# GEOTHERMAL RESOURCES COUNCIL BUILDER

Vol. 48, No. 4 July/August 2019

> GRC Annual Meeting & Expo Palm Springs, California September 15-18

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# Bulletin

Vol. 48, No.4 July/August 2019



#### **Geothermal Resources Council**

P.O. Box 1350 Davis, CA 95617-1350 Phone: 530-758-2360 Fax: 530-758-2839

www.geothermal.org

Executive Director Will Pettitt, PhD, FGS wpettitt@geothermal.org

Office & Events Manager Estela Smith grc@geothermal.org

Communications Director/Editor Ian Crawford icrawford@geothermal.org

> Membership/Expo Anh Lay alay@geothermal.org

Librarian Brian Schmidt bschmidt@geothermal.org

Graphic Designer/Advertising Chi-Meng Moua cmoua@geothermal.org

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

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COVER: "Cathedral" by Fabio Sartori, of Massa Marittima (Grosseto), Italy. Inside the cooling tower of the Sasso 2 geothermal power plant in the Larderello Geothermal Area of Tuscany, Italy, during an inspection with the plant out of service. September 2016. GRC Photo Contest 2019.



### **Executive Director's Message**

by Will Pettitt, PhD

### Welcome to the Geothermal Celebration of the Year

Welcome to the GRC Annual Meeting & Expo this year in Palm Springs, California. We are having a big celebration and are lining up a fabulous schedule of events for all our attendees, members and visitors. More on our celebrations in a moment. First, an update on some of the amazing things we've got going on.

- Two high-profile workshops gathering worldwide experts;
- > Four field trips (two local and two distant);
- Golf tournament in aid of our annual student scholarships;
- Three-day industry Expo starting with our opening reception;
- An outside Expo showcasing heavy equipment;
- Two evening parties one by the pool and one in the aircraft museum;
- Opening Plenary Session with high-profile and expert speakers;
- Two panel discussions in the Plenary Session will delve into the issues;
- Four tracks of technical sessions full of highquality papers and posters;
- Two international sessions with world-wide invited guests;
- A further two panel discussions in the technical tracks;
- Open meeting of our Policy Committee discussing legislation and regulation;
- Two special back-to-back sessions on DOE's GeoVision study;
- A student trivia contest to help support our next generation;
- Women in Geothermal (WING) events and workshop;

- A meet and greet of Board candidates in this year's election;
- Geothermal 101 presentation and Expo event open to the public;
- Membership Annual General Meeting and awards presentations.

Download the latest program<sup>1</sup> or install the conference app for a full schedule of events and participation. The agenda has been a huge undertaking by our volunteers, Organizing Committee, Board and Staff. A sincere thank you to everybody who's contributed to the agenda and to all our sponsors, exhibitors and attendees who make it all happen.

As well as our formal program there are plenty of opportunities for side meetings and corporate events that have become a hallmark of the show. Great care is taken during the management of the schedule and facilities to accommodate the needs of our individual members and corporations in the event planning: get in touch if there's anything you need. This year, I'll be having open meetings throughout the conference where any attendees can visit to discuss our community and technologies, and how we are moving the GRC forward to help build the industry and support our members.

The Annual Meeting and Expo is a celebration of many things and here's a few to be thinking about.

For a start, the Policy Committee (PC) has just had its first birthday. It was born out of the consolidation of the GRC and the Geothermal Energy Association (GEA), voted by members in 2017, with the GRC taking on the previous

<sup>&</sup>lt;sup>1</sup> http://www.geothermal.org/Annual\_Meeting/PDFs/ FINAL\_Program.pdf



Look out for our banner in downtown Palm Springs, promoting the meeting and our open doors to the public on Wednesday, September 18.

functions of the GEA. The PC is a separate entity within the GRC, independently funded by interested organizations, to advocate on behalf of the geothermal community. The PC is making a real difference in legislation and regulation. You can find out more at our open meeting of the PC on Monday September 16.

The GRC is going places. We have a vision to raise the recognition and acceptance of geothermal energy across society and around the world. We have focused that vision on our strategy to connect with local people and companies on the ground in our industry, to bring people together in research, industry and government, and to collaborate with partner organizations, thought leaders, and decision makers around the globe. You can talk with me, our staff or any of the Board members at the conference about our vision and how you can help translate that into action.

The geothermal power industry in California is going places. State agencies have decided that California needs nearly 3 GW of net geothermal power generation on the grid by 2030. This comes from the need for renewable 24/7 baseload that going places, in the U.S.A. and internationally. The Department of Energy (DOE) recently released their GeoVision report that highlights the importance of geothermal in the energy mix, not just in electricity generation but also in direct use of heat for domestic and commercial applications and ground-source (geothermal) heat pumps in buildings. For geothermal power alone, the report forecasts a near 26-fold increase from today's U.S.A. capacity to 60 GW by 2050 given improvement in technologies and methods reducing project costs and risks. Development of new geothermal power projects is substantial on the international scene with countries like Indonesia, Turkey and Kenya, amongst others, bringing new plants online at an impressive rate.

And finally, we celebrate that our conference is a gathering of our geothermal community, building relationships, reaching out to people outside our community, discussing our challenges and opportunities, and educating ourselves on the latest technologies and innovations. Now there's a celebration. Hope you enjoy the show and excited to see you there!

ensures grid reliability and resilience as the state transitions to renewable and clean energy over the next 25 years. That decision means an effective doubling of the installed geothermal capacity, using some of the state's well-known and under-developed resources. Policies for fighting climate change and lowering greenhouse-gas emissions will yield procurement of new geothermal power on an unprecedented scale.

Geothermal energy is



Join us for the greatest gathering of the geothermal industry this year. We're at the Palm Springs Convention Center adjoining the Renaissance Hotel, Palm Springs, California. Photo courtesy of Marriot Hotels.

### Communication from the GRC

by Ian Crawford **Director of Communications** 

### **Geothermal Energy Awards Announced**



The GRC has announced awards honoring the best and brightest of the global geothermal energy community. These prestigious awards have been a highlight of the geothermal calendar since the late 1970's.

Maria Richards

The GRC will present the prestigious Aidlin, Pioneer, Henry J Ramey Jr., Ben Holt and Geothermal Special Achievement awards at the GRC Annual Meeting & Expo in Palm Springs, California, September 15-18.

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



- Joseph W. Aidlin Award Maria C. Richards - For transcendent service as Board President in supporting Geothermal Resources Council staff and guiding the Board during a time of expansion.
- Geothermal Pioneer Award Leland "Roy" Mink
  - For 40 years of outstanding leadership, creative vision, and strategic planning for the advancement of geothermal resources and for being a mentor to the next generation.

- Henry J. Ramey Jr. Award Dennis Kaspereit - For unstinting devotion to innovative reservoir engineering and detailed modeling; leading to near-term reservoir management improvements, lowered field development and maintenance costs, and accurate predictions of long-term reservoir performance.
- Ben Holt Award Dr. William Harvey
  - For his significant contribution to geothermal engineering and more importantly, sharing this knowledge and passion with his many students and fellow engineers.
- Geothermal Special Achievement Awards Recognizes special or outstanding achievements in any aspect of geothermal energy development and related areas:
  - o Vincent J. Signorotti For 39 years of gracious dedication to the growth and development of geothermal projects through the acquisition, packaging, leasing and financing of real property and mineral rights.
  - o Bruce Levy For his lifelong passion for power generation, the development of new power plants, and his love of all the wonderful, diverse personalities in the geothermal industry.

### 2019 Geothermal Scholarships



John Grill, Estefanía Ramírez Restrepo and Yuran Zhang received their awards at last year's GRC Annual Meeting & Expo.

The GRC is pleased to announce the recipients of eight GRC Scholarship Awards.

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

The Undergraduate Award winners are:

• **Sharon Best** (University of California, Riverside, USA) and

• Maria Alejandra Taborda (University of Medellín, Colombia).

The winners of the *Marcelo Lippmann* Graduate Scholarship Awards are:

• José Eduardo Granados Pastrana (National Autonomous University of Mexico);

- Kurt Kraal (University of Nevada, Reno, USA);
- Catherine Lambert (Cornell University, USA);
- Kevin Mendoza (University of Utah, USA) &
- Omar Rodríguez Villarreal (Universidad Autónoma de Nuevo Leon, Mexico & Université de Pau et des Pays de l'Adour, France).

The scholarship winners will be acknowledged at the GRC Annual Meeting & Expo, to be held in Palm Springs, California, USA, from September 15-18. **The non-member registration includes GRC membership through 2020.** 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 \$175** for a three-day registration which also includes GRC membership through 2020.

Registering at the event onsite in Palm Springs incurs an additional USD 50 fee.

### **5 Easy Ways To Register:**

- 1. my.geothermal.org
- 2. Fax: 530.758.2839
- 3. Phone: 530.758.2360 ext. 100
- 4. Email: alay@geothermal.org
- 5. Mail: GRC, PO Box 1350, Davis, CA 95817



**Register Online and Save \$50** 

# The biggest geothermal energy event of the year is almost upon us! It's not too late to make last minute arrangements!

The latest information is available on the GRC website at: geothermal.org/meet-new.html, a *Program* is available to view, download and printout if you wish. Though we strongly urge you to save paper by viewing all the information on your computer or mobile device.

However, the best way to experience the GRC Annual meeting & Expo is through the Event App. See the instructions below.

**GRC members** pay **\$1,130** for a three-day registration and **non-members** pay **\$1,330**.

## Reserve your Room for the Geothermal Event of the Year

The GRC Annual Meeting & Expo will be held in the Palm Springs Convention Center. The GRC has contracted for a discounted block of rooms at two host hotels. The **Renaissance Palm Springs Hotel** is attached to the convention center and the **Hilton Palm Springs Hotel** is just one block away.

Attendees can make their reservations on secure websites prepared specially for the GRC available on the GRC Website at https://geothermal.org/ Annual\_Meeting/hotel.html.

### Communication from the GRC

### Flying to Palm Springs

The airport is a short 4 minute (1.8 mile) drive (or walk for about 40 minutes!) from the Palm **Springs Convention Center.** 

NOTE: Palm Springs is a 2.5 hour drive from Los Angeles International Airport, 2.5 hours from San Diego International Airport and 1.25 hours from Ontario International Airport. Las Vegas is a 4 hour drive.

**Eleven airlines** serve the Palm Springs International Airport with **non-stop flights** to the following twenty-one destinations which include major hubs offering travel possibilities to over five hundred cities worldwide.

- Atlanta
- New York Newark
- Bellingham Boston
- Calgary
- Chicago
- Dallas
- Denver
- Edmonton
- Houston
- Los Angeles
- Minneapolis
- New York JFK

- Phoenix
- Portland
- Sacramento
- (only from September 16!)
- Salt Lake City
- San Francisco
- Seattle
- Toronto
- Vancouver
- Winnipeg



(Courtesy Visit Palm Springs)

### 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 Palm Springs to network? The app will help you find old friends and connect with new ones.

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The app can be downloaded from a dedicated website at https://attendify.com/app/61105d/ - first you have to first download a "container app".

- 1. Download the "Attendify Network at Events" app from the App Store or the Google Play Market.
- 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 & Expo".

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.

Or scan the QR code with your Smartphone:



### Ensure You Receive Geothermal Resources Council (GRC) Emails

To ensure uninterrupted delivery of our newsletters and other email communications, please follow these steps:

• Add us to your Contacts list

Use your email client's Sender, Contacts or Address Book menu options to add us to your contact list.

In Microsoft Outlook, this option can be found under the Message menu at: **Message >> Sender >> Add to Contacts.** This may be titled differently dependent on your version of Microsoft Outlook. The option may be found elsewhere in other email clients.

• Add us to your Safe Senders list

Use your email client's Junk Email options to ensure our emails are never marked as spam. In Microsoft Outlook, do this by right-clicking one of our emails in your message list, then visiting the Junk menu and choosing the **Junk >> Never Block Sender** option. This may be titled differently dependent on your version of Microsoft Outlook. The option may be found elsewhere in other email clients.

• 'Whitelist' our IP Address

Whitelisting our IP address will ensure you get our newsletters by telling your systems that it is safe to accept email from our servers.

The dedicated IP address for all GRC electronic mail is 74.208.69.127

Contact your IT Team to perform the IP address whitelisting.

### • 'Whitelist' our Sending Domain

If your spam solution is unable to whitelist mail servers by IP address, then the next best solution is to whitelist our sending domains. We recommend that you whitelist the following domain in conjunction with the IP address: geothermal.org

Contact your IT Team to perform the IP address whitelisting.

### • Further Assistance

If you have any further questions, please call us on 530.758.2360, or email icrawford@geothermal. org

### Have Your Say!

If you would like to comment on any column

or article in the *GRC Bulletin* or have an opinion on a topical subject that will interest our readers, please email the editor, **Ian Crawford** at icrawford@ geothermal.org or mail to Geothermal Resources Council



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

# **REGISTER NOW!**



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### Inside inside Geothermal

### International Renewable Energy Agency Records Over 13 GW Geothermal Energy Capacity in 2018

IRENA records 13,277 MW of global geothermal energy capacity in 2018

The International Renewable Energy Agency (IRENA) publication Renewable Energy Statistics 2019 provides data sets on power-generation capacity for 2009-2018, actual power generation for 2009-2017 and renewable energy balances for over 130 countries and areas for 2016-2017.

The capacity figures for the **top ten geothermal** energy countries in 2018 are as follows:

- 1. USA 2,541 MW
- 2. Indonesia 1,946 MW
- 3. Philippines 1,944 MW
- 4. Turkey 1,283 MW
- 5. New Zealand 966 MW
- 6. Mexico 951 MW
- 7. Italy 767 MW
- 8. Iceland 753 MW
- 9. Kenya 663 MW
- 10. Japan 486 MW

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

*The International Lunch and Session on September* 16 at the GRC Annual Meeting & Expo will feature country updates from Canada, New Zealand, China, Africa, Latin America, Indonesia, Europe, Japan, Turkey and Chile.

### **U.S. DOE to Fund International Geothermal Research and Development Consortium**

# **GEOTHERMICA** \* announced it will

The U.S. Department \* of Energy (DOE) has

contribute up to USD 2

**million** in available funding through a joint Call for Proposals to advance geothermal research and development through a new partnership with more than a dozen European countries.

As part of its membership with Geothermica – a transnational consortium that combines financial resources and research expertise to demonstrate

and validate novel concepts in geothermal energy use - the U.S. geothermal community will be able to collaborate directly with European partners on shared research projects that leverage valuable data, field site access, and extensive expertise in geothermal research and development. European researchers will likewise benefit from shared learning with American counterparts. Global Geothermal News.....

For more information on funding opportunities see article Geothermica Second Call Announcement on page 25

### **Election for International Geothermal Association Board of Directors**



The election for the **International Geothermal** Association (IGA) Board of Directors will run until 30 September.

The IGA has announced that following the Board's decision on ensuring gender balance and equality almost 40% of current candidates are female. You can vote for up to 25 of 50 candidates from 23 countries:

- Abraham, Sam
- Aguilera, Pablo
- Ayling, Bridget
- Bignall, Greg
- Bjarnason, Bjarni
- Blair, Andy
- Brogle, Sylvain
- Brotheridge, Jane
- Capuano, Louis
- Caranto, Joeffrey A.
- Casimiro Espinoza, Emigdio
- Chandrasekhar, Varun
- Darma, Surva
- Falcone, Gioia
- Guglielmetti, Luca
- Hajto, Marek
- Harskamp, Bob
- Hillbrand, Gudrun
- Huenges, Ernst
- Izquierdo-Montalvo, Georgina
- Jahrfeld, Thomas
- Jalilinasrabady, Saeid
- Kaya, Eylem
- Kiryukhin, Alexey
- Letvin, Amelia Ida

- Li, Kewen
- Manzella, Adele
- Matsuda, Koji
- Matthiasdottir, Kristin Vala
- Meier, Peter
- Morata, Diego
- Olivar, Maria Victoria M.
- Omenda, Peter
- · Oyama, Hiroshi
- Prieto, Angela
- Rotich, Abel
- · Sabin, Andy
- Sangin, Sepehr
- Schmidlee, Virginie
- Siratovich, Paul
- Survantini, Ninik
- Svalova, Valentina
- Szita, Gabor
- Tingshan, Tian
- Utami, Pri
- Verdoya, Massimo
- Wielenga, Jelle
- · Wissing, Lothar
- Yasukawa, Kasumi
- Zemedkun, Meseret

If you are a member of an Affiliated Organization (like the Geothermal Resources Council), please contact your coordinator and get your IGA ID (log-in & password) to be able to access the IGA Voting Platform and cast your vote.

#### World Geothermal Congress 2020 -Registration Opens

27 April - 1 May, Reykjavík, Iceland

As an affiliate association of the International Geothermal Association (IGA), **GRC Members automatically get the IGA member rate.** 



More Information and Register.....

### Widespread Adoption of Renewable Energy Technologies Creates Employment Opportunities

Around 94,000 are employed in the global geothermal energy sector with about 35,000 employed in the USA and 23,000 in the European Union

FIGURE 5. RENEWABLE ENERGY EMPLOYMENT BY TECHNOLOGY



According to the *Renewable Energy and Jobs – Annual Review 2019* report by the **International Renewable Energy Agency (IRENA)**, the widespread adoption of renewable energy technologies creates employment opportunities up and down the supply chain. **Worldwide, the sector employed 11 million people at the end of**  **2018**, according to this sixth edition of the *Renewable Energy and Jobs* series.

Employment opportunities are a key consideration in planning for low-carbon economic growth. Many governments have prioritized renewable energy development, firstly to reduce emissions and meet international climate goals, but also in pursuit of broader socio-economic benefits. *Global Geothermal News*......

### Geothermal Can be a Very Economical Source of Round-the Clock Power - IRENA Report

*Renewable Power Generation Costs in 2018,* a comprehensive cost study from the **International Renewable Energy Agency (IRENA)** highlights the latest trends for each of the main renewable power technologies.

In 2018, just over 500 MW of new geothermal power generation capacity was added. Where good high-temperature resources exist, geothermal can be a very economical source of round-the clock power. In 2018, the global weighted-average Levelized Cost of Electricity (LCOE) of new geothermal plants commissioned was USD 0.072/kWh, 1% lower than in 2017.



According to the report **the market for geothermal remains modest**, with between a minimum of 90 MW (in 2011) and a maximum of 650 MW (in 2015) of annual new capacity commissioned between 2010 and 2018. Given the small number of projects commissioned each year, **the global weighted-average LCOE in any given year is heavily influenced by the site-specific characteristics of the project, as well as the country.** The global weighted average LCOE of newly commissioned geothermal plants was USD 0.05/ kWh in 2010, with this rising to USD 0.08/kWh in

### Inside Geothermal

2012, while between 2013 and 2018, the average was between **USD 0.06/kWh and USD 0.07/kWh** (See Figure above). *Global Geothermal News*......

Today, the cost of electricity from renewables is cheaper or within the range of fossil fuels



**NORTH AMERICA** 

### Biggest Ever BLM Geothermal Lease Sale in Silver State

In accordance with the Geothermal Steam Act, and the U.S. Bureau of Land Management (BLM) regulations at 43 CFR 3200, BLM is holding a competitive geothermal lease sale of 142 parcels for lease totaling 387,032.47 acres in Churchill, Eureka, Elko, Esmeralda, Humboldt, Lander, Mineral, Nye, Pershing, Washoe, and White Pine counties in Nevada. This will be the most acres offered in a geothermal lease sale by the BLM in Nevada to date. You can register to bid at energynet.com.

The sale date is **Tuesday, September 17, 2019**. The open bidding period will begin at **9:30 am Pacific Daylight Time (PDT)**. *Global Geothermal News*......

EnergyNet will have the sale running live at booth #403 in the GRC Annual Meeting & Expo.



### NREL Updates Baseline Cost and Performance Data for Geothermal Technologies

The U.S. **DOE**'s **National Renewable Energy Laboratory (NREL)** has released a 2019 update to the **Annual Technology Baseline (ATB)**, a key source of reliable electricity generation technology cost and performance data used to support and inform electric sector analysis in the United States. Now in its fifth year, the ATB documents technology-specific information on a broad spectrum of electricitygeneration technologies including geothermal.

Geothermal technology cost and performance projections have been updated with analysis and results from the *GeoVision: Harnessing the Heat Beneath our Feet* report including updates on resource potential estimates as well as current and projected capital and O&M costs based on rigorous, bottom-up modeling. *Global Geothermal News*......



### Support Team Announced for Frontier Observatory for Research in Geothermal Energy

As part of the U.S. DOE Frontier Observatory for Research in Geothermal Energy (FORGE) initiative, a diverse group of experts has been formed to support the **Utah FORGE team**. The Science and Technology Analysis Team (STAT) convened for the first time in April in Salt Lake City and in addition to members of STAT, personnel from DOE and the Utah FORGE team were also in attendance. This meeting served as a powerful reminder of the potential of the FORGE initiative to advance enhanced geothermal systems (EGS) to a place of commercial readiness. Initial public outputs of the meeting will be the release of the first round of FORGE research and development (R&D) funding opportunity announcements, scheduled for later in calendar year 2019.

Since April, the STAT has been providing technical guidance to ensure that the **Geothermal Technologies Office (GTO)**'s objectives are considered and incorporated into the execution of FORGE and R&D. Specifically, the STAT is assessing R&D needs in accordance with GTO roadmaps and goals, working to establish technical baseline information and performance specifications, and reviewing ongoing site characterization and monitoring efforts. Additionally, the team is developing topics for recurring FORGE R&D solicitations, providing guidance for review and selection of R&D projects, and developing outyear R&D strategies. The STAT will also assess the progress and results of R&D technology and techniques implemented at FORGE and provide input to the Utah FORGE team for the development of annual reports.

The STAT is comprised of the following members:

- **Doug Blankenship** (Chair) Sandia National Laboratories
- Joseph Morris (Vice Chair) Lawrence Livermore National Laboratory
- Kate Baker Independent Consultant
- Stephen Hickman U.S. Geological Survey
- Mack Kennedy Lawrence Berkeley National Laboratory
- George King GEK Engineering PLLC
- Ernest Majer Lawrence Berkeley National Laboratory, Affiliate
- Jean-Claude Roegiers Independent Consultant
- Eric Sonnenthal Lawrence Berkeley National Laboratory
- Herbert Wang University of Wisconsin, Madison

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

### GRC Urges Extension of Expired Federal Tax Credits Benefiting Geothermal Energy

In mid-June the **GRC Policy Committee** submitted, on behalf of the Geothermal Resources Council (GRC), the following written comments to the U.S. **Senate Finance Committee**'s Energy Temporary Tax Policy Task Force:



#### June 12, 2019

The Honorable Chuck Grassley 135 Hart Senate Office Building Washington, DC 20510

The Honorable Ron Wyden 221 Dirksen Senate Office Building Washington, DC 20510 The Honorable Richard Neal 2309 Rayburn House Office Building Washington, DC 20515

The Honorable Kevin Brady 1011 Longworth House Office Building Washington, DC 20515

Dear Chairmen Grassley and Neal and Ranking Members Wyden and Brady.

The Geothermal Resources Council (GRC) kindly urges Congress to immediately pass legislation to extend the expired federal tax credits benefiting geothermal energy.

The tax credits have remained lapsed since the end of 2017, creating confusion for the numerous industry sectors that utilize these incentives to support deployment of clean energy solutions. The continued uncertainty also undermines the effectiveness of these incentives and stands as a needless barrier to additional job creation and economic growth.

As the professional association for the geothermal industry and community, the GRC can attest to the vital importance of the tax credits to the success of geothermal energy business. Our industry needs an extension of the expired tax credit — two years retroactive (2018-19) and ideally at least two years forward (2020-21). The tax credits provide a predictable market signal for project development, which in turn leverages private investment and promotes job creation and local economic benefits across the country.

We strongly support the Tax Extender and Disaster Relief Act of 2019 introduced on February 28 by Senate Finance Committee Chairman Chuck Grassley and Ranking Member Ron Wyden. We applaud them for including an extension within "Section 107. Credit For Electricity Produced From Certain Renewable Resources", specifically Section 107(a)(3), which benefits geothermal energy. We urge the Senate to take up this bill as soon as possible and for the House to follow suit expeditiously. Quick action on this issue is critical. Once the extenders package is passed, we look forward to a discussion on the long-term future of geothermal energy incentives.

Geothermal power is a critical source of renewable electricity for U.S. households and businesses as we transition to a clean energy future. It is affordable, reliable and plays a critical role in maintaining a functioning electric grid – due to its position as flexible, renewable, baseload resource that can complement other intermittent renewable resources. Extension of the expired tax credits will play an important role in continuing the development and support of our industry.

The GRC is a non-profit professional association for the geothermal industry and community in the USA and abroad. We were founded in 1972 and are headquartered in Davis, California. We have over 1,300 members from around the world and are working to advance our industry by supporting the development of geothermal energy resources through communication of robust research, knowledge and guidance.

We thank you for your consideration. We are available to answer questions and discuss further at your convenience.

Respectfully,

Paul Thomsen GRC Policy Committee Chair pthomsen@ormat.com

Global Geothermal News.....

Wstell

Will Pettitt, PhD GRC Executive Director wpettitt@mygeoenergy.org

### Inside Geothermal

### Renewable Energy In USA Continues to Increase at Coal's Expense

In April 2019, U.S. monthly electricity generation from renewable sources exceeded coal-fired generation for the first time based on data in **Energy Information Administration (EIA)**'s *Electric Power Monthly*. **Renewable sources provided 23% of total electricity generation to coal's 20%**. This outcome reflects both seasonal factors as well as long-term increases in renewable generation and decreases in coal generation. EIA includes utility-scale hydropower, wind, solar, **geothermal**, and biomass in its definition of renewable electricity generation.

U.S. coal generation has declined from its peak a decade ago. Since the beginning of 2015, about 47 GW of U.S. coal-fired capacity has retired, and virtually no new coal capacity has come online. Based on reported plans for retirements, **EIA expects another 4.1 GW of coal capacity will retire in 2019**, accounting for more than half of all anticipated power plant retirements for the year. *Global Geothermal News.......* 

### U.S. Government Agency Estimates Additional 860 MW Geothermal Energy Over the Next Three Years

According to a review by the **SUN DAY Campaign** of data released by the **Federal Energy Regulatory Commission (FERC)**, the agency has dramatically revised its three-year forecast for changes in the U.S. electrical generating capacity mix.

Sharp declines are foreseen for fossil fuels and nuclear power while accompanied by even stronger growth in renewable energy (i.e., wind, solar, hydropower, biomass, **geothermal**) than projected earlier.

FERC's latest monthly *Energy Infrastructure Update* report (with data through May 31, 2019) suggests that "high probability additions" and "retirements," combined could result in effectively **no growth in the generating capacity of fossil fuels** (i.e., coal, natural gas, oil) and a net decline of over 7 GW in nuclear capacity by June 2022. FERC suggests a high probability that geothermal energy will add another 280 MW by June 2022 and a lower possibility of a total of 860 MW added over the next three years. *Global Geothermal News*......

## GEO Act Would Promote the Growth of Geothermal Energy in USA

U.S. Senator Catherine Cortez Masto (D-Nevada) has introduced the Geothermal Energy Opportunities (GEO) Act with Senator Ron Wyden (D-Oregon).

- The GEO Act establishes public-private partnerships to improve the collection of geothermal data and reduce drilling risk.
- This legislation reduces barriers to obtaining leases for geothermal energy development by allowing oil and gas leaseholders to coproduce geothermal energy without going through an additional competitive lease process.
- The GEO Act promotes geothermal heat pumps and direct use of geothermal energy by establishing a pair of programs at the DOE to promote the development and deployment of this technology both at the Department of Energy and among local entities.
- This bill ensures the federal government prioritizes the development and use of public geothermal energy.

Global Geothermal News.....

## New Legislation Aims for 50% Renewable Energy in USA by 2050

U.S. Senator Tom Udall (D-New Mexico), along with U.S. Senators Martin Heinrich (D-New Mexico), Sheldon Whitehouse (D-Rhode Island), Tina Smith (D-Minnesota), and Angus King (I– Maine), introduced legislation to achieve at least 50 percent renewable electricity nationwide in just 15 years – putting the U.S. on a trajectory to decarbonize the power sector by 2050.

Starting in 2020, the *Renewable Electricity Standard* (*RES*) *Act of 2019* would require electricity providers across the country to **increase their supply of renewable energy each year**. The senators' RES meets the recommendations of the *United Nations Intergovernmental Panel on Climate Change (IPCC)* 1.5 C Special Report, which outlines the standards that must be met worldwide to respond to the existential threat of climate change. *Global Geothermal News.......* 

### More Small Business Innovation Research Grants for Geothermal Energy R&D

The U.S. **DOE** has announced the latest **Small Business Innovation Research (SBIR)** and **Small Business Technology Transfer (STTR)** program grants. Highlighted below are grants awarded through the DOE office of Energy Efficiency and Renewable Energy (EERE) for research and development programs in geothermal energy:

Phase 2 Grants Global Geothermal News......

• **TerraCOH Inc.** - Minnesota. SBIR grant USD 999,224. Engineering Analysis and Design of CO<sup>2</sup> Geothermal Power System to Provide Dispatchable Geothermal Electricity Generation and Grid-Scale Energy Storage

• **Tech4Imaging LLC** - Ohio. SBIR Grant USD 1,050,000. *Non-Invasive Operations Tool for Dispatchable Geothermal Wells* 

**Phase 1 Release II Grants** *Global Geothermal News*......

- E-Spectrum Technologies Inc.- San Antonio, Texas. USD 194,694 - A Machine Learning Based Geothermal Drilling Optimization System Using EM Short-Hop Telemetry of Bit Dynamics Measurements
- Ozark Integrated Circuits Inc.- Fayetteville, Arkansas. USD 204,902 - Ruggedized Communication Technology for Enabling High-Temperature Directional Drilling
- **GreenBlu Inc.** Hamilton, New Jersey. USD 200,000.00 Zero discharge desalination with mineral recovery using multiple-effect vapor adsorption
- Savengy Technologies LLC Orlando. Florida. USD 200,000.00 - Novel Treatment of Produced Waters from Shale Gas with Zero Liquid Discharge by Geothermal Heat
- **Stratofire LC** Tulsa, Oklahoma. USD 199,580.00 - Integrated Sorbent-based Lithium, Power, and Water Recovery from Geothermal Brines
- **Bettergy Corp** Peekskill, New York. USD 199,982 - Novel Membrane System for Lithium Recovery from Oilfield Brines
- Technology Holding LLC Salt Lake City, Utah. USD 200,000 - Nanoporous Atomically Thin Membranes for Desalination and Rare Earth Materials Recovery

## USD 450,000 Awarded to Three Geothermal Research Programs

The U.S. **DOE** has announced over USD 24 million in funding for 77 projects supported by the **Office of Technology Transitions (OTT) Technology Commercialization Fund (TCF).** 

With matching funds from the private sector, these projects will advance the commercialization of promising energy technologies and strengthen partnerships between DOE's National Laboratories and private sector companies to deploy these technologies to the marketplace.

The geothermal energy projects awarded are:

• Argonne National Laboratory: *Ultra-Fast* and - *Thick Boriding of Geothermal Casing to Enhance Reliability*, USD 150,000. Controlled Thermal Resources Inc., El Centro, California.

• Idaho National Laboratory: Computer Programs for Analysis of Thermally Reactive Tracer Tests in Geothermal Reservoirs, USD 150,000. Geothermal Scientific Inc., Tustin, California. National Renewable Energy Laboratory, Denver, Colorado. Ormat Inc., Reno, Nevada.

• Pacific Northwest National Laboratory: Extending Magnetic Core Shell Nanoparticle Extraction Technology to Cesium and Antimony Removal from Geothermal Brines in New Zealand, USD 150,000. GEO40 Limited, Taupo, New Zealand. Global Geothermal News......

## Funding for Projects to Develop Downhole Tools to Enable Enhanced Geothermal Systems

The **Advanced Research Projects Agency-Energy (ARPA-E)** at the U.S. **DOE** has announced funding for a range of the most innovative and unconventional ideas across the energy technology spectrum, exploring high-risk R&D that could lead to the development of disruptive technologies.

One topic is to **develop downhole tools to enable enhanced geothermal systems (EGS)**, seeking to better develop novel, low-cost sensor technologies that can help mitigate risks and lower costs for deep, extremely hot EGS by better characterizing rock formations and fluid enthalpy at depth.

ARPA-E is funding two projects to develop downhole tools to enable enhanced geothermal systems:

• Lawrence Livermore National Laboratory. Next Generation High-Temperature Optical Fibers – USD 800,000.

### In<mark>side</mark> Geothermal

• Fervo Energy Company. Solve EGS: Surface Orbital Vibrator For Evaluation Of Enhanced Geothermal Systems – USD 1,180,000. Global Geothermal News......

### DOE Announces Funding for Geothermal Exploration Machine Learning Projects

The U.S. DOE has announced up to **USD 5.5 million** for 10 new projects to **apply machine learning techniques** to geothermal exploration and production.

Machine learning – **the use of advanced algorithms to identify patterns in and make inferences from data** – could assist in finding and developing new geothermal resources. If applied successfully, machine learning could lead to higher success rates in exploratory drilling, greater efficiency in plant operations, and ultimately lower costs for geothermal energy.

The projects selected by the **Office of Energy Efficiency and Renewable Energy's Geothermal Technologies Office** focus on two areas: **machine learning for geothermal exploration** and advanced analytics for efficiency and automation in geothermal operations.

The selected projects are:

- Colorado School of Mines (Golden, CO)
- Lawrence Livermore National Laboratory (Livermore, CA)
- Los Alamos National Laboratory (Los Alamos, NM)
- National Renewable Energy Laboratory (Golden, CO)
- **Pennsylvania State University** (University Park, PA)
- University of Arizona (Tucson, AZ)
- University of Houston (Houston, TX)
- University of Nevada (Reno, NV)
- University of Southern California (Los Angeles, CA)

• Upflow Limited (Taupo, New Zealand) Global Geothermal News......

#### Ormat Announces 7 MW AC Solar Expansion of Tungsten Mountain Geothermal Project

Ormat Technologies Inc. has announced commercial operation of the company's first-ever geothermal and solar hybrid project, a 7 MW AC solar expansion of its Tungsten Mountain geothermal project in Churchill County, Nevada. The Tungsten Solar expansion commenced commercial operation in July 2019.

The electricity generated from the Tungsten Solar power plant will be used to offset the equipment's energy use at the Tungsten geothermal facility, thus increasing the renewable energy delivered by the project under the **Southern California Public Power Authority (SCPPA)** portfolio contract. *Global Geothermal News*......

### Enel to Use Innovative Predictive Maintenance Software to Optimize Field Operations at Geothermal Facilities

Enel Green Power North America Inc. and Irvine, California-based NarrativeWave, a U.S. company specialized in Software-as-a-Service and Internet of Things, have signed an agreement under which Enel Green Power North America will deploy NarrativeWave's innovative predictive maintenance software to optimize field operations at its geothermal facilities.

This is the first ever use of this technology in North America at geothermal plants with **electrical submersible pumps.** 

Enel Green Power North America's **25 MW Cove Fort, 13.4 MW Salt Wells** and **33.1 MW Stillwater** facilities are the only geothermal plants in North America to use large-scale electrical submersible pumps for the extraction of geothermal fluid, a cleaner and more efficient technology that ensures zero energy losses. **These pumps operate 1,700 feet underground in 310°C water**, a challenging setting for monitoring and maintenance activities. *Global Geothermal News.......* 

### Ormat Could Drill Two New Wells at Puna Geothermal Venture

The state of Hawai'i Department of Land and Natural Resources (DLNR) has approved the drilling of two new geothermal wells at Puna Geothermal Venture (PGV).

**Mike Kaleikini**, PGV's senior director of Hawaii affairs, said the 38 MW geothermal power plant still is assessing wells that were covered by lava or plugged during the eruption. He described **the**  **applications as a contingency**. Permits for new wells would be good for one year.

PGV is allowed to build as many as 28 wells under a plan of operation approved in 2006. It currently has 11 wells — **five for injection and six for production** — that range in depths of 4,000 feet and 8,000 feet. *Global Geothermal News*......

In an interview with *Pacific Business News* (PBN), Mike Kaleikini said that **the plant is still on track to open by the end of this year.** 

"We hope to begin **powering up buildings and equipment in July**," Kaleikini said. "Lava covered three geothermal wells, two production wells, one re-injection well, and a substation."

Ormat has created a new website to keep the local community informed on activities at Puna Geothermal Venture. *Global Geothermal News*......

Mike Kaleikini said that talks on a new *Power Purchase Agreement* are ongoing with with **Hawaii Electric Light Co. (HELCO)** revolving around **delinking the cost of power from the price of oil.** During peak hours, the first 25 MW PGV sells to HELCO is tied to that cost. Essentially, that pays PGV for reducing the amount of oil the utility uses to generate power.

Kaleikini said PGV is interested in delinking the cost of power from oil to provide more certainty about its revenue. He said the parties entered those talks before the eruption started. *Global Geothermal News*......

### Hybrid Geothermal-Natural Gas Project in Canada to Generate 21 MW Power

Final engineering is underway for the construction of a pilot project that combines the power of geothermal energy with existing oil and gas infrastructure in Alberta, Canada. The project is a collaboration between researchers in the **University of Alberta's Department of Earth and Atmospheric Sciences** and Alberta-based company **Razor Energy.** 

Located in **Swan Hills, Alberta**, the project is designed to generate power from two sources that combine to 21 MW of power: **5-7 MW of geothermal energy** from a combination of hot water heat and heat recovered from all sources at the battery site and an additional **15 MW of natural gas-fired** generation. *Global Geothermal News*.......

Funding is provided through a USD 5 million contribution from Natural Resources Canada (NRCan)'s Clean Growth Program, and a USD 2 million contribution from Alberta Innovates. The company expects the **capital cost** of the project to be **USD 15 million to USD 20 million**. The balance of the project funding will be sourced internally and from new private investors within the renewable energy investment market. *Global Geothermal News*......

### Research Begun to Identify Feasibility of Geothermal Systems in Northern Quebec Region

**Concordia University's Sustainable Energy and Infrastructure Systems Engineering (SEISE)** lab has partnered with an independent Quebec-based engineering consulting firm **BBA Inc.** to spearhead a new project aiming to unlock the potential of geothermal energy for residents of the **Nunavik region** of **Quebec**, the vast majority of whom are Inuit (the indigenous people of northern Canada and parts of Greenland and Alaska).

The lab's team is led by **Fuzhan Nasiri**, assistant professor in the Department of Building, Civil, and Environmental Engineering. The researchers are currently hard at work identifying the technical and economic feasibility of geothermal systems in the northern Quebec region. *Global Geothermal News*......

#### **Good Progress at Alberta Lithium Extraction Project**

Canadian-based E3 Metals has confirmed the successful production of lithium hydroxide from geothermal brine originating from its Alberta lithium project at Leduc using the company's ionexchange extraction process. The company has reported in the past that it plans to build a binary geothermal energy plant to power a lithium extraction facility. *Global Geothermal News*......

### Funds Provided for Assessment of Geothermal Energy Potential in the Garibaldi Volcanic Belt

A USD 5 million grant from the British Columbia government will allow Geoscience BC to continue its minerals, energy and water related public earth science for an additional year, with many ongoing and new research projects set to begin in 2019-20 including a regional assessment of geothermal energy potential in the Garibaldi Volcanic Belt in partnership with the Geological Survey of Canada. *Global Geothermal News*......

### Inside Geothermal

#### Second Well at Estevan Geothermal Power Project

The first well has been drilled at the **Deep Earth Energy Production Corp. (DEEP)** geothermal power project near **Estevan** in southern **Saskatchewan**, **Canada.** DEEP has also secured the **mineral rights** for products from the geothermal brine in the area.

DEEP is now conducting a production test - **a flow and built up test** - of the well, expected to take about three weeks. That test will be used for the final design of the next well, which is planned to be drilled approximately 1.5 kilometers away from the first. *Global Geothermal News*......

In addition, DEEP announced that a \$5,000,000 private placement closed on August 20th, over subscribed to total **\$5,190,000**. *Global Geothermal News*.....

#### More World Bank Funding for 7 MW Dominica Geothermal Power Plant Project

The Caribbean island nation of the **Commonwealth of Dominica** has signed an agreement with the **World Bank** for **USD 27 million** of financing for a **7 MW geothermal power project**. Minister of Finance **Roosevelt Skerrit** said that contractors would next be selected. *Global Geothermal News*......

#### St Vincent Geothermal Project Reaches 250°C Resource at 2500 Meters

Initial reports suggest the geothermal power project in the Caribbean island nation of **St Vincent and the Grenadines** has suitable temperature and permeability to generate geothermal energy for the planned **10 MW facility**.

Prime Minister **Dr Ralph Gonsalves** said that at a depth of 2500 meters, the temperature was more than 250°C, a "great temperature" and the permeability of the soil was measured at 1.5 liters per second. He said drilling will continue in order to benefit from the greater permeability. The exploratory drilling is being carried out under the direction of the **St Vincent Geothermal Company Limited**, which is owned by **Reykjavik Geothermal** and the Government of St Vincent and the Grenadines. *Global Geothermal News*......

### **CENTRAL & SOUTH AMERICA**

## Turboden Supplies 8 MW ORC Turbine to El Salvador Geothermal Project

Turboden has signed an agreement with La Geo to supply an 8 MWe ORC turbine at the Berlin geothermal power plant in El Salvador.

The Turboden ORC unit will be integrated within the existing facility, without requiring extra drilling, **recovering heat at 172°C** before reinjection. At this temperature super saturation of silica in the geothermal brine should be avoided. *Global Geothermal News*......

Turboden will be exhibiting at **booth #230** at the **GRC Annual Meeting & Expo**, 15-18 September at the Palm Springs Convention Center in Southern California, USA.

### UN Geothermal Training Programme to Provide Services in El Salvador

A *Memorandum of Understanding* has been signed between the **Geothermal Training Programme of the United Nations University (UNU-GTP)** in Iceland and **LaGeo** geothermal company in **El Salvador** to provide geothermal training and the development of geothermal knowledge in Latin America.

In addition, a two-year co-operation agreement was signed for UNU-GTP to continue to provide a **5-month Spanish-language diploma** conducted by the **University of El Salvador**, mostly based on LaGeo teaching. *Global Geothermal News*.......

#### Las Pailas II Geothermal Plant Inaugurated

The **55 MW Palais II geothermal plant** was inaugurated July 23 in **Curubandé de Liberia**, **Guanacaste, Costa Rica.** *Global Geothermal News......* 

### San Jacinto Geothermal Project Generating Average of 64.3 MW

Toronto, Canada -based **Polaris Infrastructure Inc.** reports the **San Jacinto-Tizate geothermal power project** in Nicaragua generated 139 GWh (net) in the first quarter - **an average of 64.3 MW** (net), resulting a **27% revenue increase from**  **the higher average production.** Comprehensive preventative maintenance was completed on the Unit 4 turbine at the San Jacinto project over the course of approximately two and a half weeks in April 2019. *Global Geothermal News......* 

In addition, Polaris Infrastructure announced a **private placement of USD 20,000,000** of convertible debentures. As previously announced, the company intends to use the net proceeds of the offering for general corporate purposes and to provide the flexibility to pursue further corporate development opportunities in **Peru** and similar jurisdictions in **Latin America**. *Global Geothermal News*......

### Geothermal to be Included in New Renewable Energy Auction in Colombia

**Colombia**'s first ever **renewable auction** has been rescheduled to take place **before 31st October**, the Energy Ministry has announced. The auction – open to wind, solar, **geothermal**, small hydro and wave energy – will match renewable projects **of 5 MW or more** with potential buyers, with **contracts running for 15 years.** *Global Geothermal News*......

### 30 MW to be Added at Cerro Pabellón Geothermal Plant

Chile's environmental watchdog Servicio de Evaluación Ambiental de la República de Chile (SEA) has approved a 30 MW expansion of Enel's Cerro Pabellón geothermal power plant. Enel Generación subsidiary Geotérmica del Norte, in charge of the expansion said it is preparing to begin construction in the third quarter of 2019. *Global Geothermal News*......

### **AUSTRALASIA**

### Te Ahi O Maui Geothermal Power Plant an "Enormous" Achievement

Getting the new **Te Ahi O Maui geothermal power plant** operational was an "enormous" achievement, **Eastland Group** chief executive **Matt Todd** says.

"This is New Zealand's first major renewable power plant in almost four years. It **synced to the national grid on October 1, 2018**, and is generating around **25 MW** of clean, renewable energy enough to power 25,000 homes. It was delivered alongside our iwi partners and co-investors the **A8D Ahu Whenua Trust**."

Mr Todd said energy generated was sold on the spot market and through a *Power Purchase*  Agreement. "**Revenue from our two geothermal plants** will be roughly **NZD 20 million** or 20 percent of total Eastland Group revenue. The strong generation prices have seen Te Ahi O Maui make a significant contribution to our record-breaking year." *Global Geothermal News*......

### Mercury Reports Record Geothermal Energy Generation

New Zealand utility **Mercury**'s geothermal generation **increased year-on-year by 23 GWh** to **731 GWh** in Q4-FY2019, contributing to FY2019 geothermal generation of 2,896 GWh, the highest annual geothermal generation for the company. *Global Geothermal News*......

### Geothermal Power Plant to Supply Heat for Wood Pellet Production

Kiwi energy companies **Contact Energy** and **Nature's Flame** have signed an agreement and broken ground to build a geothermal energy supply system that will provide process heat to Nature's Flame's **wood pellet manufacturing plant** in **Taupo**.

"Contact will provide direct heat energy from our geothermal facilities to the Nature's Flame plant which will be used to **dry the wood fiber**. The majority of the energy used to dry the wood will be derived from "used" geothermal fluid downstream of the **Tenon Sawmill**, which Contact has been providing with geothermal energy since 2007. This will optimize the efficiency of the production well for both companies," says **James Kilty**, Chief Generation and Development Officer at Contact Energy. *Global Geothermal News*......

### Drilling for New Contact Energy Geothermal Power Plant to Begin August

**Contact Energy** is slated to start drilling a series of appraisal wells on **Taupo's Tauhara geothermal steamfield** as it builds towards a final investment decision for **a new power station in 2020.** 

The drilling program - involving **four appraisal** wells - was planned to commence in August and be completed in early 2020.

"A potential new geothermal power station at the foot of Tauhara Maunga is **New Zealand's cheapest** and most attractive option for renewable baseload electricity generation," said chief executive Dennis Barnes. *Global Geothermal News*......

### Inside Geothermal

### ASIA

### 10 MW Japanese Geothermal Power Plant Begins Commercial Operation

Yuzawa Geothermal Power Generation Corporation has announced the commencement of commercial operations at the 49 MW Wasabizawa geothermal power plant in Yuzawa city, Akita prefecture in northern Honshu. This is the first large-scale geothermal power plant of over 10 MW in Japan in 23 years. *Global Geothermal News*......

### Orix Corp to Survey for Geothermal Energy Resources in Aomori Prefecture

ORIX Corporation has announced it will commence an excavation survey to verify the commercial feasibility of the geothermal resource in both Kazamaura village, Shimokita county and Aomori City, Aomori Prefecture in northern Honshu, Japan.

ORIX has conducted surface surveys and obtained approval from the local community. A geothermal resource survey subsidy for 2019 has been sponsored by **Japan Oil, Gas and Metals National Corporation (JOGMEC).** *Global Geothermal News*......

## Hot Dry Rock Geothermal Resource Discovered South of Beijing

Geologists in east **China's Shandong province** have found four reserves of **hot dry rock**, equivalent to about 18.8 billion tonnes of standard coal in power production, near the cities of **Rizhao** and **Weihai**, according to the **Shandong Bureau of Coal Geology**. *Global Geothermal News*......

### EDC Has Concession to Explore for Geothermal Energy Resources in Taiwan

Filipino company **Energy Development Corporation (EDC)** is looking to expand geothermal investments to **Taiwan**. EDC Board Director **Francis**  **Giles B. Puno** noted that the company has a "concession" to explore in a geothermal service area on the island. *Global Geothermal News*......

### Local Tribe Grants 25 Year Operation at Mt Apo Geothermal Power Plants

The **Manobo people** have been successful in imploring their ancestors to bless the **Mt Apo geothermal** project site for the next quarter of a century. In exchange for royalty from the company's operation, the Manobo tribe granted **Energy Development Corp. (EDC)** free rein to tap geothermal energy in the area **for the next 25 years, until 2044.** 

The tribe has ancestral domain over the site in **Barangay Ilomavis**, where the **52 MW Mindanao 1** and **54 MW Mindanao 2 geothermal power plants** are located. *Global Geothermal News*......

### Filipino Geothermal Energy Companies Complete Consolidation

AC Energy Inc., the energy platform of Ayala Corp., has completed the acquisition of Phinma Energy Corp. for P6.3 billion.

Phinma Energy owns 50.74 percent of **Phinma Petroleum and Geothermal Inc.** and 25 percent of **Maibarara Geothermal Inc.** *Global Geothermal News......* Phinma Petroleum and Geothermal, Inc. will be renamed as **ACE Enexor, Inc.** *Global Geothermal News......* 

### Mabini Geothermal Service Contract Re-Assigned

**Basic Energy Corp.** has announced that **Phinma Energy Corp.** has assigned "its entire and undivided" 25% stake in the **Mabini Geothermal Service Contract** in **Batangas province** in the Philippines to Basic because of Phinma's withdrawal from their joint operating agreement. *Global Geothermal News*......

### Geothermal Energy Developer Raises Funds for Future Projects

**Basic Energy Corp.** is seeking to double its authorized capital stock to allow potential strategic investors to invest in the company and to secure funds in the future. Basic Energy is developing several geothermal projects namely the **Mabini** Geothermal Service Contract in Batangas, **Mt. Mariveles** Geothermal Project in Bataan and **Mt. Iriga** Geothermal Project in Albay, Philippines. *Global Geothermal News.......* 

## EDC to Expand at Existing Geothermal Power Plants

Energy Development Corp. (EDC) said it would carry out "a small expansion" of its geothermal assets. "We have a few plants lined up for EDC. They are small, less than 30 MW," said EDC President Richard Tantoco when asked what renewable-energy projects are in store for EDC this year. Tantoco said these small expansion projects involve EDC's geothermal plants at Leyte, Bacon-Manito (BacMan) and Mount Apo. "Just a couple in the pipeline and we are likely to issue notice to proceed on one of them within the next six months—geothermal, brownfield and within the existing assets for expansions," he added. *Global Geothermal News.......* 

### EDC Supplying Geothermal Energy to Local Businesses

The Mary Mediatrix Medical Center in Lipa, Batangas, Philippines has signed up for a twoyear contract for 1 (one) MW of geothermal power from Energy Development Corp. (EDC)'s Bacon-Manito (BacMan) Geothermal, Incorporated. *Global Geothermal News*......

Top garments exporter **Hamlin Industrial Corp.**, a subsidiary of the **NST Group**, has tapped **EDC** to supply power from the **BacMan geothermal** project to its facility in **Carmona**, **Cavite**. *Global Geothermal News*......

## Aboitiz to Supply Geothermal Power to Local Businesses

**Aboitiz Power Co.** is to provide **2.5 MW** of geothermal energy from the **MakBan geothermal power plant** to a **Widus International Leisure, Inc.** resort in **Pampanga**, an expansion of its previous 1.5-MW supply deal. *Global Geothermal News*......

Aboitiz Power Co. is also supplying **17 MW** to **Nestlé Philippines Inc.** in **Lipa**, **Batangas** province from the MakBan geothermal power plant. *Global Geothermal News*......

In addition, the **MORE Electric and Power Corporation (More Power)** has signed an interim power supply agreement with Aboitiz for **10 MW** of power to residents and businesses in **Iloilo City**, with an option for another 5 MW. The energy will be supplied by **AP Renewables, Inc. (APRI)**, which operates the Tiwi and **MakBan** geothermal power plants. *Global Geothermal News*......

### Groundbreaking at 10 MW Dieng Plateau Geothermal Project

**PT Geodipa Energi (Persero)** has carried out groundbreaking for a **10 MW Small Scale PLTP Geothermal Project** on the **Dieng Plateau Geothermal Field, Central Java, Indonesia.** The facility is targeted to **begin operations in 2020**. *Global Geothermal News......* 

## Ormat Invests in East Java Geothermal Power Project

**Ormat Technologies, Inc.** has announced that it has agreed to acquire from a **Medco Power** subsidiary a 49% stake in the **Ijen geothermal project** company. A subsidiary of Medco Power will retain 51% ownership in the company. Ormat and Medco will develop the project jointly.

The Ijen project assets in **East Java, Indonesia** whose final capacity will be determined after exploration, include a geothermal concession and **30-year PPA** for up to **110 MW capacity**. The project is ready for exploration and development with **some slim holes already drilled** and **commercial operation is expected at the end of 2022**. *Global Geothermal News*......

### Indonesian Government to Offer Up to 126 MW Potential Geothermal Resources for Preliminary Exploration Surveys

The Directorate General of Renewable Energy and Energy Conservation Ministry of Energy and Mineral Resources plans to offer three areas of preliminary and exploration survey (WPSPE) assignments for geothermal energy this year with a total potential capacity of 126 MW.

The three WPSPEs that will be offered this year consist of **Pentadio** in Gorontalo (**25 MW**), **Ria-Ria Sipaholon** in North Sumatra (**60 MW**), and **Lokop** in Aceh (**41 MW**). *Global Geothermal News*......

### New Service Streamlines Permitting for Indonesian Geothermal Power Plant Projects

Electricity licensing services in Indonesia can now be accessed more easily and quickly through the Online Single Submission (OSS) website at http://oss.go.id, currently handled by Badan Koordinasi Penanaman Modal (BKPM).

One of the permits handled by the OSS system is the licensing process to build a power plant. "There are 6 general electricity licenses that have been entered into OSS, as well as **4 additional permits** 

### Inside Geothermal

for geothermal plants: the Assignment of Preliminary Geothermal Survey, Geothermal Permit, Geothermal Support Business Agreement, and Permit for Use of Geothermal Explosives Warehouse. Global Geothermal News......

### Finnish Company to Help Develop Geothermal Resources in Uzbekistan

The National Agency for Project Management (NAPM) under the President of Uzbekistan and the Finnish company KaukoInternational have signed a *Memorandum of Understanding* to develop the geothermal energy sector in the central-Asian country. The proposed solution is based on innovative Finnish drilling equipment, which claims to increase drilling speed by an average of 2-4 times. *Global Geothermal News......* 

### **AFRICA**

### MOU Signed for Cooperation in Developing Geothermal Energy in Egypt

The South Valley Egyptian Petroleum Holding Company, the New and Renewable Energy Development and Use Authority and the National Institute of Astronomical and Geophysics Research have signed a three-year memorandum for better understanding of geothermal energy in Egypt. *Global Geothermal News*......

#### New Zealand Africa Geothermal Facility to Help Development in East Africa

The New Zealand Africa Geothermal Facility (NZ-AGF) is exploring ways of collaborating with Geothermal Development Company (GDC) in Kenya to boost technical capacity in geothermal development, steam field development and resource management.

NZ-AGF is also in talks with GDC to provide a financial grant in order to support the latter's quest to develop the country's geothermal resources. The facility offers responsive, flexible technical assistance and capacity building services and aims to alleviate barriers to development, improve understanding and regulation of geothermal resources, progress projects, de-risk and secure financing for investment.

NZ-AGF is being implemented under the New Zealand and the African Union Commission Partnership Arrangement, signed at the African Union Headquarters in Addis Ababa, Ethiopia in June 2017.

The target countries for the Facility are those within Eastern and Southern Africa that have geothermal potential and are eligible for Geothermal Risk Mitigation Facility funding, specifically: **Kenya, Ethiopia, Rwanda, Tanzania, Zambia, Uganda, Eritrea, Djibouti, Comoros, Burundi** and **Democratic Republic of Congo**. The overall goal of the Facility is to expand access to affordable, reliable and clean energy in East African nations through the increased use of geothermal energy resources. *Global Geothermal News.......* 

#### **Preparations at Tulu Moye Geothermal Project**

Chief Executive Officer (CEO) of **Tulu Moye Geothermal, Darrell Boyed** said that the company is currently performing various work on the project site including opening offices at the project site and in **Addis Ababa, Ethiopia** as well as constructing a road. *Global Geothermal News......* 

Kenya Electricity Generating Company (KenGen) has won a Sh5.2 billion tender to drill eight geothermal wells at the Tulu Moye geothermal project, and provide a geo-scientific survey. *Global Geothermal News*......

### Exploration Drilling for Corbetti and Tulu Moye Geothermal Power Projects to Start in September

**Reykjavik Geothermal (RG)**, is preparing to **start exploration drilling in September** at the **Corbetti** and **Tulu Moye geothermal projects**, south of the capital Addis Ababa. "All the results from the surface exploration work indicate that we are developing projects in a huge caldera, huge active volcanoes which can sustain at least 1,000 megawatts or more," **Gunnar Orn Gunnarsson**, RG's chief operating officer, said. *Global Geothermal News*......

### Olkaria V Unit 1 Geothermal Power Plant Synchronized to National Grid

Kenya Electricity Generating Company (KenGen) has announced that Olkaria V unit 1 geothermal power plant has been 'synchronized' to the national grid as of Friday 26th July. The full load of 86.6 MW is above its rate capacity of 82.7 MW. KenGen is now working on **Olkaria V Unit** 2 with a similar rated capacity as unit 1. Once complete, the combined capacity of **Olkaria V** is expected to be **a total of 165.4 MW**. According to the company Olkaria V Unit 2 is undergoing **pre-commissioning tests** in preparation for steam admission. *Global Geothermal News*.......

## Geothermal Power Plant Featured on New Kenyan Bank Note

**President Uhuru Kenyatta** of Kenya has introduced a new five-note currency. The **red 50-shilling note** has a "green energy" theme highlighting wind power, **geothermal power**, and solar power. *Global Geothermal News*......



### New Transmission Line to Deliver Olkaria Geothermal Power to Western Kenya

A more efficient transmission line is set for completion early next year connecting counties in **Western Kenya** to geothermal power plants in **Olkaria, Naivasha.** Through the 220kV/ 400kV **Olkaria-Lessos-Kisumu** line, western parts of the country will for the first time receive geothermal electricity. *Global Geothermal News......* 

## Slim Well Drill Programme Begins at Geothermal Project in Zambia

Zambian geothermal exploration company, Kalahari GeoEnergy, has announced the completion of the drilling of eight temperature gradient holes and the commencement of drilling slim wells at the Bweengwa River Geothermal Resource Area. A full technical and commercial feasibility study will commence in late 2019. The company has identified a total of six geothermal energy targets including Bweengwa River, on all of which it is conducting geothermal exploration. *Global Geothermal News.......* 

### **EUROPE**

### New Board at European Geothermal Energy Council

The new board of the **European Geothermal Energy Council (EGEC)** has been announced:

- President: Miklos Antics (GPC IP)
- Vice Presidents: **Marco Baresi** (Turboden) and **Javier Urchueguia** (Universidad Politécnica de Valencia)
- Board Members: **Sara Montomoli** (ENEL Green Power); **Robert Gavriliuc** (Romanian Geoexchange Society); **Rüdiger Grimm** (Geoenergie Konzept GMBH)
- Treasurer: Attila Kujbus (Geothermal Express) Global Geothermal News......

## European Federation of Geologists Promotes Geothermal Energy

Ambitious targets for renewable energy and for energy efficiency mean in-depth planning from both stakeholders and policy makers. The **European Federation of Geologists (EFG)** is a professional organization representing more than 45,000 geologists across Europe. The Federation's main aims are to contribute to a safer and more sustainable use of the natural environment, to protect and inform the public and to promote more responsible exploitation of natural resources.

Based on the expertise that professional geologists provide, **EFG believes geothermal energy (both shallow and deep geothermal)**, CO<sup>2</sup> capture and mineral extraction are part of the answer to meet the aforementioned targets. *Global Geothermal News*......

### **Geothermica Second Call Announcement**

The **Geothermica** consortium has announced the launch of **an additional joint call** with a deadline for pre-proposals on **September 13, 2019**.

The **Geothermica Consortium** will be broadening the scope for the Second Call, with **Norway** and **USA** joining, now giving Geothermica the weight to influence and accelerate the development of geothermal energy globally.

Geothermica 's second call objective is to accelerate the development of geothermal energy globally, by combining the financial resources and know-how of its respective partners, as well as expanding the utilization of clean and renewable low carbon geothermal energy beyond its traditional

### Inside Geothermal

markets and regions. In addition, Geothermica seeks to explore the optimization of geothermal direct use and power generation, including innovative integrated and combined systems.

In the previous call, Geothermica financed, with the support of the European Commission, eight large Inter-European projects, allocating close to EUR 30 million to innovation and technology development projects. The available budget for the Second Call is close to EUR 19 million in total - including EUR 1.7 from the USA Department of Energy (DOE).

#### Geothermica Second Call Timeline:

- 13 September 2019 Deadline for project preproposals submission
- 11 November 2019 Notification to projects that passed
- 31 January 2020 Call for full proposal closes
- 1 June 2020 Tentative date for funding recommendation and announcement of results to Main Applicants
- 1 September 2020 Tentative date for national funding decisions and contracts completed. Start of projects

More Information...... Global Geothermal News.....

### HS Orka Now a Pure Play Renewable Energy Platform

London, UK-based **Ancala Partners**, an independent mid-market infrastructure investment manager, has agreed to acquire a 50% interest in **HS Orka**, Iceland's largest private electricity generator, from Jarðvarmi, a consortium of 14 Icelandic pension funds.

Ancala and **Jarðvarmi** have further agreed to divest HS Orka's 30% interest in the **Blue Lagoon**, Iceland's leading tourist attraction, to **Blávarmi**. The sale transitions HS Orka into a pure play renewable energy platform. *Global Geothermal News*.......

### UK Project to Research Geothermal Resources Given Go-Ahead

Local councilors have unanimously approved the **British Geological Survey's (BGS)** planning application to site a **UK Geoenergy Observatory** at **Ince Marshes** in the north of **Cheshire** in north-west England.

Some **50 boreholes will be drilled down to 1,200 meters** enabling scientists to gain the clearest picture yet of the underground environment. The boreholes will be installed with **scientific sensors**, which will observe in unprecedented detail **how the underground system works**. The sensors will generate millions of terabytes of data on the chemical, physical and biological properties of the rocks over a 15-year period, providing the nation with the knowledge it needs to unlock new clean, green, low-carbon energy technologies. *Global Geothermal News*......

### Both Wells Completed at United Downs Deep Geothermal Power Project

**Geothermal Engineering Ltd** has provided an update on progress at the **United Downs Deep Geothermal Power Project** in Cornwall, England.

"We have now completed the drilling of both wells. **UD-1** reached a depth of **5,275 meters** in April and on Friday 28th June **UD-2** reached a depth of **2,393 meters**, having reached the Porthtowan Fault Zone. The drilling rig has been demobilized and all the ancillary equipment has been removed.

We will need to take time to prepare for the testing (evaluation) phase of the project. This may include the need for a '**workover**' **rig** to carry out some activities." *Global Geothermal News*......

### More Money for Upcoming UK Renewable Energy Auction

The overall budget for the third **Contracts for Difference (CfD) auction** in the UK has been increased to GBP 65 million (USD 84.7m/EUR 75.6m) from **GBP 60 million** in the draft proposal, and the final details have been confirmed.

The allocation round **starts on May 29** and will be open to all so-called **Pot 2 less-established technologies** such as offshore wind, **geothermal power**, remote island wind, and marine power, among others. All projects have to be delivered in 2023-2024 and 2024-2025. *Global Geothermal News......* 

### New Law to Encourage Investment in French Geothermal Sector

The Minister of the Ecological and Solidarity Transition of **France** has presented to the Council of Ministers, an ordinance modifying the provisions of the mining code relating to the granting and the extension of the titles of exploration and exploitation of **geothermal deposits**.

The ordinance aims to **simplify and clarify** the existing legal framework in order to encourage the actors of the geothermal sector **to invest more** in the development of this renewable energy. *Global Geothermal News*......

### VITO Spin-Off Aiming for Ten Geothermal Power Plants Over the Next Ten Years

Soudal founder Vic Swerts and two other entrepreneurs are investing EUR 3.8 million in Hita, a spin-off from the VITO research institute. Over the next ten years, it wants to develop ten geothermal power plants in Belgium for a total amount of EUR 230 million enabling the heating of 400,000 homes. *Global Geothermal News*......

VITO has published an update on what would be the first deep geothermal energy plant in Flanders at the **Balmatt site** near **Mol**. Buildings at **VITO/SCK/Belgoprocess** are being supplied with geothermal heat and the some of the heat is being used to produce electricity. With the current operational parameters and a production temperature of **121°C** above-ground, the Balmatt central produces about **4-5 MW**, or in total 1.7 GWh. The water is re-injected at **55-60°C**. *Global Geothermal News*......

## Dutch and German Institutions to Cooperate in Geothermal Energy Research

**Delft University of Technology (TU Delft)** and the **German Research Centre for Geosciences (GFZ)** have signed a *Memorandum of Understanding* concerning research into geothermal energy especially in the fields of heat storage and further underground storage possibilities. This also includes access to the GFZ's **Groß Schönebeck** geothermal research platform and to the research facilities of the faculty of **Civil Engineering and Geosciences** of TU Delft. *Global Geothermal News*......

## Shell to Explore for Geothermal Heat in the Rotterdam Region

Dutch energy companies **Eneco** and **Shell** have jointly applied to the Ministry of Economic Affairs and Climate (EZK) for an exploration permit to **search for geothermal heat** for **district heating** purposes in the **Rotterdam** region (Rotterdam, Capelle aan den IJssel, Lansingerland, Krimpen aan den IJssel and Zuidplas). *Global Geothermal News.......* 

### Holzkirchen Geothermal Power Plant Starts Delivering Electricity

Following the start of operation for district heating in December 2018, electricity was fed into the grid for the first time on 4 July 2019 as part of the trial operation of the **Holzkirchen geothermal power plant** in **Bavaria**, southern **Germany**. *Global Geothermal News*......

## Fourth Well Drilled at Munich Geothermal District Heating Project

Work on the 4th well in the **Stadtwerke München (SWM) project** at **Schäftlarnstraße** in **Munich** has been successfully completed. After a drilling distance of more than **3,700 meters**, the **Th4 well** reached its final depth in mid-June. Pumping tests have confirmed that the fourth well meets the original expectations. **A fifth well is being drilled**. *Global Geothermal News*......

SWM is also working on expanding three geothermal district heating power plants in Sauerlach, Dürrnhaar and Kirchstockach and building a district heating network in the Ottobrunn and Hohenbrunn areas of Munich. SWM has secured a permit for an exploratory seismic survey. *Global Geothermal News......* 

### Daldrup & Söhne AG to Concentrate More on Geothermal Drilling Services

The German energy company **Daldrup & Söhne AG** has announced a re-think of its business strategy after mixed financial results. A number of one-off effects, special circumstances with regard to drilling orders and lower than expected electricity production volumes at the geothermal power plants have **pushed earnings well into the red**. In particular, electricity production at the **Taufkirchen geothermal power plant** could not be implemented as planned in the year under review.

### Inside Geothermal

As a consequence of the operational development, the Management Board proposed a realignment of the group to the Supervisory Board. On the one hand, it includes a stronger concentration on the drilling services business. On the other hand, the dimensions of the project and capital risks in the power plant division are to be selected in such a way that they correspond to the medium-sized orientation of the Daldrup & Söhne Group. Global Geothermal News.....

### Third Well at Austrian Geothermal District Heating Project Successful

The third well at Austria's largest geothermal energy project, in the Ried and Mehrnbach region in the north of the country, has been successful. During a pumping test, water from more than 2,000 meters deep at more than 100°C was produced. Global Geothermal News......

#### Swiss Underground Research Laboratory Opens

An underground research laboratory to investigate the long-term use of geothermal energy has opened in the southern Swiss Alps. The Federal Technical Institute of Zurich (ETHZ) says the facilities - situated in a disused access tunnel of the Matterhorn Gotthard railways in the Bedretto Valley – are a world first.

In cooperation with national and international partners, the ETHZ has installed seven additional seismic stations in and around the rock laboratory. The **Bedretto project** wants to demonstrate that a geothermal energy resource can be controlled with the aid of hydraulic stimulation processes. Global Geothermal News.....

#### Swiss Geothermal District Heating Project Gets **Federal Grant**

The medium-depth EnergeÔ geothermal project in Vinzel (in the canton of Vaud in Switzerland), has received a Federal Office of Energy grant of more than 14 million francs, the first of such a grant agreement with the government. / <sup>2</sup> Geothermal delivered in 2019 and will produce clean electricity News.....

### Polish Government to Spend USD 160 Million on **Geothermal Energy Projects**

**Poland's National Fund for Environmental** Protection and Water Management (NFOŚiGW) has pledged to spend PLN 600 million (EUR 140 million) on geothermal energy-related projects in the country including power and district-heating projects.

As part of the "Polish Geothermal Energy Plus" scheme, half of the funds, namely PLN 300 million (EUR 70 million), will be distributed by means of donations to private investors, while the rest will be given out in loans. Geothermal News.....

### **Croation Geothermal Power Plant Declared a** Strategic Investment

The Government of Croatia has declared the AAT Geothermae geothermal project at Draškovec in the Međimurje area in northern Croatia, a strategic investment project for the country.

The planned installed capacity of the power plant is 18.6 MWe plus 75 MWth while the estimated electricity generation is 258 GWh over five years (121 GWh of electricity plus 137 GWh of heat).

AAT Geothermae, wholly-owned by Switzerland-based CLEAG, has plans to build 10 geothermal power plants in the region, including three in Croatia, two in Serbia, and one in Romania, the company said earlier. / "24" Geothermal News......

### Second Geothermal Power Plant to be Built in Croatia

Croatia's Geo Power Zagocha intends to build a 20 MW Organic Rankine Cycle (ORC) geothermal power plant in the Slatina region, according to an application submitted to the Ministry of Environmental Protection and Energy. The Zagocha geothermal power plant could be Croatia's second geothermal power plant after the 17.5 MW Velika **Ciglena** geothermal power plant. / <sup>-2</sup>¥<sup>cr</sup>Geothermal News.....

### **Climeon to Supply Geothermal Heat Power** Modules in Hungary

Swedish company Climeon has received an order for a geothermal heat power project in Hungary.

Mannvit and Cam Consulting will participate in the licensing process and the construction of the power plant. The heat power modules are to be from an already existing geothermal well in Szentes, in the south-eastern part of Hungary. / <sup>2</sup>¥<sup>a</sup> Geothermal **SCIENCE & TECHNOLOGY** *News.....* 

### Potential for Up to 68 MW of Geothermal Energy Capacity in Northern Serbia

French geothermal association **Association Française des Professionnels de la Géothermie (AFPG)** has signed a *Memorandum of Understanding* (MoU) to support the development of geothermal energy projects in **Serbia**'s northern autonomous province of **Vojvodina**.

AFPG will support Vojvodina in executing studies on the technical and economic potential of the geothermal resources in the province. A recent study by **GEODEEP** has shown that Vojvodina has the potential to develop **four geothermal heat and power projects** with a capacity of between **11 MW and 17 MW each**. / <sup>22</sup> *Geothermal News*......

### Financing will Fund 100 MW Addition to Efeler Geothermal Power Plant

The Asian Infrastructure Investment Bank (AIIB), the European Bank for Reconstruction and Development (EBRD) and the Black Sea Trade and Development Bank (BSTDB) are set to provide financing for Gürmat Elektrik's Efeler 100 MW geothermal plant expansion in Turkey.

The three banks have agreed to provide a financial package of USD 350 million for three new units at the Efeler plant: EFE-6 (22.6 MW) and EFE-7 (25 MW) have already commenced their operations, while EFE-8 with a capacity of 50 MW is still under construction.

The plant's eight units will have a **total installed capacity of 260 MW** when they are **completed in 2020.** *Global Geothermal News......* 

### **CLIMATE CHANGE**

### Global Partnership Announced to Accelerate Low-Carbon Energy Transition

The **United Nations Development Programme** (UNDP) and the **International Renewable Energy Agency (IRENA)** have announced a global partnership to **accelerate low-carbon energy transition** and offer concrete steps to achieve sustainable development.

Under the cooperation, the organizations will explore joint initiatives aimed at accelerating the implementation of the Agenda 2030, and **stimulating renewable energy investments in developing countries.** *Global Geothermal News......* 

### Promising Technique for Geothermal Reservoir Characterization Using CT Scanning

Although **computed tomography (CT-Scanning)** has been regularly applied to core analyses in petroleum geology, there is still a need to improve our ways to document porosity and porosity distribution in the entire pore scale spectrum, from the tens of nanometer to the meterscale.

**Porosity imaging** is particularly crucial for complex and heterogeneous rocks such as **hydrothermally altered and fractured carbonates.** The present work proposes an improved method using medical-CT to reliably estimate reservoir porosity.

The methodology tested on a large set of reference core material shows **a strong correlation between conventional gas porosimetry techniques and porosity from CT-scan.** The added value of the porosity measurements by CT-scan is, first of all, the generation of 3D images of pore network, allowing to assess spatial attributes of macropores, their distribution and connectivity. Secondly, the CT-scan method also provides continuous porosity profile at the millimetric scale. Both developments are crucial for the understanding of reservoir rock properties.

/ <sup>-</sup>²¥¤<sup>-</sup>/ eothermal News......

### Continuous porosity characterization: Metricscale intervals in heterogeneous sedimentary rocks

*using medical CT-scanner* by Stéphanie Larmagnata et al. *Marine and Petroleum Geology*. Volume 109, November 2019, Pages 361-380. https://doi. org/10.1016/j.marpetgeo.2019.04.039



CT-Scanner (Wikipedia Commons)

### Inside Geothermal

### Geothermal Battery Claims to Generate Electric Power at less than 100 Degrees Celsius

Researchers at **Tokyo Institute of Technology** and **Sanoh Industrial** have created **a very stable battery** cell with the potential to **directly turn heat into electricity**, thus ultimately offering a method for making use of geothermal energy in a sustainable manner.

The team of scientists, led by Dr. Sachiko



Matsushita, have made great progress in the understanding and development of **sensitized thermal cells (STCs)**, a kind of battery that can generate electric power at **100°C or less**.

The team is very excited about their discovery because of its applicability, eco-friendliness, and potential for helping solve the global energy crisis. "There is no fear of radiation, no fear of expensive oil, no instability of power generation like when relying on the sun or the wind," remarks Matsushita. Further refinements to this type of battery will be the aim of future research, with the hope of one day solving humanity's energy needs without harming our planet. *Global Geothermal News*......

### Successful Control of Induced Seismicity During Hydraulic Stimulation of a Geothermal Well

Developing an Enhanced Geothermal Systems (EGS) reservoir requires the forceful creation of fluid pathways in the deep underground by injecting large amounts of water under high pressure. Induced seismicity is an inevitable, yet poorly understood by-product of this technology, and has caused serious public concern and scepticism in the past. Managing the induced seismicity risk is therefore crucial for the development and further exploitation of EGS technology toward market-ready power and heat supply in urban environments.

In a new study now published in *Science Advances* a team of scientists reports on a successful attempt to control induced seismicity during the **deepest-ever hydraulic stimulation of a geothermal well in Helsinki, Finland.** *Global Geothermal News......* 

Controlling fluid-induced seismicity during a 6.1-kmdeep geothermal stimulation in Finland, G. Kwiatek el al., Science Advances (2019). DOI: 10.1126/sciadv. aav7224

## U.S. Lab Develops Self-Healing Cement for Harsh Geothermal Conditions

A self-healing cement developed by Pacific Northwest National Laboratory can outperform conventional concrete, offering a potentially pollution-preventing technology for the growing geothermal industry.

This game-changing combination uses a flexible ingredient, **a polymer**, to repair fractured surfaces and fill cracks, minimizing mechanical failure risks and offering a sustainable energy source.

There are large geothermal energy reserves across the country and around the world that are not in use because wellbore cement fails in hightemperature conditions and in chemically corrosive environments. *Global Geothermal News*......

*Insights into the physical and chemical properties of a cement-polymer composite developed for geothermal wellbore applications.* Kenton A.Rod, et al.

*Cement and Concrete Composites.* Volume 97, March 2019, Pages 279-287. https://doi.org/10.1016/j. cemconcomp.2018.12.022

### Shape Memory Polymers Activated by Geothermal Temperatures to Prevent Loss of Fluid in Fractured Rocks

A University of Oklahoma research team is developing smart lost circulation materials that use shape memory polymers activated by geothermal temperatures to prevent the loss of fluid in fractured rocks near the wellbore. These materials expand within the fractures to reduce non-drilling time and strengthen the wellbore in high-temperature drilling operations.

The U.S. **Department of Energy's Geothermal Technologies Office** funded the early-stage research with a **USD 1.79 million grant**. In addition, the project has more than USD 0.5 million cost share from various entities.

"The cost of drilling a geothermal well is prohibitive without new technologies to address the challenge of drilling the type of rock found in a geothermal well," said **Saeed Salehi**, project principal investigator and professor of petroleum and geological engineering, **Mewbourne College of Earth and Energy**. "The shape polymers under development for this project are novel expandable and programmable polymers that activate when drilling during high-temperature geothermal drilling operations." *Global Geothermal News*......

### Low Enthalpy Geothermal Could Power New Desalination Method

"Hypersaline brine" is industrial waste-water with salt levels that exceed even that of seawater. It's a big, expensive, destructive problem which a team of engineers at **Columbia University** in **New York** City hope to solve with their solvent-based method of desalination.

The "temperature swing solvent extraction" or TSSE method – developed by a Columbia Engineering team led by assistant professor Ngai Yin Yip – is beautifully simple. It uses a solvent with temperature-dependent water solubility. Vary the temperature, and you vary the solubility. This solvent is added to the brine, where it floats above the denser salt-laden liquid. At roomtemperature, water from the brine is drawn into the solvent. After this stage, the solvent is drawn off and warmed via low-grade heat under 70°C (158°F). The "temperature swing" nature of the solvent subsequently demixes it from the water (remember, this is a temperature-dependent solvent, where at higher temperatures, it holds less water). The resulting desalinated water then settles to the bottom, and is collected.

And speaking of sustainability, **the low-heat requirements for the process is one of its most appealing elements**. Depending on the location of the technology, **this low, sub 70°C heat** can be supplied conventionally at low cost, or sustainably from sources such as low-concentration solar, on-site waste heat from industrial processes or **shallowwell geothermal**. *Global Geothermal News......* 

Membrane-less and Non-Evaporative Desalination of Hypersaline Brines by Temperature Swing Solvent Extraction. By Chanhee Boo, et al. Environmental Science & Technology, DOI: 10.1021/acs.estlett.9b00182

### **EDUCATION**

### Educational Poster Explaining Geothermal Energy Available for Downloading

Double-sided poster available in English and Spanish

The **Geothermal Resources Council (GRC)** is pleased to announce a new poster aimed at helping educate middle-schoolers on geothermal energy and help spread the word of the industry's technologies and mission to the general public.



### Inside Geothermal

The poster is glossy, doubled sided with **English and Spanish versions** and measures **22 inches x 34 inches**, making it ideal for display in a classroom or other educational facility.

The GRC would like to thank the **Dewhurst Group** for their help in designing the poster and to the following sponsors for their support: **Horizon Well Logging: Ormat Technologies; Cyrq Energy; Coso Operating Company; EGS, Inc.,** and **the Dewhurst Group.** 

10,000 copies of the poster will be sent in school educational packs distributed by the **American Geosciences Institute (AGI)**, as part of the **Earth Science Week Toolkit**, with the main priority to support high-quality teaching and learning in Earth



science.

Copies of "Geoscience Is for Everyone," the 2019 Earth Science Week Toolkit, are available for just the cost of shipping and handling (\$8.50 for the first kit, \$2.25 for each additional kit in the United States). This price includes Library Rate shipping to U.S. addresses via the U.S. Postal Service, allowing 2-3 weeks for delivery. Order your toolkit today! https://

### store.americangeosciences.org/2019-earth-scienceweek-toolkit-geoscience-is-for-everyone.html

**Earth Science Week**, from **October 13-19**, is an important annual outreach by the U.S. geoscience community. "Aligned with efforts to enhance diversity, equity, inclusion, and accessibility in the geosciences, this year's theme of "Geoscience Is for Everyone" [provides] materials that emphasize the importance of the geosciences in the lives of all people."

A further 5,000 printed copies of the Geothermal Poster will also be available for distribution directly by the GRC and, for instance, **will be freely available at this year's Annual Meeting & Expo** in Palm Springs, California from 15-18 September. **Electronic versions of the poster are available for download from our website** at https://geothermal. org/poster.html.



# JOIN the COMMUNITY

### DONATE tothe GRC

# **GeoSmart: Towards Flexible and Efficient Geothermal Systems**

by GeoSmart Consortium



The European Strategic Energy Technology Plan<sup>1</sup>, commonly referred to as the SET plan, focusses on fostering the development and implementation of low-carbon technologies. Geothermal, energy harvested from the earth's core, is a renewable technology with capacity to offer a low-carbon, clean and non-intermittent energy resource. Despite the opportunities, exploitation of geothermal power has traditionally lagged behind as opposed to wind and solar technologies. Geothermal is currently engineered as an "always on" baseload supply, due to the limited flexibility to throttle the well without scaling and liner fatigue problems, and is engineered for maximal efficiency at this output level. Project GeoSmart (https://www.geosmartproject. eu/), funded by European Commission's H2020 program, aims to address the strategic flexibility required from European geothermal installations, as they become significant energy sources over the next 20-30 years, replacing decommissioned fossil fuel plants.

### **GeoSmart Excellence and Impacts**

GeoSmart aims to optimise and demonstrate innovations to improve the flexibility and efficiency of geothermal heat and power systems, by developing a suite of equipment and tools including:

- Energy storage and power block management innovations to provide daily flexibility
- Integration of more flexible Organic Rankine Cycle (ORC) systems that can cope with

variations in needs in the electricity markets

• Combined Heat and Power (CHP) supplier to extract more heat from the post-generator ("waste" heat) brine outflows when required for increased heating supply during colder weather

The technology will be demonstrated in working geothermal plants of two variants, thus meeting the different flexibility needs of low and high enthalpy CHP provision. As such, GeoSmart technology concept will allow the geothermal plant to be operated in flexible mode to produce power and heat in cost competitive way. The project kicked-off in June 2019 and will run over a period of 48 months.

### **GeoSmart Consortium**

The consortium consists of 19 members including the research institutes, SMEs and plant operators including TWI (UK), VITO (Belgium), Zorlu Energy (Turkey), CEA (France), Atlas Copco (Belgium), EGEC (Belgium), Fraunhofer (Germany), Spike Renewables (Italy), ON power (Iceland), University of Iceland (Iceland), Middle East Technical University (Turkey), BERTIN (France), Gerosion (Iceland), Kadir Has University (Turkey), Technovative solutions (UK), Flowphys (UK), PVALD (Iceland), COSVIG (Italy) and Innovation Centre Iceland (Iceland).

#### Funding

The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under 2020 grant agreement No 818576. ■

<sup>1</sup> https://ec.europa.eu/energy/en/topics/technology-and-innovation/strategic-energy-technology-plan

# The U.S. Department of Energy's GeoVision Analysis: Highlighting the Potential of the Heat beneath our Feet

by Dr. Susan G. Hamm, Geothermal Technologies Office Director for the Office of Energy Efficiency and Renewable Energy

#### Introduction

Several aspects of geothermal make it unique among energy resources: it's an "always on," renewable, 50-state solution that can provide flexible electricity, heating and cooling solutions to all Americans while offering economic and environmental benefits. The geothermal industry has long been aware of the benefits of sourcing more of the nation's energy needs from geothermal resources. To grow as a national solution for the United States, however, geothermal energy must overcome significant technical and non-technical barriers in order to reduce cost and risk.

To evaluate barriers and opportunities for geothermal energy, the Office of Energy Efficiency and Renewable Energy's Geothermal Technologies Office (GTO) within the U.S. Department of Energy (DOE) initiated the *GeoVision* analysis. The analysis is based on rigorous modeling and simulation that enabled a team of experts to assess the state of geothermal energy, quantify growth opportunities and associated impacts on the nation, and formulate actions to increase geothermal deployment. The analysis culminated in the *GeoVision: Harnessing the Heat Beneath our Feet* report, that was recently announced by U.S. Secretary of Energy Rick Perry in Salt Lake City, Utah. The *GeoVision* report summarizes the analysis (DOE 2019) and provides a glimpse into the abundant opportunities geothermal energy has to offer the nation.

As a basis for the *GeoVision* analysis, GTO identified three key objectives that must be addressed to realize greater levels of geothermal deployment:

- 1. Increased access to geothermal resources
- 2. Reduced costs and improved economics for geothermal projects
- 3. Improved education and outreach about geothermal energy through stakeholder collaboration

These key objectives underlie the analysis and were instrumental in developing the GeoVision Roadmap—a compilation of technical, economic, and institutional actions across the geothermal community that can help address barriers and optimize the continued contribution of geothermal energy as a renewable and diverse solution for the United States.



Together, the geothermal community can support actions to increase geothermal electricity generation 26-fold and skyrocket the use of geothermal heat pumps and district heating by 2050. For details, see DOE's report, GeoVision: Harnessing the Heat Beneath Our Feet.

### A Comprehensive and Collaborative Process

The DOE's strategy for developing and carrying out the GeoVision analysis included the understanding that the work needed to embody input from a range of stakeholders. As such, the analysis centered on a collaborative process to collect and vet data, develop content, and review the findings. The analysis was

founded on the collection, modeling, and analysis of robust datasets gathered by DOE's National Laboratory partners. The National Laboratories and GTO task-management assembled seven technical task forces to provide expertise to the *GeoVision* analysis:

- 1. Electric Sector Potential to Penetration
- 2. Environmental and Social Impacts
- 3. Geothermal Hybrid Systems
- 4. Institutional and Market Barriers
- 5. Reservoir Maintenance and Development
- 6. Resource Exploration and Confirmation
- 7. Thermal Applications of Geothermal Resources

The task forces performed the quantitative and qualitative assessment for the *GeoVision* analysis and detailed the findings in eight supporting task force reports (DOE 2019). Findings from the reports will be presented at the Geothermal Resources Council's Annual Meeting and Expo in September 2019.

The *GeoVision* analysis also included a wide range of stakeholders who were instrumental in documenting the state of the industry. Inputs, content, and reviews were provided by industry, academia, National Laboratories, trade organizations, and other federal agencies. This participation included a group of 20 senior peerreviewers, called "Visionaries," who iteratively and transparently vetted the work of the task forces, as well as an external review group of 34 experts who reviewed the draft prior to publication and were not otherwise involved in the analysis or the report. Through this cross-stakeholder process, DOE assured compliance with federal informationquality standards and obtained practical, diverse perspectives and feedback. In all, more than 115 individuals from more than 65 organizations contributed technical knowledge, content, or review comments to the *GeoVision* report.

#### What Did the GeoVision Analysis Tell Us?

Until the landmark effort of the *GeoVision* analysis, geothermal deployment potential had never been quantified at a national scale or across a broad range of technology applications. The *GeoVision* analysis, however, did both. The study evaluated nationwide potential for conventional geothermal electricity generation and geothermal heating and cooling applications, as well as future potential for evolving technologies such as enhanced geothermal systems (EGS), lowtemperature and sedimentary geothermal resources, and hybridized geothermal applications. The analysis quantifies the potentially sizable role geothermal resources could play in meeting the nation's 21st-century energy demands.



The *GeoVision* analysis used a variety of modeling scenarios to assess opportunities for both electric and non-electric geothermal uses. The scenarios are progressive and cumulative. Three scenarios provided insight into the electric sector: Business-as-Usual (BAU), Improved Regulatory Timeline (IRT), and Technology

Improvement (TI). The non-electric sector assessed geothermal heat pumps (GHPs) by comparing a 2012-installed baseline against a BAU scenario and a Breakthrough (BT) scenario that included cost reductions and efficiency gains from technology improvements, while direct-use district-heating applications were modeled using BAU and TI scenarios. This section provides a brief sampling of some *GeoVision* analysis results, primarily for the electric sector. Additional summary results, including those for the non-electric sector, are available in the *GeoVision* report. Details about the assumptions and findings for all GeoVision analysis results are available in the task force reports. In addition, readers can visit the GeoVision Scenario Viewer (https://openei.org/apps/geovision/) to interact with and download the GeoVision analysis data using a series of dynamic charts.

The *GeoVisio*n analysis also assessed the effect of potential regulatory reforms that could reduce development timelines for geothermal electric-sector projects. Exploration that supports conventional hydrothermal resource growth in the electric-sector IRT scenario results from shorter permitting timelines, which enhance developer access to resources and increase the amount of exploration that can be performed in a given time period. The results indicate that—using existing geothermal technologies—total geothermal electricity-generation could reach nearly 13 gigawatts-electric (GWe) by 2050, double the installed capacity in 2050 under the BAU scenario.



Improving the technologies used for exploration, drilling, and production can help reduce project development and operation costs, which is essential to achieving the full potential of geothermal energy. Results of the GeoVision analysis illustrate the importance of technology advancements in growing geothermal deployment. For instance, in the electric sector, the results of the TI scenario indicate the potential for more than 60 GWe of geothermal power generation net summer capacity, the majority of which would come from deep-EGS resources after 2030 (Figure 2). In the non-electric sector, technology improvements could support GHPs to provide heating and cooling to the equivalent of 28 million U.S. households, as well as 17,500 district-heating installations nationwide.

#### What's Next?

The results of the GeoVision analysis provide a case for the potentially sizable role that geothermal resources could play in meeting the nation's 21st-century energy demands. The analysis confirms significant growth opportunities across the geothermal spectrum, along varying pathways that target reductions in cost and risk. For proven technologies, industry growth to maximum deployment will primarily require stakeholders to collaborate on overcoming barriers related to project financing, regulatory timelines, outreach and education, and market structures. For unproven and developing geothermal technologies, deployment growth will be advanced most effectively through research, development, and technology advancement. In particular, the commercialization of EGS resources is paramount to long-term, step-change growth in geothermal energy.

The *GeoVision* analysis included the development of the *GeoVision* Roadmap, a call to action intended to stimulate broadly inclusive, multi-stakeholder engagement to advance geothermal energy. Many of the Roadmap actions focus on areas related to cost: reduced development timelines, which can improve project economics; improved technologies that can more reliably explore for and target wells; and improved technologies that can reduce well-drilling costs and improve well productivity through

#### Electricity

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EGS 8.5% of total generation by 2050 (20.4% of all RE generation)



GHP 2 million installed vs. 28 million potential

Heating/Cooling



Direct Use (EGS) 0.1 GW installed vs. 320+ GW potential

novel stimulation techniques. The Roadmap also discusses actions related to high-resolution resource assessments, geothermal market structures, added-value streams, and workforce education. The combined body of actions in the Roadmap can take geothermal from being a niche energy source to playing a measurable role in America's energy future.

Just as developing the *GeoVision* analysis required collaborative engagement, ensuring the continued contribution of geothermal energy as a renewable and reliable energy solution for the United States will require collective commitment from the entire geothermal community. Executing the actions in the GeoVision Roadmap and continuing to seek new and evolving opportunities for geothermal energy can help stakeholders realize the common goal of achieving high levels of geothermal deployment. Realizing the deployment potential of geothermal resources can provide benefits to the United States and contribute to America's diverse, affordable, and secure energy future.

# # #

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#### GeoVision at the GRC Annual Meeting & Expo

The DOE *GeoVision* Report will be the subject of much discussion at the meeting in Palm Springs, California from 15-18 September. There will be a panel session on the "State of the Industry" during the Opening Session on Monday, 16th September and on Tuesday morning, September 17 a three hour plus time-slot will be devoted to the GeoVision Report and its ramifications for the geothermal energy industry.



GRC ANNUAL MEETING SEPTEMBER 15-18, 2019

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# The Relationship between Geothermal Fluid Flow and Geologic Context: A Global Review

Irene C Wallis<sup>1</sup>, Julie V Rowland<sup>1</sup>, and David Dempsey<sup>2</sup> <sup>1</sup>School of Environment, University of Auckland, 23 Symonds Street, Auckland Central, New Zealand <sup>2</sup>Engineering Science, University of Auckland, 70 Symonds Street, Auckland Central, New Zealand

### Keywords

- Global Review
- Permeability
- Structure
- Intrusive
- Basement Rocks
- Conceptual Model

### ABSTRACT

Geothermal fluid flow is related to geologic context from the global or district scale down to the reservoir scale. We present a discussion of that relationship that is based on a review of hightemperature geothermal reservoirs worldwide. Initially we focus on large-scale geological controls on productive geothermal reservoirs, such as the role crustal-scale structural discontinuities play in localizing highly productive geothermal reservoirs. We present five district-scale case studies including: the Taupō Volcanic Zone in New Zealand, the Great Sumatra Fault in Indonesia, the East African Rift System that hosts geothermal development in Kenya and Ethiopia, the spreading plate boundary that bisects Iceland, and the Great Basin in western US.

In the second half of this paper we review the control geological context has on the natural state reservoir geometry. We demonstrate that the degree of influence of a geological discontinuity (e.g., structure, contact zone or unit with high hydraulic potential) on reservoir geometry typically reflects how focused that resource is. Focused reservoirs have high well-to-well temperature gradients and complex thermal geometry. Broad reservoirs with low temperature gradients between wells show less influence from geological discontinuities in the natural state. We conclude with an exploration of the influence that basement or intrusive rocks have on the geometry of reservoir permeability and the distribution of productive zones. We illustrate these interplays between geology and reservoir geometry using published cases from a range of geological settings.

#### 1. Introduction

Considering the relationships between geology (lithology, structure, and alteration) and permeability, from global, through district, and down to reservoir scale, enables us to identify favorable conditions for reservoir localization. This also permits us to quantify the diversity of reservoir geometry. To undertake this work, we conducted a global review of developed, high-temperature geothermal systems using published literature. Herein we summarize the results of review to date.

The paper is structured according to scale, with the global distribution of geothermal systems presented first. District-scale controls on the localization of geothermal systems are then explored using five case studies. For the reservoir scale, we first propose a framework for comparing the geometry of the permeable reservoir and then explore one kind of geologic context—the role crystalline rocks play in reservoir permeability. The discussion of reservoir architecture and crystalline rock is contextualized by a set of conceptual models compiled from the published literature.

#### 2. Global-Scale Distribution of Reservoirs

It is well known that tectonic processes, including subduction zones, spreading ridges and rifts, and intraplate hot spots such as Hawaii or Yellowstone, drive a high heat flux though the Earth's crust and that these are ideal conditions for localizing high-temperature geothermal reservoirs (Acharya, 1983; Chi and Lin, 2015; Moeck, 2013; Muffler, 1976). This relationship is illustrated by the way most of the 159 developed reservoirs cluster along active plate boundaries (Figure 1). These same tectonic settings are foci for volcanism, a more punctuated method of fluxing heat from the crust. Traces of magmatic input are common in reservoir fluids (Giggenbach, 1995). However, some reservoirs show no sign of magmatic input, including systems in the Great Basin (Simmons et al., 2017) and the back-arc setting of Honduras (Laughlin and Goff, 1991).

The map in Figure 1 plots developed geothermal systems and, therefore, illustrates the distribution of those resources that possess three key criteria for sustaining an energy project sufficient temperature and permeability, and a benign (or manageable) chemistry (Cumming, 2016). However, there is bias in this distribution of



Figure 1: Global distribution of geothermal systems developed for electricity (compiled from Bird, 2003; NaturalEarth, 2017; ThinkGeoEnergy, 2017) and the five case-study districts in Figure 2 are highlighted: (1) Great Basin, US, (2) Iceland Ridge, (3) East African Rift System, (4) Sumatra, Indonesia, and (5) the Taup Volcanic Zone, New Zealand.

developed reservoirs because there are also social, cultural, environmental, and economic reasons that preclude reservoir development. The process of development, to a greater or lesser extent, characterizes the subsurface. Nearly 70% of energy developments have < 50 MWe installed but 11 geothermal systems host > 300 MWe of installed generation (ThinkGeoEnergy, 2017). The earliest development was in 1905 at Larderello, Italy (Parri and Lazzeri, 2016). Then in the late 50's to early 60's global geothermal development ramped up with projects in Japan, Russia, the US, and New Zealand (ThinkGeoEnergy, 2017).

#### 3. District-Scale Controls: Five Case Studies

We reviewed five districts that host geothermal development: the Taupō Volcanic Zone in New Zealand, the Great Basin in the US, the Great Sumatra Fault in Indonesia, the Iceland Ridge, and the East African Rift System that traverses the eastern corner of the African continent (Figure 2). These case studies illustrate a range of tectonic settings and enable us to investigate the control that regional structure may have on the localization of reservoirs.

#### 3.1 Great Basin, US

The Great Basin (GB: Fig. 2) is a ~600 km wide extensional domain that initiated between ~16-18

Ma ago as a result of evolving plate interactions along the North American Cordilleran margin during the Cenozoic period (Dickinson, 2002; Dickinson, 2006; Porter et al., 2014). Today, the GB comprises elongate horsts or tilt blocks that form ranges with sedimentary basins in the intervening fault-angle depressions (Dickinson, 2002). Strikeslip faults and pull-apart basin geometries are prevalent on the western boundary (Walker Lane fault system, eastern Californian shear zone) and this area overlaps with the numerous <8 Ma old volcanic centers of the Cascade Arc.

Many studies have assessed the role that structure plays in the localization of geothermal systems within the GB (including Bell and Ramelli, 2009; Blewitt et al., 2003; Cashman et al., 2012a; Cashman et al., 2012b; Coolbaugh et al., 2003; Faulds et al., 2006; Faulds et al., 2012a; Faulds et al., 2012b; Faulds et al., 2013 and others). Overall, these studies find that the largest reservoirs are located at the tips of major fault zones and at dilatational fault intersections where major graben-bounding faults are intersected by transversely orientated transfer faults that are undergoing oblique slip. Reservoirs also typically localize at steps, fault intersections, and overlapping or terminating locations but rarely form at displacement maxima or mid-segments of normal faults (Faulds et al., 2011). Faulds et al. (2012b) found that the distribution of reservoirs correlates with areas of higher strain rate; although the presence of recent (<0.5 Ma) magmatism may also play a role.

#### 3.2 Iceland Ridge

The oceanic spreading ridge traverses on shore in Iceland to form a complex series of rift segments and transform zones (Khodayar et al., 2010) that accommodate ~18 mm/yr of spreading between the Eurasian and North American plates (Sigmundsson, 2006). The ridge comprises three purely divergent segments: the Northern, Western and Eastern Rift Zones, where the latter two lie subparallel in the south (Ziegler et al., 2016). The plate boundary comes on shore at the Western Rift Zone and traverses the South Iceland Seismic Zone before extending northward though the Eastern and Northern Rift Zones (Figure 2).

All of Iceland's 33 geothermal systems are located within these rifts (Ármannsson, 2016).

Similarly, active volcanism, which consists of central volcanoes and dike-fed fissure eruptions, is found along the rift axis (Sigmundsson, 2006). The relationship between the volcanic features and geothermal systems of the Iceland Ridge is remarkable. At Krafla, the deep upflows are thought to be localized by fissure swarms (Langella et al., 2017) and Nesjavelliar, a reservoir within the Hengill system, is contained within a rift that extends northward from a central volcano (Zakharova and Spichak, 2012). However, the active transfer zones that cross the north and south extents of the Iceland Ridge also appear to play a role in localizing geothermal fluid flow (Khodayar et al., 2010; Lupi et al., 2010): All developed reservoirs are clustered on these intersections (Figure 2).

#### 3.3 East African Rift System

The East Africa Rift System (EARS: Figure 2) is a continental rift organized into branches, each a narrow zone of thinned crust that is aligned along pre-existing continental weaknesses, and is intruded by asthenospheric mantle (Chorowicz, 2005). These narrow zones of deformation comprise graben systems that are linked and segmented by transfer zones (Ebinger et al., 1999). Overall, the East African Rift System has an average spreading rate of 3.2 mm/yr with rates > 6 mm/yr to the north of the Aswa transform and < 4.3 mm/yr to the south where two rift segments accommodate for the relative eastward movement of the Somalian plate from the Nubian plate (Stamps et al., 2008).

There are reports of around 30 geothermal systems in the EARS (Demissie, 2010; Pürschel et al., 2013), and four have been developed to date. All but one of the developed geothermal systems are located within the central portion of the Kenyan rift where it takes a sharp bend from its overall northward trend to a northeast orientation. The diffuse Aswa transfer zone meets the rift at this bend before continuing southeast of the Kenyan Rift to form the North Tanzania volcanic and fault belt (Figure 2, Chorowicz, 2005). Aluto-Langano geothermal system is associated with a dormant volcanic center within the Main Ethiopian rift (Abebe et al., 2016).

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#### 3.4 Great Sumatra Fault, Indonesia

The Great Sumatra Fault (GSF: Figure 2) is a 1660 km long, segmented, right-lateral strike-slip fault system that bisects Indonesia's largest island (Bellier and Sébrier, 1994; Sieh and Natawidjaja, 2000). This mega-shear initiated in the mid-Miocene through a pre-Tertiary basement that is dominated by metasediments, Tertiary age volcanic rocks and intrusions, and sedimentary basin deposits (Barber et al., 2005). A subduction-related, late Pliocene to Quaternary series of volcanic centers is spatially coincident with the GSF but a causal link between the GSF and distribution of volcanism is debated (Bellier and Sébrier, 1994; Sieh and Natawidjaja, 2000). The geometrically complex, segmented form of the GSF is unusual. In contrast with the San Andreas Fault in the US, which has a single stepover discontinuity wider than one kilometer, the GSF has more than a dozen such discontinuities with widths that range between ~5 and 12 kilometers (Sieh and Natawidjaja, 2000). Similarly, the San Andreas Fault only has two large bends whereas the GSF has ~8 (Sieh and Natawidjaja, 2000).

Around 30 high-temperature geothermal systems have been identified in Sumatra (Hochstein and Sudarman, 1993), but only five are developed or near commissioning. Sumatra contains systems whose locations appear to be strongly correlated to the GSF (e.g., Muara Laboah: Mussofan et al., 2018) and others whose position appears more related to the volcanic arc (e.g., Sibayak: Hochstein and Sudarman, 1993). The five developed systems occur close to the ends of segments defined by earthquake clusters (Figure 2, Burton and Hall, 2014). These seismogenic segments closely resemble those defined geologically by Sieh and Natawidjaja (2000) on the basis of geomorphological features, including fault bends and step overs, and the distribution of rock type. None of the geologically defined surface ruptures cross the seismogenic segments but some surface ruptures were combined into a single seismogenic segment. Burton and Hall (2014) argue that the latter is reasonable because surficial fault manifestations are secondary to the deep structure that seismicity defines. When all Sumatran reservoirs are considered, the spatial relationship to seismogenic segments disappears.

#### 3.5 Taupō Volcanic Zone, New Zealand

The Taupō Volcanic Zone (TVZ: Figure 2) is a ~300 km long, NE-trending arc that includes an anomalously hot and highly productive central silicic segment (Wilson and Rowland, 2016). This arc is widening (~12 mm/year in the central TVZ: Wallace et al., 2004), and extensional strain is accommodated by a series of NE-striking rift segments and NW-to-NNW trending transfer zones whose geometry is, in part, controlled by inherited structures (Rowland and Sibson, 2004; Seebeck et al., 2014). The central TVZ contains deep (>3000 m) rift basins through metasedimentary basement that are infilled with the products of ~2 Ma of volcanic evolution from a typical andesitic arc to a vigorous silicic system dominated by caldera-forming eruptions (Wilson et al., 1995). Accordingly, the rift basins have complex stratigraphy, dominated by quasi-layer cake volcaniclastic products, their reworked equivalents (predominantly lake deposits), and lavas, and is pierced by intrusions and associated domes (Downs et al., 2014 and references therein).

In central TVZ, 23 active geothermal systems are delimited (Bibby et al., 1995), and seven of these have been developed for electricity generation. Modern geothermal activity forms two belts parallel to the rift fabric on either side of the Taupo Fault Belt. Although that fault belt currently lacks geothermal activity, it has hosted systems in the recent past (Kissling et al., 2018). The greatest heat output occurs in, and on the flanks of, the Taupo-Reporoa Basin, which is rapidly subsiding yet lacks the fault morphology apparent in the Taupo Fault Belt to the west (Rowland et al., 2010). The exceptional heat output in this basin may reflect, in part, its tectonic position at the margin of the predominantly extensional TVZ and the rightlateral strike slip North Island Fault System, and also its magmatic position above the axis of the arc (Rowland et al., 2010). Geothermal systems also occur on NW-to-NNW alignments that are contiguous in places with alignments of young (<61 ka) silicic vents, and spatially coincident with transfer zones between rift segments that are inferred to align with basement structures (Rowland and Sibson, 2004; Rowland et al., 2010). Based on geomorphic and geophysical data (Henderson et al., 2016; Rowland et al., 2016),

such transfer zones appear to be contiguous with major faults of the Hauraki Rift, a lithosphericscale feature that lies to the north of the TVZ and parallels major sutures between basement terranes. Most developed systems cluster where the Hauraki Rift intersects the TVZ. Kawerau is the only system that falls outside this cluster. However, basement structures associated with the North Island Fault Belt intersect the TVZ in this area (Figure 2).

### 3.6 Key District-Scale Findings

At the district scale, our review confirms the increasingly well-established links between structure and geothermal circulation (Blewitt et al., 2003; Curewitz and Karson, 1997; Faulds et al., 2012b; Faulds et al., 2013; Hinz et al., 2016; Micklethwaite and Cox, 2004; Rowland and Sibson, 2004; Rowland and Simmons, 2012). Previous reviews of the relationship between structure and geothermal systems within the Great Basin (Faulds et al., 2013) and arc settings (Hinz et al., 2016) showed that geothermal systems are commonly associated with interaction zones and intersections, while rarely associated with simple fault traces. Hinz et al. (2016) demonstrated that the most favorable tectonic settings for productive geothermal systems are extensional, transtensionalextensional and transtensional-strike slips. Our district-scale case studies agree with these findings and highlight the role of regional transfer zones (e.g., South Iceland Seismic Zone or Aswar transfer in East Africa: Figure 2). Inherited structure, such as that which localizes the Hauraki Rift in the TVZ, appears to influence the geometry of these transfer zones as well as the productivity of geothermal systems. In the case studies, we repeatedly found a strong spatial relationship between district-scale structure and developed geothermal systems, but these relationships do not hold when undeveloped resources are included. It is possible that developed reservoirs represent a special subset of sites where regional structure preferentially localizes systems with attributes that are favorable for energy development.

#### 4. Reservoir-Scale Controls

In geothermal resource development, the foremost tool for describing the nature of a reservoir is the conceptual model. White's

(1968) definition of Steamboat Springs was one of the earliest conceptual models to appear in published literature and its format is archetypal: diagrammatic sections that typically comprise hydraulic arrows, temperature isotherms or a vertical temperature profile, and relevant components of the geology and alteration. Sections are typically accompanied by explanatory text and may, as illustrated by the vignettes presented in Figure 4, also include details like fluid geochemistry and phase.

An existing nomenclature accompanies the conceptual model. Some terms most reflect the liquid geochemistry (amagmatic, volcanic), while others describe reservoir thermodynamics (liquiddominated, vapor-dominated). Distributed and fault-hosted are the common terms deployed to describe the geometry of the permeable reservoir—a core area of interest in our review. However, we found this existing terminology too binary to describe the range of reservoirs reviewed. Furthermore, fault-hosted (the inverse of distributed) was too genetic—faults are not the only feature that host a non-distributed reservoir.

In response, we proposed a framework for discussing the architecture of the permeable reservoir that uses a continuum between two geometrical end-members, termed focused and unconstrained flow (Figure 3: Wallis et al., 2017). Rather than a system of absolute categorization, this continuum is a tool for comparing reservoirs and considering the degree of influence that geological features may have on the geometry of the plume. As illustrated by Figure 4, the plume is defined by the natural state distribution of isotherms. If reservoir paragenesis is simple and without a complexly overprinted record of the system waxing and waning, then patterns of hydrothermal alteration, mineral geothermometers, and fluid inclusions may also be used.

A focused reservoir is restricted to structural damage zones, such as those associated with faults (e.g., Dixie Valley in the GB: Benoit, 1999), fissures (e.g., Puna, Hawaii: Lewis-Kenedi et al., 2010), or intrusions (e.g., Yamagawa: Sasada et al., 2000). Lithological unit(s) with comparatively high permeability may also result in focused reservoirs that are elongate in the horizontal dimension (e.g., Yangbajing: Jianyun et al., 2015). As illustrated by



Figure 2 (NEXT PAGE):Five district-scale case studies illustrating the relationship between geothermal reservoirs and geologic setting: Great Basin (Blakely et al., 2007; Faulds et al., 2006; Faulds et al., 2012b; Porter et al., 2014; USGS, 2017), Great Sumatra Fault (Barber et al., 2005; Burton and Hall, 2014; Hochstein and Sudarman, 2015; Natawidjaja, 2018; Sieh and Natawidjaja, 2000), Iceland Ridge (Ármannsson, 2016; Arnórsson et al., 1983; Bourgeois et al., 2005; Khodayar and Björnsson, 2014; Khodayar et al., 2010), Taupō Volcanic Zone (Heron, 2014; Rowland and Sibson, 2004; Wilson and Rowland, 2016), and East African Rift System (Chorowicz, 2005; Demissie, 2010; Pürschel et al., 2013). Compiled from published literature as cited and adapted from Wallis et al. (in review).

the Dixie Valley and Hatchobaru-Otake in Figure 4, the temperature distribution of a relatively focused reservoir tends to be complex and include steep gradients. The permeability of a focused reservoir is typically highly anisotropic and may be compartmentalized. Subsequently, fluid flow within adjacent reservoir zones may have different chemistry, temperature, or pressure.

At the other end of the continuum is a hypothetical member where all of the geological architecture, aside from the clay cap, is above the limit for convection. Therefore, an absolutely unconstrained reservoir will form vertically above the upflow zone and mushroom symmetrically near the surface. Depending on hydrologic drivers, such as topography or large bodies of surface water, the plume may be somewhat inclined (Ratouis and Zarrouk, 2016). Although no reservoir reviewed to date is absolutely unconstrained, this geometry is the true antithesis of a focused reservoir.

A range of geometries lie between the focused and unconstrained end-members where the permeable volume and, therefore, geothermal plume may bend around or be contained within major contrasts in permeability created by abutting lithologies, alteration zones, or major faults. For instance, the southeastern extent of the Putaha reservoir in Indonesia is truncated by what is thought to be up-faulted, low-permeability basement rock (Figure 4: Layman and Soemarinda, 2003). A single system can comprise multiple reservoir geometries. For example, both Rotokawa and Nagamariki consist of a deep, relatively



Figure 3: (A) A graphical definition of the geothermal system and a reservoir within it; noting that several reservoirs may be associated with a single system. The dashed box equates to the extent of the reservoir and the geometries depicted in the lower half of the figure. (B) Cross sections representing the continuum of reservoir permeability geometry from focused to unconstrained flow. Along this continuum, the geothermal plumes are variously influenced by geologic context. Figure adapted from Wallis et al. (2017).



Figure 4 (NEXT PAGE): Conceptual model vignettes that have been compiled from published studies of eight geothermal systems: Dixie Valley (Blackwell et al., 2000; Lovenitti et al., 2011), Sillangkitang (Gunderson et al., 2000; Hickman et al., 2004; Moore et al., 2001), Mori (Hanano et al., 2005), Hatchobaru-Otake (Fujino and Yamasaki, 1984; Hirowatari, 1991), Patuha (Layman and Soemarinda, 2003), Rotoaka (Sewell et al., 2015; Wallis et al., 2013), and Ngatamariki (Boseley et al., 2010; Buscarlet et al., 2015; Chambefort et al., 2016). Compiled from published literature as cited and adapted from Wallis et al. (in review).

unconstrained reservoir that is overlain by a focused intermediate aquifer that is constrained within a layer of rhyolite lavas sandwiched between zones of smectite-altered rock (Figure 4, Boseley et al., 2010; Sewell et al., 2015).

Metamorphic and intrusive rocks, which can be referred to collectively as crystalline rocks, influence reservoir geometry. They have low primary porosity and their permeability depends on secondary porosity. Therefore, the tectonicgeological history and the active stress state have great influence on the permeability distribution, so permeability can vary over a huge range (Figure 5, Achtziger-Zupančič et al., 2017). Depth of burial also influences the permeability of crystalline rock: mean permeability at the surface is 10-13 m2 whereas the mean at 2 km depth is 10 17 m2 (Achtziger-Zupančič et al., 2017), where the latter is below the limit for convection (~10-16 m2: Hanano, 2004).

Deep crystalline rocks tend to result in focused or truncated reservoirs unless fault-fracture networks proliferate. For example, at depth, Coso consists of four weakly connected reservoirs hosted in fractured Mesozoic intrusive and metamorphic rocks (Adams et al., 2000). Permeability is high within these reservoirs but low in the surrounding rock, and faults play a significant role in the reservoir geometry (Davatzes and Hickman, 2010; Newman et al., 2008). At Sillangkitang, Indonesia, the reservoir extends west from the fault zone into rhyolitic tuff but not east into the basement (Figure 4: Hickman et al., 2004). At Ngatamariki, the geometry of the permeable reservoir is truncated by the intrusive complex and the overlying zone of intense high-temperature alteration (Figure 4: Chambefort et al., 2017; Clearwater et al., 2015).

Despite their overall low permeability, the margins of intrusions and basement unconformities may provide sweet spots for geothermal production because these zones can be foci of intense fracturing. Despite the generally low permeability of the hot and potentially productive basement at Ohaaki, New Zealand, drilling losses are only observed in the upper ~200 m of that unit (Wood et al., 2001). A similar pattern is seen at Hatchobaru-Otake, Japan, where the deep, fault-focused reservoirs spread in lateral extent at the contact between the basement and overlying volcano-sedimentary sequence (Figure 4: Fujino and Yamasaki, 1984). At Ngatamaiki, wells completed into the pluton found low permeability except where they encountered damage zones at the edge of the intrusions (Clearwater et al., 2015). Not all intrusions result in local permeability increase. For example, Wood et al. (2001) described a well at Ohaaki that intersected an ~10 m wide dike in the basement without any noticeable increase in permeability. Permeability would depend on the persistence of open fractures in the face of alterations and their connection with the surrounding reservoir.

### 6. Concluding Remarks

We have summarized our multi-scale review of the relationship between geologic context and geothermal permeability. The key points are listed below.

- Our review is consistent with previous studies demonstrating that geothermal systems are prolific in regions with active tectonic processes: in particular, extensional or transtensional tectonic settings. Although there is a spatial overlap with the distribution of recent volcanism, this may be coincident because amagmatic reservoirs exist and both are methods of fluxing heat from the crust.
- Developed geothermal systems are often associated with regional transfer zones (i.e., zones that accommodate stress between major structural alignments). In turn, the localization and geometry of those transfer zones are influenced by the deep-rooted basement structure.
- Using case studies, we demonstrated that crystalline rocks play a major role in reservoir permeability, such that they influence both the overall geometry of the convection cell and the distribution of well productivity (sweet spots).
- The existing nomenclature for describing the architecture of the permeable reservoir was found inadequate for capturing the global diversity. Therefore, we proposed a continuum that supports characterization of the relationship between geology and permeability, as well as reservoir-to-reservoir comparison.

Our review provides a robust conceptual framework for planned further research into the causal relationships between geologic context (structure, lithology and alteration) and permeability in high-temperature geothermal reservoirs.

#### ACKNOWLEDGEMENTS

The research is funded by a University of Auckland Doctoral Scholarship. The authors thank Bill Cumming for his insightful comments and discussion which contributed to the development of this work. The literature review benefited greatly from the ready access to grey literature provided by the IGA and GRC conference paper databases.

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# Geothermal Well HGP-A: Hawai'i's First Successful Geothermal Well

By Hawai'i Groundwater and Geothermal Resources Center

Due to interest in geothermal energy, the University of Hawai'i (UH) coordinated geothermal research and established the Hawai'i Geothermal Project in 1972. Geologists and engineers from two UH units--Hawai'i Institute of Geophysics and Planetology (HIGP), School of Ocean and Earth Science and Technology, and College of Engineering--conducted geophysical, geological, and geochemical research and found areas of geothermal interest on Hawai'i island by 1974.

HIGP chairperson Agatin Townsend Abbott led the geological research from February 1974 and formed a committee to select experimental drilling sites. Reviewing the research, the committee selected the eastern flank of Kīlauea Volcano as a site for deep-test boring. On July 31, 1975, Dr. Abbott passed away at the age of fifty-seven. To recognize his integral role in the project, the Hawai'i Geothermal Project was renamed "Hawai'i Geothermal Project -- Abbott" (HGP-A).

After an extensive geophysical survey and experimental drilling in the lower Kīlauea East Rift Zone, in 1976, UH drilled Hawai'i's first geothermal well to produce steam. With a rotary rig, UH drilled the well HGP-A just south of Pu'u Honua'ula, the initial vent site of the 1955 eruption, in Puna, Big Island. At 6,450 feet deep, HGP-A operated as one of the hottest geothermal wells in the world. HGP-A reached a maximum temperature of 676°F (358°C) and a total mass flow of approximately 100,000 pounds per hour, with nearly equal amounts of both liquid and steam at a surface temperature of 365°F (186°C).

From July 1981 to 1989, a 2.8-megawatt electric plant used HGP-A's energy to power the Hawai'i Electric Light Company's grid. The plant's flowing pressure and steam fraction kept constant.

HGP-A sparked for-profit geothermal exploration and development in the Kilauea East Rift Zone. From 1981 to 1985, Barnwell Industries and Thermal Power Company drilled and tested wells, but abandoned them without profiting. In March 1986, Puna Geothermal Venture (PGV) and Hawai'i Electric Light Company entered a contract in which PGV would supply 25 megawatts of electricity to Hawai'i Island by 1993. The first and only commercial geothermal power plant in the Hawaiian islands, PGV supplied Hawai'i Island electricity from 1993 to mid-2018, when the Kilauea eruptions buried parts of the power plant. In 2017, PGV provided about a third of Hawai'i Island's electricity and half of the island's renewable energy. PGV plans to reopen by 2020.

Originally designed as a two-year demonstration project, HGP-A continued operating until the end of 1989. In 1986, the U.S. Department of Energy transferred the HGP-A facility to the State of Hawai'i for further research. Eventually, the well was plugged and abandoned. In 2018, Kīlauea's lava buried the HGP-A site.

The National Science Foundation, U.S. Department of Energy, and the state and county governments funded this research.

More historical information and materials about Hawai'i's geothermal development can be found at the Hawai'i Groundwater and Geothermal Resources Center's website: https://www.higp. hawaii.edu/hggrc/.

### Photographs (see the next two pages)

- 1. Dr. Agatin Townsend Abbott, the first leader of HGP-A's geological research and the namesake of the "A" in "HGP-A."
- 2. The conceptual design of the HGP-A facility
- 3. HGP-A Site Layout
- 4. Visitors tour the HGP-A facility during the transfer ceremony on November 13, 1986.
- 5. A Hawaiian minister blesses the HGP-A facility during the transfer ceremony on November 13, 1986.
- 6. The HGP-A facility during maintenance on September 20, 1989.
- 7. The rock muffler system on September 20, 1989.
- 8. Dr. Donald Thomas takes water samples from HGP-A on December 5, 1989.
- 9. Another research tests the valves on HGP-A's well head on December 5, 1989.
- 10. HGP-A gas separator on December 5, 1989
- 11. The downhole coaxial heat exchanger project by the Pacific International Center for High Technology Research on March 29, 1991 (5 photographs). ■



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# The Energy Potential Still Beneath Our Feet: How Germany's Energy Future May Stem From Its Past

By Clinton Smith, MBA, EIT

University of Kentucky, Humboldt Fellow, 2018-19 and past president of the GRC Student Committee.



During my time here working as a guest researcher in Germany's North Rhine Westphalia (NRW) region, it has been my duty to cover the transitional phase that they are undergoing in pursuing alternative energy sources compared to

traditional forms-namely coal. Since the 90's and the influx of the Red-Green party coalition led by then Chancellor Gerhard Schröder, the foundation was laid for the continued dominance of the Social Democratic Party (SDP) and environmentally minded Bundesrat (or congress) to push forward several environmentally friendly and innovative policies, in addition to the rising costs associated with coal power domestically. Which brings us to today: the Energiewende movement started back in 2010 with the ambitious goals of reduced green house gas emissions by 40% in 2020 and 55% by 2030. What results though have come about in the NRW, and how have these events intrinsically changed a landscape once so dominated and supported by coal?

I sit on the campus of the University of

Duisburg-Essen in a corner office with a nice view of Prosper Haniel, the last hard coal mine shutdown in 2018 with one of the key researchers involved in a project which came about as a result of this shutdown, Dr. Andre Niemann. This view speaks volumes, with the history of the region so closely in view from the innovative bodies which wish to change the landscape of the area. When talking back on the way in which the project was conceived, Niemann believes the process goes further back than Merkel's announcement in 2010.



Dr. Andre Niemann (left) and author Clinton Smith.

"It was a decided process... In the UK you saw the shutdown of UK manufacturing in the 80's. Then the rioting on the streets—the same with mining in the North of France. We decided to do it differently."

He insists the slow conversion process, and

government subsidies were the reason that the region was able to deal with the transition so well. "... We didn't do it [that way]. We decided to pay for it and give it [government] subsidies to put it at the market price. Of course, because of this you have the time to fade out slow(ly). This gave us time to convert these mining sites."



All political influences aside, the project itself was still an amazing and ambitious goal to set for a group of scientists and researchers from the region to undertake. With input from the universities of Duisburg-Essen, and Ruhr University of Bochum, as well as independent engineering agencies and cooperation from the representative organization of the coal industry, Ruhrkohle AG (RAG). It was only with the single-minded approach of all these entities coming together both as an academic and economic pursuit, which made this possible. Even professor Niemann himself was somewhat surprised at how smoothly it went at some points. Niemann chuckling while recalling is his first interaction with RAG regarding the project, "They called me [stating]: 'my name is --blank-- with RAG and I wanted to inform you that we will cooperate, and tomorrow it will be in the media.""

#### The Project

The project first started from looking at the different possibilities leading up to the decision by the government. Niemann states, "We wanted to look at the mine afterward for follow-up purposes. There was the remaining gas in the shaft, then there was the geothermal heat aspect, with overall 40 square kilometers of potential heating area, and finally the usage of the mining water already present for heat storage."

Ultimately, they decided that the best way to go would be the latter, utilizing the existing infrastructure to create an energy storage device. Niemann states, "The Energiewende is going along now with SPV and wind power plants with completely a decentralized structure... with 30% energy demand being met by alternative energy, and of course in times of no wind or solar, there will be a need for a system of energy storage."

Taking advantage of the already possessed knowledge by the RAG they conducted a thorough assessment of the mine's structure and found that with a nearly 600-meter (≈1970 feet) elevation differential, they could create a pump hydro design to effectively store energy deep underground. The question then became what is the most costeffective manner to create such a system?

Niemann says it came down to two options, "We checked the geology and looked at either using the existing coal transportation (tunnels) of the mines, or to create an entirely new ring structure for permanent storage of water."

"These (existing) opportunities were something that nobody had realized before," Niemann remarks. "... Having this idea in mind, we had a conversation with the mining operators and our politicians, and they (were) really fascinated by this idea and requested that we conduct a feasibility test."

The test was comprehensive. After being granted just north of €3 million Niemann and his team of experts went to work. Working with at one time the project consisted of up to 50 researchers analyzing all aspects of the project. With Dr. Eng. Hermann Wagner from Ruhr University Bochum leading the work done for the underground energy storage capacity, Dr. Ulrich Schreiber of University Duisburg Essen, the initial conceiver of the project leading the work to be done for the Geological and Geotechnical analysis, Tobias Friedrich from DMT GmbH mining consultants and the Ruhr Institute for Social Research and Policy Consulting (RISP), they set out to cover every side of the potential project's feasibility.

With widespread acceptance from both the public, regional and federal governments, as well as the RAG themselves, the next step was to present their findings in their research. Dr. Niemann mentions, "We carried out our research and the project development in a very public way. Every step of the investigation was open to the public. We even discussed as, 'is there a different idea or a better solution for our problems we are tackling?"

The final findings from the project was that the safest and most cost-effective method would be to construct an entirely new 15 km long inclined "ring" or "loop" design with the help of existing mine infrastructure and utilizing a tunnel boring machine than to spend money on reinforcing the



existing structures to withstand the new pressure gradients that would be potentially present under future use. This final design concept gave way to a potential final project finding of a new energy storage site capable of holding up to 200 MW of power.

#### Aftermath and the Status of the Energy Market

Despite overall positive public sentiment, government and business cooperation, in late 2018 Niemann and his coalition were forced to announce that the project would not be coming to fruition. With the current status of the energy market and lowering costs for natural gas, the business proposal and "the return on investment is not clear to companies," contends Niemann. Perhaps an even greater obstacle he thinks though was the obstacle of *time*. Despite having nearly nine years to perform these analyses, "we were always in a hurry," he says.

The date of late 2018 being the time in which their decision was made to abandon the project should also come as no surprise or coincidence. This was the timeline for the end of hard coal mining to be completed in Germany. As a result, "The RAG company has no miners left to be in the ground for us... and so then we would be forced to change our plans," remarks Niemann. And of course, with any large project, changes like those come at a large cost. At the scale of nearly €2 million per month to keep the mine, even if only partially, open for further construction of their project.

When asking him how long he would expect necessary for a top-to-bottom project like the one he and his team sought to realize Niemann thinks it would be more prudent to aim for 15 to 20 years.

But Niemann remains positive, and for good reason. Following the beginning of his team's project, it has continued to receive both national and international attention and acclaim. News organizations like National Geographic and Deutsche Welle have published articles and videos, respectively covering the potential for projects like this to high acclaim. In addition to other regions taking their project idea into consideration, foreign governments have taken notice as well, with countries such as Poland, France, Belgium, South Africa, and China sending delegations and requests for inquiry. Even the US has shown interest with parties from the State of Virginia having come over to investigate what kind of potential these kinds of post-coal renovation projects could hold for them.

Personally, I also agree and believe that what Niemann and the region of North Rhine Westphalia have accomplished here is monumental. Although they were not able to see their research through to reality, they have been able to lay the groundwork and open the possibility for innovation in the future, which ultimately is how we seek and pursue opportunity both in our world of geothermal and alternative energy.

### **Calendar of Events**



#### 43rd GRC Annual Meeting & Expo

**15-18 September, Palm Springs, California, USA** www.geothermal.org/meet-new.html

### Energy Policy Research Conference (Energy Policy Institute )

**29 September - 1 October, Boise, Idaho, USA** https://www.boisestate.edu/epi/eprc9/

#### 1st Philippine Geothermal Conference (National Geothermal Association of the Philippines) Beyond Conventional: Low-Medium-Enthalpy Geothermal Resources and Applications

**2-3 October, Manila, Philippines** https://www.ngaphil.com/

#### **Praxisforum Geothermie.Bayern** 7-9 October, Munich, Germany

www.praxisforum-geothermie.bayern/en

#### European Geothermal Workshop 2019 -Characterization of Deep Geothermal Systems 9-10 October, Karlsruhe Institute of Technology, Germany

http://www.agw.kit.edu/EGW2019.php

#### Earth Science Week - American Geosciences Institute 13-19 October, USA http://www.earthsciweek.org/

#### Demonstration of deep geothermal in Europe – MEET H2020 technical workshop (MEET project) 23 October, 9am-7pm, Palais des Congrès, Arcachon, France Workshop is free

https://www.eventbrite.fr/e/billets-demonstrationof-deep-geothermal-in-europe-meet-h2020-technicalworkshop-63956357186

### 7th London Geothermal Symposium (Geological Society)

5 November, Burlington House, London, United Kingdom https://www.geolsoc.org.uk/GSL-7th-London-

Geothermal-Symposium

#### **IGC Turkey Geothermal Congress & Expo**

**6-8 November, Izmir, Turkey** https://www.igc-turkey.com/

#### Der Geothermiekongress 2019

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

#### **1st Canadian Geothermal Students Day**

**21-22 November, Québec City, Québec, Canada** https://canadiangeothermal.wixsite.com/cgsd

#### Joint EAGE/BVG/FKPE Workshop on Borehole Geophysics and Geothermal Energy

**22 November, Munich, Germany** https://eage.eventsair.com/boreholegeophysics2019/ event-overview

#### 41st New Zealand Geothermal Workshop (NZGW)

25- 27 November, University of Auckland, Auckland, New Zealand https://nzgeothermal.org.nz/

#### 4th National Geothermal Conference -RENAG - Colombian Geothermal Association (AGEOCOL)

**25-28 November, Medellin, Colombia** https://renagcolombia.wixsite.com/2019

#### **COP 25 - Climate Change Conference**

**2-13 December, Santiago, Chile** https://unfccc.int/santiago

### American Geophysical Union - Annual Fall Meeting

**9-13 December, San Francisco, California** https://www2.agu.org/en/Fall-Meeting

#### GT'2020 Türkiye Jeotermal Kongresi

**5-6 February, 2020, Ankara, Turkey** https://geothermalturkey.org/

#### **GeoTHERM - Expo & Congress**

**5-6 March, 2020, Messe, Offenburg, Germany** https://www.geotherm-offenburg.de/de/geotherm\_ messe\_kongress\_geothermie

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

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

### Publications, Websites, Videos & Maps

by Ian Crawford



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Geothermal Well Test Analysis -Fundamentals, Applications and Advanced Techniques - Elsevier Inc.

By Sadiq J. Zarrouk, Senior Lecturer of Geothermal Engineering,

Department of Engineering Science, The University of Auckland, New Zealand and Katie McLean, Geothermal Reservoir Engineer, Contact Energy Ltd., New Zealand.

More Information.....



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### Geothermics



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### In Memoriam

### Subir Kumar Sanyal: An Appreciation of His Life

by James Koenig, Ann Robertson-Tait and James McNitt



The geothermal world has lost a creative, articulate and multi-talented scientist and engineer with the passing of Subir Kumar Sanyal on 28 June 2019, in Santa Cruz, California.

Subir was born in Calcutta in 1943, and as a young child

experienced the chaos and uncertainty of the 1947 partition into Pakistan and India. His family owned - and lost - land in what became East Pakistan (now Bangladesh), but they were not poor: his father was a professor of physics at a university in Calcutta. As the oldest of seven children, Subir was trained by his father to value precision, clarity and dedication in both schoolwork and personal relationships. This did not prevent him from getting into numerous mischievous scrapes while growing up.

Subir attended the Indian Institute of Technology, obtaining a Master of Science (MS) degree in Applied Geology/Geophysics in 1966. After a season doing geophysical fieldwork, he was awarded a Fellowship to the University of Birmingham in the UK. There he joined a prestigious dining club, appearing for meals in cap and gown. He obtained his second MS in Petroleum Engineering the following year.

From Birmingham, Subir next went to Stanford University, studying under Professors Sully Marsden and Hank Ramey. Subir's PhD in Petroleum Engineering was awarded in 1971. His work on temperature and pressure fronts in low-permeability rock was published in various journals, and served as a basis for later work on the low-permeability matrix of The Geysers geothermal system.

In the process, Subir had the distinction of winning advanced degrees from prestigious universities on three continents.

While at Stanford, Subir met and married Mary Elizabeth Murray, to whom he remained married for the rest of his life.

His next professional job was with Texaco, working offshore in the Gulf of Mexico, designing wells, and doing well-log interpretation and numerical simulation of subsea reservoirs. In 1975, Subir was employed as a Senior Specialist with the U.S. Geological Survey, doing research into welllog analysis, and modeling offshore oil and gas reservoirs.

Subir returned to the geothermal industry in 1975 as manager of reservoir engineering and geothermal operations for Geonomics, a company founded by the late Tsvi Meidav. By 1977, Subir had left Geonomics and returned to Stanford as Consulting Professor and Manager of Stanford's Petroleum Research Institute, specializing in secondary oil recovery and geothermal reservoir engineering.

Over the next three years, Subir developed contacts with GeothermEx, Inc., a privately owned consulting company, and in 1980, Subir once again left Stanford to become GeothermEx's Vice President for Engineering. He remained at GeothermEx for the next 35 years, succeeding founder Jim Koenig as President upon the latter's retirement in 1995.

GeothermEx's work activity was worldwide, and Subir had a leading role in almost all major projects. Much of his work focused on practical engineering solutions (designing, conducting and analyzing well tests; optimizing the output of pumped wells; numerical simulation and estimation of reserves), but he was also deeply involved the analysis of investment risk in geothermal projects.

Perhaps Subir's greatest contribution to the geothermal industry was his work on geothermal project financing. This began in the early 1980s, when he convinced Morgan Guaranty Trust Company to make the first-ever non-recourse geothermal loan (to Magma Power for its first



Subir Kumar Sanyal thanks his colleagues after receiving the Henry J. Ramey, Jr. Geothermal Reservoir Engineering Award in 2013, recognizing outstanding achievements in the field of geothermal reservoir engineering. In addition Subir was also a recipient of the Joseph W. Aidlin Award in 1997, recognizing his outstanding contributions to the GRC and to the development of geothermal resources. Subir was also a long-time member of the GRC Board of Directors.

power plant at Salton Sea). Thereafter, GeothermEx provided technical due diligence for the financing of geothermal projects representing thousands of MW of clean power. A key element of these due diligence efforts was Subir's refinement of the USGS volumetric resource estimation methodology to yield a range of long-term production capacity values (and their associated cumulative probabilities) for developing projects. This approach provided comfort to lenders about the most fundamental requirement of any geothermal project - the capacity of the resource - and facilitated financing for many greenfield geothermal projects. Subir's work in this area significantly advanced the global geothermal industry.

In his work for project developers, investors and financiers, Subir worked closely with GeothermEx colleagues Eduardo Granados, Chris Klein, Tony Menzies, Jim McNitt, Ann Robertson-Tait, Minh Pham, Jim Lovekin and James Morrow. In one memorable project, Subir worked with Menzies, Klein, McNitt and Granados to model an active geothermal system that is associated with a massive gold deposit in a volcanic caldera on Lihir Island in Papua New Guinea. Their modeling work convinced the project owner that open-pit mining could proceed, despite temperatures in the geothermal aquifer exceeding 200°C at 300 meters. Pressure-relief wells and dedicated geothermal wells were later used to generate electricity for the mining operation.

Most of the results of GeothermEx's many projects are proprietary to its clients. Nevertheless, Subir authored or co-authored more than 100 papers on aspects of geothermal resources that varied from case histories to benefit:cost analyses to training manuals. One of his most interesting, non-intuitive and widely read papers was "Why Hotter Is Not Always Better," which identified the productivity gap in the "no man's land" between pumped wells with temperatures up to 190°C, and self-flowing wells with production temperatures of 220°C or more. Subir also served as expert witness in cases in three countries, never being on the losing side.

There was nothing Subir liked better than programming. Together with James Morrow and Philip Brown, he wrote and compiled numerous Fortran programs to solve the many problems associated with well testing, numerical simulation and other engineering issues. He was also fascinated with pure mathematics and how nature seemed to be based on mathematical concepts.

It wasn't all work at GeothermEx - over the years, a tradition had developed of celebrating Friday close-of-work. There might be bottled beer or wine or single-malt whisky, but Subir made and served killer Martinis. Although that tradition ended with the acquisition of GeothermEx by Schlumberger in 2010, it is remembered fondly by GeothermEx staff and many clients and colleagues who happened to be in the office on a Friday evening.

Among Subir's varied interests was collecting edible mushrooms from undisclosed sites in Marin and Sonoma Counties. A rarity among the fungi he hunted in the forests was the chicken-of-the-sea mushroom, which smelled mouthwateringly like freshly roasted chicken. An enthusiast of Cajun cooking from his days on the Gulf Coast, Subir often hosted multi-course Cajun dinners that he fastidiously planned, prepared and generously shared with friends and family alike. Not one to remain idle, Subir was also an avid gardener. He grew topical fruit trees and wrote papers for the California Rare Fruit Growers (a horticulturist society). He and Mary Elizabeth bought a 20-acre property in the hills above the Sonoma coastal town of Gualala, and lovingly rebuilt existing structures and added new ones, and made many wonderful gardens. One of Subir's projects at Gualala was a supposedly ecologically self-perpetuating fishpond. It was not one of his better ideas: birds ate the fish, and he had to raise baby ducklings in an indoor bathtub to keep the snakes from eating them.

Never downcast for long, Subir was outgoing, charming, impulsive, highly inquisitive and creative; and also opinionated, stubborn, and unreliable about time. He was one-of-a-kind: the good Lord broke the mold when Subir was created.

Subir is survived by his wife, Mary Elizabeth, their son Nicholas Sanyal, and four grandchildren, Lucia, Olivia, Cooper and Gavin.

### **Alfonso Dodong Teves**



Conceivably the father of the southern Negros Geothermal Project, being its first general manager of PNOC at the Palinpinon geothermal site, Engr. Alfonso "Dodong" S. Teves, Jr., lived a full life of service to God and man. He passed away peacefully at the age

of 87 at the Silliman Medical Center Monday July 8.

Dodong Teves was first connected with DPWH and later the National Power Corporation, then as resident manager of Tolong Sugar Milling, after which he joined the PNOCEDC team that explored the potential of geothermal in the Philippines. He was the first project manager of the Southern Negros Geothermal Project, which started exploration in 1973 and commissioned its first power plant in 1983. He became the geothermal operations manager of PNOC-EDC handling all geothermal operations in the Philippines. He retired in 1991. (*Negros Chronicle* - Wednesday, July 17)

### George William Grindley 1925- 2019



George Grindley played a major role in the exploration and development of geothermal energy in New Zealand, including the first hot water geothermal field to be developed for electricity production in the world, at Wairakei.

He recognized the importance of active faults in siting new drill holes. He also worked on geothermal development projects overseas, including in Mexico and the Philippines. Once, during field work near hot springs, he stepped into a boiling mud pool severely burning his leg. But such incidents did not deter him from further work in geothermal areas. (*The Dominion Post* - Full article......)



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