scale trials. A pilot scale test rig for such trials was constructed on site at MB Century, Taupo, New Zealand, and commissioned in September 2017. The test rig uses lamella separation technology for recovery of NCaSilH and other species from brine. The development and implementation of this technology in the test rig is outlined. Early results showed that the source of silica is quite variable and comparatively low in silica and high in carbonate content. However, it served to show that our NCaSilH approach to removing problematic supersaturated dissolved silica species from a geothermal brine works. Removal efficiencies for various species were between 95% and 99%, slightly lower than laboratory results due to low silica levels. The test rig demonstrates that the technology is very robust in operation and offers a novel disruptive approach to facilitate the reduction in silica scale-forming species by removing most or all of the problematic dissolved silica species from such geothermal brines, along with calcium carbonate and some other species.

1. Introduction - Geothermal Energy and the Formation of Silica Scale

Geothermal energy is an attractive natural renewable energy resource, as it can produce large quantities of heat and electrical energy continuously and also on demand. The potential for harvesting geothermal energy is present, when underground water reservoirs a few hundred meters to several kilometers below the surface, are located close to geothermal heat sources (e.g. magma). Water reservoirs can be natural or artificially generated. The hot geothermal water is piped to the surface and flashed to produce a wet steam which is used to drive a turbine and produce electricity. The flashing simultaneously produces a separated geothermal water or brine flow, which is usually supersaturated in dissolved silica species, for further binary cycle electricity generation, heat recovery uses, discharge or re-injection. Re-injecting the separated brine and the condensed water from the steam turbines into a geothermal reservoir increases the life time of this underground reservoir, prevents subsidence and places this method of energy generation firmly into the realm of both benign and renewable energy resources.

Due to microbial and chemical processes, the sub surface rock containing and surrounding geothermal water reservoirs is partially dissolved, resulting in a cocktail of species (cations and anions) and suspended particles within the sub surface hot geothermal water. During utilization of this hot geothermal water resource, these dissolved species, notably silica and carbonate entities, can precipitate out to form an intractable scale, which blocks pipes, valves, heat exchangers and other process equipment. They can also be carried over with wet steam to damage turbines. Therefore, wet steam is scrubbed and treated to reduce the amount of carry-over, which leads to a loss of energy. Issues surrounding dissolved and suspended species become further problematic in the separated brine, as the species are concentrated up due to the flashing of about 30 % of the water flow into steam and downstream extraction of further heat energy resulting in a lowering of the brine temperature, hence increasing the silica deposition. This is a major problem in the recovery of heat energy in the heat exchangers in a binary cycle electricity producing plant as well as for the general operation.

The composition of the separated brine is somewhat production well and process specific, and various levels of toxic species, such as arsenic or selenium, valuable species, such as lithium, zinc, boron or gold, and environmentally harmless but problematic species, such as dissolved silica and calcium carbonate, are invariably present at different levels. The dissolved supersaturated silica species in the separated brine are therefore particularly problematic as they can precipitate out and form a hard amorphous silica scale that needs to be removed using considerable mechanical force and effort, or by the use of corrosive hydrogen fluoride or both. These dissolved silica species become concentrated to supersaturation levels after the generation of steam in the flashing process and/or after reduction in the brine temperature in a binary plant. For example, sub surface geothermal water at 260^{o}C can contain up to 600 mg/kg of dissolved silica (Iler, 1979). Upon flashing at the surface about 30% of this water is transformed into steam and the concentration of dissolved silica in the residual separated brine representing about 70% of the mass flow increases to approximately 800-900 mg/kg. The temperature of the brine correspondingly decreases to about 120 - 160^{o}C as heat energy is removed with the steam. At 120^{o}C only approximately 350 mg/kg of silica are soluble in water. The separated brine therefore becomes supersaturated with dissolved silica, which can condense (polymerize) and precipitate to form a hard, amorphous silica scale blocking pipes, heat exchangers and re-injection wells.

Costs associated with the re-drilling of re-injection wells and cleaning of pipes and equipment are significant and present one of the major challenges and impediments facing geothermal energy generation. Several methods have been investigated to address the issue of silica scale formation. Examples of these are the addition of acid (Dubin, 1984; Gunnarsson and Arnórsson, 2005) to partially delay the condensation of the dissolved silica species, the addition of silica seeds (Sugita et al., 1999; Sugita et al, 2003) to capture such dissolved silica onto a pre-existing silica material, and the addition of aluminum species, EDTA and other compounds to form silica and silicate species that do not precipitate (Gallup, 1999; Sugita et al., 1999). Gill, (1998) presents a good

overview regarding this problematic issue of silica scale formation and the effect of pH and other ionic species on it. In a parallel development, we (Harper et al., 1992) and a group from Japan (Sugita et al., 1999 and 2003) realized that the use of calcium ions (dissolved lime) allowed removal of silica from geothermal brine. We focused on the silica-derived products building a pilot plant to precipitate a silica product with a network structure from geothermal brine for use as a filler to enhance the optical and print quality of paper. Meanwhile Sugita et al., (1992) carried out successful trials in the reduction of dissolved silica species in geothermal systems in New Zealand (Mokai) and Japan but they appeared not to have realized the nature and potential of the silica and silicate species they generated.

In 2008, we shifted our focus away from the production of fine chemicals towards the geothermal energy sector as we realized that one of the materials we produced, notably nano-structured calcium silicate hydrate, NCaSilH, offers a disruptive and attractive potential solution to preventing the occurrence of silica scale. The technology works by transforming the reactive silica species which is present at supersaturated levels in separated geothermal brine, into NCaSilH which forms readily, does not polymerize further and does not bind to metal surfaces. Instead the NCaSilH particles remain suspended in the geothermal brine flow and can be separated out as a useful product. The level of dissolved silica species remaining in the brine can be controlled to below the equilibrium solubility level at the brine temperature down to the essentially zero, depending on the amount of calcium ions used in relation to the dissolved silica species in the water.

Through laboratory scale and field trials, we have successfully developed the NCaSilH geothermal technology and have constructed a small-scale pilot plant test rig to address the following research questions, process chemistry issues and product characteristics:

1. Can our NCaSilH technology, which has been successfully demonstrated in laboratory and field scale work, prevent silica scale formation in an operational geothermal field?
2. What are the preferred process chemistry and operating conditions to effectively prevent scale formation in an operational geothermal environment?
3. Individual geothermal wells essentially have different brine compositions in terms of its ionic and particulate content and undergo comparatively rapid cyclic changes in terms of their flow and chemistry. Is the NCaSilH technology robust enough to work under these conditions? Which dissolved and particulate species are captured along with NCaSilH material in its formation?
4. The NCaSilH product needs to be recovered from the cooled brine prior to reinjection. What is the best process chemistry technology available for this and how will it be interfaced and implemented? The important issue here is dealing with the high flow rates of the brine stream which contains the suspended NCaSilH particulates.

There are likely further issues to be addressed which will become apparent during the program, which we will investigate in future studies.

In this paper, we describe the design and operation of our pilot scale test rig and some of the considerations leading to its development.

2. Recovery of NCaSilH from Geothermal Brine – from Settling Tanks to Lamella Separators

In a parallel development, Harper and Johnston in New Zealand (Harper et al., 1992) and a group from Japan (Sugita et al., 1999 and 2003) realized that the use of calcium ions (dissolved lime) allowed removal of silica from geothermal brine. Our more detailed work has shown that if the dissolved silica is reacted with small doses of lime (Ca/Si <0.4) a silica material, with a type I network structure, precipitates (Iler, 1979, Harper et al., 1992, Sugita et al., 2002, **Figure 1a**). The use of larger amounts of lime (Ca/Si>1.3) results in the formation of calcium silicate hydrate species (C-S-H) like tobermorite and jennite (Richardson, 2008). In our detailed studies of the reaction of sodium silicate solution and also geothermal brine with different quantities of lime under controlled pH conditions, we found that when using a calcium to silicon ratio of 0.8 a novel nano-structured calcium silicate hydrate, NCaSilH, material **(Figure 1b**) is produced very rapidly from either synthetic or natural sources of dissolved silica (Johnston et al., 2006).

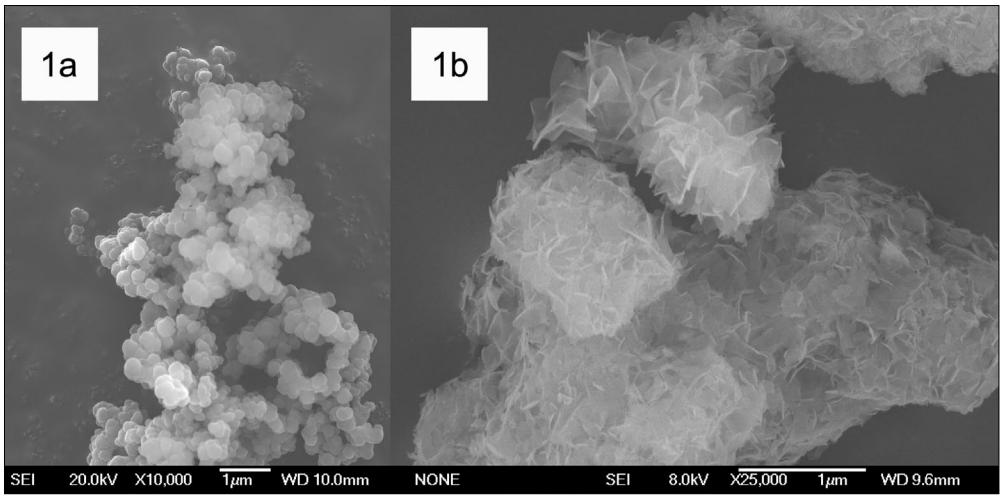

Figure 1: Scanning electron microscope images. A silica with a type I network structure (a) and nano-structured calcium silicate (b).

NCaSilH is distinct from other forms of precipitated silica in that the base unit present is related to the calcium silicate wollastonite CaSiO3 structure, shown by Borrmann et al., (2006 and 2008), in a study of the material using nuclear magnetic resonance, ion bombardment and X-ray photoelectron spectroscopy. In contrast to other C-S-H phases and silicates, NCaSilH it is not crystalline or has the long-range order prevalent in these other structures (Borrmann et al., 2006 and 2008). Fundamental silicate units do however link together to form the backbone of the NCaSilH structure and provide an open framework similar to "desert rose", where the calcium ions are accommodated on the surface of the particles. This gives NCaSilH a slightly positive surface charge and hence the ability to bind other silica or ionic species to such surfaces (Johnston et al., 2006, Cairns et al., 2006, Borrmann et al., 2011). In the presence of anions such as carbonate or phosphate, the surface calcium ions can form insoluble calcium carbonate species (aragonite, **Figure 2a**), or calcium phosphate in the NCaSilH particle matrix. The large available surface area resulting from the open framework nature of the NCaSilH structure is important here. Also, cations react with surface silanol groups or exchange against calcium and bind to the silicate surface (Borrmann et al., 2011). Additionally, NCaSilH has a variety of pores from nano- to meso- in size, which allow it to act as a sponge and filter material and trap other solid particles on its surface (for example calcite crystals as shown in **Figure 2b**).

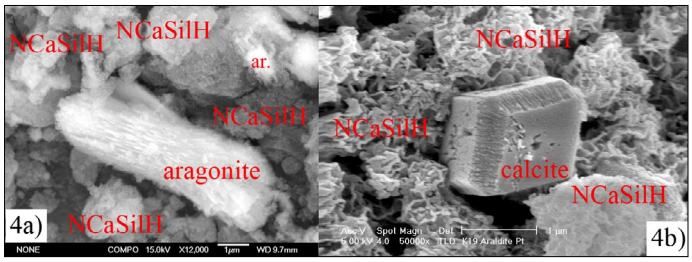

Figure 2: Scanning electron microscope images. Calcium carbonate trapped in NCaSilH; (a) aragonite, (b) calcite (b).

The particles observable in the scanning electron microscope images (Figure 2) are about 1 to 5 microns in diameter. The open framework structure is observable. Number weighted particle size measurements using the dynamic light scattering measurement method, also show that about 99 % of the particles fall within this size range. However, our laboratory work has shown that the small particles have a tendency to agglomerate and form clusters of several microns in diameter. This is verified by volume weighted particle size measurements, where particles with a diameter of 10 micron, being agglomerates of about one thousand 1 micron particles are observable (Borrmann, 2009). Although it is possible that the individual 1 micron NCaSilH particles could likely be reinjected with the cooled brine, the larger 10 micron particle agglomerates would probably block the pores in an underground geothermal reservoir rock formation. Hence it is most likely that the NCaSilH material needs to be removed from the geothermal brine before reinjection. A positive side effect of these larger agglomerates is that two sources of scale forming species, silica and calcium carbonate are removed from the brine at the same time by our NCaSilH technology. In current geothermal resource field operation and management, while calcium carbonate scales tend to be soft and brittle compared to the silica scale, the carbonate occurrence is still problematic and the consequent need for its removal also entails operational down times and expenditures, as does the silica scale removal.

Our laboratory and field results present a further strong argument as to why the NCaSilH material should be removed from the brine. The surface chemistry of NCaSilH changes over time depending on the pH of the environment. As a result the calcium is very slowly leached from the platelet surfaces starting within minutes of the NCaSilH formation. This is particularly evident as the pH is lowered. The vacant sites then react with water to release hydroxide ions into solution. The calcium and hydroxide ions remain closely associated with the silicate particles and tend to facilitate reactions on the particle surface, so this is not an immediate issue. However, after several hours or days the NCaSilH does begin to dissolve noticeably releasing monomeric silica and silicate species back into solution, depending on the pH, ionic content and temperature (Barassi, 2013). This means that although NCaSilH acts to capture the reactive silica species and hence prevent the formation of the unwanted hard silica scale, if the NCaSilH material is not removed from the brine in a reasonable timeframe, this slow dissolution characteristic may result in silica precipitation. However, in reality this is not an issue as the water flow rates in geothermal pipework are fast and hence the residence time for a particular volume of brine and the associated precipitated NCaSilH material in the system before removal, is very short. In contrast to several other treatment technologies, NCaSilH can be removed from the brine thereby irreversibly lowering the risk of silica scale formation. Other researchers like Sugita et al., (2002), have also realized that removal of the solids offers this opportunity. While some other research groups have investigated the generation and removal of silica materials from geothermal brines (Bourcier et al., 2006 and 2014), our NCaSilH technology offers several opportunities and competitive advantages based on its process chemistry and the particulate structure and nature of the surface morphology of the material, which are not provided by such other approaches (Johnston, 2002, 2006, 2008, and Borrmann, 2011).

The removal of nano-structured calcium silicate hydrate (NCaSilH) from geothermal brine is a solid-liquid separation, which is non-trivial due to the high surface area and pore volume of NCaSilH, low difference in the respective bulk densities of NCaSilH (1.6 g.cm-3) and water (0.998 g.cm-3), and the low mass concentration of NCaSilH in geothermal brine, about 0.1 %wt. This is aggravated by the comparatively high brine flow rates found in geothermal power plants.

2.1 Settling Behavior and Settling Tank Sizes

Despite the aggregation of particles and formation of larger (10 to 60 micrometer) agglomerates, the sedimentation of NCaSilH was slow. The aggregates of NCaSilH were very porous. BET surface area measurements delivered results in the range of 100 to 500 m2.g-1 of material. Oil absorption measurements showed that a typical sample of NCaSilH could absorb up to 1 to 7 times its weight in oil (or water), which indicated that the pores were quite accessible. The openness of the structure in combination with the mass concentration lead to zone settling behavior. Therefore, the settling rate of the particles had to be determined empirically. Most of the sedimentation was completed after approximately 4 minutes (the compression point was reached), after which a very slow compression of particles occurred. This means that the settling process could be terminated after about 4 minutes, as further sedimentation is not economically viable after the compression point. Prior to the compression point settling velocities were constant. All NCaSilH samples studied displayed zone settling behavior. The rate of the settling process was determined to be about 50 mm.Min-1. Based on this settling rate the minimal theoretical size of a settling tank could be calculated. It needs to be noted that no safety factor was included in the calculation; for a real life example a safety factor of about 50 % of the surface area would have to be included, which is equal to a 22 % increase in the diameter of a settling tank. Furthermore, the settling rate is strongly dependent on the salt content of the brine. Increasing the salt content of the brine reduces the solubility and miscibility of silica and related species. Impurities, like silica, zinc or iron, can bind to NCaSilH raising its density and hence lead to an increased settling rate. Additionally, at higher temperatures, the viscosity of the fluid is lower and consequently the settling rate is elevated. Taking into account the settling rate for samples investigated here a tank diameter of 30 m for a flow rate of 3000 m3.h-1

would be necessary; if a safety factor is included that diameter would need to be about 37 m, which is comparatively large.

2.2 Lamella Separator

Several solid liquid separation technologies were considered in the approach for separating NCaSilH from geothermal brine. While rotary drum filters, band filters, continuous centrifuges and filter presses could deal with the challenges presented by NCaSilH, they all have moving parts, require electricity and are comparatively expensive. At the volume and flow rates and low concentrations of NCaSilH particles present they were considered uneconomical. Filter cartridges and membranes were tested successfully in the separation of NCaSilH and geothermal brine but experienced fouling. The pressures and temperatures prevalent in geothermal energy producing environments put considerable stress on the filters and membranes, which implied that their service life might be prohibitively short. Hydrocyclones are very efficient at solid-liquid separations and have a comparatively low footprint. Additionally, their principle use is familiar to the geothermal industry in the form of cyclone separators used in flash plants to separate steam from brine. However, the turbulences and fluid velocities present in hydrocyclones would very likely break up agglomerates of NCaSilH and consequently might prove inefficient. On advice from Edgar Schicker, Technical University Nürnberg, Germany, we started to investigate lamella separators. Lamella separators are also referred to as lamella clarifiers or inclined plate settlers. These separators are characterized by an array of inclined parallel plates providing a large settling surface. Because the plates are stacked a lamella separator has a comparatively small footprint (20 to 35 % of the size of a comparable settling tank). A schematic showing the main flows and settling along the plates is shown in **Figure 3.**

A lamella separator can operate on the principle of a counter-current separator. Water rises up in the separator. Due to their higher density and related settling velocity particles progress at a slightly flatter angle than water and impact on the surface of the lamella, where they aggregate and slide down to a collection chamber and outlet at the bottom of the separator. Generally low flow velocities (and therefore low Reynolds numbers) mean that a lamella separator works very efficiently. Low flow velocities are desirable as it is less likely that turbulences occur, which disturb the settling process. Instead a laminar flow system is present. In the geothermal context, there is the possibility of the occurrence of temperature gradients, which introduce convection currents. Hence, steps need to be taken to avoid these, like insulating the surfaces of a lamella separator. The occurrence of convection currents was confirmed in laboratory tests.

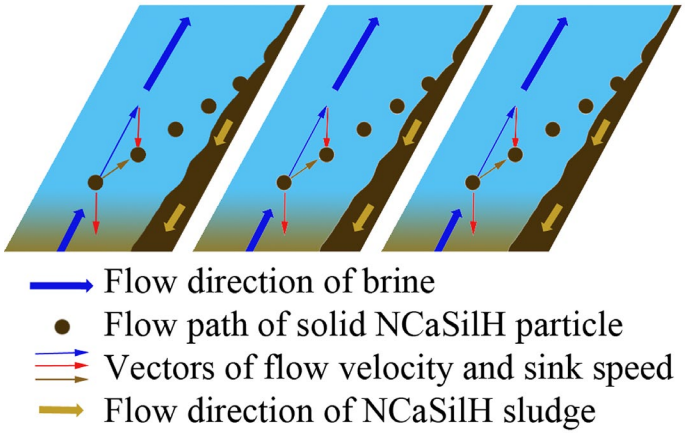

Figure 3: Schematic showing particle flows along the plates of a lamella separator.

The dimensions and arrangement of lamella in each lamella separator is specific to the solid and liquid that require to be separated as well as to the ambient conditions present. Due to having no prior experience in the construction of a lamella separator a rapid prototyping, empirical approach was chosen for developing a suitable separator. For dimensioning of the lamella area a numerical model was developed to calculate the required settling surface for a given volume flow. Next, a laboratory model was constructed that allowed observation of the flows in the model and then refinement based on the observations. The refinement process took two iterations until a model was constructed that had a separation efficiency above 99 percent (**Figure 4**). The first model developed an unwanted turbulence, where particles rapidly moved along the outside wall of the separator (**Figure 4**, **top, yellow arrow**), hence creating a circular current within the separator. This was thought to be due to the vertical entry of fluid and the wall angles within into the separator. Baffles added to the front of the separator intended

to break the fast inflow resulted in some solid-liquid separation (**Figure 4, top, red arrow**) but managed to only attenuate the circular current.

To prevent the occurrence of the circular current found in the first model, the entry into the second model was flattened to reduce fluid velocities. Tests showed that a laminar flow transported the fluid directly towards the first lamella (**Figure 4, middle**). Initially this was thought to be due to a thermal current but addition of insulation did not resolve this matter. Once past the first lamella a comparatively high current directed towards the outlet meant that only the first lamella was contacted by the fluid. Most of the fluid in the rest of the separator was still and did not participate in any settling process as shown in dye experiments. Due to the flat angle of the intake area particles agglomerated and settled in the middle of the separator (orange circle).

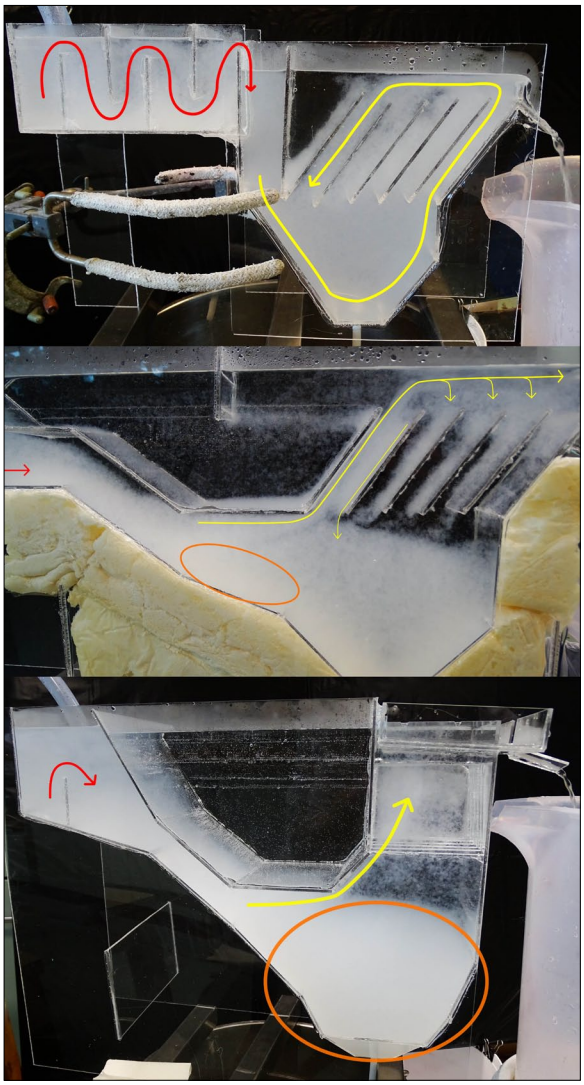

Figure 4: Perspex lamella separators tested in the laboratory. Top: Model 1. Middle: Model 2. Bottom: Model 3.

For the third model (**Figure 4, bottom**) the lamella were turned by 90 degrees to ensure that all lamellae were active, and the outflow area was widened to reduce flow velocities towards the outlet. A laminar flow was observed as in model 2 (yellow arrow). However, most particles settled directly into the compression area (orange circle). The rest of the particles entered the lamella area. Due to the turning of the lamella the flow went past every lamellae, making use of their full surface area for settling. A flow breaker was added at the inlet (**Figure 4**, bottom, red arrow) to distribute the flow over the whole length of the inlet. A separation efficiency of 99.4 % was achieved. The residual NCaSilH particles that were transported into the supernatant were very small (not visible).

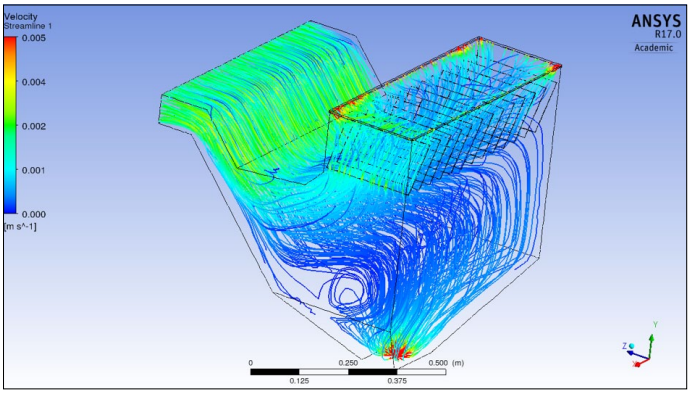

Figure 5: CFD model showing the velocities and stream lines in a large-scale lamella separator based on Perspex laboratory model 3.

Based on the laboratory model a larger separator (for a flow rate of 8 L/Min.) to be used in our pilot plant test rig was constructed. Results from the use of the larger scale separator in a pilot plant will be presented in future publications. To confirm our laboratory results, for this larger separator a computational fluid dynamics (CFD) model of the flows in the separator (Figure 5) was simulated by Haiam Abbas of the Heavy Engineering Research Association (HERA). Velocities and stream lines in the CFD simulation were the same as those observed for model 3 (**Figure 4**, bottom).

The CFD simulation **(Figure 5)** was produced using ANSYS R17.0 software.

(continued on page 50)

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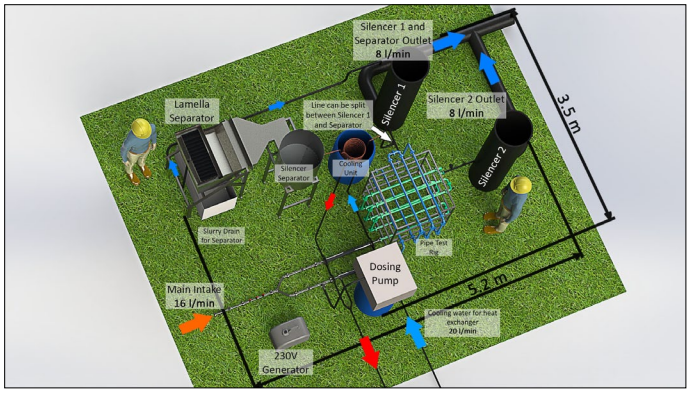

Figure 6: Design sketch of pilot scale test rig.

3. Pilot Scale Test Rig – Sketch, Photos and Early Results

In January 2017 plans were developed for a pilot scale test rig. While the test rig was being built by Nick Grinter in the workshop of Victoria University, the settling characteristics and particle size distribution of NCaSilH were studied. As it became apparent that NCaSilH needs to be recovered from the brine a lamella separator addition to the test rig was designed (**Figure 6**). A stainless-steel lamella separator was built by AE Tilley, Wellington, New Zealand, in July 2017. MB Century, Taupo, New Zealand, provided a site, where the test rig could be placed, and access to brine from the Wairakei Power Plant located about 500 m away downhill.

Figure 7: Photographs of test rig.

In August 2017, the test rig was assembled on site and commissioned (**Figure 7**). Operation of the test rig started in September 2017.

Early results showed that the flow rate silica and carbonate content of the brine received by the test rig changed widely and comparatively rapidly (**Figure 8**).

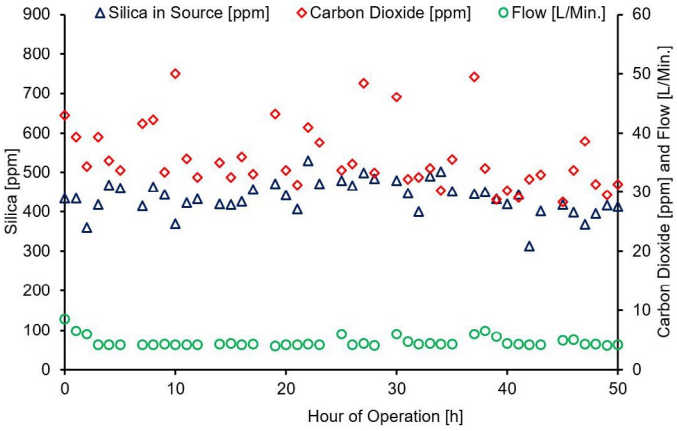

Figure 8: Variations in brine flow, silica and carbonate levels encountered.

Despite those variations the technology worked very successfully with separation efficiencies for the separator ranging from above 95% to 99% (**Figure 9**). Furthermore, the separator proved to be effective in recovering all sorts of particles not just NCaSilH (see calcite and NCaSilH recovered in **Figure 2b**).

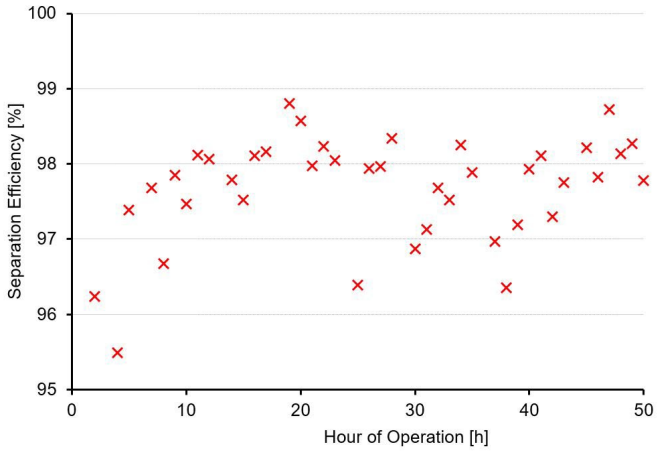

Figure 9: Separation efficiency of lamella separator used in test rig.

4. Conclusions

The formation of silica scale can be prevented by transforming the silica into nano-structured calcium silicate (NCaSilH). Due to its particle size and chemistry NCaSilH needs to be removed from geothermal brine to avoid the risk that it would block up reinjection wells and geothermal reservoirs. Lamella separators were successfully tested for the removal of NCaSilH from geothermal brine, reaching a solid-liquid separation efficiency in the laboratory of 99.6 % and in the field of above 95%. The lower efficiency in the field was due to the silica levels present in the brine treated, which were between 300 to 500 ppm, 400 ppm on average, which meant that agglomerates were less likely to form, which in turn meant that separation by gravity became less likely. However, the residual supernatant was free of visible particles and silica levels in the supernatant were below saturation levels.

The shape and configuration of the lamella separator was determined empirically using rapid prototyping approach. Transparent models were build that allowed observing the flows in them. Based on the findings a pilot scale lamella separator was constructed and commissioned. The validity of the up-scaled model was confirmed in a computational fluid dynamics simulation. The fluid velocities and stream lines in the model were the same as in laboratory model 3. Lamella separators were chosen for the recovery of NCaSilH from brine due to their comparatively small footprint compared to settling tanks and as they don't contain any movable parts easing maintenance. Other solid-liquid separation techniques were not explored at this stage in the project. NCaSilH is only going to be concentrated to a solid content of about 0.25 % in the lamella separator. Therefore, it is necessary that a secondary solid liquid separation technique will be employed. This along with uses for the recovered NCaSilH will be considered in future projects. It appears important to collect sufficient amounts of samples of NCaSilH for analysis and to provide material for end user testing and evaluation purposes. Initial samples of NCaSilH have been collected but due to low levels of silica in the brine and comparatively low flow rates the test rig will produce these comparatively slowly. Therefore, a larger separator and test rig is in development.

Overall, NCaSilH technology offers the opportunity to reduce the levels of not only the problematic dissolved silica species, but also calcium carbonate trapped in the silicate hydrate, to below levels were scale formation of either occurs. The separator removed particulate matter independent of its nature. Gravel and plant matter was found in the collected product. Consequently, the residual brine could be used to harvest valuable compounds from it, which were so far inaccessible due to destructive species, such as silica. This opens up possibilities for geothermal mining and access to new revenue streams. Future research projects will investigate this possibility more closely. Looking at some projects aimed at gaining access to supercritical geothermal resources, the need to solve the silica scale issue becomes even more pressing. Under supercritical conditions it is likely that the dissolution of the sub surface reservoir rock, the saturation of geothermal water and oversaturation of separated brines becomes a much more significant issue and problem to address. This is an interesting possibility in the medium and long term. However, our current focus is on the successful implementation and demonstration of the NCaSilH technology and the removal of the NCaSilH on large scale, and also on establishing potential uses for the material. The possible issue of contamination of the NCaSilH material with a variety of other species will also be explored in future studies.

ACKNOWLEDGEMENTS

We thank Edgar Schicker for advice on solid liquid separation techniques and technologies and Haiam Abbas and HERA for modelling the flows in the lamella separator. We wish to acknowledge the Ministry of Business, Innovation and Employment, New Zealand Endeavour Research grant RTVU1604 for funding, and MB Century Ltd, Taupo, especially Richard Adams for collaboration in our pilot plant development.

REFERENCES

Barassi G. "A Study of the Uptake of Cu2+ by Calcium Silicate by Batch and Continuous Reactors for Potential Commercialisation." *Ph.D. thesis, Victoria University*, (2013). http://researcharchive.vuw.ac. nz/handle/10063/2639

Borrmann T., McFarlane A.J., Johnston J.H., Markwitz A., and Dytlewski N. "Heavy-ion elastic recoil detection analysis as a useful tool for tracking experimental modifications in bulk calcium silicates." *Surf. Interface Anal.*, 27, (2006), 695-698.

Borrmann T., Johnston J.H., McFarlane A.J., MacKenzie K.J.D., and Nukui A. "Structural elucidation of synthetic calcium silicates." *Powder Diffraction*, 23 (3), (2008), 204-212.

Borrmann T., Johnston J.H., and McBrearty R. "Nano-Structured Calcium Silicate - A Solution to the Formation of Silica Scale in Geothermal Water." *GRC Transactions*, 33, (2009), 695-698.

Borrmann T., Cairns M.J., Anderson B.G., Hoell W., and Johnston J.H. "Nanostructured Calcium Silicate as Sorbent in a Study of Artificial Mining Waste." *International Journal of Environmental and Waste Management*, 8 (3/4), (2011), 383-403.

Bourcier W.L., Mackenzie Johnson W.R., Bruton C., and Gutierrez P. "Silica Extraction at Mammoth Lakes, California." *Proceedings of the International Mineral Extraction from Geothermal Brines Conference. International Mineral Extraction from Geothermal Brines Conference; 09/04/2006; Tucson, Arizona: Geothermal Resources Council*, (2006) 1-6

Bourcier W.L., and Bruton C.J. "Silica extraction from geothermal water." *United States Patent*, (2014), US8840859 B2;

Cairns M.J., Borrmann T., Johnston J.H., and Hoell W. "A Study of the Uptake of Copper Ions by Nano-structured Calcium Silicate." *Microporous Mesoporous Mater.*, 95, (2006), 126-134.

Dubin L. "Silica inhibition: prevention of silica deposition by boric acid/orthorborate ion." *United States Patent*, (1984), 4584104.

Gallup D.L. "Inhibition of silicate scale formation." *United States Patent*, (1999), 5858245.

Gill J.S. "Silica scale control." *Materials Performance*, (1998), 41–45.

Gunnarsson I. and Arnórsson S. "Treatment of Geothermal Waste Water to Prevent Silica Scaling." *Proceedings World Geothermal Congress 2005. Antalya, Turkey, 24-29 April 2005. International Geothermal Association*, (2005).

Harper R.T., Thain I.A., and Johnston J.H. "Towards the Efficient Utilization of Geothermal Resources." *Geothermics*, 21 (5/6), (1992), 641-651.

Iler R.K. "The chemistry of silica: Solubility, Polymerization, Colloid and Surface Properties, and Biochemistry." *John Wiley and Sons. New York*, (1979).

Johnston J.H., McFarlane A.J., and Borrmann T. "New high performance calcium-silica materials for filled and specialty papers." *Appita Annual Conference Proceedings*, 56, (2002), 453-457.

Johnston J.H., McFarlane A.J., and Borrmann T. "Nano-structured Silicate, Functionalised Forms Thereof, Preparation and Uses." *NZ Patent Specification*, (2006), No. 537747, PCT Application PCT/NZ2006/000003.

Johnston J.H., Borrmann T., Rankin D., Cairns M.J., Grindrod J.E., and McFarlane A.J. "Nano-structured Composite Calcium Silicate and Some Novel Applications." *Current Applied Physics*, 8 (3-4), (2008), 504-507.

Richardson I.G. "The calcium silicate hydrates." *Cement and Concrete Research*, 38 (2), (2008), 137-158.

Sugita H., Kato K., Ueda A., Matsunaga I., Sakurai Y., Yasuda K., Bando Y., and Nakamura M. "Field tests on silica removal from geothermal brines in Sumikawa and Onuma geothermal areas." *Journal of Chemical Engineering of Japan*, 32 (5), (1999), 696-700.

Sugita H., Matsunaga I., Yamaguchi T., Kato K., and Ueda A. "Silica removal performance of seed from geothermal fluids." *Geothermics*, 32 (2), (2003), 171-185. ■

Lava Eruption Disrupts the Puna Geothermal Venture - The Background

by Michael Mathioudakis, Molly Johnson, Katie Huang, Jon Golla, and Theo Renaud
GRC Student Committee

The Kīlauea volcano has been continuously featured in international headlines since it began erupting in May, due to its adverse effects on both local residents and on the only geothermal power plant in Hawai'i. The lava flow has surrounded the Ormat Puna Geothermal Venture power plant, forcing a shutdown of activities, and the evacuation of thousands from nearby neighborhoods.

Lava Surrounds Geothermal Power Plant

As of the time of publication, Kīlauea Volcano, located on the Island of Hawai'i ("Big Island"), is still erupting from the summit caldera and from the Lower East Rift Zone (LERZ) in the Leilana Estates and Lanipuna areas. As magma steadily moves from the reservoir to the East Rift Zone and on to the ocean, the area around the caldera continues to experience small explosions, fissure eruptions, and earthquakes.

Remarkably, this is the first time that lava flow has affected operations of a geothermal power plant. The volcanic activity has caused the shutdown of the Puna Geothermal Venture (PGV), a 38 MW installed capacity plant operated by Ormat Technologies Inc. The lava flows surrounding PGV have blocked road access and have prompted officials to shut down the plant and take precautionary measures to prevent lava from reaching the wells. Despite best efforts, three wells have been covered in lava.

Kīlauea Volcano

Kīlauea is a relatively young, basaltic shield volcano east of Mauna Loa Volcano on the Island of Hawai'i (red deposits in **Figure 1**). Erupting 34 times since 1952, it is one of the most active volcanoes in the world [1].

The plumbing system of Kīlauea Volcano extends up to 60 km depth and feeds only the volcano[1]. Research by Lin et al. (2014) suggests the presence of a deeper crustal magma reservoir that may supply magma to the deep East Rift Zone [3]. Pietruzka et al. (2016) support this theory, and further suggest that magma intrusion from the summit reservoir into the LERZ is rare and accounts for major volcanic events [4].

The complicated plumbing system at Kīlauea may result in periodic shifts in magma composition. For example, a shift to a more Mg-O enriched magma composition in 1983 suggests a mixing of rift zone stored magma with mantle-derived magma. Furthermore, an eruption hiatus lasting only a few days may cause crystal fractionation and thus change the eruption magma composition [5].

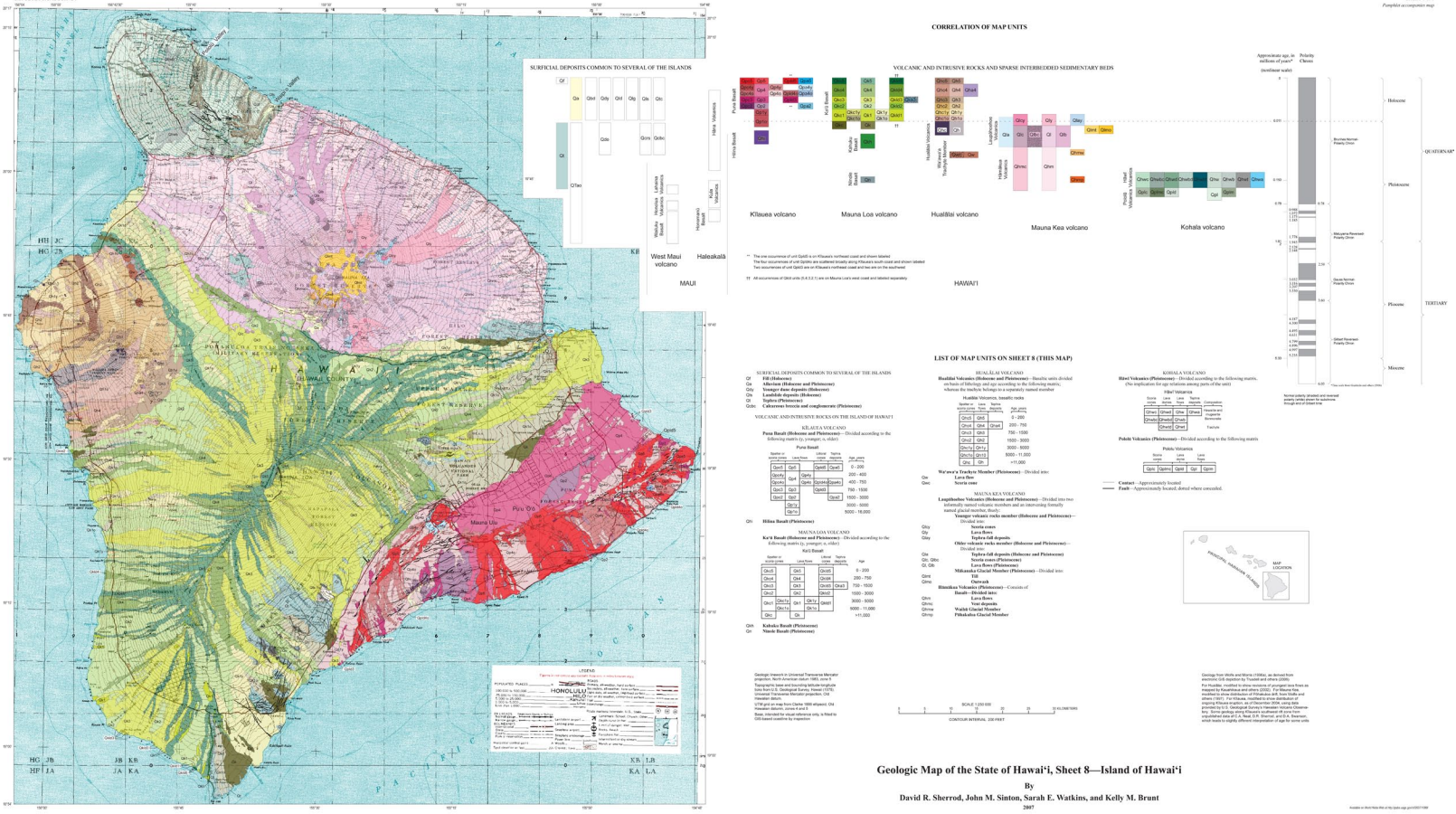

Figure 1: Geologic map of the Island of Hawai'i showing deposits from the five volcanoes on the island. Kīlauea is the easternmost volcano[2].

The active lava pond and gas plume of Kīlauea's summit caldera contribute to the eruption patterns of the volcano. The summit lava lake is directly connected to the summit magma reservoir, controlling the eruptive style (**Figure 2**)[6]. Initially, an abundant magma supply allows the summit caldera to fill and may eventually produce large lava flows from the summit and from rift zone vents at the caldera floor. However, in the current situation, a low magma supply has caused the caldera to collapse down to the water table, resulting in large steam explosions. As the magma supply re-entered the system, the lava has flowed into the rift zone vents causing effusive eruptions along the rift zone to the east.

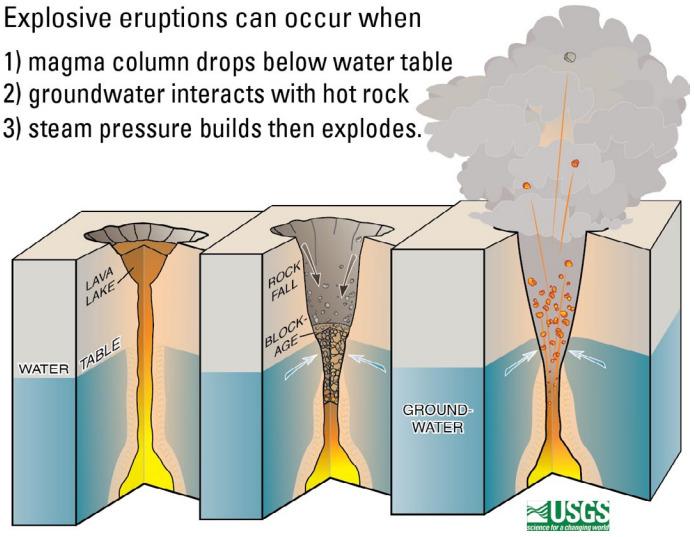

Figure 2: Kīlauea has three eruptive styles, depending on the magma supply. This graphic shows the process of steam explosions when magma supply drops, causing a caldera collapse and magma interaction with groundwater [6].

The 2018 Eruption

Indications of an impending eruption were noticed as early as April 17 2018 when the United States Geological Survey (USGS) noted pressurization of the magma system beneath Pu'u 'Ō'ō, a volcanic cone within the Eastern Rift Zone

of Kīlauea. On April 26, lava overflowed onto the Halema'uma'u crater (a pit crater within Kīlauea) floor at the summit of the volcano [7]. Four days later, the Pu'u 'Ō'ō crater collapsed, inducing seismicity and deformation down the rift of the vent, and increasing the risk of a Lower East Rift Zone (LERZ) eruption. The increased pressure beneath Pu'u 'Ō'ō formed a magma pathway from Pu'u 'Ō'ō crater to the LERZ, and, just two days later, small ground cracks began to open in the Leilani Estates area and the summit lava lake started to drop [8]. Finally, on May 3, a 5.0 magnitude earthquake caused Pu'u 'Ō'ō to collapse and release an ash plume; a few hours later, an eruption began on the LERZ with a 150m long vent opening and releasing molten lava to the surface[8]. In the following week, LERZ fissures steadily opened up and the summit lake continued to drop; by May 9, there were 15 new fissures and cracks opening.

As magma continues to move from the reservoir to the ERZ, the reservoir pressure continues to decrease and the Kīlauea Caldera floor has subsided further [9]. This subsidence stresses the faults in and around the caldera, causing continuous pulses of seismic activity [9]. A 6.9 magnitude earthquake, the strongest seismic event in Hawai'i since 1975, was recorded on May 11 -- eight days after the start of the eruption.

Puna Geothermal Venture

The Puna Geothermal Venture (PGV) is a geothermal power plant operated by Ormat Technologies Inc. and located approximately one mile east of Leilani Estates (Figure 3). Opened in 1992, the power plant manages 11 active wells that reach depths of 6,000 to 8,000 feet. The steam extracted is directed to turbine generators and also used to vaporize a working fluid for a second turbine. The condensed steam is then re-injected into the geothermal reservoir together with the unused brine [10]. With an installed capacity of 38 MW, PGV supplies 25% of Big Island's electricity, and represents 4.5% of Ormat's total generating capacity [11, 12].

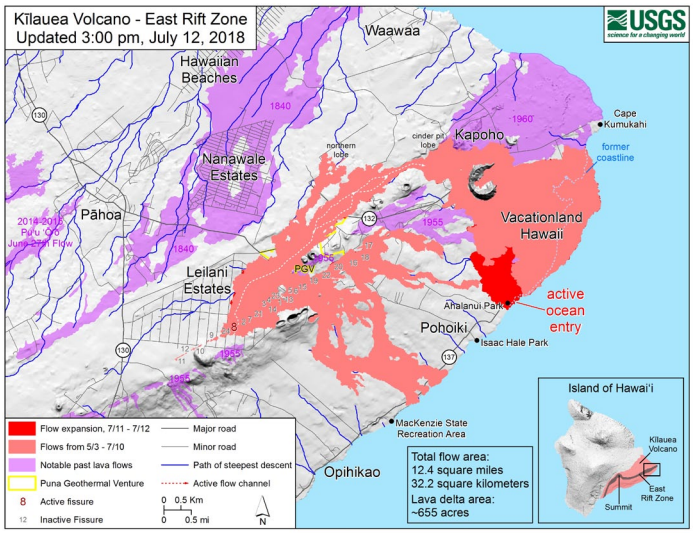

Figure 3: Flow expansion map since the beginning of the eruption on May 3 2018. The Puna Geothermal venture (PGV) is surrounded from the west by the lava flows. (Modified from USGS [1])

Protecting the Infrastructure

Due to the proximity of the lava flows, officials decided to shut down PGV on May 3, 2018. Over the next few days and weeks, Ormat personnel worked to shut down all wells, remove flammable materials, and install physical barriers to protect the plant's infrastructure from lava intrusion [12].

Experts from the geothermal energy community, including personal from the USGS, University of Hawai'i at Hilo, Ormat geologists and engineers, a wireline company and equipment suppliers, were brought in to help with the effort. Ormat also deployed a "mudman" who advised on the well quenching process. Charlene L. Wardlow, who oversees the Northern District of the California Division of Oil, Gas, and Geothermal Resources (DOGGR),

Charlene Wardlow *at the Puna Geothermal Venture* (Courtesy Charlene Wardlow).

was recruited by the Hawai'i Emergency Management Agency to join their Geothermal Task Force to secure PGV wells from potential lava intrusion. Wardlow described the process in an interview on June 20 2018: "Usually a geothermal well can be quenched by pumping cold water; however, the intrusion of the 2000+°F magma nearby and on the surface changed the wells' behavior and [the water] didn't work well at first on some of the wells." According to Wardlow, the operators of PGV were able to collect downhole temperature and pressure measurements before the lava had entered the facility. One of the wells had measured temperatures of 100°F greater than normal, even at 2500 ft depth. In addition to salt water, this well had to be quenched with a mud-barite mixture, which is intended to generate a ceramic seal upon exposure to high temperature conditions.

Figure 4: Aerial image of Puna Geothermal Venture (PGV) and the surrounding lava flows. PGV was built on high ground in order to mitigate risks from potential eruptions, and this strategic placement has mostly saved the plant from destruction. (USGS Facebook page)

The team also encountered problems due to delays in equipment delivery (especially bridge plugs) to the islands. "Overnight mail doesn't exist [on Hawaii]." noted Wardlow. As soon as the bridge plugs arrived, they were installed in the wells to isolate the lower part of the wellbore. "Ultimately, the wells were quenched and bridge plugs were run into the production wells using a wireline unit." This quenching operation, which involves injecting water so that the hydrostatic pressure exceeds the pressure of the volcanic stream below, is essential for ensuring the mechanical integrity of the wells. By May 21, all the wells were quenched and sealed with metal caps.

Meteorological conditions were monitored throughout this process, as the eruptions were emitting large amounts of sulfur dioxide (SO_2) and hydrogen sulfide (H_2S) gas. To date, three wells, an equipment warehouse, and switchyard and access roads have been covered with lava [13]. "It is an island in between the active lava flows." said Wardlow. PGV was built on high ground in order to mitigate risks from potential eruptions, and this strategic placement has mostly saved the plant from destruction **(Figure 4).** Dr. Nicole Lautze, Director of the Groundwater & Geothermal Resources Center at the University of Hawaii, hopes that people will appreciate the success of Ormat's mitigation measures: "This eruption has shown that infrastructure on topographically high locations along Kilauea's East Rift Zone can survive eruptions along the rift, and [that] the mitigation measures initiated by PGV/Ormat worked. More broadly, the eruption demonstrates that there will be value in finding geothermal across the state, including in locations less prone to natural hazards."

Geothermal Power Plants and Other Natural Disasters

The future of PGV is difficult to assess as the eruption continues. Although most commercially producing geothermal power plants are built near or around volcanic centers, this is the first time geothermal operations have been interrupted by volcanic activity, so there are no case histories from which to draw comparisons or adopt compatible countermeasures. However, this is not the first instance when a geothermal power plant has had to endure threat from and damage by natural disasters: nearby geothermal plants survived

the disastrous earthquake and tsunami during the 2011 Fukushima Daiichi nuclear disaster; Typhoon Haiyan led to the decommissioning of three geothermal power plants in Tacloban City, Philippines in 2013; cooling towers at a geothermal power plant in The Geysers in Northern California were damaged by wildfires in 2015 [14].

Hawaii's Energy Future

The State of Hawai'i has recently vowed full reliance on low-carbon power in the near future, after Governor David Ige signed and passed a bill (H.B. No. 623) in 2015 to set a 100% renewable portfolio standard by 31 December 2045 [15, 16]. Hawai'i is the most fossil-fuel-dependent state in the United States of America largely due to geographic isolation, but it is also one of seven states with utility-scale geothermal production[15]. The PGV plant, the lone geothermal energy source of the state, has been a steady contributor of renewable energy since the early-to-mid '90s. As mentioned previously, geothermal energy has most recently accounted for about a quarter of total electricity supply for Big Island. Coincident with improvement of solar and wind energy implementations, dependence on petroleum has decreased by ~12% from 2005 through 2016 [15]. In order to meet the renewable standard by the 2045 deadline, Dr. Lautze believes that more test wells are needed on other Hawaiian islands to determine viable locations for development: "Geothermal is the only viable baseload renewable energy source. There is a lot of talk about solar and storage here, but the fact is that issues with long-term storage remain. To me, geothermal is key."

Conclusion

Despite general uncertainty and upcoming challenges involving PGV, there is optimism amidst the concern: the wells could be re-opened and operations begun again within two to three years. This phenomenon is a 'first' for the geothermal industry. Mass communication of ensuing events and underlying science have signified the integral role of geothermal energy to local parties and have alerted geothermalists worldwide to adapt from such a situation, should this ever happen again. Although this eruption has caused a hiatus in energy production at PGV, the media coverage it received has revealed the need for careful and elaborate emergency response for geothermal plants in active volcano zones. The minimal damage to the facility proves that with clever design (built on high ground) and quick action to threats, geothermal energy may and will continue to be a stable source of baseload energy. Increasing geothermal baseload capacity throughout the Hawaiian Islands will reduce the negative effects of temporary shutdowns, which must be expected when facilities are built next to and depend on such powerful natural systems like Hawaii's Kilauea volcano.

[1] *https://volcanoes.usgs.gov/volcanoes/kilauea/*
[2] *https://pubs.usgs.gov/of/2007/1089/HawIsland_zone5_2007.pdf*
[3] *https://pubs.geoscienceworld.org/gsa/geology/article-abstract/42/3/187/131485*
[4] *http://adsabs.harvard.edu/abs/2016AGUFM.V53A3078P*
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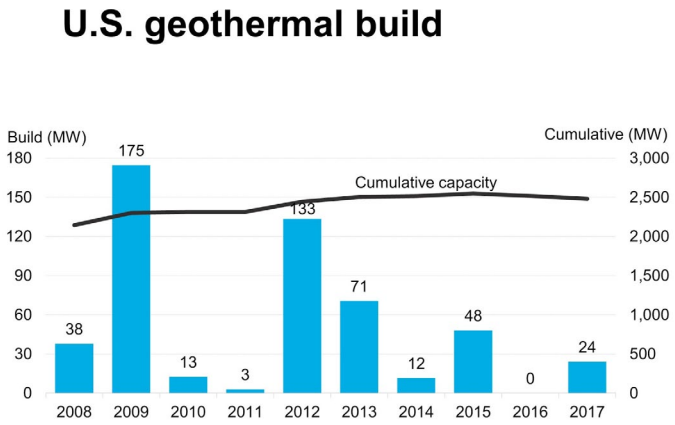
[12] *http://investor.ormat.com/file/Index?KeyFile=393508375*
[13] *http://investor.ormat.com/file/Index?KeyFile=393711325*
[14] *Garthwaite, J. "Geothermal at the foot of Kilauea". Stanford Earth: School of Earth, Energy, & Environmental Sciences, 5/25/2018. Accessed 6/30/2018 https://earth.stanford.edu/news/geothermal-foot-kilauea*
[15] *https://www.eia.gov/state/?sid-HI* ■

Publications, Websites, Videos & Maps

by Ian Crawford

The Growth of Hybridization in US Geothermal

The 2018 edition of the *Sustainable Energy in America Factbook* – produced for the **Business Council for Sustainable Energy (BCSE) by Bloomberg New Energy Finance** has some promising news about geothermal energy in the USA.

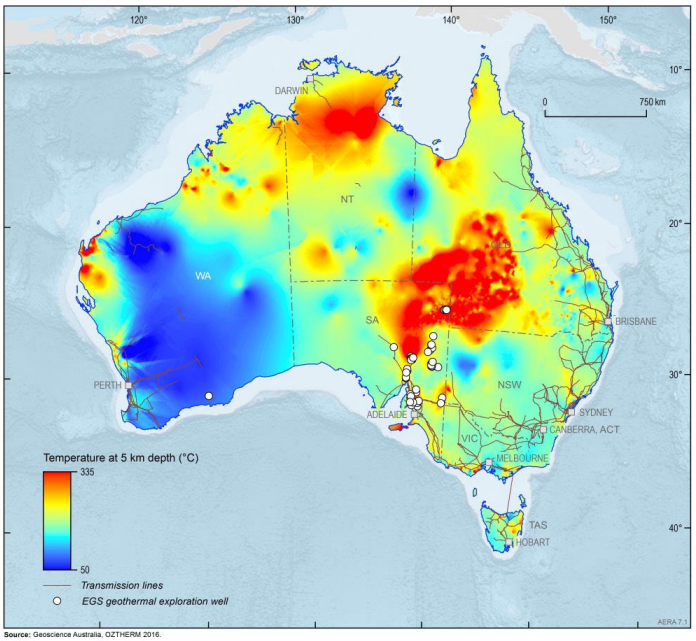


The report measures meager growth in the US geothermal energy industry over the last decade.

After building **no new geothermal plants in 2016**, the U.S. **added the 24 MW Tungsten Mountain plant in 2017**. Unlike many other renewable resources, geothermal projects have long project completion periods of 4-7 years. In addition, the technology lacks strong policy support and face high development costs. These factors contribute to the **low build volumes**.

Another key area of activity within U.S. geothermal is **hybridization** – the combination of geothermal with another technology to enhance output. Two such facilities by **Enel Green Power** began operation in 2016. The first was at its **Stillwater plant** in Nevada, where photovoltaic and solar thermal have been integrated into the geothermal plant. The second project added a hydroelectric generator to an injection well at Enel's existing **Cove Fort geothermal power plant** in Utah. *Download the Report.....*

Report Includes Snapshot of Geothermal Energy in Australia



Map of Australia showing the temperature at 5 km depth and the location of EGS exploration wells (Courtesy Geoscience Australia)

The 2018 edition of the *Australian Energy Resources Assessment (AERA)* has been developed by **Geoscience Australia** in collaboration with the **Department of the Environment and Energy** and support of the **Australian Renewable Energy Agency**, and provides a snapshot of Australia's energy resources and the demand for them in both domestic and international energy markets.

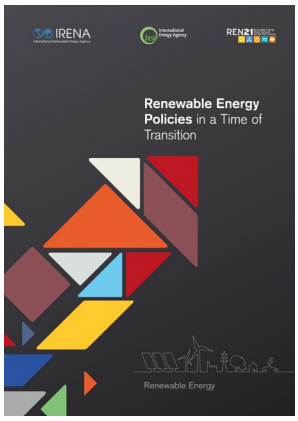
Australia has significant hot rock geothermal resources that could be used to produce super-heated water or steam suitable for base load electricity generation. There are also lower temperature geothermal resources in a number of sedimentary basins that are potentially suitable for electricity generation or direct-use applications.

Approximately 440,570 PJ of potentially viable deep geothermal resources were identified in the decade to 2013, but due to technical challenges, lack of capital investment and reduced electricity demand, these estimates are no longer considered current.

While **Birdsville is currently the only geothermal plant generating electricity**, new low-temperature geothermal power plants are being built to supply small towns in outback Queensland, including **Quilpie, Thargomindah, Normanton**

and **Longreach. The Winton geothermal power plant was due to be operational in June 2018.** *More Information.....*

Report Identifies Key Barriers and Highlights Policy Options to Boost Geothermal Energy Deployment



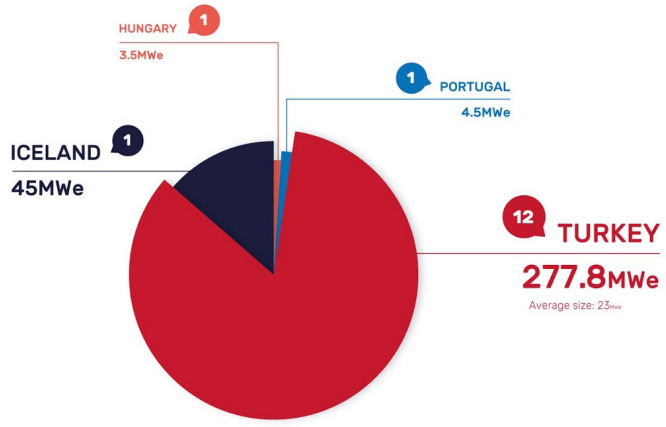
This report *Renewable Energy Policies in a Time of Transition*, prepared jointly by the **International Renewable Energy Agency (IRENA),** the **International Energy Agency (IEA)** and the **Renewable Energy Policy Network for the 21st Century (REN21),** identifies key barriers and highlights policy options to boost renewable energy deployment including for geothermal energy.

The report concludes that supporting geothermal power by reducing risk is the best medicine for the industry.

Global potential for geothermal energy is estimated at 70 to 80 GW. However, because of several barriers, **only 15% of the potential capacity is being harnessed** globally. One key challenge relates to the **high risks and upfront costs** associated with exploration, as well as **overall project development costs,** which occur over a relatively longer period of time. *Download the Report.....*

EGEC Geothermal Market Report 2017

The **European Geothermal Energy Council (EGEC)** *Geothermal Market Report* confirms the trend towards the steady growth observed in recent years, but also notes the need for greater recognition in order to enable the full deployment of geothermal energy in Europe.



The new additions in 2017 are quite significant, with 330 MWe of new geothermal electricity capacity coming online, mainly in Turkey. (Courtesy EGEC)

Installed geothermal electricity capacity in Europe amounts to **2.8 GWe**, producing **over 15 TWh per year.** In Europe **there are 117 plants,** 16 of which were inaugurated in 2017. The new additions are quite significant, with **330 MWe of new geothermal electricity capacity** coming online, **mainly in Turkey.**

The use of geothermal for heating is also increasing, supported by the construction of **new district heating networks** and the retrofitting of old ones, thanks to local and national planning identifying geothermal heat as a cost-efficient solution to meet heating needs. In 2017, **9 new plants were inaugurated, adding over 75 MWth** across France, the Netherlands and Italy. The number of new plants coming online each year is on an upward trend, with an average **annual growth rate of 10%** in recent years. *More Information.....*

Report of the relevant needs of Stakeholders in the field of Near-surface Geothermal Resources (GRETA)

12 partners from 6 different countries formed the **GRETA project** with the aim of demonstrating the potential of **Near-Surface Geothermal Resources (NSGE)** in the **Alpine Space** and to share their knowledge to foster the integration of this technology into future energy plans in the region.

Focus Groups in the pilot areas of **Germany, Italy and Slovenia** were asked about the differences and similarities of barriers and needs regarding the expansion of the geothermal system. **The report identifies the initial installation cost of the geothermal energy project as a common barrier.** *Download the Report.....*

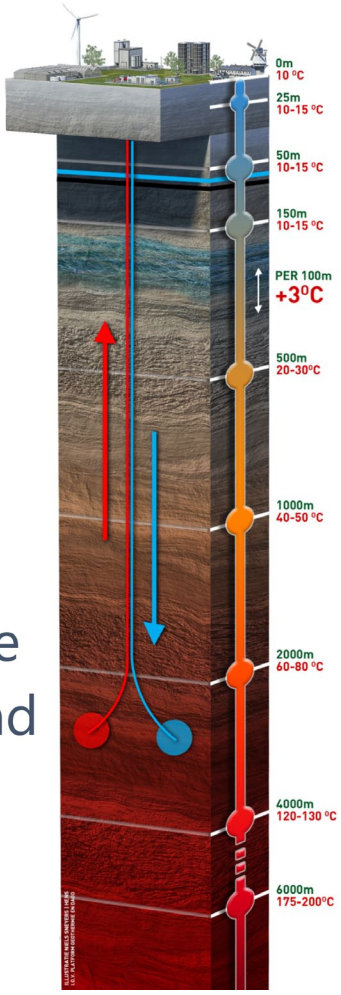
Geothermal Energy for EU Islands (EGEC)

A new factsheet from the **European Geothermal Energy Council (EGEC)** looks at how European islands often face significant challenges when it comes to energy supply and energy costs. Due to geographic location, small economies of scale, and limited or absent interconnection to the mainland or to other islands, **many islands are still heavily dependent upon costly imported fossil fuels** to generate electricity or to meet their heating and cooling needs.

Unlike other intermittent energy sources, **geothermal energy could provide a stable, sustainable, and affordable energy supply** for a wide variety of potential uses that are not restricted to electricity generation, but encompass many types of direct uses. *More Information.....*

A Masterplan for Dutch Geothermal Heating

The *Geothermal Energy Master Plan* (with the subtitle 'a broad basis for a sustainable heat supply') has been prepared by the **Dutch Association of Geothermal Operators (DAGO), Stichting Platform Geothermie, Stichting Warmtenetwerk** and **EBN**, supported by the Ministries of Economic Affairs and Climate and Home Affairs and Kingdom Relations. *Download the Report.....*



Mexico's Renewable Energy Future (The Wilson Center)

Mexico's Renewable Energy Future

A Working Paper

Geothermal energy, which currently accounts for about 1 percent of installed capacity in Mexico, has significant growth potential. Mexico already has the fifth-largest installed geothermal power capacity after the United States, the Philippines, Indonesia, and New Zealand, and **another 13.4 GW of potential.**

The government has put significant funding into developing new technologies through its **Geothermal Innovation Center.** As a volcanic region, Mexico has significant potential for geothermal, with the resource potential spread throughout the country, but concentrated in the volcanic central, eastern, and southern regions. *Download the Report.....*

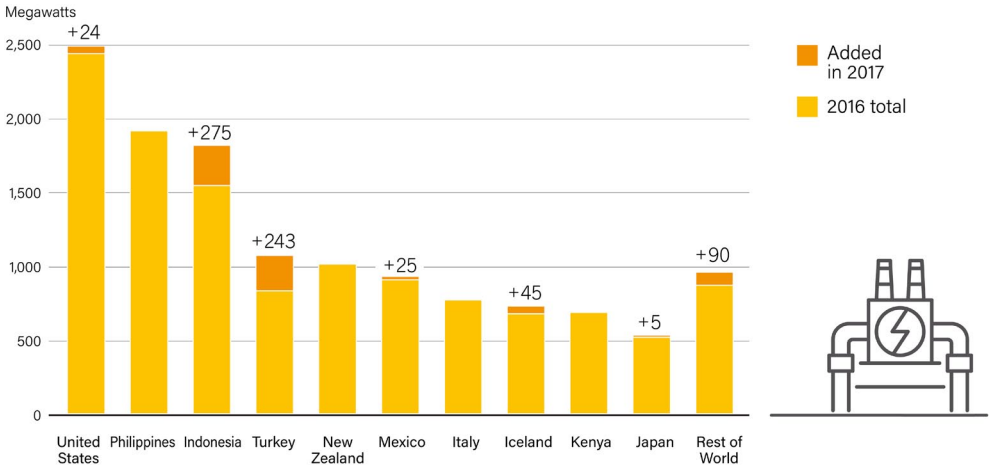
REN21's Renewables 2018 Global Status Report

Renewable power accounted for 70% of net additions to global power generating capacity in 2017, the largest increase in renewable power capacity in modern history, according to **REN21**'s *Renewables 2018 Global Status Report (GSR).* But the heating, cooling and transport sectors – which together account for about four-fifths of global final energy demand – continue to lag far behind the power sector.

The geothermal industry in 2017 remained constrained by various sector-specific challenges, such as long project lead-times and high resource risk, **but technology innovation continued** and prompted optimism about future prospects. The industry focused on advancing technologies to **reduce development risk** and to cost-effectively tap geothermal resources for heat and power in more locations, as well as to reduce the potential environmental consequences of geothermal energy production.

Among the various renewable energy technologies, geothermal energy is not unique in having to contend with **high upfront project costs.** However, the inherent high risk of geothermal exploration and project development, and the **lack of adequate risk mitigation**, continues to be a focus of attention for the industry. The uncertainty about the geothermal resource in any given location often stands in the way of mobilizing enough capital, especially private capital, to fund the expensive exploratory drilling that must occur at the outset to establish the size, temperature and other parameters that define the viability of a resource. *Download the Report.....* ■

Geothermal Power Capacity and Additions, Top 10 Countries and Rest of World, 2017



REN21 RENEWABLES 2018 GLOBAL STATUS REPORT

GEOTHERMAL LIBRARY

The GRC Library can be accessed at:
www.geothermal-library.org

In Memoriam

Ruggero Bertani
Died 21, June 2018

The international geothermal community mourns the loss of Ruggero Bertani, who recently lost his life after a battle with cancer.

Mr. Ruggero Bertani held a Degree in Physics from Pisa University. From 1979 to 1982 he worked for different Nuclear Physics Laboratories in Italy (INFN, Roma and Pisa) and abroad (CERN, Geneva and Fermilab, Chicago). In 1982 Mr Ruggero Bertani started working for ENEL and was Project Director in the Innovation Department at Enel Green Power and Manager of Geothermal Business Development at Enel's International division in Italy since 1982.

At ENEL Ruggero was responsible for development projects in Berlin and Ahuachapán (El Salvador) and for reservoir assessment in Italy and geothermal field acquisitions in USA.

During his career Ruggero actively participated in a range of different international activities. For example, as member of the Consulting Panel of Experts for Geothermal Energy in the 6th Framework Programme, Executive Director and Board member of the International Geothermal Association (IGA), President and Board member of the European Geothermal Energy Council (EGEC), Coordinator for the DESCRAMBLE H2020 project, and Chairman of the European Technological and Innovation Platform (ETIP) on Deep Geothermal.

He was the main author of the geothermal chapter of the Intergovernmental Panel on Climate Change (IPPC) report 2009 and leading author of the geothermal chapter in the Special Report on the Renewable Energy Sources (SRREN) of the IPCC working group, and published an important book in 2017 on "Perspectives for Geothermal Energy in Europe". He also was the author of the Global Updates for the Geothermal Power Sector for the World Geothermal Congress of the International Geothermal Association (IGA) since 1995.

Ruggero participated in the International Panel of the International Energy Agency (IEA) for the elaboration of the geothermal roadmap. Furthermore he was author or co-author of more than 60 papers, published in International Journals as well as in official publications of International Bodies (including the Transactions of the Geothermal Resources Council).

"With Ruggero Bertani, the international geothermal energy community has lost one of its most influential individuals. His dedication to geothermal energy and its promotion through his work at IGA, first as Executive Director, then Board Member and Vice President, and as of late as President of EGEC, has been remarkable and incredibly important for us as an industry. We are eternally grateful for his contribution and extend our condolences to his family and colleagues at Enel in Italy," said Alexander Richter, President of the International Geothermal Association.

In the words of Miklos Antics, EGEC vice-President: "He was a unique asset to the geothermal community and we will cherish his memory forever." And from Javier Urchueguia, EGEC vice-president: "He always was a warm and excellent person." **Thanks to Gregor Rumberg, IGA.**

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Ruggero's long and impressive career in geothermal energy and his contribution to the community have been covered by other colleagues. Ruggero was in the geothermal business for nearly 40 years, and had the medals to prove it. My perspective is more of a personal one.

Ruggero, Iris (Perticone) and I, for a long period, formed a small team involved in IGA activities in the run-up to the World Geothermal Congresses held in Italy (1995), Japan (2000) and Turkey (2005). Ruggero and Iris were with ENEL and I was with CNR (the Italian National Research Council). These years also coincided with the IGA Secretariat at ENEL (1998-2004) and my term as Chairman of the Information Committee (1998-2001).

From the start Ruggero was a joy to work with: nothing could faze him, no problem was unsurmountable, and no effort was spared. He was always calm, cheery, optimistic and thoroughly reliable. You could trust Ruggero to come through, to pull his weight (he rarely delegated work, just got on with it himself) and to crack a joke or give you a word of encouragement when things got really hectic. I can't remember him ever being in a bad mood. It is very sad to know he is no longer with us. The loss must be immense indeed for his wife and two sons. **Thanks to Mary Helen (Marnell) Dickson.** ■
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Calendar of Events

GEOHEAT International Geothermal Conference
4-7 September, Petropavlovsk-Kamchatsky, Russian Federation
https://pbs.twimg.com/media/DLsAdQDW0AAxWj9.jpg

6th Indonesia International Geothermal Convention and Exhibition (IIGCE)
5-8 September, Jakarta Convention Center, Indonesia
http://www.iigce.com/

2018 Energy Policy Research Conference (Energy Policy Institute)
6-7 September, Boise State University, Boise, Idaho, USA
http://epi.boisestate.edu/eprc/

GRC Annual Meeting & Expo
14-17 October, Reno, Nevada, USA
www.geothermal.org/meet-new.html

6th National Geothermal Congress - Polish Geothermal Association
23-25 October, Zakopane, Poland
www.energia-geotermalna.org.pl/vi-ogolnopolski-kongres-geotermalny/

7th African Rift Geothermal Conference (ARGeo-C7)
29 October–4 November, Kigali, Rwanda
www.theargeo.org

U.S. Hot Springs Conference
7–9 November, Glenwood Springs, Colorado, USA
https://www.hotspringsconnection.com/

The 12th Asian Geothermal Symposium (AGS12)
9-12 November, Daejeon, Republic of Korea
https://www.aist.go.jp/fukushima/en/AGS12/index.html

GEORG Geothermal Workshop
14-15 November, Reykjavík, Iceland
https://geothermalworkshop.com/

NZ Geothermal Workshop
14-16 November, Taupo, New Zealand
www.geothermalworkshop.co.nz/

German Geothermal Congress- Der Geothermiekongress (DGK) 2018
27-29 November, Essen, Germany
www.geothermie.de/aktuelles/der-geothermiekongress-2018.html

3rd Colombian National Geothermal Meeting - Reunión Nacional de Geotermia (RENAG 18)
13-15 December, Bogotá, Colombia
https://www.ageocol.org/

GeoTHERM - Expo & Congress
14-15 February 2019, Offenburg, Germany
www.geotherm-germany.com/

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

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