GEOTHERMAL RESOURCES COUNCIL

Bulletin

Vol. 48, No. 3
May/June 2019

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

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Bulletin

Vol. 48, No.3
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Geothermal Resources Council

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

Advertisers

COVER: *Beautiful sunsets and graceful palm trees abound in Palm Springs.* Courtesy Visit Palm Springs.

President's Message

by Andrew Sabin

Tomorrow May Never Come... But it Needs To

Several years ago I was part of a small group invited to hear President Bill Clinton speak in Colorado Springs. Clinton said that he had "more yesterday's than tomorrows" in an effort perhaps to qualify his accrued wisdom. His perspective on many issues was insightful, honest and hopeful. I see many parallels between us. We are both Presidents, we both have more yesterdays than tomorrows and we both try to honestly convey our thoughts and opinions on topics that matter. We both also represent the correct positions on issues that some current leaders around the globe do not necessarily support. The similarities break down after this. Clinton speaks passionately to millions about the need for a free press, fundamental human rights and democracy. I advocate for geothermal heat and power in elevators, at small meetings and in this column.

My first encounter with the GRC was in the early 1990s through reading this *Bulletin* and attending the GRC Annual Meeting. Both are excellent vehicles for our industry. However, our focus on budget cuts recently had adversely affected the *Bulletin*. A transition to digital rather than the traditional hard copy of the GRC *Bulletin* occurred in January 2018 in order to cut printing costs. While this was the prudent decision under the circumstances, the change didn't really achieve its intended mark. To make sure more of our members have access to the *Bulletin*, a smaller digital version of this valuable publication is now being directly e-mailed to our members. Look for an attachment to the email announcing the *Bulletin* .

In the meantime, the Annual Meeting & Expo is still the very best venue for our membership and our industry to gather, exchange technical, business and other geothermal topics and generally have a great time. My weeks spent each year at the Annual Meetings have always been educational, opened many doors through the networking opportunities and been quite enjoyable. This year's September 15-18 meeting in Palm Springs, California will be no different. Among the many opportunities for our members, I plan to help lead a post-meeting fieldtrip to the Coso geothermal field to study this incredible operation and its young volcanic setting and to learn first-hand about GreenFire Energy's unique closed-loop demonstration project.

Our GRC Board of Directors is also in the midst of transition. As the industry waxes, wanes and evolves, the GRC and its Board must evolve to meet changing needs. Our Board took a hard look in the mirror and determined that we needed to modify ourselves to provide better governance. You will soon be informed of what we want to do and why, and then asked to vote on bylaws changes so that we can complete this part of the transition. Stay tuned.

On the topic of tomorrows, I have one last point…for now. GRC and all similar organizations around the globe, small and large, must think and act collaboratively if we hope to be sustainable and relevant. We operate in the zero-sum game of finite dollars. We also live in a world of endlessly streaming data and information. It is difficult to differentiate among the valuable information, the semi-truths and the complete fabrications. It is impossible to do this with limited funding. Our organizations need to promote the value of geothermal to all sectors of our population and we should not be doing it by ourselves. Each organization has a valuable charter that may be serving some unique sector of the geothermal population. But are each of us really best serving the community that we all work in and love if we are going at it alone? If we do not start working collectively to achieve the goals that we all share, then while we may be growing our local constituency on the one hand, we may be confusing and even marginalizing the bigger message on the other hand. Instead of competing with one another for a voice, relevance and possibly even money, we should be relentlessly working with one another to provide a singular and clear voice for our membership and industry, not to mention our planet. ■

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Andy Blair, Andrew Sabin and Paul Brophy represented the GRC at the International Geothermal Association Board meeting in Hungary in May.

JOIN the COMMUNITY

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Executive Director's Message

by Will Pettitt, PhD

California is on the Brink of a Geothermal Boom... and this is Exciting News for the USA and the World

California is going through an amazing transition to 100% renewable and clean power by 2045[1], and what's incredibly exciting for our international community is that geothermal energy will be a major piece of that transition. The GRC is a worldwide organization with over a third of our members based outside the USA, so why focus on California so much? Two reasons:

1) The GRC's Annual Meeting & Expo this year, titled *"Geothermal: Green Energy for the Long Run"*, is in Palm Springs, California in September, which is close to the Imperial Valley, one of the centers of geothermal power in California and considered as having the largest resource in the world available for development in the relative short term (Figure 1); and,
2) The USA is the largest market for geothermal power in the world, and California alone is the fifth largest economy[2] in the world (greater than the United Kingdom, India and France, the next three ranking economies), so with California leading the world in transitioning to renewable power, and with large geothermal resources at its fingertips, the Golden State is also leading the way for our industry in the world.

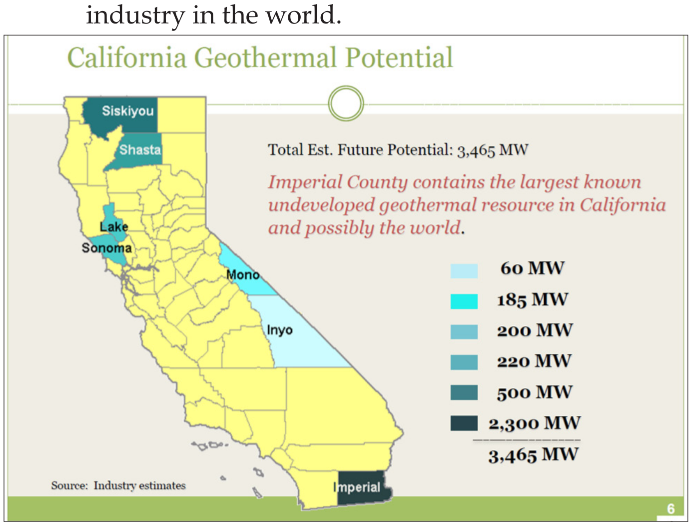

Figure 1: Estimated known geothermal resources in California based on previous industry research by the Geothermal Energy Association (GEA), now being updated by the Geothermal Resources Council (GRC). Graphics courtesy of Jonathan Weisgall, Berkshire Hathaway Energy.

We'd best take notice and come together as a community and industry to help make this transition work!

Let's review some metrics. The USA is the largest producer of geothermal power in the world, with 3x the installed Nameplate Capacity than any other country[3]. However, growth in the USA has stagnated over the past 7 years or so (Figure 2) at about 3,700 MW. The total installed capacity for the world is about 14,000 MW and in California it's about 2,500 MW (2/3's of the USA capacity or about double the next highest-ranking country, Turkey, at 1,300 MW). The reason for the growth stagnation in

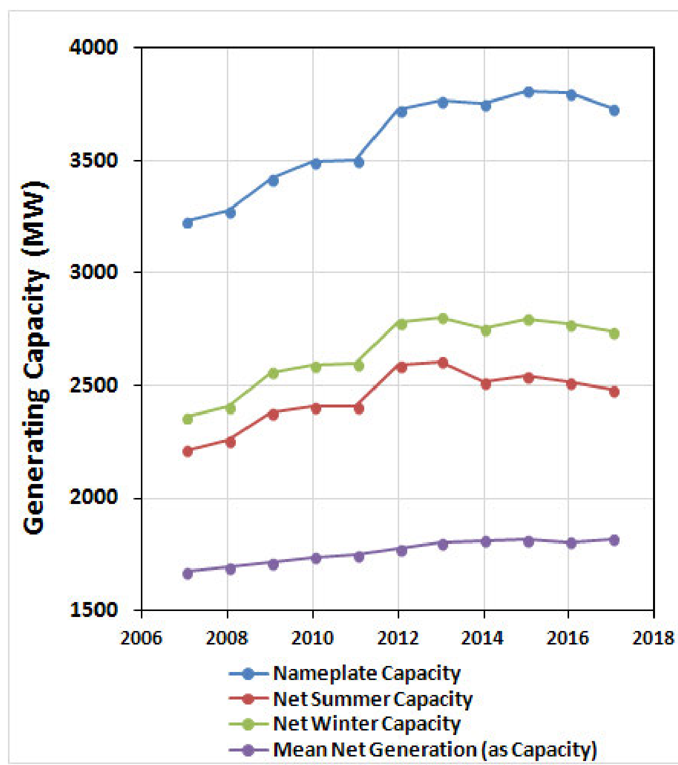

Figure 2: Geothermal capacity and production metrics for the USA, compiled by the Geothermal Resources Council (GRC) as part of current industry research. Data provided by the Energy Information Administration (EIA).

[1] http://www.cpuc.ca.gov/rps/
[2] http://www.cbsnews.com/news/california-now-has-the-worlds-5th-largest-economy/
[3] http://www.thinkgeoenergy.com

the USA is open for debate at the GRC's Annual Meeting & Expo, where we will have a number of expert panels discussing the issues. For sure, (in my opinion) hurdles to growth include a lack of investment in the industry as a key factor, accompanied by a lack of reducing the barriers to that investment, combined with a lack of utility procurement based on transmission system need rather than solely MWh price. We'd best overcome these hurdles if we're going to be successful through the energy transition over the next 10-30 years!

There are a number of public agencies and bodies that influence the power markets in California, including, amongst others: the State Legislature (Assembly and Senate); the Office of the Governor; the California Public Utilities Commission (CPUC); the California Independent System Operator (CAISO), and the California Energy Commission (CEC). The CPUC has gone through a multi-year process of modeling the future power generation mix out to 2030 in an Integrated Resource Plan (IRP) and published an important decision for the industry in April[4]. The goal of the IRP is to provide a guide for independent utilities within their procurement plans so that the State's Renewable Portfolio Standard (RPS), Green-House Gas (GHG) and Resource Adequacy (RA) goals can be achieved.

The CPUC decision is a step in the right direction for geothermal as it calls for 1,700 MW net capacity of new geothermal build-out for 2030 supplying the CAISO transmission region (note the IRP uses Net Capacity that is supplied to the grid rather than Nameplate Capacity that is a measure of the theoretical resource supply). This is on top of an assumed baseline of 1,200 MW of existing geothermal currently supplying the CAISO region (so a total of 2,900 MW net capacity target for 2030). The daily geothermal production as recorded by CAISO Renewables Watch[5] this year hovers around 1,000 MW (the rest of the state's geothermal nameplate capacity is not available or supplied elsewhere).

The CAISO also published an important report on California's Transmission System that is consistent with the CPUC decision and shows that renewable baseload power is essential for grid stability when decommissioning existing nuclear power and older gas-fired power stations (decisions already made by the State for the next decade). This lands the geothermal industry and community with an interesting challenge that we are more than capable of achieving: we'll need to develop about 2,500 MW of new geothermal nameplate capacity in California over the next 10 years, and that's assuming today's current generation is sustainable over that period. That is a doubling of today's installed capacity, meaning that California will be the largest producer of geothermal power in the world by a very large margin and meaning that it will be a huge contributor to technology research and development over that period. We'd best be getting some strategies together to meet this challenge!

There's been a lot of hard work done by the geothermal community over many years to achieve this latest policy result. There's still a lot more needed to ensure this power target is procured effectively, the transmission system is adequate enough to supply this power, that geothermal power production is sufficiently recognized for its critical role in grid resilience, stability, and reliability, and that we get the investment needed to explore and develop the necessary resources that the state needs, like new power plants in the Imperial Valley (Figure 3).

Figure 3: Aerial photograph of the North Brawley Geothermal Power Plant operated in the Imperial Valley by ORMAT Technologies Inc. Photograph courtesy of OpenEI.

California is leading the charge on combating climate change and geothermal power is at the front of that charge through its unique position as a flexible, renewable, baseload energy source that can underpin (and thus help build) intermittent renewable power such as solar and wind. Other states in the USA are following California's example on RPS and GHG targets , and other nations are also making the renewable energy transition. How we achieve these industry and environmental goals will be a large part of the debate at our Annual Meeting & Expo in Palm Springs this year. We'd best get to it!

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

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[4] http://www.cpuc.ca.gov/irp/
[5] http://www.caiso.com/market/Pages/ReportsBulletins/RenewablesReporting.aspx
[6] http://www.caiso.com/planning/Pages/TransmissionPlanning/2018-2019TransmissionPlanningProcess.aspx
[7] http://www.ncsi.org/research/energy/renewable-portfolio-standards.aspx

Communication from the GRC

by Ian Crawford
Director of Communications

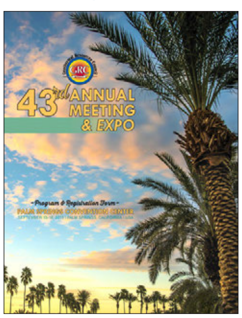
2019 GRC Annual Meeting & Expo

Registration is Now Open

Geothermal: Green Energy for the Long Run

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

Preparations are almost complete for the 2019 GRC Annual Meeting and Expo. The latest information is available on the GRC website at: www.geothermal.org/meet-new.html.



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

Early birds who register **before July 31** pay only **$980** as Geothermal Resources Council (GRC) members for a three-day registration or $1,180 as non-members. **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 $150** for a three-day registration which also includes GRC membership through 2020.

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

REGISTER NOW!

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

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

Early bird discount ends July 31st.

Reserve Your Hotel Room

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

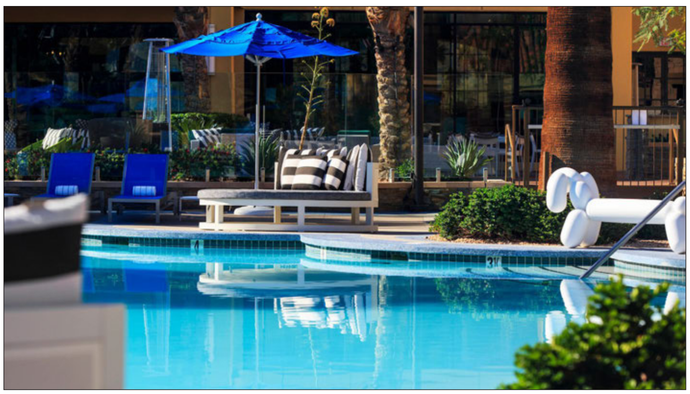
The GRC has contracted for a discounted block of rooms at two host hotels. The **Renaissance Palm Springs Hotel** and the **Hilton Palm Springs Hotel.**

Due to scheduling issues, the **Renaissance Palm Springs Hotel room block is only available from 14-22 September.** Those attending pre-meeting workshops and fieldtrips and needing a room 12 & 13 September at the GRC rate will have to make a reservation **at the Hilton Palm Springs Hotel where the room block is available 12-19 September.** We apologize for the inconvenience.

The discounted rate is available until 21 August.

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

The pool at the Hilton Palm Springs.



Poolside at the Renaissance Palm Springs Hotel.

Workshops at Palm Springs Convention Center Announced

In addition to the main event of the GRC Annual Meeting & Expo taking place September 15-18, 2019, there will be two workshops before and a special presentation open to the general public during the conference.

On Friday and Saturday, September 13 and 14 a **New Frontiers in EGS Technology workshop** will consider how development of cost-effective Enhanced Geothermal Systems (EGS) technology is critical to the long-term viability of the world-wide geothermal industry. The leaders are **Sabodh K. Garg, Azadeh Riahi, William M. Rickard**, and **Will Pettitt.**

On Saturday September 14 another workshop on **Supercritical and Superhot Geothermal Resources** will present information on how such systems could yield an order of magnitude more power than that currently produced from typical hot geothermal wells. **Wilfred Elders** (Professor Emeritus, University of California, Riverside) will lead the discussions.

A special **Geothermal 101 presentation** will be held on Wednesday, September 18 where the general public will be invited to learn about and view the practical applications of geothermal energy technology in a guided tour of the Expo hall.

More information on the workshops, including more detailed agendas and cost, can be found on the GRC Annual Meeting website at: www.geothermal.org/meet-new.html.

GRC Workshops are an ideal forum for an exchange of ideas.

Fieldtrips from Palm Springs Meeting Announced

There will be a grand total of four fieldtrips before and after the GRC Annual Meeting & Expo.

Just before the start of the conference two half-day trips will offer a chance to relax and enjoy the fantastic scenery and culture of the Palm Springs area. On Saturday a **three hour off-road ride in a jeep** will take you into the California Desert, along the **San Andreas fault-zone** through slot canyons and a natural palm oasis. On Sunday morning a two-mile hike into the **Palm Canyon** will visit a special place for **the Agua Caliente (Hot Water) Band of Cahuilla Indians** among the trees in a beautiful palm oasis.

On the last day of the GRC Annual Meeting & Expo a two-day fieldtrip will take advantage of a rare opportunity to explore operations, volcanic geology and hydrothermal features of the **Coso geothermal field** located at the **China Lake Naval Air Warfare Station (NAWS),** California. This tour will also include a visit to **GreenFire Energy**'s experimental project demonstrating **closed-loop geothermal power production technology** using both water and supercritical CO_2 as working fluids.

Communication from the GRC

The Coso geothermal power plant.

On Thursday, September 19 another two-day fieldtrip will visit the **Imperial Valley**, home to the world renowned **Salton Sea geothermal field**. In addition to stops at the **John L. Featherstone** and **Heber geothermal power plants**, there will also be up-close observations of quaternary volcanoes, mud volcanoes, hot springs and an actively spreading mud pot! The valley has become a significant hot spot for renewable energy – with production from geothermal, solar, wind and biofuel – and possibly soon to be one of the most important regions for lithium mining.

More information on the fieldtrips, including more detailed itinerary and cost, can be found on the GRC Website at www.geothermal.org/meet-new.html.

Book Your Booth

More than 50 exhibitors have already signed up! Book your booth now!

The Palm Springs Convention Center.

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

Get Exposure!

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

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

Download the Sponsorship flyer.......

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!

GRC Annual Meeting & Expo

Download Attendify, our official mobile app and join the event community.

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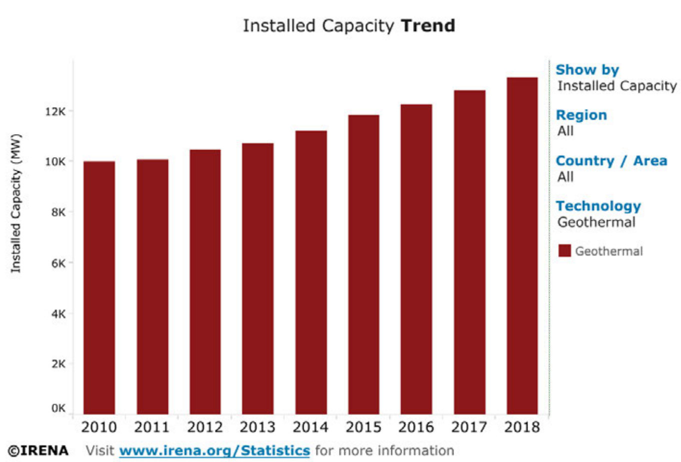
Inside Geothermal

Geothermal Energy Increased by 539 MW in 2018 - IRENA

The decade-long trend of strong growth in renewable energy capacity continued in 2018 with **global additions of 171 GW**, according to new data released by the **International Renewable Energy Agency (IRENA)**. The annual increase of 7.9% was bolstered by new additions from solar and wind energy, which accounted for 84% of the growth. **A third of global power capacity is now based on renewable energy.**

IRENA's annual *Renewable Capacity Statistics 2019*, indicates growth in all regions of the world, although at varying speeds.

Geothermal energy capacity increased by 539 MW in 2018 - an increase of 4.2%, with most of the expansion taking place in Turkey (+219 MW) and Indonesia (+137 MW), followed by the USA, Mexico and New Zealand. The **total geothermal capacity at the end of 2018 is 13,329 MW.** *Global Geothermal News..........*

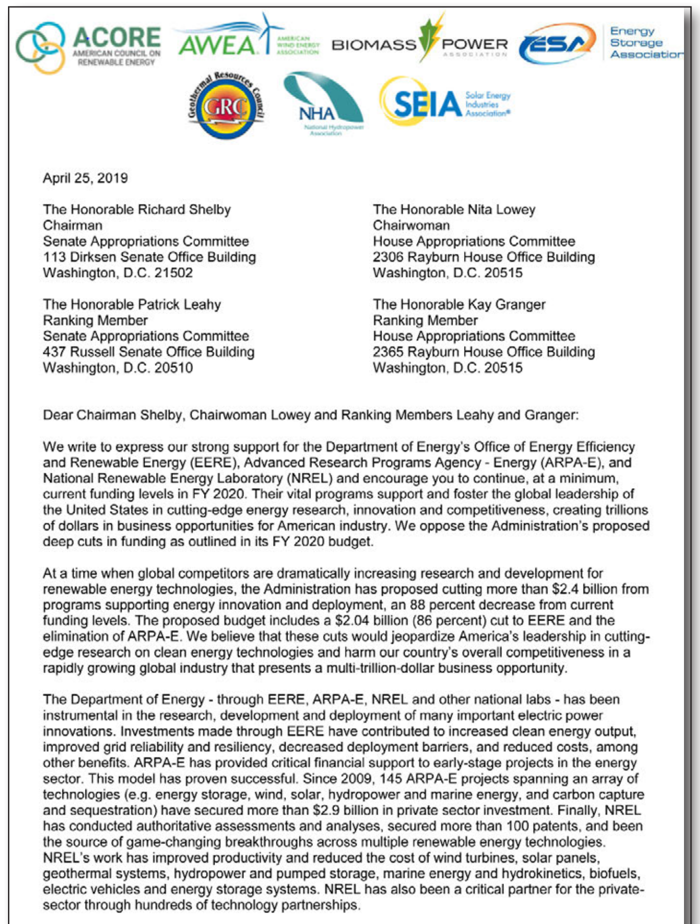


NORTH AMERICA

Geothermal Resources Council Joins Renewable Energy Groups to Urge Consistent Funding for Energy Innovation

The **Geothermal Resources Council** along with the **American Council on Renewable Energy (ACORE)**, the **American Wind Energy Association, the Biomass Power Association**, the **Energy Storage Association**, the **National Hydropower Association and the Solar Energy Industries Association** sent a joint letter to the U.S. Congress urging consistent funding for energy innovation in the **Department of Energy**'s FY 2020 Budget and opposing the Trump administration's proposed deep cuts.

The administration has **proposed cutting more than USD 2.4 billion** from programs supporting energy innovation and deployment, an 88% decrease from current funding levels. The proposed budget includes a **USD 2.04 billion (86%) cut** to the office of **Energy Efficiency and Renewable Energy (EERE)** and the elimination of **Advanced Research Projects Agency-Energy (ARPA-E)**. *Global Geothermal News..........*



April 25, 2019

The Honorable Richard Shelby
Chairman
Senate Appropriations Committee
113 Dirksen Senate Office Building
Washington, D.C. 21502

The Honorable Nita Lowey
Chairwoman
House Appropriations Committee
2306 Rayburn House Office Building
Washington, D.C. 20515

The Honorable Patrick Leahy
Ranking Member
Senate Appropriations Committee
437 Russell Senate Office Building
Washington, D.C. 20510

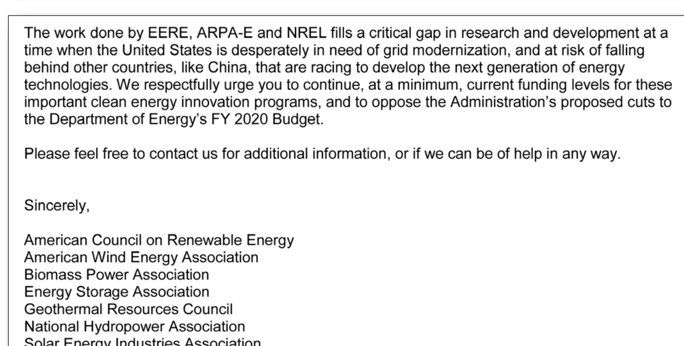
The Honorable Kay Granger
Ranking Member
House Appropriations Committee
2365 Rayburn House Office Building
Washington, D.C. 20515

Dear Chairman Shelby, Chairwoman Lowey and Ranking Members Leahy and Granger:

We write to express our strong support for the Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE), Advanced Research Programs Agency - Energy (ARPA-E), and National Renewable Energy Laboratory (NREL) and encourage you to continue, at a minimum, current funding levels in FY 2020. Their vital programs support and foster the global leadership of the United States in cutting-edge energy research, innovation and competitiveness, creating trillions of dollars in business opportunities for American industry. We oppose the Administration's proposed deep cuts in funding as outlined in its FY 2020 budget.

At a time when global competitors are dramatically increasing research and development for renewable energy technologies, the Administration has proposed cutting more than $2.4 billion from programs supporting energy innovation and deployment, an 88 percent decrease from current funding levels. The proposed budget includes a $2.04 billion (86 percent) cut to EERE and the elimination of ARPA-E. We believe that these cuts would jeopardize America's leadership in cutting-edge research on clean energy technologies and harm our country's overall competitiveness in a rapidly growing global industry that presents a multi-trillion-dollar business opportunity.

The Department of Energy - through EERE, ARPA-E, NREL and other national labs - has been instrumental in the research, development and deployment of many important electric power innovations. Investments made through EERE have contributed to increased clean energy output, improved grid reliability and resiliency, decreased deployment barriers, and reduced costs, among other benefits. ARPA-E has provided critical financial support to early-stage projects in the energy sector. This model has proven successful. Since 2009, 145 ARPA-E projects spanning an array of technologies (e.g. energy storage, wind, solar, hydropower and marine energy, and carbon capture and sequestration) have secured more than $2.9 billion in private sector investment. Finally, NREL has conducted authoritative assessments and analyses, secured more than 100 patents, and been the source of game-changing breakthroughs across multiple renewable energy technologies. NREL's work has improved productivity and reduced the cost of wind turbines, solar panels, geothermal systems, hydropower and pumped storage, marine energy and hydrokinetics, biofuels, electric vehicles and energy storage systems. NREL has also been a critical partner for the private-sector through hundreds of technology partnerships.



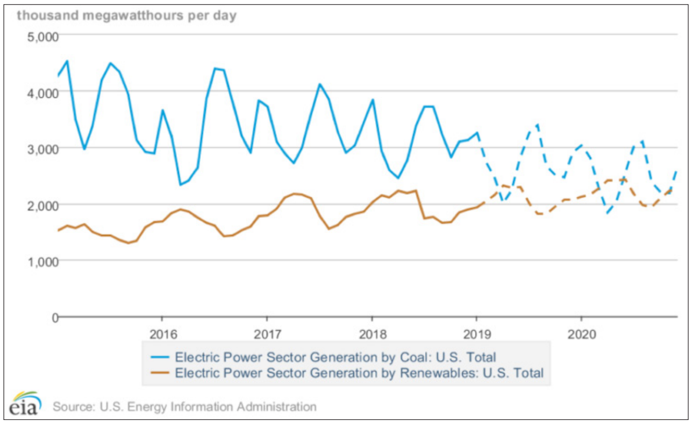
The work done by EERE, ARPA-E and NREL fills a critical gap in research and development at a time when the United States is desperately in need of grid modernization, and at risk of falling behind other countries, like China, that are racing to develop the next generation of energy technologies. We respectfully urge you to continue, at a minimum, current funding levels for these important clean energy innovation programs, and to oppose the Administration's proposed cuts to the Department of Energy's FY 2020 Budget.

Please feel free to contact us for additional information, or if we can be of help in any way.

Sincerely,

American Council on Renewable Energy
American Wind Energy Association
Biomass Power Association
Energy Storage Association
Geothermal Resources Council
National Hydropower Association
Solar Energy Industries Association

Renewable Energy in USA Surpasses Coal for First Time



In April, for the first time ever, the U.S. renewable energy sector (hydro, biomass, wind, solar and **geothermal**) was projected to **generate more electricity than coal-fired plants**, which totals about 240 GW of still-operating capacity. According to data in the Energy Information Administration (EIA) *Short-Term Energy Outlook*, renewables may even trump coal through the month of May as well. *Global Geothermal News..........*

Employment in U.S. Geothermal Energy Sector Increases

The *2019 U.S. Energy and Employment Report* finds that employment in the geothermal power sector **increased by 599 to 8,526 in 2018, an increase of 7.6%**. *Global Geothermal News..........*

Corporate Giants Band Together to Buy Renewable Energy

Some of the USA's top tech firms, manufacturers and consumer companies are banding together to create a boom in renewable energy purchases throughout corporate America.

The corporate giants and their nonprofit partners have launched the **Renewable Energy Buyers Alliance (REBA),** a trade organization that will help companies take advantage of new ways to **purchase clean energy**. The goal is to support construction of new green power projects by striking renewable energy deals pioneered by companies like **Google**-parent **Alphabet**, **General Motors** and **Walmart** in recent years.

Through last year, companies signed enough corporate renewable deals to support nearly **16 gigawatts of new renewable energy capacity** in the U.S. REBA aims to accelerate that activity and **grow the market to 60 gigawatts by 2025**. *Global Geothermal News..........*

BLM Removes Sage Grouse Protections in Western U.S.

The Trump administration has released final land-management plans that would wipe out critical protections for imperiled greater **sage grouse** in seven western states. *Global Geothermal News..........*

Enel Transfers Ownership of U.S. Geothermal Power Plants Within Group

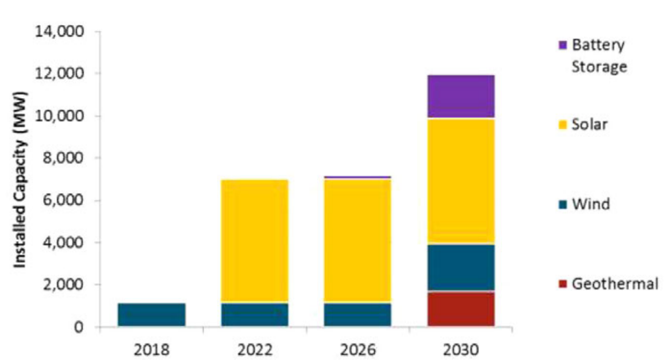
Enel S.p.A., acting through its renewable subsidiary **Enel Green Power North America Inc.,** has finalized the acquisition of 100% of **seven fully operational renewable plants, including geothermal,** totaling 650 MW from Enel Green Power North America Renewable Energy Partners, LLC, an equally owned joint venture between EGPNA and **GE Capital's Energy Financial Services**, the energy investing arm of General Electric. *Global Geothermal News..........*

California Public Utilities Commission Recognizes Geothermal Energy in New Recommended Portfolio

The **California Public Utilities Commission (CPUC)** has voted 5-0 to adopt a *Integrated Resource Plan* that includes 12 GW of new solar, wind, battery storage **and geothermal resources** the state will need to procure by 2030 to meet ambitious greenhouse gas reduction goals. New calculations aim to **add an additional 1,700 MW of geothermal capacity by 2030**. *Global Geothermal News..........*

The *Integrated Resource Plan* approved by the **California Public Utilities Commission (CPUC)** relies on **Community Choice Aggregators (CCAs)** procuring the new clean energy resources the state needs over the next decade to meet its climate goals. *Global Geothermal News..........*

New Resource Buildout Requirements for Preferred System Portfolio



Testing Begins at Coso Closed-Loop Geothermal Power Generation Project

GreenFire Energy Inc. has announced the completion of construction and the beginning of testing of the world's first field-scale demonstration of a closed-loop geothermal power system. The project uses an inactive well in the **Coso, California, geothermal field**. *Global Geothermal News..........*

A fieldtrip to the Coso geothermal field and the GreenFire Energy demonstration project will depart the GRC Annual Meeting & Expo on Wednesday, September 18 for an overnight trip. More information.......

Hell's Kitchen Lithium-Geothermal Project Breaking Ground

Controlled Thermal Resources (CTR) reports that preliminary work has commenced on site in preparation for the **Hell's Kitchen Lithium-Geothermal Project** in **Imperial Valley, California.** *Global Geothermal News..........*

Also, in a world-first, CTR, **EnergySource**, and **Western Falcon Energy Services** are working together to develop the first PEEK-lined pipe for application in geothermal operations. **PEEK (Polyether ether ketone)** is a material that is resistant to corrosion and scale build-up, and can be manufactured at a low cost. This is the first time in the world PEEK has been built to this size and run in a geothermal operation. *Global Geothermal News..........*

Ormat Signs PPA for 16 MW from Casa Diablo-IV Geothermal Project

Ormat Technologies Inc. has announced the signing of a *Power Purchase Agreement (PPA)* between a subsidiary of the company and **Southern California Public Power Authority (SCPPA).** Under the PPA, SCPPA will purchase 16 MW of power generated by the expected **30 MW Casa Diablo-IV (CD4) geothermal project** located in **Mammoth Lakes, California.** SCPPA will resell the output to the City of Colton in the County of San Bernardino in **Southern California.**

The CD4 power plant will be the first geothermal power plant built within the California Independent System Operator (CAISO) balancing authority in the last 30 years. *Global Geothermal News..........*

New Nevada RPS Target is 50% Renewable Energy by 2030

Nevada **Governor Steve Sisolak** has signed a bill into law raising the state's **renewable portfolio standard (RPS)** to **50% by 2030**. This bill comes after Nevadans voted to approve the changes in a ballot measure this past November. *Global Geothermal News..........*

City of Boise Plans to Expand Use of Geothermal Energy

Boise City Council in **Idaho** wants to have the entire city **powered by renewable energy by 2040.** Even though the goal is ambitious, city officials say it's attainable by using energy efficiency and existing renewable resources, **including geothermal energy,** along with advocating for new sources of energy.

The City of Boise operates the largest direct-use geothermal system in the USA, serving a number of the community's buildings with renewable energy for space heating, water heating, and sidewalk snow melt. *Global Geothermal News..........*

Federal Funding for Closed-Loop Geothermal Demonstration Project in Alberta

The **Honourable Amarjeet Sohi**, Minister of Natural Resources in **Canada**, has announced **CND 6.7 million in federal funding** to support **Eavor Technologies Inc.**'s prototype for a closed-loop geothermal system.

The federal funding will go toward construction of the **Eavor-Lite demonstration facility** near **Rocky Mountain House, Alberta, Canada.** Interestingly, oil company Shell is a collaborative partner through its **Shell New Energies** division together with Precision Drilling, and other partners. *Global Geothermal News..........*

Canadian Geothermal Company Offloads Geothermal Assets in Iceland

Canadian company **Innergex Renewable Energy Inc.** has announced that an agreement has been reached to sell its wholly-owned subsidiary **Magma Energy Sweden A.B.**, which owns an equity interest of approximately 53.9% in **HS Orka hf.** The purchase price is **USD 304.8 million** (CND 408.8 million) and the buyer is a **Macquarie Infrastructure** and **Real Assets** managed European infrastructure fund.

HS Orka owns the **Reykjanes** and **Svartsengi** geothermal plants totaling 174 MW, as well as a 30% equity interest in the **Blue Lagoon Geothermal Spa and Resort** in Iceland. *Global Geothermal News..........*

Yukon Aquaponics Farm to Use Direct Source of Geothermal Heat for Plant Growth

Yukon company **North Star Agriculture** is planning an **aquaponics facility** near **Takhini hot springs**, outside **Whitehorse**, to raise fish and vegetables indoors.

CEO **Sonny Gray** says that using geothermal power for the project could reduce energy costs by at least a third. The plan is to use warm water that drains from the **Takhini Hot Pools** through a heat-exchange. *Global Geothermal News..........*

Greenhouses to Source Heat from Saskatchewan Geothermal Power Plant

Excess heat from the **Estevan Geothermal Power Plant** in southern **Saskatchewan**, being developed by **DEEP Earth Energy Production Corporation**, will also be fed to a **45-acre greenhouse** for commercial use. *Global Geothermal News..........*

Drilling Begins at Saint Vincent Geothermal Power Project

Drilling has begun at the **10 MW Saint Vincent geothermal project** in the Caribbean island nation of **St. Vincent & the Grenadines**. *Global Geothermal News..........*

More World Bank Funds for 7 MW Dominica Geothermal Power Project

A financing package for **Dominica's Geothermal Program** has been secured. The funding, which includes **USD 22 million** in grants, was approved by the **World Bank.** The funds will help purchase **two turbines of 3.5 MW each**. *Global Geothermal News..........*

CENTRAL & SOUTH AMERICA

New Well at San Jacinto Geothermal Project Reaching a Stable State

In its latest operating results **Polaris Infrastructure Inc.** of **Toronto, Canada**, has reported record-level annual power generation and revenue at the **72 MW San Jacinto project** in **Nicaragua.** This was due to the completion of new well, connected to the plant in March 2018 which is now at, or very close to, reaching a stable state. *Global Geothermal News..........*

Start of Operations at 55 MW Las Pailas II Geothermal Plant Brought Forward

The **Costa Rican Electricity Institute (ICE)** has decided to advance the launch of the **55 MW Las Pailas II geothermal plant** due to the negative effects that a drought has had on hydroelectric generation in the country. *Global Geothermal News..........*

Tender Awarded for Construction of Geothermal Power Plant in Bolivia

A consortium formed by **Sacyr Industrial**, a Spanish construction company based in Madrid, together with **Ormat**, has been awarded a contract to construct the **Laguna Colorada geothermal plant** in **Potosí, Bolivia.**

The plant will become the **highest altitude geothermal plant in the world** (4,980 meters above sea level), and consist of a pilot binary cycle geothermal plant, using **132,000 kg/h** of geothermal fluid at **170°C** to generate **5.6 MW** of electrical energy. *Global Geothermal News..........*

License Granted for Exploration for 50 MW Tolhuaca Geothermal Project in Chile

The Chilean Energy Ministry has granted **Transmark Chile SpA** a geothermal exploitation license for the **Peumayén** concession located in **southern Chile**.

The project consists of the initial development of a **50 MW power plant** on the north-western flank of the Tolhuaca volcano, with a potential that could reach up to 200 MW. *Global Geothermal News..........*

AUSTRALASIA

New Zealand Geothermal Power Plant to Help Produce Hydrogen

Hydrogenics Corporation has announced that it has entered into an agreement with **Halcyon Power** – a joint venture of New Zealand-based **Tuaropaki Trust** and **Obayashi Corporation** of Japan – to build a hydrogen production facility in **Mokai, Taupo.**

The facility will use **1.5 MW** of electricity from the **Tuaropaki geothermal power plant** operated by **Mercury Energy.** The project is scheduled to be in operation by 2020. *Global Geothermal News..........*

Geothermal Energy Helps to Increase Renewables Share of Generation in New Zealand

According to the latest *New Zealand Energy Quarterly*, the overall **renewable share** of generation rose from 81.9% in the December 2017 quarter to **84.5%** in December 2018. This was largely as a result of **higher geothermal generation**. In 2018 geothermal energy generated **7,377 GWh of electricity**, around **15% of New Zealand's electricity generation**. *Global Geothermal News..........*

ASIA

Expanding Oil Company Plans More Investment in Geothermal Power

Leading Japanese oil wholesalers **Idemitsu Kosan** and **Showa Shell Sekiyu** have merged becoming the second-largest oil wholesaler in Japan. The company says it plans to invest in renewable energy including **geothermal power**. *Global Geothermal News..........*

Iwate Geothermal Power Plant Starts Operations

A **7.5 MW geothermal power plant** in **Matsuo-hachimantai District, Iwate Prefecture, Japan** started operations in late January. Built by **Iwate Chinetsu KK** this is the first time in 22 years that a geothermal power plant with an output higher than 7 MW has begun operation in Japan. Electricity generated at the plant is sold to **Tohoku-Electric Power Co. Inc.** at a price of **¥40/kWh** based on the feed-in tariff (FIT) scheme. **JFE Engineering Corp.** provided construction services for the plant. *Global Geothermal News..........*

Geothermal Powered Train Starts Service in Tokyo

Tokyu Corp. has begun a train service on its **Setagaya Line** that uses electricity generated **100% from renewable energy** sources - a first in Japan. The suburban Tokyo service is powered by **geothermal** and hydro-electric power supplied by the **Tohoku Electric Power Co.** group which, according to its website has **189 MW** of geothermal energy capacity from **4 plants**. *Global Geothermal News..........*

EDC Allocates Over PHP 7 Billion to Improve Reliability of Geothermal Power Plants

Energy Development Corp. (EDC) has allocated over **PHP 7 billion** in capital expenditures (capex) this year to improve the reliability of its geothermal facilities in the Philippines. About PHP 6.56 billion, will finance acquisitions to support the operations and maintenance requirements of the geothermal plants in **Leyte, Negros Island, Bacon-Manito** and **Mt. Apo.** *Global Geothermal News..........*

Bacon-Manito Geothermal Plant to Power Local Factories

Snack manufacturer **Mondelez Philippines** has tapped **Energy Development Corp.** to supply **100% geothermal power** from the **150 MW Bacon-Manito Geothermal plant** to the former's manufacturing plant in **Sucat, Parañaque City** in the **Bicol** region. *Global Geothermal News..........*

The Bacon-Manito Geothermal plant will also provide electricity to the factory of **Neltex Development Co. Inc.,** the country's largest plastic pipe manufacturer, in **Dasmariñas, Cavite**. *Global Geothermal News..........*

Kalinga Geothermal Power Project Almost Ready to Start Drilling

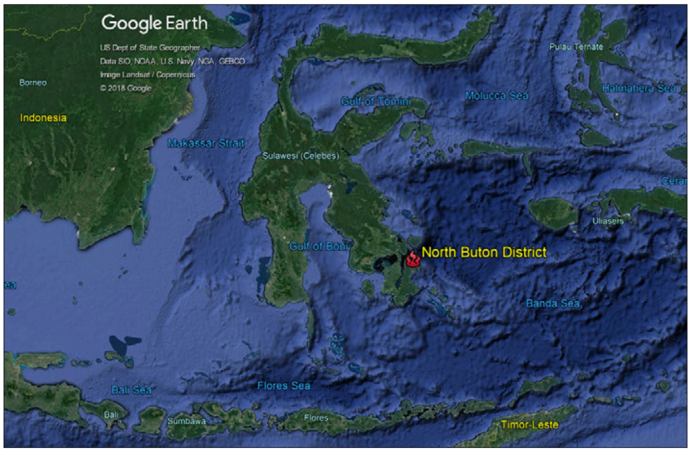
Aragorn Power and Energy Corp. and partners have announced they are ready to start exploratory drilling for the proposed **120 MW Kalinga geothermal power project** in **Pasil, Kalinga** province in northern **Philippines**. *Global Geothermal News..........*

Construction Starts at Java Geothermal Power Plants

Geo Dipa Energi has started on the construction of two geothermal power plants in **Dieng, Central Java** and **Patuha, West Java** in **Indonesia**. Each will have a power generating capacity of **60 MW**. The electricity will be sold to **PLN** at **USD 8.12 per kilowatt-hour (kWh)**. *Global Geothermal News..........*

Good Potential for Geothermal Energy in South-East Sulawesi

A number of hot-springs and fumaroles have been discovered in the **North Buton District** in **Southeast Sulawesi Province** in **Indonesia**, promising a potential for future geothermal exploration. *Global Geothermal News..........*



Location of North Buton District in Southeast Sulawesi Province in Indonesia.

Possible Geothermal Energy Resources in North Sulawesi Province

An official in **Tomohon City, North Sulawesi province** in Indonesia has suggested local geothermal resources have the potential to generate **1,400 MW** of electrical power and that several Chinese investors have expressed an interest. *Global Geothermal News..........*

Geothermal Power Plant in India May Have Started Operations

A **10-20 kW Organic Rankine Cycle (ORC) geothermal power plant** was slated to have started operating in **Dholera** in **Ahmedabad district, Gujarat, India** in April. **Pandit Deendayal Petroleum University (PDPU)** is sourcing the ORC unit from the French firm **ENOGIA**.

PDPU has also announced plans to tap abandoned **Oil and Natural Gas Corporation (ONGC)** wells in the **Gandhar** region for geothermal power. *Global Geothermal News..........*

AFRICA

Portuguese Company to Survey Geothermal Potential in Morocco

Gesto - based in **Algés, Lisbon, Portugal** - has been awarded a project to identify areas of geothermal potential in the provinces of south Morocco or **Moroccan Sahara.** *Global Geothermal News..........*

Egyptian Government to Develop Map of Geothermal Energy Resources

Egypt's **Ministry of Electricity and Renewable Energy (MIIC)** is seeking international funds to publish a **geothermal energy map of Egypt.** *Global Geothermal News..........*

New Legislation Advances Geothermal Development in Ethiopia

A new bill that eases registration and licensing processes for geothermal development companies has been submitted to the Ethiopian **Council of Ministers** for approval.

The draft regulation categorizes the resource as **Grade one** where a geothermal resource is able to generate electric power, and **Grade two** for agricultural, industrial, medical and recreational purposes.

The bill has also identifies three types of licenses for geothermal developers. **Reconnaissance, exploration and well-field development.** *Global Geothermal News..........*

Three New National Entities to Manage and Regulate Energy Resources in Kenya

The newly enacted **Energy Bill 2017** establishes three national entities to manage and regulate Kenya's energy resources: the **Energy and Petroleum Regulatory Authority**, the **Rural Electrification and Renewable Energy Corporation**, and the **Nuclear Power and Energy Agency**. *Global Geothermal News..........*

Invitation to Bid for Contract to Rehabilitate Olkaria 1 Geothermal Power Plants

KenGen is inviting offers to rehabilitate the **Olkaria 1 Units 1, 2 and 3 geothermal power plants.** A loan from **Japan International Cooperation Agency (JICA)** will help towards the cost. Bids must be delivered **on or before 21st August, 2019**. *Global Geothermal News..........*

Chinese Company Wins Contracts for Sosian Menengai Geothermal Power Project

Zhejiang Kaishan Compressor has landed a **USD 65 million** engineering, procurement and construction (EPC) contract to build the **35 MW Sosian Menengai geothermal power plant** in **Nakuru, Kenya**. The company also penned a 14-year operation and maintenance (O&M) deal worth **USD 18 million** for the plant. *Global Geothermal News..........*

Who Has the Single Biggest Geothermal Well in Africa?

Kenyan geothermal energy developers **KenGen** and **Geothermal Development Company (GDC)** are both laying claim to ownership of the biggest geothermal well in Africa.

KenGen claims its single most productive well in **Naivasha**'s **Olkaria** steamfields has a capacity of **30 MW**. GDC holds that its **Well 1A** at **Menengai** in **Nakuru** has a capacity of **30.6 MW.**

However, at 30 MW, Kenya's best performing steam wells are behind others in **Indonesia** and **California** of **up to 40 MW per well.** *Global Geothermal News..........*

Plans for 200 MW Geothermal Power in Tanzania by 2025

The **Tanzania Geothermal Development Company (TGDC)** has said a **30 MW geothermal power plant** will be built at **Lake Ngozi, Mbeya Region** by 2021 and a drilling rig had been purchased. **Three geothermal wells will be complete within 22 months.**

TGDC's General Manager, **Mr. Kato Kabaka**, said the government is going to amend the law which will facilitate management of geothermal development in the country and start on seven more geothermal energy power plant projects between 2021 and 2025, for a **total of 200 MW capacity**. *Global Geothermal News..........*

EUROPE

New Geothermal District Heating Project Planned in Norway

A geothermal district heating project with 1,500 meter deep wells is planned for the new **National Police Emergency Center** under construction at **Taraldrud** in **Ski Municipality**, south-east of **Oslo**. The heat will be used for melting snow on helicopter pads, street heating and heating of an indoor shooting range. *Global Geothermal News..........*

Geothermal Heat Power Investment Company Raises Funds

Baseload Capital, the project investment firm that provides capital to develop modular geothermal energy power plants using technology developed by its Swedish parent company **Climeon**, has issued its first **green bond**. The proceeds will be used to invest in and develop low temperature heat power plants in specific markets. *Global Geothermal News..........*

In addition, **Breakthrough Energy Ventures**, the investment firm financed by billionaires like **Jeff Bezos, Bill Gates,** and **Jack Ma** that invests in companies developing technologies to decarbonize society, is investing USD **12.5 million** in Baseload Capital. *Global Geothermal News..........*

Opportunity for Deep Geothermal to Compete for Contracts for Renewable Projects in United Kingdom

The third allocation round for the UK **Contracts for Difference (CfDs)** subsidy scheme, has opened for renewable energy projects to compete for an annual budget of **GBP 60 million** for **delivery years 2023/24 and 2024/25** – the capacity is to be capped at 6GW. Eligible technologies include **geothermal**. *Global Geothermal News..........*

Drilling of Production Well Completed at United Downs Deep Geothermal Project

On April 24th the **United Downs Deep Geothermal Project (UDDGP)** reached the end of the final bit run and **finished the drilling of the UD-1 production well,** at a total measured **depth of 5,275 meters** equating to a true vertical depth below ground of 5,057 meters.

Geophysical logs were conducted over the open hole interval and a short production test was carried out. The drilling rig was then moved 8 meters to the south, to **begin drilling the 3,000 meter UD-2 injection well**. The aim is to build a **1-3 MW pilot geothermal power plant** to demonstrate the technical and commercial viability of supplying both electricity and heat. *Global Geothermal News..........*

Downhole Data Confirms 260 Degrees Fahrenheit Irish Offshore Geothermal Resource

Providence Resources PLC, the Irish based energy company, has provided a technical update regarding its ongoing geothermal resource assessment of the **Dunquin North Lower Cretaceous carbonate build-up** in the southern **Porcupine Basin**, offshore **Ireland**.

Providence's Technical Director, **Dr. John O'Sullivan,** said the well data confirms the presence of a massive porous over-pressured LK carbonate reservoir system with a **TD reservoir temperature of c. 260°F.** *Global Geothermal News..........*

Suburban Paris Geothermal District Heating Project Advances

A public service concession agreement has been made for a **geothermal district heating project** in the municipalities of **Champs-sur-Marne** and **Noisiel** to the east of **Paris**. *Global Geothermal News..........*

Exploration for Danish District Heating Geothermal Resources to Begin

With two new permits from the **Danish Energy Agency** in hand, **AP Møller Holding Invest IV** can now proceed to drill exploration wells for geothermal district heating projects in **Aalborg** and **Aarhus**. *Global Geothermal News..........*

Pump Tests Commence at Munich Geothermal District Heating Project

Pump tests have started for **Well Th3** at the **Stadtwerke München (SWM) Schäftlarnstraße geothermal district heating project** in **Munich, Germany** following the successful drilling of the third of six wells. The results of the previous 2 wells have been very promising. The final geothermal power plant will have a capacity of **50 MWth** and supply heat for a least 80,000 homes in the Sendling district in Munich. *Global Geothermal News..........*

Successful Production Well Drilled at Schwerin-Lankow Geothermal Project in Northern Germany

The first production well has been completed at a **geothermal district heating project** in the city of **Schwerin**, the state capital of **Mecklenburg-Vorpommern** in northern **Germany**. Yield and resource temperature are well above expectations. *Global Geothermal News..........*

SCIENCE & TECHNOLOGY

New Research on How Geothermal Fluids Flow Through Fractures

To fully understand the risks and benefits of underground activities such as oil/gas production, geothermal energy production, or carbon sequestration, energy industry scientists need a detailed understanding of how fluids flow through fractures deep beneath the Earth's surface. Contaminants or other tracers in fluids such as water can diffuse through porous rock following a pattern similar to diffusion in other materials—a process called **Fickian diffusion**—but when the rock contains a network of fractures, the process

may become more complex. The interplay between the fracture geometry and the fluid velocity can speed up or slow down diffusion, in the form of "anomalous transport".

MIT Earth Resources Laboratory researchers **Peter Kang, Stephen Brown,** and **Ruben Juanes** found that standard diffusion in a rough-walled fracture can transition to anomalous transport at higher stress, as the fluid organizes itself into channels and no-flow zones, causing both early arrival and long residence times of contaminants. In a 2016 paper in *Earth and Planetary Science Letters*, they proposed a new model that explains both types of diffusion and quantitatively describes the transition between them in a single fracture. In a new paper in *Water Resources Research*, Kang, Juanes and co-workers extend their analysis to a network of fractures, and applied it to a real fracture network from a natural outcrop. *Global Geothermal News..........*

Stress-induced Anomalous Transport in Natural Fracture Networks, by Peter K. Kang, et al. First published: 17 April 2019. *Water Resources Research* https://doi.org/10.1029/2019WR024944

Using Machine Learning to Better Predict Seismic Activity During Geothermal Exploration

The work aims to use machine learning both to better predict seismic activity during geothermal exploration and to optimize geothermal energy production.

Geothermal systems require the creation of fractures through hydraulic stimulation. This fracture formation and stimulation is associated with microearthquakes (MEQs) that can damage buildings and other surface structures. **Chris Marone**, professor of geosciences and **Jing Yang**, assistant professor of electrical engineering at **Pennsylvania State University**, hope that by using Yang's machine learning algorithms they will be able to forecast and predict seismic events such as MEQs. *Global Geothermal News..........*

Using Electric Plasma Bursts to Increase Rate of Penetration in Geothermal Drilling

One remaining challenge associated with drilling geothermal wells is the presence of hard rocks, such as granite, that slow down the process and wear down drill bits. In turn, this causes drilling time and expenses to increase.

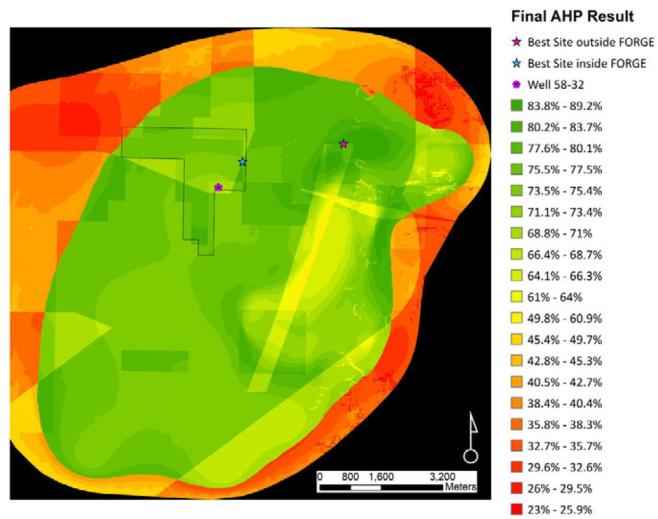
To combat this, a team of researchers from the **J. Mike Walker '66 Department of Mechanical Engineering** at **Texas A&M University** is developing **Shockwave and Plasma Accelerated Rock Cracking (SPARC)** drilling technology. By making the creation of wells more efficient, accessible and cost effective, their **U.S. Department of Energy** funded project will help make geothermal energy a more viable alternative to fossil fuels.

According to **Dr. David Staack**, associate professor, Sallie and Don Davis '61 Career Development Professor, and College of Engineering director of laboratory instruction, the team's SPARC technology will **equip traditional drill bits with high voltage electrodes on the tip** that emit a microscopic plasma discharge to shock the rock and crack it like a tiny explosion. Creating fractures and weakening the rock will allow the drill head, affixed with conventional diamond cutters, to have an easier time breaking through the material. *Global Geothermal News..........*

EDUCATION

DePaul University/Georgia Institute of Technology Wins Geothermal Design Challenge

The U.S. **Department of Energy (DOE) Geothermal Technologies Office (GTO)**, in partnership with the **Frontier Observatory for Research in Geothermal Energy (FORGE)** and the **Idaho National Laboratory (INL)**, invited both high school and university (undergraduate & graduate) teams to explore the future of geothermal energy and visualize the world of geothermal energy by participating in the **2019 Geothermal Design Challenge™.**



Analytic Hierarchy Process (AHP) generated suitability map calculated by weighting each of the eight criteria layers. Suitability scores ranged from 89.2% (most favorable) to 25.9% (least favorable), visualized from a dark green to dark red. From the first place winner from DePaul University/Georgia Institute of Technology.

Teams of 2 or 3 members researched data, interpreted information and created a data visualization portfolio that tells a compelling story about geothermal energy. Take a look at the winning portfolios:

- First place winner: DePaul University/Georgia Institute of Technology
- Second place winner: Colorado School of Mines
- Third place winner: Stanford University

Global Geothermal News.......... ■

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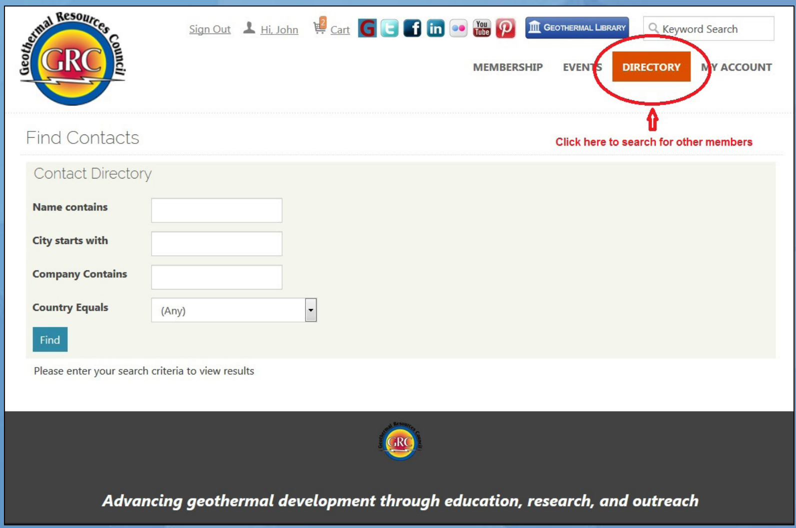
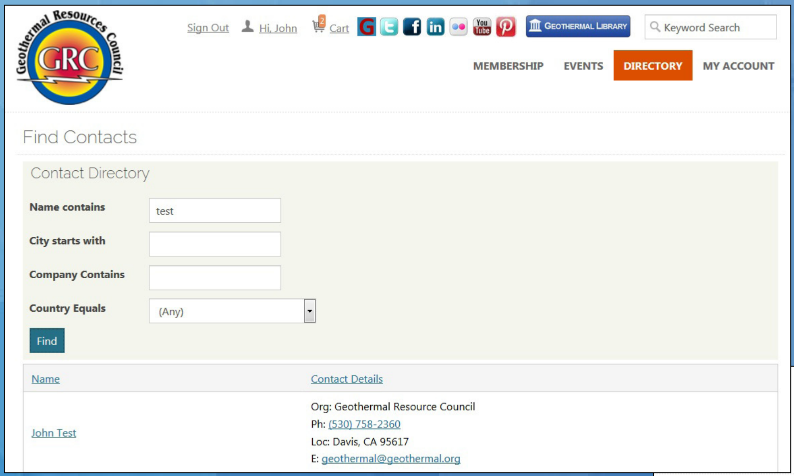


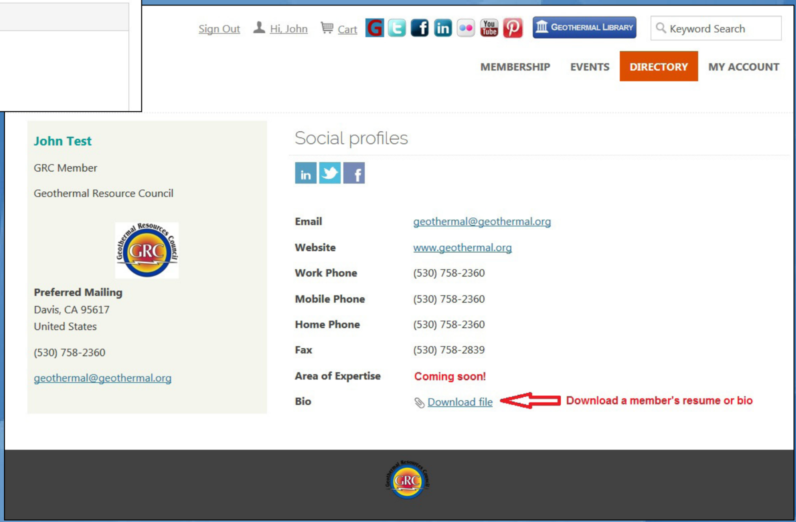
Step 2

Click on the Directory Tab



Step 3

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



Step 4

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

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

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

Geothermal Energy in Mining – A Renewable and Reliable Energy Solution

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Hatch Ltd, Mississauga, Canada

Keywords
- Geothermal
- Energy
- Mining
- Synergies
- Carbon Emissions
- Renewable Power

ABSTRACT

This paper presents the business case for utilizing geothermal potential to support mining operations with available and favorable geothermal conditions. Global factors are creating continuing energy and carbon challenges within the mining sector for which no single solution exists. Whether it is a remote or grid connected operation, the challenges facing mining companies include: high energy costs, volatile fossil fuel pricing, carbon pricing and energy security to name a few. The opportunity exists to develop new solutions to improve operations and economics, leading to more environmentally friendly, long-term solutions. Although the role geothermal plays in the utilities sector is well understood, the potential in mining has remained underdeveloped. Mining operations typically have large process heat and electrical demands, which are frequently supplied by isolated and expensive diesel/fuel oil systems involving their own cost, supply chain, and logistical challenges. In terms of risk and reward, it is well understood that the greatest risk involved with geothermal projects is in making capital investment and development time during exploration and drilling, with the reward of significant reductions in operating costs and carbon emissions. Those involved in the mining industry have a more analogous view of this risk profile than utility market players. It is proposed in this paper that there is opportunity to seek solutions to provide mining operations with geothermal heat and power where it may not yet have been considered. An overview of mining operations and favorable geologies, as well as geothermal technologies and applications, similarities within the mining industry requirements and processes, and specific case studies are presented.

1. Introduction

Geothermal power as of 2018 represents less than 1% of total installed global generating capacity. The earth's natural heat reserves are estimated to store considerably greater thermal energy than the world's total primary energy consumption. Estimates of accessible electrical potential range from 35GW to 200GW, representing 16 times the current installed global generating capacity (Montague, 2016).

On a global scale, market conditions are constantly transforming as stalled global economics, reduced investment activity, weaker global trade and geopolitical turmoil drive significant change in industry. On top of this the realities of climate change are transforming the global energy mix. Emerging technologies and previously underdeveloped technologies are speeding the transition to a more harmonious mixture of traditional and greener energy sources. In terms of renewables, technologies like energy storage, hydro dams, wind turbines and solar arrays have dominated the emerging market. However, governments today are supporting new developments, research and development institutions, and industry leaders who are working toward solutions that expand upon traditional renewables. This is causing costs to inch down and come closer to attaining grid-parity with larger conventional sources. Many within the energy community believe geothermal is emerging as one of the technologies that will play a larger role in the energy mix as a base-loaded renewable energy source, which is being further substantiated year after year as exploration and developments continue to grow.

Apart from the better understood role geothermal plays in the utility sector, global factors are creating continuing energy and carbon related challenges within the mining sector for which there is not yet a clear solution. Whether their assets are remote (islanded) or grid connected, companies today are continuously searching for solutions to the following major energy challenges:

- Addressing high energy costs (especially in remote operations) and volatile fossil fuel pricing
- Impact of carbon pricing on energy choices and energy costs (both capital and operating)
- Searching for energy solutions that provide reliable power on a large scale that address the above two challenges
- Security of energy supply and logistical simplicity

The mining sector requires long-term power supply options that can address the challenges above. Energy mixes of renewables (traditionally being wind, solar or hydro), energy storage and conventional thermal systems are the focus of studies and research. Geothermal represents another renewable power supply that eliminates many of the complications currently present with wind and solar, such as reliability, adjustability of load, and predictability. Additionally, geothermal presents secondary applications and benefits such as direct heating and cooling applications and mineral recovery, to name a few. It is possible that geothermal could be a viable and competitive solution that will play a larger role in the mining industries future.

2. Current Geothermal Energy Outlook

It can be suggested that the most pressing issue on a global scale in terms of energy, to-date, is limiting carbon emissions through increasing system efficiencies and increasing the percentage of installed renewables in the global energy mix. This is being done at many levels, from public and corporate policy to research and development. A recent example of major policy on a global scale is the Paris Climate Accord which is an agreement within the United Nations Framework Convention on Climate Change dealing with greenhouse gas emission mitigation, adaption and finance. As of 2018, 194 members have reaffirmed their commitment to mobilize $100 billion a year in climate finance by 2020 and have agreed to continue mobilizing finance at the level of $100 billion a year until 2025 (United Nations Framework Convention on Climate Change, 2018). Although this number encompasses all types of energy, geothermal very much falls under the umbrella. This example represents the largest scale policy development, however there are more examples among various governments that are adapting policy specific to geothermal, which in turn can shape corporate policy for operations within a government's jurisdictions.

Global geothermal power capacity is expected to grow 5GW (or 30% of 2015 global capacity) through 2021. Projected spending for this is estimated to be $25B in less than 10 years (Matek, 2016). This is shown in the figure below (figure 1).

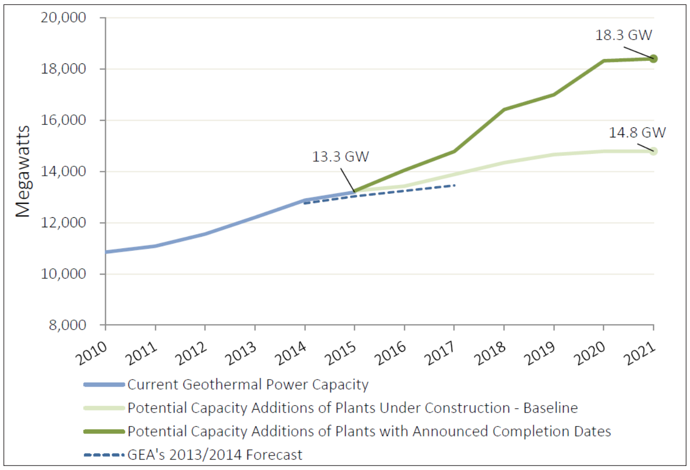

Figure 1: International geothermal power nameplate capacity (MW) (Matek, 2016).

Currently there are a few 'active and attractive' regions for geothermal potential, including Eastern Africa, Central and South America, Caribbean, Japan, China and the South Pacific (all within the Ring of Fire). Indonesia has reorganized their government's policy on geothermal assets to promote development, with the United States, Turkey and Kenya doing the same. To provide a better picture, the graph below (figure 2) shows both the targeted and potential geothermal energy production for countries in 2030.

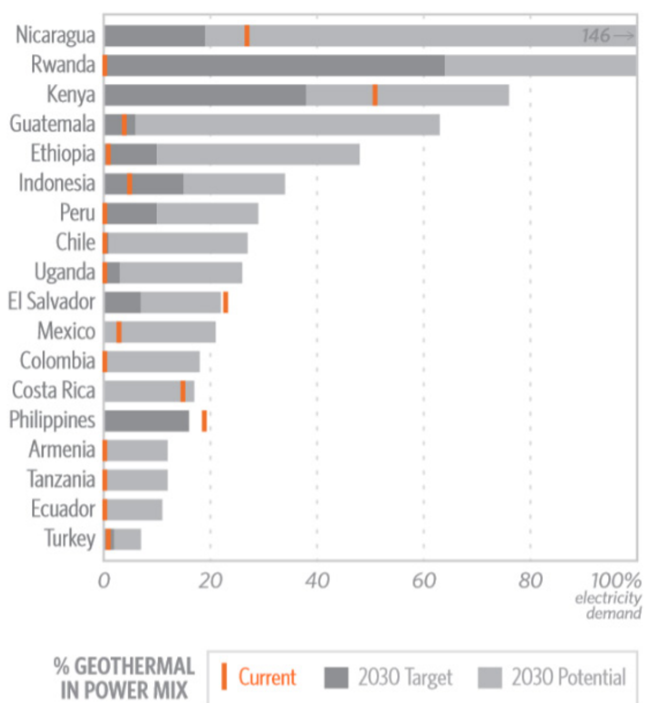

Figure 2: Potential role of geothermal energy in electricity demand (Oliver, 2015).

3. Geothermal and Mining

3.1 Global Geothermal Potential and Mining

3.1.1 Overview

The mining industry is one of the largest industries in the world with clients on every continent (except Antarctica). Whether the mine is interconnected with a local grid or produces off-grid power, the capital cost, operating cost and sustaining capital requirements associated with the energy supply represents a large percentage of the overall operation's budget. Within the topic of energy, mines are under constantly increasing pressure to tackle modern challenges such as the high cost of power, carbon taxes, and more stringent emissions requirements. Many companies are constantly exploring ways to reduce the cost of power through increased efficiencies and incorporating renewables into their energy mix.

Mining operations tend to congregate around geological formations, the result of past or present geothermal activity. This is evident in the Figures below (figure 3 & 4). This conclusion suggests there is opportunity to investigate solutions to power mining operations with geothermal power. Geothermal is a well-established technology with more than 100 years of experience and an estimated 13.2GW of installed global capacity (Matek, 2016). The true implication is not proof of concept but determining where there is sufficient geothermal potential to support a mining operation's power demand and how to de-risk the capital investment required.

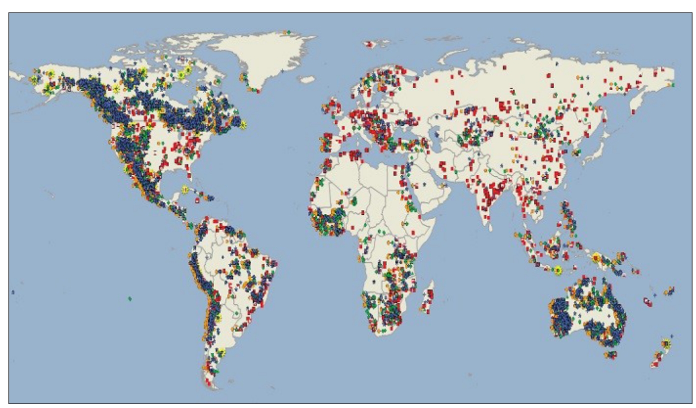

Figure 3: Global mining operations (INFOGRAPHIC: locating the world's minerals and mines, 2013).

Figure 4: Geothermal 'hot spots' (Sullivan, 2011).

3.1.2 Business Case

The mining industry today requires long-term reliable power supply, sometimes for more than 50 years mine-life. Uncertainty in fossil fuel pricing threatens a mine's value proposition due to resulting high-power costs. Geothermal represents a potentially co-located, renewable power supply that can provide base load power as well as direct use applications (such as heating, ventilation and air conditioning, process heating, etc.) (Jensen, 1983). Additionally, the long-term low cost of power (average levelized cost of electricity quoted by the US Department of Energy for resources entering service in 2022 of 3 to 6 cents/kWh) is very competitive compared to the alternative conventional thermal power supplies (U.S. Energy Information Administration, 2018).

Geothermal provides to a mining operation the following:

- Reduction in fuel supply logistics (most beneficial in remote locations)
- Elimination or limiting of future greenhouse gas and carbon tax risks
- Opportunity to improve overall project economics
- Physically secure relative to fossil fuels (collocated, only applies to mines with remote generation or power supply)

3.1.3 Business Compliment

Geothermal and mineral exploration risk have similar risk profiles. Mining companies understand this risk profile. At the risk of losing capital investment and development time for exploration and drilling, significant reductions in operating costs as well as reduced environmental impact are realized. This is not to say the concept applies to all mining operations globally (just as for wind, solar and hydro), but where geothermal potential can be proven and realized. The question now becomes how can mining companies use information they have available to de-risk geothermal exploration.

To identify geothermal potential, various methods have been implemented. Organizations have extensively mapped various regions to provide quick reference heat maps, such as the Oregon Department of Geology and Mineral Industries and Southern Methodist University have done in the United States (State of Oregon, n.d.) (SMU, n.d.). However, in the past drilling has always been the most effective means of providing initial justification for a comprehensive resource review. This allows mining exploration activities to be used as a "leg up" to quickly evaluate geothermal potential at mine sites with a degree of accuracy. In fact, many of the heat maps produced (including those developed by the above parties) use bottom hole temperature measurements from mining exploration sites to estimate thermal gradients. Exploration drill core data offers a determination if any geothermal potential exists at a site for a minimal, incremental investment. Stage-gated approaches implementing available mine data can mitigate potential risks, reducing the risk of exploration and technology to companies using existing mineral exploration data. If a viable opportunity is found, available mine data can be further leveraged to minimize the effort that is required for determining delineation wells and field development.

Secondly, companies can leverage geothermal power during the exploration phase of a geothermal field (if exploration is conducted). Companies can use successful wells, once drilled, to generate power for forward construction and exploration camps (likely in the range of 5 to 15 MW). Special purpose temporary geothermal turbine/generator sets are available that make use of standard test ("slim hole") wells to take advantage of this resource, prior to full field development.

Thirdly, a benefit many mining operations in the preliminary stage present is the ability to manage and understand the drilling aspect of geothermal. In the past, a major hurdle that has

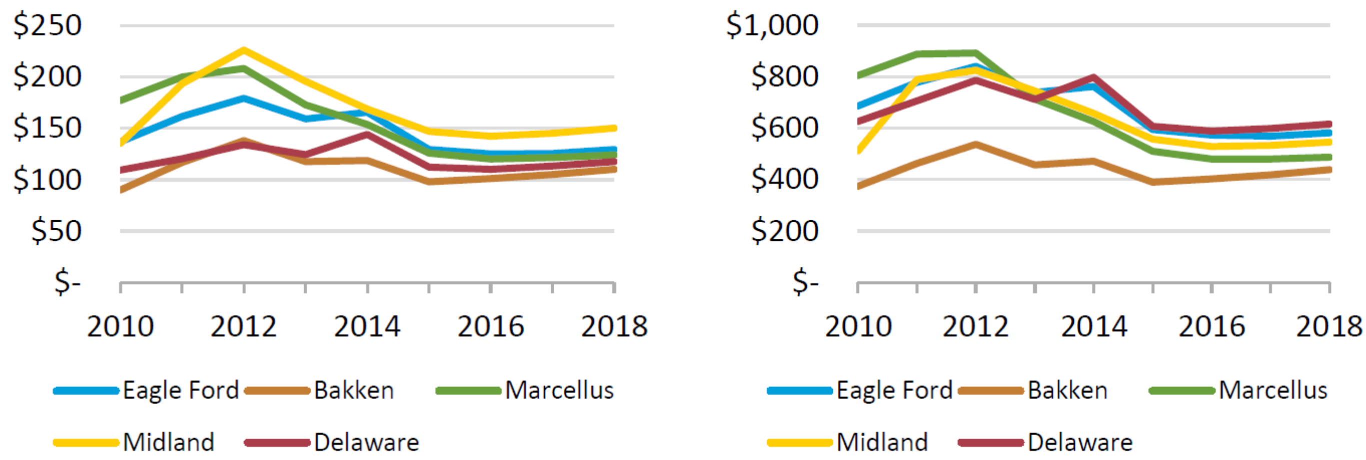

Figure 5: Cost per vertical depth and horizontal length. Left – Drilling cost per total depth (USD per foot). Right – Completion cost per lateral food (USD per foot) (U.S. Energy Information Administration, 2016).

halted many geothermal projects from moving forward is the costs required for drilling the wells, especially deep wells. However, in the past decade the cost of drilling deep wells has declined significantly as a result in advances from the shale oil and gas industry. These reduced drilling costs are greatly helping to reduce the upfront cost of geothermal developments. To further reduce these costs, many mining operations will already have drilling rigs on-site with planned drilling programs. This offers the ability to drill slim holes (or if plausible production holes) quickly for testing and further resource verification at lower cost. For reference, the EIA has made the tables above showing the cost of drilling over the past decade (figure 5).

Lastly, there is benefit aside from electricity production that geothermal may offer a mining operation. Given a geothermal heat source, some direct uses can include heating and cooling for HVAC systems, process heating (for example ore pre-heating and product drying), mineral production from brines, greenhouse heating, remote food production and agricultural drying (E. Patsa, 2015). To gain a broader idea of possible direct uses for geothermal, refer to the Figure below (figure 6).

Based on these benefits, one can derive that the critical factors for determining the suitability of geothermal energy in a mine include: quantity and flowrate of fluids available, fluid temperature, fluid quality and composition, mine infrastructure, proximity to energy user, specific energy needs, remoteness of location and price of energy, and the climate (E. Patsa, 2015).

3.2 Geothermal Use in Active Mining Operations

Geothermal energy has significant potential for integration within the mining industry on a global scale; however as of 2013, it was estimated that less than 20 mining sites were using geothermal energy (Younger, 2014). Most of these sites were inactive mines that were flooded in order to capture low-grade geothermal fluids for distribution to local communities as district heating. The potential to increase the use geothermal heat for this application, at a minimum, is substantial with the already substantial and continuously growing number of inactive mines worldwide, many of which could benefit from a district heating and

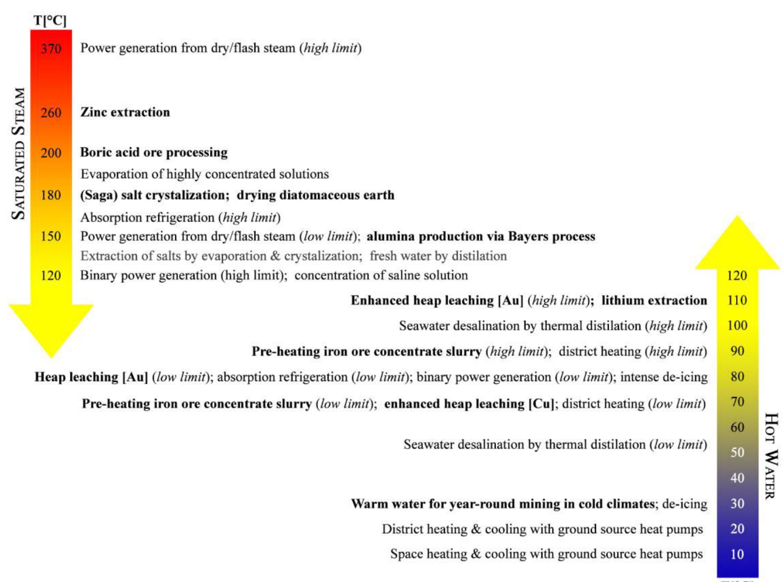

Figure 6: Geothermal resource potential use based on extraction temperature for various mining activities (E. Patsa, 2015).

cooling system (because of demand at the mine or at nearby communities).

Within Canada alone there are over 200 active mining installations, 55 of which are deemed to have usable geothermal energy sources for low grade use at a minimum. It has been estimated that typical Canadian mining operations utilize 20MW of heat which can correspond to an annual savings of approximately $3.5 million CAD if replacing natural gas or about three times that amount if replacing electricity (from a local grid) (Koufos, 2011). A separate study estimated that Canadian mines could potentially save $1.5 million CAD per year using 21MW of geothermal energy (in combination with heat pumps), saving 19,000 tons of carbon dioxide per year. This would only require underground fluid temperatures around 22°C (Koufos, 2011). However, the larger picture is for active mining sites to take advantage of geothermal resources to provide low cost energy and enhance operational sustainability.

Given geothermal energy's proven reliability, it is recommended that it be used to provide a baseload energy supply to mining operations with other systems in place for peaking requirements. These other systems may rely on grid connections, energy storage or small conventional power installations. Experience has demonstrated that due to high energy demands at most active mining sites, geothermal sources alone would, in many cases, not meet on-site demands, but still significantly reduce conventional fuel requirements and the mine's carbon footprint. Furthermore, following the mine's closure, existing geothermal energy infrastructure can be used to supply energy or heat to nearby communities as an additional post-mine cash flow.

The explanation for the lack of geothermal use within the mining industry on active sites is not abundantly clear. The largest cost associated with this form of energy is well understood to be upfront capital investment required for the combination of drilling and above ground infrastructure. One benefit of mining operations is that drilling related work (a prerequisite for any mining operation) are already being undertaken, and site infrastructure already envisioned for conventional power generation. Operationally, once the initial investment is made, the cost of power is lower with regards to geothermal energy than conventional fossil fuels, especially in remote locations where fuel supply logistics are perpetually complicated and expensive.

4.3 Outlook on Electrification of Mines

Driven by environment, regulatory and economic pressures, one of the current goals that many mining companies would like to achieve is the electrification of as much of their operations as possible. In combination with a base loaded renewable power supply, this would represent a "greener mine". While the use of energy storage technologies in battery-operated vehicles and mining equipment, as well as grid scale storage are becoming more prominent, the levelized price of electricity and reliability of its supply are still the main drivers. As a result, global operations remain highly dependent on fossil fuels.

The electrification of mines is the trend of using an increasing quantity of direct electrical energy instead of fossil fuels converted to create energy on-site to run a mine's operations, much like the trend of vehicle electrification towards battery powered cars. Unless a grid connection is readily available, mines that are remotely located have traditionally relied on diesel as a multi-purposed fuel. An electrification strategy for companies serious about the idea comprises of several stages which complement the mine's needs and lead to increased energy efficiency and decreased emissions. For example, being able to support a fleet of electrical mining vehicles can lower the need for energy-intensive ventilation in underground mines.

A general pathway for electrification could involve the following:

1. A base case is representative of conventional power generation and fossil fuels acting as the primary source of energy delivered to the mine. Mine electrical drives (such as vehicles, crushing and processing equipment) are running primarily on diesel. This requires a fuel supply network inclusive of transportation and storage.
2. Renewable energy is added according to the asset's assessments (geothermal, wind, solar, hydroelectric) to provide part of the load. Conventional power generation operation

is reduced, and in the case of multiple generators, some may be taken offline (potentially kept as emergency back-up). Energy storage can be added to ensure higher penetration of renewables and optimize the energy system; such as maximizing the runtime of generators at their peak efficiency. This can also include considerations of diesel-hybrid or fully electric drives. At this point a mine may employ microgrid protocols and controllers to optimize the system, and can be programmed for either lowest cost, lowest emissions, or highest energy efficiency.

3. The share of renewable generation has increased in the mine's energy mix, while conventional power generation has been minimized. At times, the mine can run on 100% renewable power, and only run on conventional generation for back-up power, much like grid connected mines. The share of electrified mine equipment can now grow to make use of the renewable energy available and minimize curtailment through smart charging of batteries.
4. Mine drives are now fully electrified and can run on renewable energy and energy storage batteries, and are managed by the mine's central (microgrid) controller and renewable power supply. Here other aspects of the mine (such as ventilation needs) can be minimized, and further optimization with added energy storage can allow the mine to operate on 100% renewable electricity, if not most of the time. In cases where the mine's consumption cannot be reliably met by renewable energy alone, there are options that will allow for load following capabilities to become a "set-and-forget" form of emissions limiting generation. Currently these technologies are limited in practice to conventional generators, however in the future may include small modular nuclear reactors.

3.4 Mineral Extraction

There exists an untapped secondary market in the geothermal industry, that being mineral extraction from geothermal brines. Depending on the location and depth of a geothermal brine, there is a possibility that dissolved minerals exist at large enough concentrations they become economically viable to extract and sell as a by-product. Among the various minerals that have been found in brines, such as manganese, boron, and zinc (to name a few), the most sought after in the current market is lithium. This additional opportunity can be very attractive to mining operations that better understand the mineral market, as this is in essence "mining of geothermal brines" and can transform a plant into a "mineral processing plant with thermal power". The resale of these minerals will help to bring down the cost of geothermal power, making it more competitive to conventional generation and, in select cases, drastically improving the net present value of a project.

To-date the focus for mineral extraction from a geothermal brine has been within the Salton Sea area of California. It is believed this region, on top of being one of the most attractive geothermal resources within the United States, has high concentrations of lithium within its brines from which geothermal plants are already producing electricity. It is estimated that millions of tonnes of lithium could be produced from the reservoirs, enough to produce a significant number of the world's electric cars. More specifically, Neupane and Wendt stated the majority of geothermal brines (from a sample of more than 900) have a lithium concentration of 20 mg/kg of brine, however within the Salton Sea area they have been found to be as high as 400 mg/kg (Wendt, 2017). To put this into perspective, current technologies are claiming extraction efficiencies of up to 99% are achievable from geothermal brines, which at a current market price of 16,500 USD/tonne presents a significant revenue stream (Lithium Price, 2018). However, although much research and development has gone into this geothermal field (including pilot projects), there has yet to be a technology commercialized and brought to market.

4. Risks and Opportunities

When it comes to evaluating the risks associated with geothermal developments, there is one challenge that is unique from both the renewable and conventional energy industry. That being every geothermal field is unique; sections within a geothermal field may exhibit different characteristics or development challenges (even throughout a single geothermal field). As a result, investment in geothermal projects has significant upfront costs that must be spent prior to validating the performance (or lack thereof) of an exploitable resource. This investment is used to drill test wells to generate brine flow and test performance of the well. Additional to this, what are called delineation wells are drilled at the boundary of the field to test how the performance may vary across the field. This large upfront investment raises the risk for investors as they must commit capital without complete reassurance on the return profile for the project. This reassurance and risk reduction is only truly provided upon completion of test wells and delineation wells, as they can outline the performance of the project with real time data.

The risk profile in geothermal projects is demonstrated graphically in the figure below (figure 7). It's worth noting that, although this profile is being explained in the context of the geothermal industry, it is applicable and well understood within the mining industry.

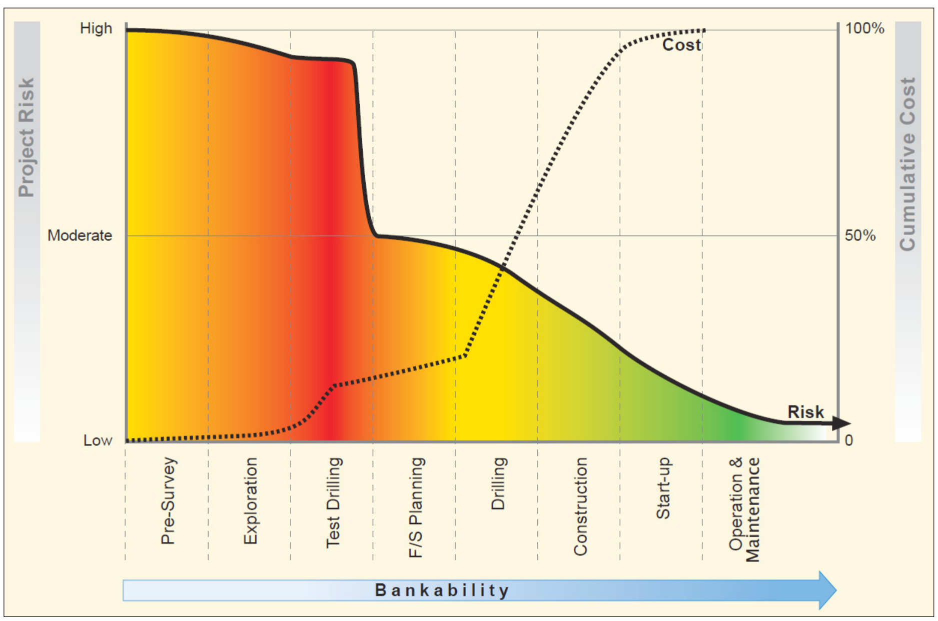

Figure 7: Geothermal development risk profile (Loksha, 2012).

It can be inferred that the risk versus the opportunity geothermal presents in mining applications is relatively polarizing. That is the higher risk comes at a higher reward. However, this statement is also subject to a case by case basis and much of the risk can be reduced due to favorable project conditions (readily available and proven resource). The major risks and opportunities with geothermal power developments that would be of greatest concern to mines are outlined below.

4.1 Risks

High Risk – There is risk in the capital investment and development time (exploration and drilling) if an adequate resource is not identified. This is a risk related to any resource development and would have to be considered along with the development time of the mine.

Medium Risk – Depending on the location and requirements of the project, permitting the production wells, transmission, power interconnection and land ownership (surface and mineral rights) would have to be considered in the context of supporting the project and timelines. The capital cost and margins may be impacted by this.

Low Risk – There is a risk that fossil fuel prices trend downward with time over the development period of a project impacting the geothermal cost margin as opposed to the alternative. In terms of operational costs this is considered low risk impact as operating cost margins for geothermal power versus fossil fuel power are often large, however there may be considerable impact on the initial capital cost/benefit trade-off to the alternative.

4.2 Opportunities

Significant Cost Impact – The operating cost margins between geothermal power and conventional power are large and often imply good payback on capital investment as well as operating costs and project free cashflow after payback. Additional to this, depending on the local jurisdiction there is a possibility for environmental credits or other government subsidies to decrease either the initial capital or operating costs for a project.

Environmental Impact – The usage of geothermal power has a positive impact on project's CO_2 footprint and will lower other emissions such as NOx. This drives the opportunity for projects to acquire carbon credits and other subsidies, depending on the jurisdiction they operate within.

Implementation Flexibility – Given the long development schedule for geothermal power, it can be considered a "bolt-on" option in the later years of a project, including existing projects, if another power supply option is initially carried forward or in place, respectively. The large operating cost margin will allow it to be considered for fossil fuel replacement in support of operating cost reductions. This type of implementation would fit well with a project that can generate free cash flow quickly after capital payback or if fossil fuel pricing spikes in the future.

5. Case Studies

5.1 Geothermal Electricity on Active Mining Sites

Mines in tectonically active regions of the globe may have access to high energy geothermal systems that can be used directly for electricity production. Possibly the only existing mining facility generating on-site geothermal electricity has been in Papua New Guinea. The Lihir Mine is currently one of the largest open pit gold mines in the world using conventional leaching processes for gold recovery. The gold deposit is within the Luise Caldera, an extinct volcanic crater that is geothermally active. Currently the mine's installed electrical capacity sits at a combined output of 172MW, made up of 22 Wartsila engines. Originally geothermal development played the role of dewatering and depressurization of the mine (for use in processes), however as drilling activities increased and to offset fossil fuel requirements, geothermal exploration began in 2001 with a 6MW pilot plant being brought online in 2003 using 240 - 300^{o} brine (M. Melaku, 2010). A full scale 50MW facility was commissioned in 2007 and further exploration drilling has proceeded since. All units have operated with high availability of greater than 95%. This has resulted in an estimated CO_2 emissions reduction of roughly 250,000 tons per annum (Newcrest Mining Limited, 2012). This provides recognition that geothermal energy can be delivered to support mining operations and reduce dependency on conventional power plants given the right location.

Figure 8: Lihir Gold Mine, Papua New Guinea. Geothermal power plant to the left side (Zealand, 2017).

A geothermal power generation plant was also considered at the Veladero Goldmine in Argentina in 2013 with a proposed capacity of 8 – 14MW using a binary power plant design (low temperature application). This plant would have provided 66 – 100% of the active site's operational requirements, but a lack of current information leads one to speculate the project never came to fruition, likely due to external economic influences (Richter, 2013).

5.2 Geothermal Ancillary Applications on Active Mining Sites

One example of an older active mine utilizing low-grade geothermal energy for heating was the Henderson Molybdenum Mine in Colorado. Water at about 30ºC was used to heat mine air to control working temperatures and prevent equipment from icing in the cold Colorado climate. Geothermal heating allowed for an increase in air temperature of 9.4ºC, providing 5.9MW of energy (Jensen, 1983). This provided a very inexpensive source of heat energy. If additional heating was required above the geothermal capabilities, an on-site boiler was available.

Mining activities can also use geothermal brines for direct mineral extraction if they are in the form of concentrated brines. This extraction method has the potential to be more lucrative for certain precious metals, such as lithium, than conventional rock mining. Additionally, geothermal fluids can be used to run desalination plants which will become more important as water shortages become increasingly commonplace world-wide. Given that most mining operations require large volumes of water, desalination facilities could be necessary or even mandated by some governments in the near future. Geothermal desalination processes often use 55 - 99^{o}C fluids to thermally distill seawater (E. Patsa, 2015).

Finally, mineral processing methodologies themselves can be improved with the use of energy from geothermal fluids. One such process is enhanced heap-leaching which recovers minerals from low-grade metal ores that contain uranium, gold, silver or copper. The use of heated fluids can speed up and improve the yields from this process. In Nevada alone, 10 such heap-leaching mining sites exist with near-by geothermal resource capabilities. Two highlighted facilities that have used geofluids are the Round Mountain Goldmine using 82°C fluids with a capacity of 14.1MW and the Florida Canyon Mine using 99°C fluids at 1.4MW (E. Patsa, 2015). Previously, the Freeport Jerritt Canyon Mine and the Gooseberry Mine also utilized similar geofluid-enhanced mineral extraction processes.

5.3 Geothermal Use in Northern Mining Operation

An assessment was recently done by a Canadian engineering firm of the geothermal potential at a northern mining site located within North America with an anticipated mine life in excess of 40 years. The remoteness of the mine resulted in studies for more than 300 km of transmission lines as well as remote site power generation and fuel storage. The potential for geothermal power was identified previously by the Southern Methodist University (SMU) utilizing bottom hole temperatures from existing exploration drill core data, offering a fast and cost-effective method of determining site suitability. Using the available data, an analysis of the site and surrounding area was undertaken to compare the possible costs of geothermal versus on-site diesel or natural gas generation. From the drill core data, it could be inferred that 120 - 150°C could be achieved at depths of roughly 5 km. The conditions at this site were determined to be unfavorable compared to others on a basis of initial capital investment. It was estimated that a geothermal facility would cost more than double that of a diesel power plant, however the benefit in the reduced operating costs would represent a reduction of more than 90% compared to a diesel power plant.

5.4 Geothermal Assisted Power Generation

Another promising application of geothermal is the integration with conventional steam power plants through geothermal pre-heating, more specifically those supplying mining operations. Existing coal fired power plants can increase their overall plant efficiency by installing geothermal pre-heaters for the boiler feedwater (thus increasing overall system efficiency). Conventional feedwater heaters, which use steam extractions from the various steam turbine stages to preheat the boiler feedwater for higher plant efficiency, could be replaced by geothermal feedwater heaters. Geothermal preheaters function similarly to conventional preheaters, except geothermal fluid would circulate through the heat exchangers instead of extracted steam. By reducing the steam extracted, more steam passes through the turbine resulting in a lower fuel demand from the boiler. The number of feedwater heaters that could be replaced depends on the temperature and flow rate of the geothermal source and the plant's design. Although not all feedwater heaters can be feasibly replaced with geothermal, significant benefits could be realized by the replacement of even one or two.

A model was developed to assess the potential of geothermal pre-heating. An existing 300MW coal fired power plant with a circulating fluidized bed boiler was modelled. The two lowest temperature feedwater heaters were replaced with geothermal pre-heating and the third lowest feedwater preheater benefitted from partial pre-heating using the geothermal source. A representative geothermal source of 175°C was used. A potential increase in gross power of 2% to 3% (9MW) was realized for the same fuel consumption with one-third of the capacity of one geothermal well (approximately 30 kg/s of brine flow).

Geothermal pre-heating is not a new concept. It has been considered since the 1970s, but the high capital cost has been off-putting to investors and owners. However, it is proposed to employ geothermal pre-heating as the first step in a phased implementation approach to a full geothermal power conversion. This approach is attractive to investors as it offers mitigation of major risk, deferred capital expenditure, a more inviting cash-flow and a test period for geothermal technology in operation.

The main benefit of this proposal lies in risk mitigation and evaluation of the technology in operation. By developing only a few wells and subsequently implementing geothermal pre-heating, the quality and availability of the geothermal resource will be confirmed prior to investing the larger upfront cost required for the geothermal power plant. The returns on investment for these wells will not appear attractive when looked at separately from the downstream benefit. The phased approach also allows the owners and operators to evaluate the technology in operation before converting to a geothermal power plant.

6. Conclusion

It is clear geothermal and mining have historically had little engagement between industries due to a lack of economical and practical applications. Recently, the geothermal industry has been working towards reducing costs and expanding exploration and opportunities where previously believed to not be plausible. In conclusion, there are now evident synergies between the geothermal and mining industries which could benefit one-another given the right opportunity. Although it may not be realized the mining industry already plays a large role in front end identification of geothermal resources. As inevitable trends such as climate change and renewable energy continue to drastically change the markets, mines will be looking for solutions that offer the most benefit. It is possible that within the future energy mix, geothermal can play a much larger role.

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

Preliminary Assessment of Offshore Geothermal Resource Potential of Portugal - The Case of Azorean Deep-Sea Hydrothermal Vents

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Keywords
- Offshore geothermal energy
- Hydrothermal vents
- Resource assessment
- Volumetric method
- Azores archipelago
- Portugal
- Supercritical

ABSTRACT

Hydrothermal vents are submarine hot springs and geysers that originate in volcanically active areas often at mid-ocean ridges, where the planet tectonic plates are spreading apart and magma wells up to or close to the surface of the seafloor. Hydrothermal circulation at the deep ocean ridges is an essential complex process regulating mass and energy transfer from the interior of the Earth through the oceanic lithosphere, to the hydrosphere and the atmosphere. Hydrothermal venting has long been recognised to provide significant fluxes of both heat and chemicals to the deep ocean. Hydrothermal fluids are generally with high heat flows and dissolved minerals, making them an excellent target for exploitation of hydrothermal energy and mineral resources. The energy extraction from the hydrothermal vents could provide a carbon-free and sustainable source of energy for the future generations.

A substantial number of hydrothermal fields are located in the vicinity of the Azorean archipelago (Portugal) comprising high-temperature fluids under supercritical conditions. The hydrothermal vents of the Azores are a chain of vents that are fragments of the Mid-Atlantic Ridge. These geological structures, developed from masses of basalt, are of a geomorphological interest, in addition to being a rich ecosystem of diverse subaquatic plant and animal life.

Although challenges and barriers exist in exploring mid-ocean ridge hydrothermal vents, these resources remain to be one of the

most potential and stable sources of renewable energy. The study at hand presents a preliminary assessment of geothermal resource potential of the Azorean hydrothermal vents using a modified version of the volumetric stored-heat assessment method developed by the United States Geological Society (USGS) (1979) and the energy balance method presented by G.Hiriart (2010). The further part of the study aims at using the obtained data to assess the technological and economic potential of energy extraction from the hydrothermal vents.

1. Introduction

The recent and estimated trends indicate that renewable resources will provide a rising contribution to the global power systems in the coming decades. Though renewable energy is one of the fastest growing markets in the world, much of geothermal energy resources has remained unexplored. Geothermal power generation is low carbon, a cost-competitive source that offers a stable base-load power output, that must overcome several challenges and perceived barriers to capture a more significant share of renewables (Deloitte, 2008).

Offshore geothermal energy has remained highly an underdeveloped energy resource with massive potential. In the contexts of climate change and energy security, offshore geothermal acts as an excellent resource as it bridges both the conventional feedstock and renewable energy options for electric power generation. It is because geothermal power provides base-load generation allowing it to compete with other baseload feedstocks such as coal and natural gas. At the same time, it is clean and renewable that competes with other renewable energy options such as wind and solar.

The ocean has immense resources that could support the humanity energy needs. Mid-ocean ridges are one such kind of sources with significant potential of geothermal energy. The hydrothermal fluids in these settings are observed with extreme heat flows making them highly attractive for energy extraction (Hiriart et al, 2010a). As described in (Pedamallu et al, 2017) the Azorean archipelago is one such setting with an extensive number of hydrothermal fields containing high-temperature fluids under supercritical conditions.

The geothermal resource evaluation is made to confirm the existence of a geothermal resource that can be exploited at a reliable capacity for a specified period with distinct fluid characteristics and resource management. The study at hand presents a preliminary assessment of theoretical geothermal resource potential of the Azorean hydrothermal vents using a modified version of the volumetric stored-heat assessment method developed by the United States Geological Society (USGS) and the energy balance method (Hiriart et al, 2010b).

2. Site Description/ Study Area

2.1 The Azorean Archipelago & the Mid Atlantic Ridge

The archipelago of the Azores is a cluster of nine volcanic islands situated in the North Atlantic Ocean with an Exclusive Economic Zone (EEZ) of one million square kilometres and a mean depth of about 3000 m (Peran et al, 2016). The Islands of the Azores are located between 37° and 40° N latitude and 25° and 31° W longitude, placed along a narrow area that extends for about 600 km. It includes the Western Group (the Flores and Corvo Islands), the Central Group (the Terceira, Graciosa, São Jorge, Pico and Faial Islands) and the Eastern Group (the São Miguel and Santa Maria Islands and the Formigas Islets) (Oliveira et al, 2004). The islands are dispersed along a general WNW–ESE trend crossing the Mid-Atlantic Ridge in the area where the Eurasian, African and North American lithospheric plates meet. Seamounts are the most common features in the Azores and occupy 37% of the total area of the exclusive economic zone of Azores (Morato et al, 2008).

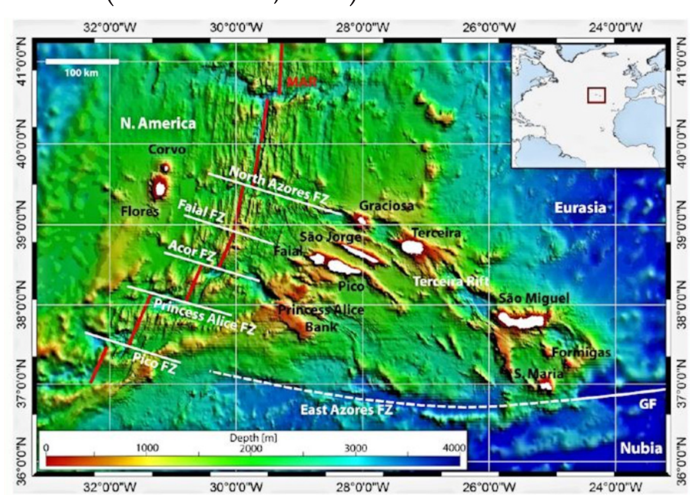

Figure 1: General Tectonic Framework of the Azorean Archipelago (adopted from - Weiß et al, 2014)

The Mid-Atlantic Ridge (MAR) is about 3 km in height above the ocean floor and 1000 to 1500 km wide, has several transform faults and an axial rift valley along its length (Centre, 2018). The MAR detaches the North American Plate from the Eurasian Plate in the North Atlantic, and the South American Plate from the African Plate in the South Atlantic as shown in figure 1.

The MAR near the Azores has four known major hydrothermal vent fields (figure 2) namely, Menez Gwen located at (37°51′N, 31°31′W, 800m depth) (Cerqueira et al, 2015), Lucky Strike located at (37°18′N, 32°16′W, 1738m) (Langmuir et al, 1997), Saldanha located at (36°34′N, 32°26′W, 2200 m) (Biscoito et al, 2006), and Rainbow (36°14′N, 33°54′W, 2250m depth) (Khripounoff et al, 2001). Each site presents specific geological, chemical, hydrothermal, and biological characteristics.

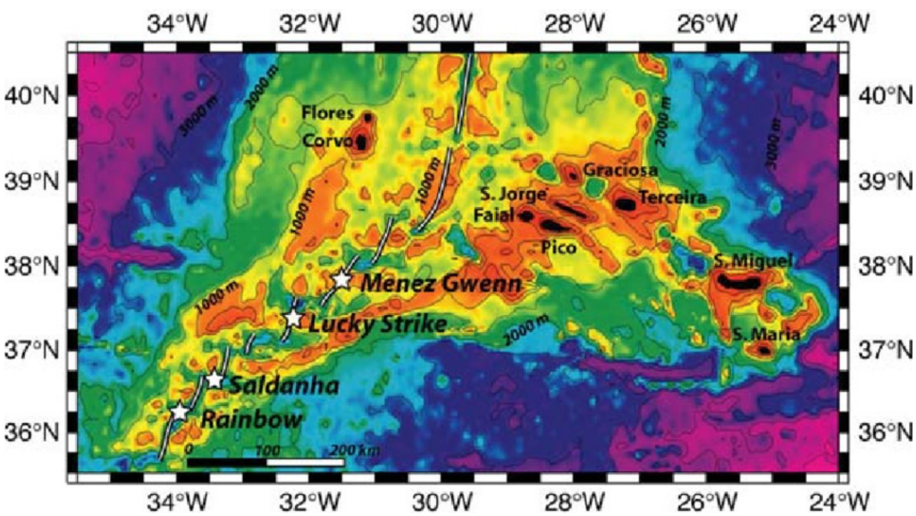

Figure 2: Location of the hydrothermal vent fields (white stars) near the Azores Triple Junction (Colaço et al, 2010)

2.1.1 The Lucky Strike Hydrothermal Vent Field

The Lucky Strike hydrothermal vent field was the first Atlantic site found on crust that is dominated by a hot spot signature which was discovered in 1992 during the US mission Fazar. It is the largest known hydrothermal field within the Azorean archipelago with an area of 50 sq.km along with 21 active vents that extend over approximately one square kilometre along the sea floor (Ventsdata. interridge.org, accessed. May 2017). The Lucky Strike Hydrothermal Field is located in a depression formed by the lower slopes of three extinct volcanoes surrounding a lava lake at ca. 1700 m depth. These volcanoes are at the summit of the Lucky Strike Seamount (37°17.5′N) emerging from the MAR rift valley. Many individual sites as shown in figure 3 are found in the vent field that exhibit diverse manifestations of hydrothermal activity, ranging from black smokers to flanges (Saldanha et al, 1996). Vent morphologies range from flanges and chimneys with pool temperatures of 200-212°C to black smoker chimneys with temperatures up to 333°C (Charlou et al, 2000) and chimneys discharging lower temperature diffuse fluids.

The vents at Lucky Strike surround a flat expanse of ropy lava and spectacular pillar structures, interpreted as a fossil lava lake (Fouquet et al, 1995). Hydrothermal vents to the south and the west of the lava lake are built on a unique formation of layered basaltic breccia; sometimes silica-cemented, that forms a slab-like material up to a meter-thick (Langmuir et al, 1997), (Ondréas et al, 1997), (Humphris et al, 2002).

2.1.2 Saldanha Hydrothermal Field

The Saldanha hydrothermal field (36°34′ N; 33°26′ W) (NTO5), is located at the MAR, south of Azores Archipelago between the Pico Fracture Zone (PFZ), and the Oceanographer Fracture Zone (OFZ) (Dias et al, 2006).

Saldanha is a diffuse hydrothermal system where transparent and low-temperature fluids (6-9°C) emanate from discrete orifices on the seafloor, triggered by ultramafic and mafic heat sources. The lower temperatures measured

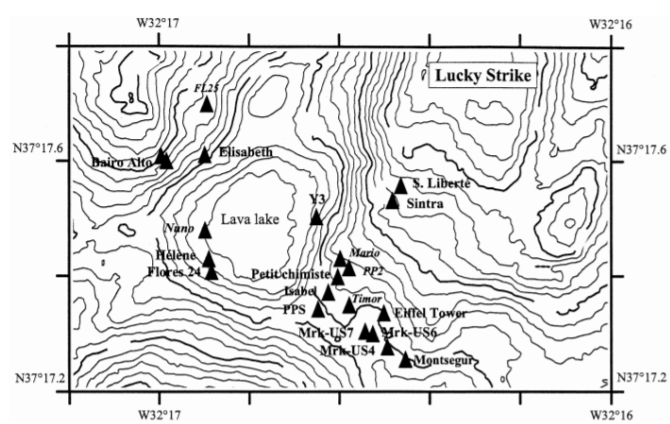

Figure 3: Lucky Strike Hydrothermal Field (Charlou et al, 2000)

at the diffuse vents are probably a consequence of cooling effects during conductive circulation and seawater interactions. The mineralogy of the sediments, in particular, the occurrence of sulphide, suggests higher temperatures for this system than the ones measured at the vents. Petrographic and geochemical studies of sediments from this vent area, collected by a gravity core during CD167 in 2004, revealed that hydrothermal fluids have reacted with these sediments at temperatures higher than 250 °C (Dias et al, 2010).

The Mount Saldanha is a submarine hill of about 700 m with an area of 400 sq.m located at a depth of 2200m (Barriga et al, 1998; Biscoito et al, 2006). The top of the mount contains rock types like gabbros, basalts, etc. depicting varying degree of hydrothermal alterations. The observed hydrothermal alterations suggest higher temperatures of 300-400°C immediately under the sediment. The Mt. Saldanha may represent the earliest phase of the hydrothermal field (Barriga et al, 1998).

2.1.3 Menez Gwen Hydrothermal Field

The Menez Gwen hydrothermal vent field is located at (37°51′N, 31°31′W) is a ridge centred, basalt-hosted hydrothermal complex, at 850 m depth in the Mid-Atlantic Ridge, inside the Portuguese exclusive economic zone within the Azores Marine Park (Cerqueira et al, 2015). The Menez Gwen hydrothermal field was discovered in 1994 during the DIVA expedition (Saldanha et al, 1996). It is the shallowest known vent system on the Mid-Atlantic Ridge that host chemosynthetic communities. The Menez Gwen seamount has a diameter of 17 sq.km, and the active vent field is located at the topographic high of the ridge segment as represented in figure 4. The central part of the volcano consists of an axial graben with an area of 12 sq.km and 300m depth filled with fresh lava (Saldanha et al, 1996). The lava has no sediment cover, and it has been suggested that the entire small volcano built up during the latest eruptive episode (Ondréas et al, 1997). The hydrothermal activity at Menez hydrothermal activity is mainly concentrated over small areas, primarily on a small volcano located at the top central area of the field and whose highest point reaches 800 m below the sea surface (Marcon et al, 2013). The diffuse fluid temperature extends between 10 and 56 °C while the hottest spotted fluid escapes from chimneys at an approximate temperature of 284 °C (Cerqueira et al, 2015).

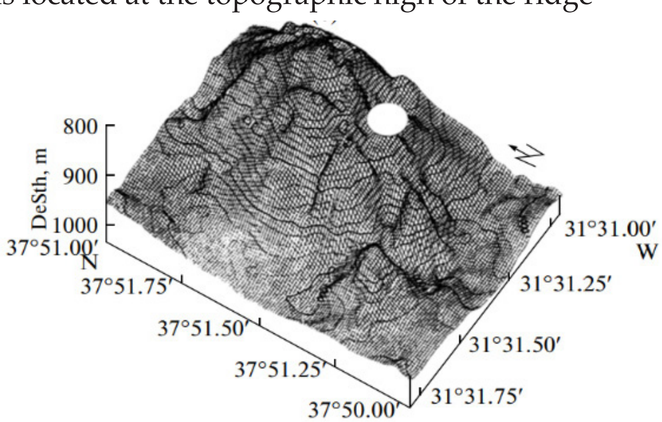

Figure 4: Block Diagram of Menez Gwen Volcano (Lein et al, 2010)

2.1.4 Rainbow Hydrothermal Field

The Rainbow field is situated at 36°14′N, 33°54′W, southwest of the Azores on the Azorean fragment of the MAR at a depth of 2270 m (Christiansen et al, 2003; Charlou et al, 2002). Rainbow was discovered during the FLORES diving cruise in 1997 (Fouquet et al, 1997). Rainbow is based on ultramafic rocks, causing the fluid to be more acidic with higher metal and methane concentrations (Douville et al, 2002). The active vent field is spread over an area of 15 sq.km, that is located on the western flank of the Rainbow ridge (Fouquet et al, 1997). Rainbow was found to have ten groups of active black smokers (see figure 5) owing to the high temperatures 364°C, which have some of the strongest plumes, whereby diffusion could be 10-15 km from the vent (German et al, 1996). The Rainbow consists of active vents that vigorously emit fluids with uniform chemical composition of major, minor, trace elements (Douville et al, 2002).

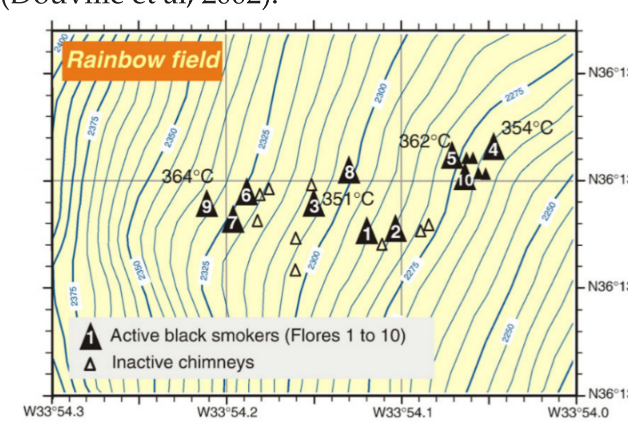

Figure 5: The Rainbow Hydrothermal Field (Konn et al, 2009)

3. Methods of Assessment

The geothermal resource assessment is required to confirm the existence of a geothermal resource that could be exploited at a guaranteed capacity for a specified period with well-defined fluid characteristics and resource management (Sarmiento et al, 2011).

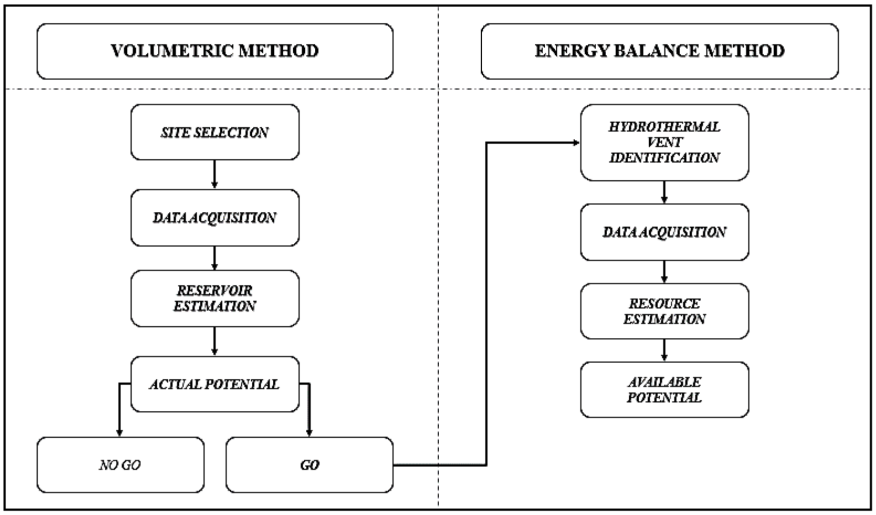

Figure 6: Framework of Assessment

The study considers two important methods of resource assessment (see figure 6) to estimate the available resource potential.

A modified version of the volumetric stored-heat assessment method is used (Equations 1,2 and 3) to assess the geothermal reservoir potential. The volumetric stored-heat method was developed by the USGS in the 1970s to assess the production potential of geothermal systems (Muffler, 1979). The volumetric method refers to the review of thermal energy in the rock and the fluid which could be mined based on specified reservoir volume, reservoir temperature, and reference or final temperature. The actual available power is assessed using Equation 4. The analysis is made for two scenarios with a heat recovery factors of 0.1 and 0.05 and conversion factors of 0.15 and 0.06.

$$E_t = E_f + E_r \quad (1)$$

$$E_r = A \times h\,[\rho_r.C_r.(1-\emptyset).(T_i - T_f)] \quad (2)$$

$$E_f = A \times h\,[\rho_f.C_f.(\emptyset).(T_i - T_f)] \quad (3)$$

$$P = \frac{E_t \times R_f \times C_e}{P_f \times t} \quad (4)$$

Where, E_t, E_r, E_f are total energy (kJ/kg), energy in rock, and energy in fluid respectively; A, h, t are area (m^2), height (m) and time in years; ϱr, ϱf are rock density and fluid density (kg/m^3); Ø is rock porosity; C_r, C_f is specific heat of rock and specific heat of fluid (kJ/kg.°C); R_f, C_e, P_f are recovery factor, conversion efficiency and plant factor; T_i, T_f is initial temperature of fluid, rejection temperature of fluid, measured in °C.

Further, the energy escaping from the individual vent is assessed using the energy balance method as shown in Equation 5. The energy balance considers the submarine technology with one heat exchanger in the bow and one in the stern. The heat exchangers are located on top of the vent, and the other is exposed to the cold water of the deep sea. Inside the submarine, a binary cycle plant is operated between those two, hot and cold, spots.

The obtained results were used to identify the available potential of the hydrothermal vents using Equation 6. For the power plant sizing, the heat exchanger efficiency and cycle efficiency of the chosen technology Table1 is considered.

Where D is the diameter of vent in meters; υ is the velocity of exiting fluid (m/s); T_h and T_c are temperature of vent fluid and temperature

$$E_{HV} = \frac{\pi}{4} D^2 \times \upsilon \times \rho_{avg} \times C_f \times (T_h - T_c) \quad (5)$$

$$P_{HV} = E_{HV} \times \eta_{HEX} \times \eta_{CF} \quad (6)$$

of surrounding water measured in °C; P_{HV} is the power potential of hydrothermal vent; E_{HV} is the total thermal energy; η_{HEX} is the efficiency of heat exchanger; η_{CF} is the conversion efficiency.

3.1 Parameters, Assumptions & Limitations

An extensive review of the literature has been made on the mid-ocean ridge hydrothermal vent fields of the Azores. A wide range of parameters were considered for the estimation of the resource potential of the hydrothermal fluids. Previously published geological, geochemical, and geophysical data on the hydrothermal fields and the hydrothermal fluids of the Azores were included in the study. The theoretical available thermal power in the discrete hydrothermal vent fluids are assessed using the parameters of fluid flow, vent diameter, fluid temperature, and depth.

Table 1: Input Variables

Input Variables	*Units*	*Hydrothermal Vent Fields*			
		Menez Gwen	*Saldanha*	*Lucky Strike*	*Rainbow*
Number of Active Vents	-	10	1	22	10
Vents Considered (this study)	-	1	1	16	10
Fluid temperature	^0C	284	6	333	360
Depth	m	850	2200	1700	2200
Pressure	bar	86	221	171	221
Rock Density	kg/m^3	2000			
Fluid Density	kg/m^3	746.35	-	649.66	576.74
Heat capacity of the rock	kJ/kg.K	2			
Heat capacity of the fluid	kJ/kg.K	5			
Porosity of Rock	-	10 %			
Fluid Velocity	m/s	3			
Rejection Temperature	^0C	90 (Binary Plant)			
Vent Diameter	m	0.3			
Recovery Factor	-	0.1 (case1) & 0.05 (case2)			
Conversion efficiency	-	0.15 (case1) & 0.06 (case2)			
Heat Exchanger efficiency	-	13 %			
Cycle efficiency		31 %			

In arrears to the early stage of the research on offshore geothermal utilisation and due to the limited availability of data, few assumptions have been made in order move further with the analysis. The rock density has been considered the same for all the vent fields since all of them are volcanic rocks. Though the temperature of the fluid and the depth of each vent in the vent field may be different, this study considers the same temperature and depth for all individual vents located in the vent field. The rock porosity is assumed as 10% as stated in (Suarez, 1998) however the effective porosity must be considered to obtain more accurate results. The fluid velocity and the diameter of the typical vents are considered as shown in Table 1 and could be different from the actual scenario since it is site-specific in nature.

The limitations of the study include the avoided drilling scenario as described in Parada et al, (2012) and Hiriart et al (2010a). The energy estimates include only the use of thermal fluids that are fuming out of the hydrothermal vents. Higher energy output can be achieved if conventional methods are used. These calculations are restricted to the submarine areas of the Azores.

4. Results & Discussion

As a preliminary assessment, the reservoir estimation has been made using the equations 1, 2, 3 and 4. The analysis is presented for the complete study area, and the hydrothermal field Saldanha has been excluded from the study due to its lower temperature fluids and low reservoir potential. The obtained results as presented in figure 6, suggest that the vent fields Lucky Strike, Menez Gwen and the Rainbow have a huge reservoir potential and can be a reliable source for geothermal energy production.

Since the hydrothermal vent fields are environmentally sensitive areas with diverse species, drilling must be avoided to obtain environmental sustainability. To make sustainable use of the available resource, the energy content of the fluids escaping from the vent orifice has been assessed using Equation (5&6) The energy of the escaping fluids from the discrete hydrothermal vents can be readily captured and used for power production.

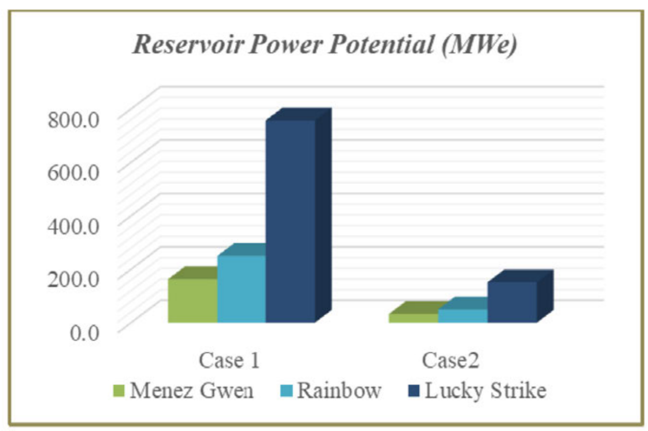

Figure 6: Reservoir Power Potential

The results as presented in figure 7 suggest that the hydrothermal vents in the Lucky Strike hydrothermal field have greater power potential of 9.1 MWe for single vent followed by Menez Gwen with 8.8 MWe and Rainbow with 8.7 MWe. However, considering the total number of vents in the hydrothermal vent field, Lucky Strike hydrothermal vent field constitutes greater power potential of 145 MWe followed by Rainbow with 87 MWe and Menez Gwen with 8.8 MWe. The observed differences are explicitly due to the variations in fluid temperatures, depth, and number of vents in the hydrothermal vent fields.

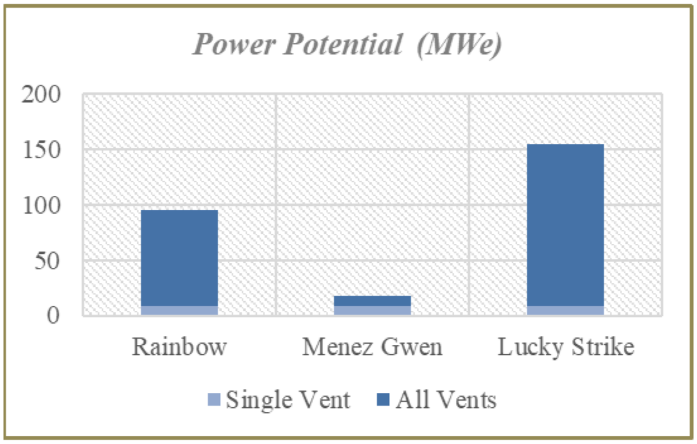

Figure 7: Actual power potential in MWe of single and group of hydrothermal vents in the vent field

5. Conclusion

Many factors affect the power production potential of the vent fields. An in-depth analysis, site surveys and multidisciplinary approach is needed in these kinds of studies in order to make their exploitation for power production a reality. The further part of the study aims at using the obtained data to assess the economic potential of energy extraction from the hydrothermal vents.

Acknowledgements

The authors acknowledge the financial support from FCT/Portugal for the PhD scholarship PD/BD/128055/2016 under the MIT-Portugal Program & Energy for Sustainability Initiative, University of Coimbra, Portugal, as well as the logistical support from the Research Institute of Volcanology and Risk Assessment from the University of the Azores, Portugal.

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S4CE: Science for Clean Energy project seeks to develop a scientific workflow for informing policy makers and the wide public

By TWI Ltd., Cambridge, United Kingdom

A project, which aims to implement innovative technologies within different field sites to monitor, manage and mitigate environmental risks, has received funding support from the European Union's Horizon 2020 programme. The multi-disciplinary consortium behind the successful funding bid comprises 22 partners from nine countries representing: ten academic institutions; three subsurface industry energy operators, one of which is a small to medium sized enterprise (SME); seven industrial partners including SMEs; and three major research institutes. S4CE: Science for Clean Energy commenced in September 2017 and is due to complete in August 2020.

The 10m EUR, S4CE project includes fundamental studies of fluid transport and reactivity, production of new instruments for the detection and quantification of emissions, analysis and modelling of micro-seismic events, and the testing of cement casings. During the development process, the new system's cutting-edge instrumentation will be deployed and put through its paces in three existing field sites: the CarbFix site in Iceland; a deep drilling, deep geothermal operation in Cornwall, UK and a 4450 m gas-water bearing well in St. Gallen, Switzerland.

Geothermal wells capture energy from the earth and could be an extremely efficient way to address climate change. Adequate inspection of the well casings, which are essentially large diameter pipes, is a key part of well management. Existing techniques include mechanical integrity testing, pressure and temperature monitoring, underground water sampling and distributed temperature sensing. All of these techniques are used either to monitor a specific part of a borehole or for generic well monitoring. For that purpose, utilizing condition monitoring techniques could increase the lifetime of the equipment through early detection of well casing failures and lead to lower maintenance costs.

TWI's role in the project is to identify the most appropriate technique, or combination of techniques, for monitoring geothermal well casings, with the objective of identifying any failure in advance of it happening and consequently avoiding catastrophic failure. At this stage of the S4CE project, acoustic emission and guided wave techniques have been applied to the testing of a 6m long, concrete-covered metal pipe, then subsequently tested on a well casing from the geothermal field site of Cornwall. The testing team found that while the emitted waves and guided waves propagate in the structure, they suffer a gradual decrease in amplitude, which reduces the range of inspection. Therefore, the attenuation effect on the propagating waves is tested. The results have shown that the attenuation rate is very promising in terms of the possibility of identifying a crack while the crack is being developed. Vibration analysis has also revealed a much higher attenuation rate compared to the other two techniques, the outcome being that acoustic emission in combination with guided wave is the most promising solution for condition monitoring of geothermal well casings. Based on the experimental findings, TWI is developing a platform that accommodates different condition monitoring techniques and an appropriate signal processing algorithm, that can be used to assess the condition of the well casings and identify a defect well in advance it propagates along the structure.

The next stage of the project is to test the most appropriate technique in the St. Gallen field site in Switzerland. The ultimate target is to verify the capability of deploying the platform in Cornwall where a novel concept for harnessing geothermal resources is currently being performed through the United Downs Deep Geothermal project.

Engineering sub-surface geo-energy operations is essential for our society. Operations such as carbon sequestration and geothermal energy can be seen as necessary to reduce the carbon footprint of our expanding society, while the production of hydrocarbons is needed to secure our standards of living until renewable energy sources are available in sufficient amount. Sub-surface geo-energy operations, however, carry intrinsic environmental risks. Quantifying the possible risks, identifying best practice procedures, implementing mitigation strategies and, when necessary, remediation methods is required for the responsible implementation of such operations.

S4CE is a project funded by the European Union's H2020 research and innovation program under grant agreement No 764810. The S4CE website is http://science4cleanenergy.eu. ■

Geo-Drill: A Holistic Drilling Technology For Geothermal Systems

By Geo-Drill Consortium

Geothermal drilling is by far the major element of cost in any geothermal project. This is particularly true for deep Engineered Geothermal Systems (EGS) in hot dry rocks where the costs increase due to increased drilling distances, tripping times and harsher environments. According to an estimate, drillings costs alone can contribute to about 30-70% of the overall project development expenditure for a deep geothermal project [1] — costs associated with use of expensive drilling rigs, drilling times including time spent to tackle drilling wear and trouble-shooting.

Drilling operation.

Project Geo-Drill is a collaborative project with an aim to develop drilling technologies that have the potential to reduce the cost of drilling. "Our aim is to develop holistic drilling technologies that have the potential to drastically reduce the cost of drilling to large depths, 5km or more and at temperatures as high as 250°C", says Geo-Drill consortium. The project kicked-off on 3rd April with a consortium meeting hosted by TWI Ltd. and will run for a period of 42 months.

Geo-Drill Concept and Technologies

The primary concept of Geo-Drill is based on three technology pillars: a) reduced drilling cost through hydraulic Down-the-hole (DTH) fluid/mud hammer; b) advanced drill monitoring through low-cost and robust 3D printed sensors; c) improved component life through advanced materials and coatings. In the Geo-Drill project, the strength of these technologies are combined to meet the unified objective of developing novel drilling

[1] Report on Geothermal Drilling, P. Dumas, M. Antics, P. Ungemach, 2013

Drill String.

technologies that will significantly reduce the cost of deep geothermal drilling. Additionally, the technology pillars are over-arched with a knowledge-based system (KBS) coupled to cost- and environment modelling and a decision support system (DSS) — A suite of design DSS, informed with the relevant information from flow assurance & drill string physics simulators and KBS, to produce reliable lifecycle estimates for performance, operational costs, environmental impacts and risks.

Geo-Drill Impacts:

Geo-Drill aims to develop economic and efficient methods, materials and designs for high performance drilling in deep and high temperature geothermal drilling environments. The new fluidic hammer, drill monitoring system and improved longer lasting drilling components developed through the project are intended to improve the rate of penetration, lifetime and reliability compared to existing commercial technologies. As such, Geo-Drill will enhance the growth of geothermal energy by significantly reducing geothermal power plant capital expenditure (CAPEX) spent on drilling while also significantly reducing the environmental impact during installation.

The Consortium:

The Geo-Drill consortium is of a complementary nature including product developers and end-user/ geothermal drilling operator ID, engineering firm, universities and research institutes. These include TWI Limited (Coordinator, UK), Hochschule Bochum (Germany), Geolorn Limited (UK), Jardboranir HF (Iceland), Precision Varionic International Limited (UK), Technovative Solutions Ltd (UK), Flowphys AS (Norway), Commissariat A. L. Energie Atomique et Aux Energies Alternatives (France), Gerosion EHF (Iceland), Haskoli Islands (Iceland), Rina Consulting – Centro Sviluppo Materiali SPA (Italy) and Graphenea SA (Spain).

Acknowledgement

The project has received funding from the European Commission H2020 program, grant agreement number 815319. ■

One of the requirements for a 2018 GRC Undergraduate Scholarship is to write an essay on the awardees experience in the local geothermal community. Here we present a submission from Christ Quinicot, a Bachelor of Science candidate in Geothermal Engineering at the College of Engineering & Architecture, Negros Oriental State University, Dumaguete City, Philippines describing his studies and the place of geothermal within the local community.

Geothermal in Negros Oriental

By Christ Quinicot, Negros Oriental State University

Tourism is a great source of additional revenue for any community in particular and for a country like the Philippines in general. Including geothermal energy in the tourism industry boosts support for the geothermal power plant operators and their investors and adds to the many ways visitors can experience the unique beauty of the Philippines. As the slogan says "It's More Fun in the Philippines" - even more so with geothermal!

The tourism industry in the Philippines has become more diversified. The islands are famous for sun-kissed tropical beaches, but increasingly visitors are also interested in the country's resources. For example, agri-tourism highlights the rich agricultural resources of the Philippines providing activities that bring visitors to a farm or ranch to experience a more interactive and purposeful activity. Geothermal power plants can do the same and more!

Geothermal energy in the Philippines is used mostly for power generation. According to the Philippine Department of Energy (DOE) 2017 Power Statistics report, the installed capacity for the renewable energy sector in the Philippines amounts to 31.1% of the total installed generating capacity in the country. The renewable energy sector is composed of Geothermal – 8.4%, Hydro – 16.0%, Biomass – 1.0%, Solar – 3.9%, and Wind – 1.9%. Though the total installed capacity of geothermal is only 1,916 MW as of April 2018, the government plans to increase it by another 1,371 MW by 2030.

The government is also considering the development of low to medium enthalpy or direct use geothermal areas in the country. This is a new focus of the government's 2030 roadmap because even though the country hosts marginalized low enthalpy geothermal resources, they have remained untapped. Effective utilization of these geothermal prospects will be another alternative for off-grid power generation and will be beneficial to the host community as they are typically located in remote areas. The DOE is now concentrating on developing direct use geothermal projects on Banton Island in Romblon, Balut Island in Davao Occidental, and on Maricaban Island in Batangas. However, there are other locations with opportunities for development of low to medium enthalpy geothermal like in my home province of Negros Oriental.

Negros Oriental is home to the second largest geothermal power production area in the Philippines mainly because of the presence of the inactive Cuernos de Negros volcano in Valencia. The geothermal resource extends from the municipality of Dauin in the south to the municipality of Sibulan in the north. Energy Development Corporation (EDC) manages the geothermal reserve in Valencia. Their plants have a total capacity of 112 MW. Aside from providing jobs to the local community in their power plants, the company also provides opportunities to work in various other indirect programs. One good example is the watershed program that helps in recharging the geothermal reservoir by planting more trees. EDC hires locals to plant and tend the trees as they grow. Furthermore, EDC also educates the locals about the positive impact of geothermal on the environment and to the health of every individual.

Another display of geothermal wonder that can be found in Valencia are its hot springs. On the way to the geothermal plant in Ticala, Valencia a number of hot spring resorts can be seen. A fumarole can also be seen from the road before reaching the resorts.

The Red Rock Hot Spring and Ocean 24 resorts use geothermal waters for the heating of their swimming pools. A lot of foreign tourists and locals come to the hot springs to unwind and relax. However, the only thing you can do at these resorts is swimming and bathing. The operators fail to see that there is more to the hot springs than this. Another possible direct use application of geothermal energy is for a geothermal sauna. This would be new to the locals and would attract many more tourists.

The geothermal sauna project is one of the target projects of the Geothermal Engineering department of Negros Oriental State University. The department's vision is to use geothermal energy in every possible way, especially direct use, to contribute to Philippine local communities. Other projects include using geothermal heat to dry fruit, incubate duck eggs, and in milk pasteurization.

A milk pasteurization project is the subject of my research. The use of geothermal heat for milk processing is widely used in Indonesia, New Zealand, and in Kenya but not here in the Philippines. The project may only be for a small volume, but what is important is proving the feasibility of the study. Through further research, a larger production of geothermally pasteurized milk is possible. However, to ensure that this research is sustainable, the students and faculty need financial support. The university is supporting the department every way it can but it sometimes proves insufficient. That is why scholarships like from the Geothermal Resources Council can contribute to the success of the research. It certainly helped me in my research by helping me buy the raw milk samples. I was able to transport my test samples to the laboratory for analysis, passing the Philippine standards. This financial aid is essential for the realization of the goals and projects of the program.

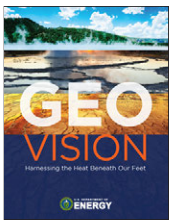
A project uses geothermal heat in the pasteurization of milk.

In addition, a partnership with a governmental organization will also help the program achieve its goals. The Department of Science and Technology (DOST) is providing financial assistance to researchers and projects that are innovatively helpful to communities. In the same way, the Department of Energy is also giving assistance by providing information on the places with geothermal direct use potential. A connection with the private sector will also be helpful in the research. Also, connections with international individuals and institutions would be helpful in boosting the utilization of geothermal energy through partnership with countries that have already exploited geothermal energy for direct use. ■

Publications, Websites, Videos & Maps

by Ian Crawford

Instead of a lengthy description of each of these recommended publications, we ask you to open the report webpage or download the report itself. Click on the live links in blue to open them in your browser.



GeoVision: Harnessing the Heat Beneath Our Feet - U.S. Department of Energy
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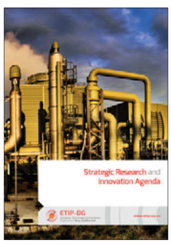

Strategic Research and Innovation Agenda for Deep Geothermal - European Technology & Innovation Platform on Deep Geothermal (ETIP-DG)
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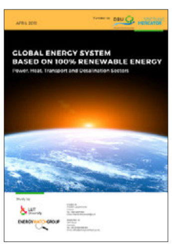

Global Energy System based on 100% Renewable Energy - Energy Watch Group
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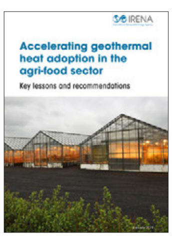

Addressing Food Security and Boosting Development with Geothermal Heat - International Renewable Energy Agency (IRENA)
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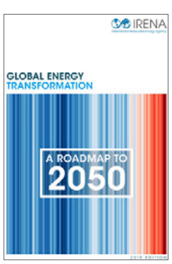

Global Energy Transformation: A Roadmap To 2050 - International Renewable Energy Agency (IRENA)
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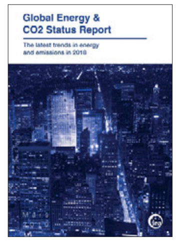

Global Energy & CO_2 **Status Report - International Energy Agency** (IEA)
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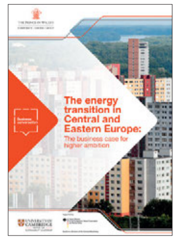

The Energy Transition in Central and Eastern Europe: The Business Case for Higher Ambition - The Prince of Wales's Corporate Leaders Group
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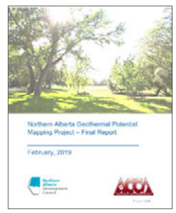

Northern Alberta Geothermal Potential Mapping Project - Final Report - Northern Alberta Development Council (NADC)
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How Multi-Technology PPAs Could Help Companies Reduce Risk -World Business Council for Sustainable Development
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Seismic Hazard Assessment at the Fallon, Nevada, Frontier Observatory for Research in Geothermal Energy Site - United States Geological Survey (USGS)
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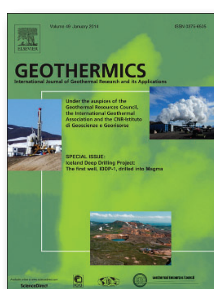

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Calendar of Events

NZGA Seminar: The Future of Geothermal in a Low-Carbon Economy.
11 July, New Zealand
https://nzgeothermal.org.nz/nzga-seminar/

6th Geothermal Congress for Latin America and the Caribbean (GEOLAC)
17-18 July, Santiago, Chile
http://newenergyevents.com/geolac/

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

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

6th China International Geothermal Energy Technology & Equipment Exhibition & 11th Chinese GSHP Conference & Exhibition 2019
18-20 August, Beijing, China
http://www.dyrbw.com/news/show.php?itemid=75860

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

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

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

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

Geothermal Resources in Sedimentary Basins Conference
15-18 October, Edmonton, Alberta, Canada
http://gssb2019.com/

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

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

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 ■

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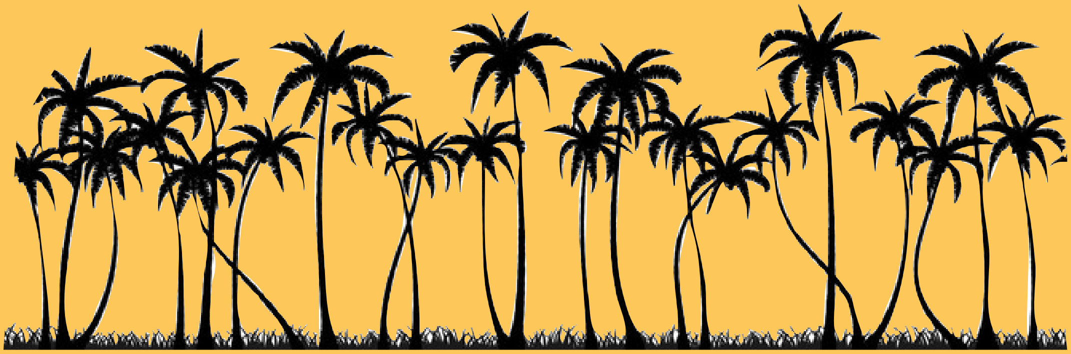

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GRC ANNUAL MEETING

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