GEOTHERMAL RESOURCES COUNCIL

Bulletin

Vol. 47, No. 3
May/June 2018

Geothermal Energy Hybridization

Oil & Gas, Hydrogen, Solar-Thermal Co-production

GRC Annual Meeting & Expo

Latest news of the geothermal energy event of the year

Geothermal Resource Group

TAPPING THE EARTH'S ENERGY

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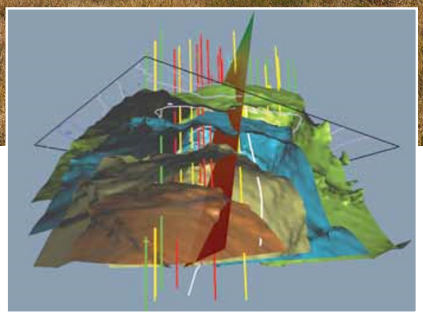

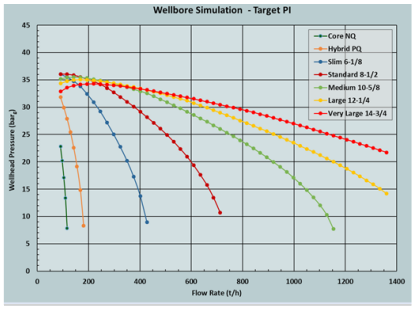

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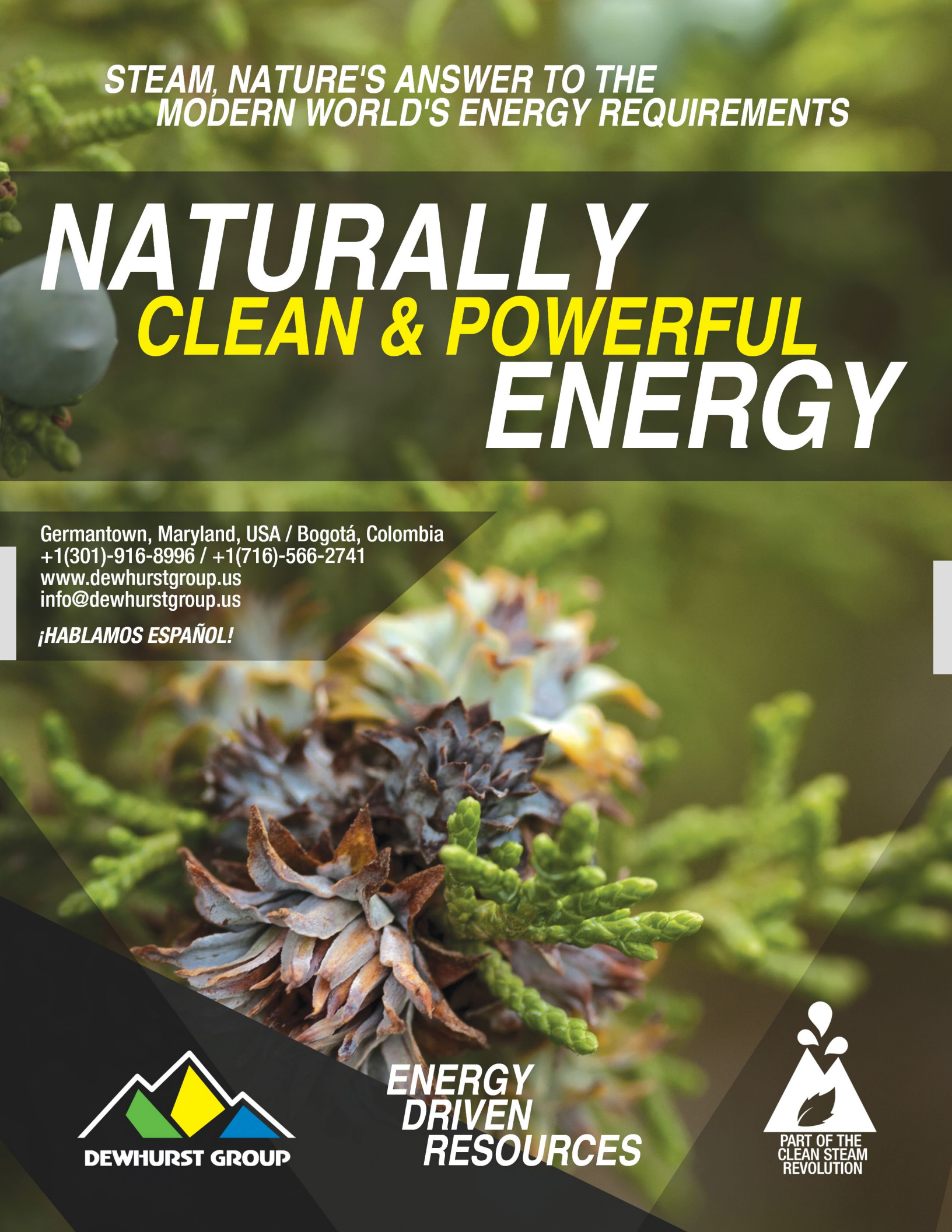
TAPPING THE EARTH'S ENERGY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Bulletin

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COVER: *Aligned Pipes in Ulubelu Steam Gathering Facility.* By **Muchsin Chasani Abdul Qadir, Jakarta**, Indonesia. The picture was taken February 28, 2017 during a supervision mission conducted by the World Bank at Ulubelu Unit 3-4 Geothermal Project, located at Lampung, Sumatera Island, Indonesia. The project is developed by PT. Pertamina Geothermal Energy and completed in June 2017. GRC Photo Contest 2017.

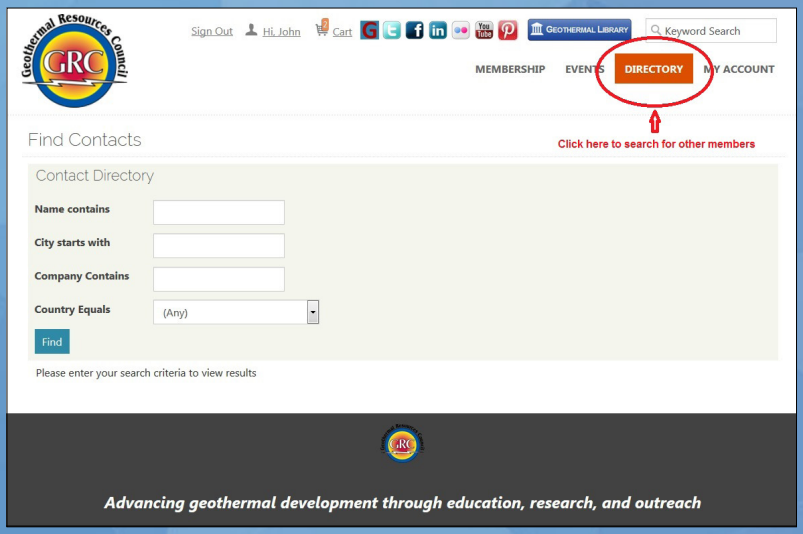
The GRC Membership Directory At Your Fingertips

www.my.geothermal.org

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

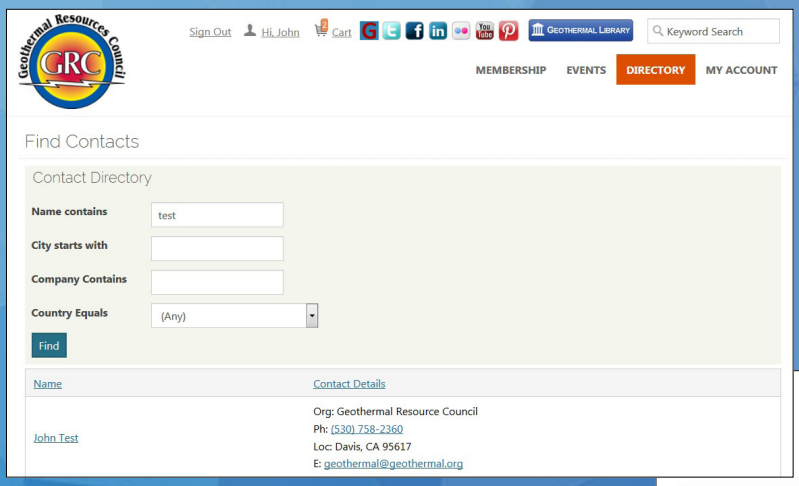
Step 1

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



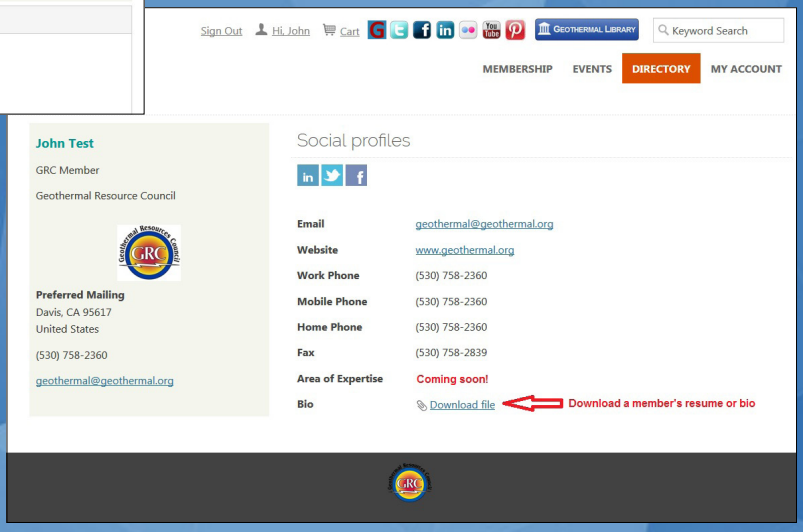
Step 2

Click on the Directory Tab



Step 3

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



Step 4

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

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

President's Message

by Maria Richards

This month's *Bulletin* articles are right up my alley with opportunities to learn more about geothermal power and how it can overlap with other industries. The one I know most about is the article on the UND-CLR Binary Geothermal Power Plant by Will Gosnold, Michael Mann, and Hossein Salchfar. They're using low-temperature geothermal fluids in an oil and gas setting. Oil and gas fields are still a new area for geothermal energy development. When everyone was discussing coproduction, Will thought outside-the-box with water floods to get this project off the ground. The article discusses how there continues to be potential for overlapping with the fossil fuels industry. He and SMU have learned that working with new equipment is not for the faint of heart and yet UND led by Gosnold continues to find new opportunities for geothermal projects. I'm often asked at meetings if geothermal can become a community-based power elective for customers, similar to solar arrays today. These smaller (<1MW) technology projects have that development potential in sedimentary basin settings.

Did you know that you can submit an article for future *Bulletins*? Marcelo Lippmann is one of the top article writers for the GRC. His variety of timely articles over the years have been helpful in keeping us all updated. This time he wrote an article with Ron DiPippo about the recent changes in the electrical grids of Central America. Their tables of installed and net generation paint the 1000 words as to the impact of wind and solar versus geothermal on grids. With the new focus on Mexican geothermal projects, I expect their development success will transfer to more geothermal in the core areas of Central America over the next ten years.

Hydrogen can be stored and transported along with natural gas in our existing pipelines! If this is new information to you, then read more about it in the other article by Marcelo Lippmann, Ron DiPippo, and Wilfred Elders. This is one of the areas our Icelandic members can teach us more about, on how to commercialize new products from geothermal resources.

Kevin Kitz (one of our GRC Board Members) moved from U.S. Geothermal to his own company – KitzWorks LLC. His skill-sets are highlighted in the article he submitted discussing the research being completed with NREL, INL, and POWER Engineers. There was a lot of publicity over the first geothermal – solar project installed by ENEL in Stillwater, Nevada. Reading the article, Solar Thermal and Geothermal Hybrid Power Plant Study, I found myself surprised by the results. Read it and tell me if you too were expecting something different for how to combine geothermal resources with solar thermal.

After being in the geothermal industry for 23 years, I finally was able to use my GRC President card for a delightful lunch date. I had never met our original GRC Executive Director, David Anderson. I'm happy to report he lives in Davis, is healthy, and full of ideas! His wife, Eva, also joined us. She is certainly the first WING member. She reminded me of how GRC used to have wives' events at the Annual Meeting. She quickly pointed out, they were fun and a social track doesn't have to be just for wives anymore. What Eva didn't know - our current WING members coordinate social, mind-body, and educational opportunities for everyone.

As we've gone digital, this *Bulletin* can be easily added to your summer reading list on your tablet, or read on the ride into work on the train. Keep in mind, we appreciate your feedback on how to keep improving it. ■

Maria Richards flanked by Eva and Dave Anderson.

Maria Richards and Dave Anderson.

Communication from the GRC

by Ian Crawford
Director of Communications

The GRC Awards - Seeking the Best in Global Geothermal

The Geothermal Resources Council (GRC) is pleased to announce the opening of nominations for this year's GRC Awards. The awards recognize distinguished colleagues in the geothermal community from around the world and have been a highlight of the geothermal calendar since the late 1970's.

The winners will be honored at the GRC Annual Meeting & Expo in Reno, Nevada, USA from October 14–17.

The Joseph W. Aidlin Award recognizes outstanding contributions to the Geothermal Resources Council and to the development of geothermal resources.

The Geothermal Pioneer Award is given for outstanding achievements in the development of geothermal resources. It recognizes the pioneering efforts of members of the geothermal community who have made lasting contributions to the industry, worldwide.

The Henry J. Ramey, Jr. Geothermal Reservoir Engineering Award recognizes outstanding achievements in the field of geothermal reservoir engineering.

The Ben Holt Geothermal Power Plant Award honors outstanding achievement in the field of geothermal power plant design and construction.

The Special Achievement Award recognizes special or outstanding achievements in any aspect of geothermal energy development and related areas.

The recipients of these awards often have a lifetime of achievement in the academic, scientific and commercial geothermal communities and the awards themselves are considered among the most prestigious in the geothermal community.

Nomination Form (PDF).....
Nomination Form (Word Doc).....
The deadline for nominations is July 6, 2018.

Kevin Kitz, P.E. *(center) won last year's Ben Holt Award for outstanding achievements in designing geothermal power plants, including innovative geothermal ORC power plants. On the left is* ***Susan Hamm****, Director of the U.S. Geothermal Technologies Office (GTO) and on the right is* ***Shigeto Yamada****, Chair of the GRC Awards Committee in 2017.* Photo by Chi Meng-Moua.

Reserve your room now.....

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

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

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

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

The discount ends September 19, 2018.

Attendees can make their reservations on a secure website prepared specially for the GRC. The

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

link is available from the GRC Annual Meeting website at: www.geothermal.org/meet-new.html.

Exhibitors - Reserve a Booth

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

The Expo hall in 2017 Photo by Ian Crawford.

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

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

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

2018 Amateur Photo Contest

Submissions can now be made for this year's Amateur Geothermal Photo Contest. The purpose of the contest is to showcase quality photography featuring geothermal energy around the world.

The winners will be announced at the GRC Annual Meeting & Expo being held in Reno, Nevada, USA from October 14-17.

The first place winner will receive $150, second place - $100, and third place - $75. Honorable Mention photos will receive certificates.

Photographs on any subject related to geothermal energy can be submitted such as geothermal energy production, Enhanced Geothermal systems (EGS), direct use and geothermal heat pumps. These can include photos of well testing, drilling, operation of geothermal equipment, newly developed equipment, or plant operation, construction of a geothermal plant or plant site, and geological areas or surface manifestations (holding potential for geothermal

*FRP Pipe In A Row, by **Aldio Dwi Perkasa**, Menteng, Jakarta Pusat, Indonesia. Honorable Mention 2017 Photo Contest.*

exploration or development). New this year are acceptance of "GIFs" - short animated movies of a few seconds each.

More information on the GRC Amateur Photo Contest.....

Submission form.....

The deadline for submissions is August 24, 2018. ■

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.

Inside Geothermal

NORTH AMERICA

U.S. Geothermal is Now Part of Ormat

Ormat Technologies, Inc. has closed the acquisition of **U.S. Geothermal, Inc.** for a total consideration of approximately **USD 110 million**.

At a special meeting of shareholders of **U.S. Geothermal Inc.** held on April 19, 2018, the company adopted and approved the *Agreement and Plan of Merger* entered into on January 24, 2018 to become a wholly owned subsidiary of Ormat. **13,236,961 shareholders voted for the merger, 715,398 against.**

Ormat has announced a comprehensive integration plan to assure continuous operation of U.S. Geothermal's assets. **The company says it will retain a number of U.S. Geothermal employees and welcome them to Ormat.** *Global Geothermal News.....*

Ormat Technologies will be exhibiting at the GRC Annual Meeting & Expo from 14-17 October at the Peppermill Resort Spa Casino, Reno, Nevada, USA.

Funding Opportunity for Advancing Geothermal Drilling Technologies

The U.S. **Department of Energy (DOE)** has announced up to **USD 14.5 million** in new funding to advance geothermal energy development. The **Efficient Drilling for Geothermal Energy (EDGE)** funding opportunity announcement (FOA) will focus on geothermal drilling in support of accelerating the research and development of innovative geothermal energy technologies in the United States.

"Advancing research in geothermal drilling technologies will help harness the heat beneath our feet to expand our domestic energy resources," said **Daniel Simmons**, Principal Deputy Assistant Secretary for **Energy Efficiency and Renewable Energy (EERE). "Geothermal is a reliable, baseload renewable energy source with firm and flexible operation, allowing it to provide a range of essential services that contribute to our nation's grid stability and resiliency."**

The EDGE FOA aims to continue and expand GTO's R&D in geothermal drilling by covering three topic areas:

- Topic Area 1 focuses on **early-stage R&D projects to reduce common delays in drilling operations** like lost circulation, stuck pipe, unstable wellbores, and other issues that take time away from deepening the hole, typically referred to as non-drilling time.
- Topic Area 2 focuses on early-stage R&D projects in innovative drilling technologies that **improve the rates of penetration for drilling geothermal wells.**
- Topic Area 3 focuses on exploring innovative approaches and models to accelerate the transfer of geothermal drilling and related technologies from the laboratory into the real world by focusing on **building partnerships that will increase adoption of nascent technology and improving knowledge transfer** in the geothermal industry.

The application process will include two phases: a *Concept Paper* phase and a *Full Application* phase. **Applicants must first submit a Concept Paper by 5 PM ET on May 31, 2018 to be eligible to submit a *Full Application.***

More information on the EDGE FOA can be found on the EERE Funding Opportunity Exchange. *Global Geothermal News.....*

Drilling FOA

Efficient Drilling for Geothermal Energy (EDGE)

- Open: April 23, 2018
- Up to **$14.5 million** in new funding
- Application process:
  - ✓ Concept paper (mandatory)
  - ✓ Full application
- Concept papers due May 31, 2018
- Questions about this FOA?
  - ✓ Email: **EDGE@ee.doe.gov**

Topic Area 1	Early-stage R&D projects to reduce common delays in drilling operations.
Topic Area 2	Early-stage R&D projects in innovative drilling technologies that improve rate of penetration.
Topic Area 3	Innovative approaches and models to improve knowledge transfer in the geothermal industry.

U.S. DOE Announces USD 2 Million Funding for Geothermal Energy Research

As part of the USD 99 million announcement by the **U.S. Secretary of Energy Rick Perry** for **Small Business Innovation Research (SBIR)** and **Small Business Technology Transfer (STTR)** research and development projects, the Office of **Energy Efficiency and Renewable Energy (EERE)** will manage seven new projects across seven states,

totaling USD 7 million in funding. Two projects involve geothermal energy research:

- **E-Spectrum Technologies, Inc., San Antonio, Texas**

  USD 985,773 for a Near-Real-Time Electromagnetic Data-Link for Geothermal Downhole Instruments

  This effort proposes a high-temperature electromagnetic tool to provide wireless, near-real-time access to geothermal well downhole data in reservoirs up to 300°C. The proposed effort will leverage existing electromagnetic data transmission technology used for oil and gas exploration to provide a cost-effective means to characterize underground environmental variables such as bit vibration, downhole temperature, and pressure conditions. This capability will minimize risks associated with developing geothermal energy as a viable power source.

- **Olympic Research, Inc., Port Townsend, Washington**

  USD 1,009,468 for Controlled-Porosity Ceramic Materials for High Temperature Downhole Applications

  Advanced geothermal energy production is challenged by the harsh thermal and chemical environments posed by fluids produced in geothermal wells. This technology introduces a novel method of forming high performance ceramic components in place to extend the operating life of the well components.

Global Geothermal News.....

Renewable Energy Groups Express Concern Over DOE Budget Cuts

The **American Council on Renewable Energy (ACORE)** and other renewable energy groups, including the **Geothermal Resources Council (GRC)**, have submitted a joint letter to the U.S. Congress expressing serious concern regarding proposed cuts to the **Department of Energy (DOE)**'s budget for FY19 and encouraging continuing current funding levels for vital DOE programs in FY18 appropriations:

Dear Chairmen Cochran and Frelinghuysen and Ranking Members Leahy and Lowey,

We write to express the serious concern of the U.S. renewable energy industry regarding proposed cuts to the Department of Energy (DOE)'s budget for Fiscal Year (FY) 2019, and to encourage you to continue current funding levels for vital DOE programs in FY 2018 appropriations.

At a time when global competitors are drastically increasing research and development funding for renewable energy technologies, the Administration has proposed cutting more than USD 1.9 billion from programs supporting energy innovation and deployment, a 43 percent decrease from current annualized funding levels. The proposed budget includes a USD 1.3 billion (66 percent) cut to the Office of Energy Efficiency and Renewable Energy (EERE) and an elimination of the Advanced Research Programs Agency – Energy (ARPA-E) program.

We believe that such cuts in FY 2018 or FY 2019 would seriously 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.

Global Geothermal News.....

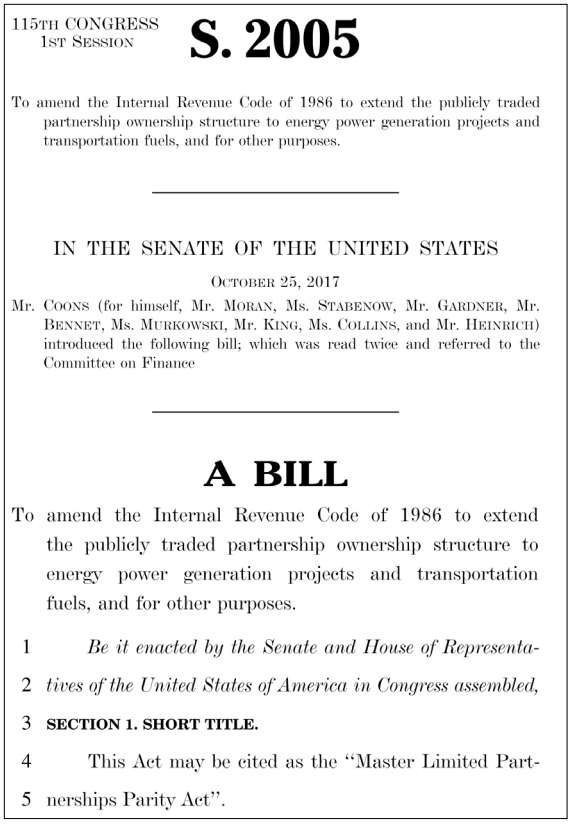
Future Bright for Renewable Energy Financing Legislation

The **Master Limited Partnerships Parity Act**, a bill that would allow U.S. renewables companies to adopt the tax-advantaged **Master Limited Partnerships (MLP)** structure, stands a good chance of becoming law this year, says Republican **Senator Lisa Murkowski,** chair of the powerful **Senate Energy and Natural Resources Committee.**

"There's a growing group of supporters for moving forward on [MLPs], to allow for this financing opportunity within the renewables sector," Murkowski said at the Renewable Energy

Policy Forum, hosted by the **American Council on Renewable Energy (ACORE).**

The MLP Parity Act would expand the structure to companies working with a range of renewable technologies, including geothermal energy. **Latest Action: 10/25/2017 - Read twice in the Senate and referred to the Committee on Finance.** *Global Geothermal News.....*



115TH CONGRESS
1ST SESSION

S. 2005

To amend the Internal Revenue Code of 1986 to extend the publicly traded partnership ownership structure to energy power generation projects and transportation fuels, and for other purposes.

IN THE SENATE OF THE UNITED STATES

OCTOBER 25, 2017

Mr. COONS (for himself, Mr. MORAN, Ms. STABENOW, Mr. GARDNER, Mr. BENNET, Ms. MURKOWSKI, Mr. KING, Ms. COLLINS, and Mr. HEINRICH) introduced the following bill; which was read twice and referred to the Committee on Finance

A BILL

To amend the Internal Revenue Code of 1986 to extend the publicly traded partnership ownership structure to energy power generation projects and transportation fuels, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

SECTION 1. SHORT TITLE.

This Act may be cited as the "Master Limited Partnerships Parity Act".

Lithium and Other Minerals Sourced from Geothermal Brine are Critical to the Nation's Security and Economic Prosperity - President Trump

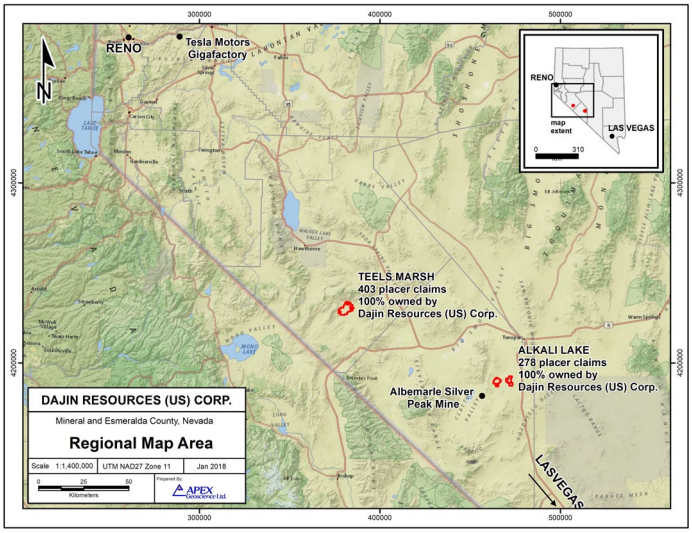
On December 20, 2017, **President Trump** issued *Executive Order 13817*, **A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals (Critical Minerals Executive Order).** The Trump Administration has also released two more important documents that support the Executive Order, the *Draft List of Critical Minerals and Assessment of Critical Minerals: Updated Application of Screening Methodology*, which will help ensure that the United States has an adequate and affordable supply of minerals that are vital to the Nation's security and economic prosperity. *Global Geothermal News.....*

JV Agreement Signed on Joint Lithium Extraction and Geothermal Power Project

Vancouver, Canada-based **Dajin Resources Corp.** has announced that it has signed a *Joint Venture Agreement* (JV) with **Geothermal Development Associates (GDA)** of Reno, Nevada.

GDA holds geothermal leases that overlap Dajin's placer claims in the **Teels Marsh Valley** in western Nevada.

As a result of this JV, GDA and Dajin will share exploration data with the ultimate aim of supporting the **development of a Lithium brine extraction facility** as well as **development of a geothermal plant** for electrical generation and the production of direct-use thermal water. This agreement outlines a cooperative relationship where both companies will be focusing on their key strengths to mutually develop Lithium brine and renewable energy resources. *Global Geothermal News.....*



Location of the Teels Marsh site south of Reno, Nevada and the Tesla Motors Gigafactory. Courtesy Dajin Resources Corp.

Proposed Changes for Managing Sage Grouse Could Open up More Areas for Geothermal Energy Development

The Trump administration has proposed changes to how Nevada manages **sage grouse** populations on public lands in the western USA.

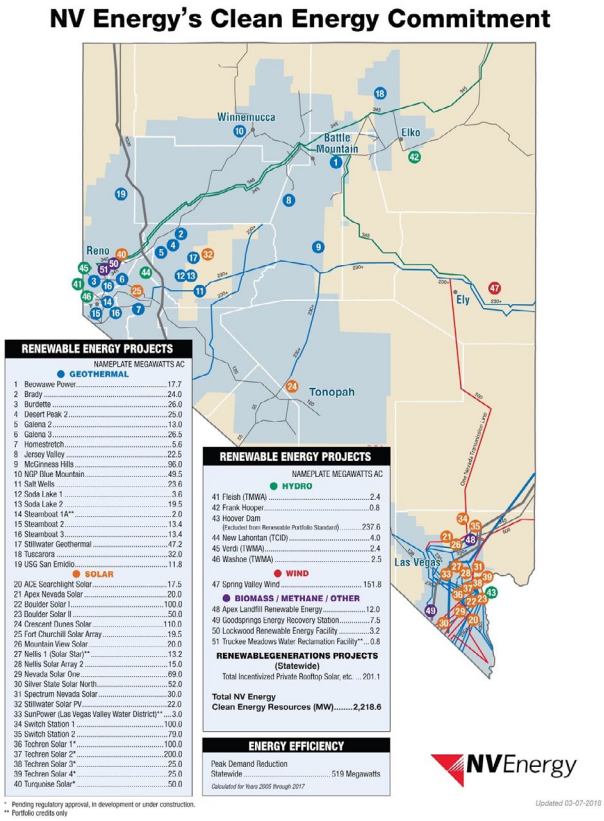
The draft *Environmental Impact Statement* calls for more flexibility to update the framework for Nevada and more case-by-case exceptions to sage grouse rules, granting greater authority to the state

Greater Sage-grouse, by Bureau of Land Management - Greater Sage-Grouse Conservation, Public Domain, https://commons.wikimedia.org/w/index.php?curid=42087592

director for the **Bureau of Land Management (BLM)**, the agency responsible for managing nearly 70 percent of all the land in Nevada. The changes would also **remove a special habitat designation** that limited some mining and geothermal development on certain lands marked as sage grouse habitat. *Global Geothermal News.....*

472 MW Geothermal Energy Helps Nevada Surpass Renewable Portfolio Standard Requirement

NV Energy filed its 2017 *Renewable Portfolio Standard (RPS) Annual Report* with the **Public Utilities Commission of Nevada (PUCN)**, showing that the company achieved a 25.5% renewable energy and related credits level in northern Nevada and 23.1% in southern Nevada, for **a combined weighted average of 23.8%.**



All of the NV Energy geothermal power plants are located in the north of Nevada.

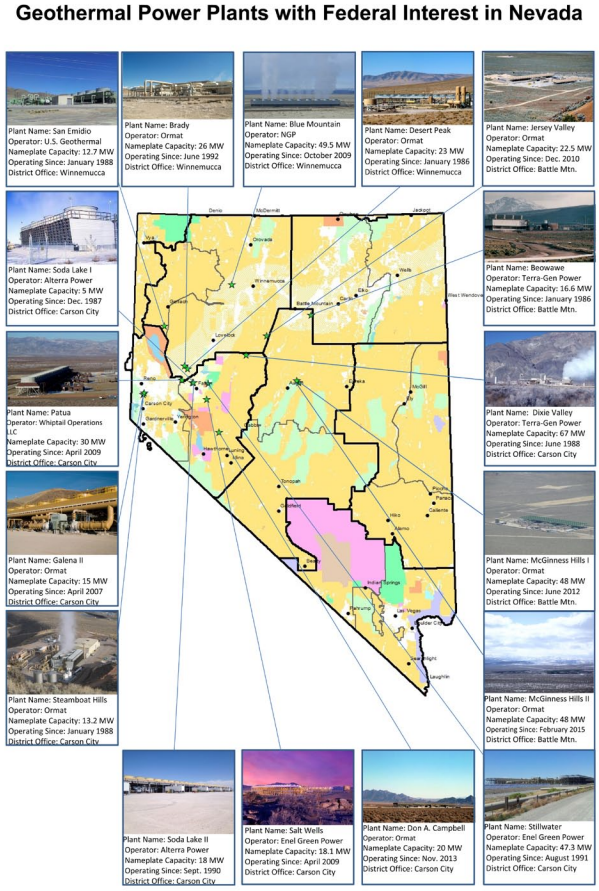
This is the eighth year in a row that NV Energy has exceeded the state's renewable energy requirement, which currently sits at a 20% level. Separate from this legislated mandate, **NV Energy has set a goal to double its renewable energy portfolio by 2023.**

Currently NV Energy customers benefit from 46 separate renewable energy projects in Nevada including **19 geothermal plants**.

Additionally, the company and an independent evaluator **are reviewing more than 100 bids for renewable energy projects** and battery-energy storage systems proposed for 26 separate sites throughout Nevada. **The winning bids will be submitted for approval to the PUCN by June 1, 2018.** *Global Geothermal News.....*

Map of Nevada Geothermal Power Plants on Federal Land

The **Bureau of Land Management (BLM) - Nevada** has provided a good reminder of U.S. government interest in our industry in the Silver State. The BLM has published a good graphic showing that there are **18 geothermal power plants in Nevada with federal interest.**



Inside Geothermal

The U.S. Bureau of Land Management (BLM) will be exhibiting at the GRC Annual Meeting & Expo from October 14-17 at the Peppermill Resort Spa Casino, Reno, Nevada, USA.

Ormat Receives USD 100 Million Loan to Help Long-Term Growth Strategy

Ormat Technologies, Inc. has announced that it has entered into a loan agreement with affiliates of the **Migdal Group**, one of Israel's leading insurance companies and institutional investors, to provide the company with **a USD 100 million senior unsecured loan.**

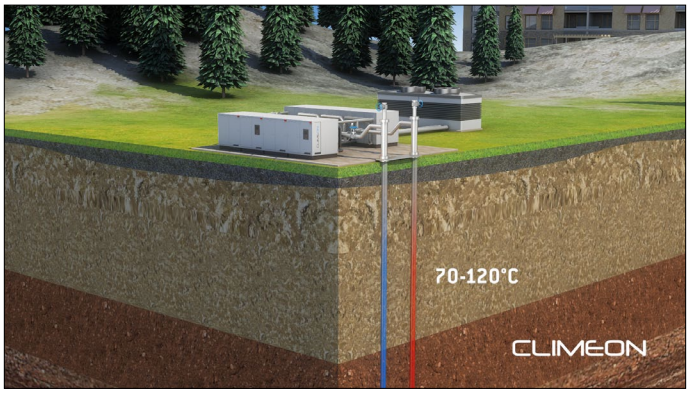
Ormat intends to use the proceeds of the loan to fund its capital needs to support its growth plans. *Global Geothermal News.....*

Ormat Technologies will be exhibiting at the GRC Annual Meeting & Expo from 14-17 October at the Peppermill Resort Spa Casino, Reno, Nevada, USA.

Climeon Wins Order for First Geothermal Power Plant in Canada

Swedish company **Climeon** has received the world's first order for a geothermal power plant in Canada from **Borealis GeoPower**. The order relates to a demonstration project named **Sustainaville**, in **Valemount, British Columbia**. It includes delivery of **three 150 kW Climeon modules** and is valued at approximately **EUR 1,000,000**.

Drilling of the wells will start in the Spring of 2018 and the delivery of the Climeon Heat Power modules is planned for the end of 2018. *Global Geothermal News.....*



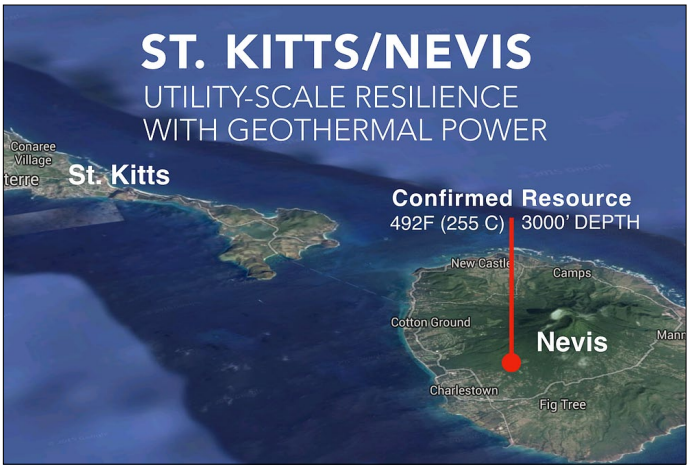
Courtesy Climeon

Testing Confirms Commercial Viability of Nevis Geothermal Power Project

California-based **GeothermEx** - a GRC Member Company - contracted by **Nevis Renewable Energy International (NREI)** has confirmed the requisite temperature and flow necessary for a sustainable supply of geothermal energy on Nevis.

As of mid-March, the test results at **Hamilton** continue to hold steady with **surface reading temperatures of 255°F (124°C), steam temperatures of 411°F (211°C)** and a well temperature reading of **492°F (256°C) at a depth of 2,990 ft.**

According to **Bruce Cutright**, CEO of NREI, a subsidiary of **Thermal Energy Partners, LLC** of Texas, the testing operations at Hamilton are complete. Though the initial drilling plan was to go to 4,000 feet, they entered the geothermal reservoir at a much shallower depth. **The resource is estimated to have a capacity exceeding 5 MW. Drilling for the production wells on the site are expected to begin late this summer.** *Global Geothermal News.....*



Courtesy Thermal Energy Partners

Work on Dominica Geothermal Power Project Should Begin by Year End

The construction of a **7 MW geothermal power plant** on **Dominica** is still on track. In March, representatives of the **World Bank** were on the island to assess the damage done to the plant by **Hurricane Maria**. Chairman of the Geothermal Negotiating Team, **Dr. Vince Henderson** said that the Geothermal Development Program is progressing satisfactorily despite the impact of the hurricane.

Dr. Henderson said work on the plant **should commence by the end of this year** into early 2019 and should **be completed by 2020**. *Global Geothermal News.....*

Government Increases Share in St. Vincent Geothermal Power Project

The government of **St. Vincent and the Grenadines** now owns **a 49% stake** in the geothermal plant being developed on St. Vincent.

Originally, **Emera** of Nova Scotia, Canada and **Reykjavik Geothermal** of Iceland were to own 75 per cent of the plant, with the remainder going to the government. But **Prime Minister Ralph Gonsalves** has announced that the USD 100 million dollar deal has been renegotiated. *Global Geothermal News.....*

CENTRAL & SOUTH AMERICA

35 MW Platanares Geothermal Plant Inaugurated

On Monday, April 30, **President Juan Orlando Hernández** participated in the inauguration of the first geothermal energy plant in **Honduras**, in the community of **Platanares**, La Unión, Copán.

Ormat Technologies Inc. announced that its Platanares project subsidiary and the **Overseas Private Investment Corporation (OPIC)**, United States government's development finance institution, signed a *Finance Agreement* to provide a loan (on a non-recourse project finance basis) totaling up to USD 124.7 million for the 35 MW Platanares geothermal power plant. *Global Geothermal News.....*

Construction of Las Pailas II Geothermal Project is Currently at 80%

The **Las Pailas II Geothermal Project**, located in Curubandé de Liberia, province of Guanacaste, **Costa Rica**, has reached 80% of the target towards construction. The assembly of the turbine is moving at an accelerated pace and is already beyond half-way complete.

According to the progress to date, preliminary tests are estimated to start in October. **Commercial operation is on course for the first quarter of 2019**. *Global Geothermal News.....*

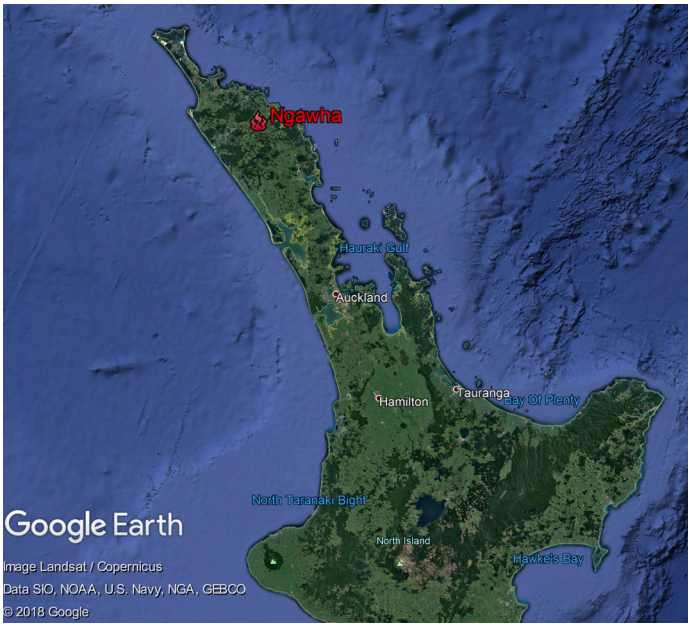
AUSTRALASIA

Geothermal Powered Industrial Park Gets Go-Ahead on North Island

Far North District Council voted to borrow **NZD 5 million**, which council-owned company **Far North Holdings (FNH)** will use to buy a dairy farm at **Ngawha** and turn it into a "market ready" industrial park **powered by geothermal energy.**

The idea is to lure industry with completed infrastructure and resource consents, but the real draw will be cheap power from the nearby **Ngawha geothermal power station.**

FNH chief executive **Andy Nock** told councilors that Top Energy could supply power to the park at a discount of 30-40% and with no line charges. There is also potential to supply heat and CO^2, for hydroponic horticulture. *Global Geothermal News.....*



Location of Ngawha on the North Island of New Zealand.

ASIA

ElectraTherm Commissions 65 kWe ORC Geothermal Power Plant in Japan

ElectraTherm of Reno, Nevada, USA, has commissioned a **Organic Rankine Cycle (ORC) Power+ Generator®** at a geothermal site in the northern part of Japan. The site is adjacent to an onsen (hot spring) where the local community has enjoyed bathing for centuries.

The **Power+ Generator** produces electricity from low temperature heat ranging from **77°C to 116°C** and flow rates up to 45.4 m^3/hr. *Global Geothermal News.....*

Continued on page 18...

Renewable Energy Contribution to the Central American Electricity Market: 2012-2016

Marcelo J. Lippmann[1] and Ronald DiPippo[2]

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The Central American economy and infrastructure continues to struggle to keep up with the rising population, which was estimated to be about 42.7 in 2012 and 46.8 million in 2016. In recent years, however, the economy has stabilized and the regional GDP has risen (World Population Review, 2017), but the population has not.

In December 2017, a report on the statistics of the 2016 Central American electricity market was issued by the Economic Commission for Latin America and the Caribbean, known by its Spanish acronym, CEPAL (Rojas Navarrete, 2017). Presented here are data from that report assumed to be of most interest to the readers of the *Bulletin*; far more information is available at: https://repositorio.cepal.org/bitstream/handle/11362/42720/4/S1701275_es.pdf. Data corresponding to the 2010-2015 period are given in Lippmann and DiPippo (2017).

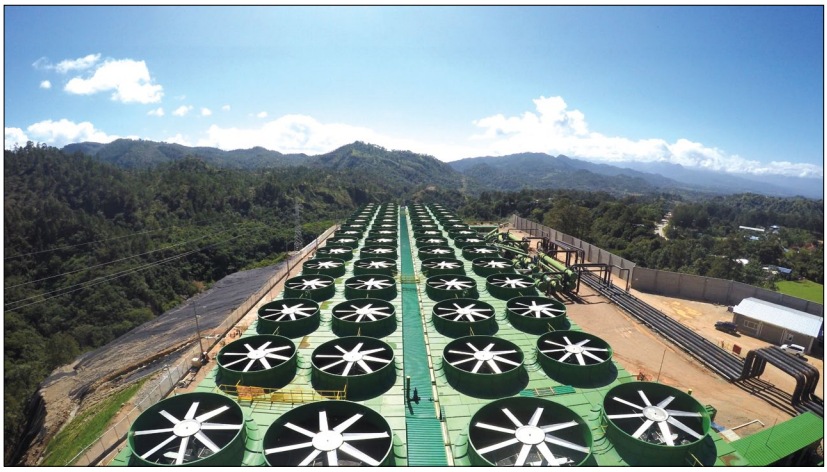
Because of the small contributions from cogeneration, biomass and biogas, and because some of that data in the CEPAL report are somewhat confusing, we decided to exclude those energy sources from our analysis.

Presented here are data corresponding to the 2012-2016 period during which the installed capacity of the Central American electricity market increased by 29.0% and the total electricity generated by 12.4% (Table 1). The dominant energy source to produce power continues to be hydro. Remarkable is the recent growth of the amount of electricity generated based on renewables and the decrease in fossil fuel usage despite a modest increase in installed fossil capacity.

Worth noticing in Table 1 is that the contribution of the different energy sources to the installed capacity was not uniform and changed from year to year. Between 2012 and 2016, hydro increased by 28.4%, fossil by 12.1%, while the "other renewables" (solar, wind, and geothermal) increased by an outstanding 116.8%. Solar and wind contributed most to this large increase, mainly owing to the ease and rapidity with which these units can be deployed.

	Installed Capacity (MW)				
	2012	2013	2014	2015	2016
Hydro	5337.6	5433.9	5779.2	6074.1	6854.7
Geothermal	635.6	625.6	625.6	625.5	615.0
Wind	395.8	416.7	589.7	944.7	1026.2
Solar	1.0	1.5	8.9	528.8	597.1
Fossil	5185.6	5404.8	5418.7	5750.2	5815.2
Total	**11,555.6**	**11,882.5**	**12,422.1**	**13,923.3**	**14,908.1**
	Net Generation (GWh)				
	2012	2013	2014	2015	2016
Hydro	22,352.2	21,929.9	21,598.1	22,459.8	22,843.5
Geothermal	3542.4	3778.7	3819.0	3664.5	3725.2
Wind	1191.5	1351.4	2080.0	3122.7	3279.3
Solar	0.3	2.0	10.7	591.3	1166.7
Fossil	15,683.3	16,900.5	17,366.0	17,290.9	17,066.0
Total	**42,769.7**	**43,962.5**	**44,873.8**	**47,129.2**	**48,080.7**

Table 1. Central American electricity sector: Installed capacity and net generation by technology for Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama (excluding cogeneration, biomass and biogas).



Platanares Geothermal Power Plant, Honduras. Courtesy Ormat Technologies

However, the amount of electricity generated over the five-year period grew by only 12.4%. Again, the growth varied between the different energy sources (Table 1). Hydro increased only by 2.2% and fossil by 8.8%. Again, the other renewable energy sources (solar, wind, and geothermal) played an increasingly important role in the Central American electricity market: the total electricity generated by those sources grew by 72.6%; here again wind and solar showed remarkable increases.

In the case of geothermal (Table 2), there were only small changes in installed geothermal capacity, while the amount of electricity generated increased by 5.2%. The table shows a decrease in installed geothermal capacity in Costa Rica in 2016,

	Installed Capacity (MW)				
	2012	2013	2014	2015	2016
Costa Rica	217.5	217.5	217.5	217.5	206.9 [1]
El Salvador	204.4	204.4	204.4	204.4	204.4
Guatemala	49.2	49.2	49.2	49.2	49.2
Nicaragua	164.5	154.5	154.5	154.5	154.5
Total	**635.6**	**625.6**	**625.6**	**625.6**	**615.0**
	Net Generation (GWh)				
	2012	2013	2014	2015	2016
Costa Rica	1402.6	1516.7	1538.1	1375.6	1339.5
El Salvador	1420.4	1442.4	1443.9	1432.4	1467.1
Guatemala	245.6	212.3	246.6	251.5	289.1
Nicaragua	473.8	607.3	590.4	605.0	629.5
Total	**3542.4**	**3778.8**	**3819.0**	**3664.6**	**3725.3**

[1] According to ICE, the installed capacity was 217.5 MW in 2016.

Table 2. Central American electricity sector: Geothermal installed capacity and net generation.

down to 206.9 MW. However, according to sources from the Instituto Costarricense de Electricidad (ICE), the capacity has not actually changed since 2011; it remains at 217.5 MW. What has varied is the amount of electricity generated by the different geothermal units because their production was not kept to the maximum for different operational reasons (e.g., to protect the commercial life of the reservoir, lack of steam, high content of non-condensable gases in the steam).

Starting in 2017, after the period reported here, the slow growth in geothermal may begin to change when the new 55 MW Las Pailas II plant comes on line in Costa Rica, and additional wells may come into production in Guatemala and Nicaragua that could lead to more power plants. The new 35 MW Platanares power plant in Honduras has started operation recently. No new geothermal projects are close to completion in El Salvador and none are being considered for Belize since no high-temperature resources have been identified in the country.

One remarkable fact is that for 2015 and 2016 Costa Rica generated over 98% of all its electricity from renewable sources - a record unmatched by any other country in Central America, and even among all countries in the world that use a diversified portfolio of resources including hydro, fossil, geothermal, wind, solar, biomass and biogas.

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Inside Geothermal

Continued from page 15...

Iceland to Advise Mongolia on Geothermal Energy Development

Icelandic Ambassador **Gunnar Snorri Gunnarsson** has offered to share his country's geothermal energy experience with the government of **Mongolia**. The parties agreed to train Mongolian specialists on this matter in Iceland. *Global Geothermal News.....*

Joint Venture Formed to Develop Geothermal Energy in Tibet

China Nuclear Power Company, CNNC (Tibet) Industrial Development Co., Ltd. has signed an agreement with **CNNC KunHua Energy Development Co., Ltd.** on the development and operation of geothermal energy projects in **Tibet**. *Global Geothermal News.....*

Sinopec to Provide Geothermal Heating to About 2.1 Million Urban Residents in Capital Region by 2023

China Petroleum & Chemical Corporation, or **Sinopec** has launched its **Green Action Plan**, aiming to become a clean, efficient and low-carbon enterprise by 2023.

Sinopec plans to **boost its geothermal heating capacity** to 120-150 million square meters by 2023, providing geothermal heating to about 2.1 million urban residents.

In addition, **Asia Development Bank (ADB)** said it would provide a **USD 250 million** loan to **Sinopec Green Energy Geothermal Co (SGE)** and Iceland's **Arctic Green Energy Corp (AGE)** to develop clean geothermal heat in smog-prone northern China. SGE is a joint venture set up by China's state-owned oil giant Sinopec and AGE.

The project will focus on the **Beijing-Tianjin-Hebei region**, but SGE chairman **Liu Shiliang** said the partners plan to "replicate their successful collaboration across Asia." China has planned to develop geothermal energy in the Beijing-Tianjin-Hebei belt as part of its anti-smog campaign, the country said in guidelines published in January. *Global Geothermal News.....*

First Chinese Hot Dry Rock Well Reaches 4,387 Meters and 185°C

The pilot well for a Hot-Dry-Rock (HDR) well was drilled in **Hainan Province**, a south-eastern province of China, in mid March by **LandOcean Hainan Company**, a subsidiary of Land Ocean Energy Service Co. Ltd, to a true depth (TD) of **4,387 meters**, and a temperature of **185°C (365°F)**. *Global Geothermal News.....*

Courtesy LandOcean Hainan Company

12 MW Second Unit of Maibarara Geothermal Power Plant Connected to Grid

Maibarara Geothermal Inc. (MGI) has secured a *Certificate of Compliance* (COC) for its **12 MW Maibarara-2** power station in **Santo Tomas**, Batangas in the **Calabarzon region** of the **Philippines**.

Individual plant-equipment testing started in early-2018, culminating in the synchronization and first delivery of power to the Luzon grid on March 9. *Global Geothermal News.....*

Maibarara geothermal plant (Courtesy PetroEnergy)

World Bank Helps Philippine Geothermal Power Plants Recover from Earthquake

Energy Development Corp. (EDC) has secured a **USD 90 million loan** financing deal with **World Bank Group**'s private sector arm **International Finance Corp. (IFC)** to partly fund its capital requirements for the return of services of its **Leyte geothermal power plants** hit by an earthquake in July 2017. *Global Geothermal News.....*

Earthquake damage after the quake with the Leyte geothermal power plants in the backgroud. Photo courtesy of **Cathy Ig-agao Pabganiban.**

Third Unit at Sarulla Geothermal Power Plant Begins Commercial Operation

Ormat Technologies Inc. has announced that **NIL 2**, the third unit of the **Sarulla geothermal power plant**, has commenced commercial operation, bringing the project to its **full capacity of 330 MW**.

Located in **North Sumatra**, Indonesia, the 330 MW Sarulla power plant has three units of approximately 110 MW each.

SIL, the first unit of the power plant, commenced commercial operation in **March 2017** and **NIL 1**, the second unit, commenced commercial operation in **October 2017**. Both units are performing well. **NIL 2**, the third unit, commenced commercial operation on **May 4, 2018**, reaching full completion under the *Energy Sales Contract* on schedule. *Global Geothermal News.....*

PLN Invites Tenders for 1 GW of Geothermal Energy Projects in Indonesia

Indonesian state-owned utility **PT PLN (Persero)** has issued a *Request For Proposals* (RFP) for up to **1 GW of geothermal projects**. Interested parties are invited to submit bids to develop both geothermal steam fields and power plants with **at least 5 MW capacity.**

Eligible parties **must be based in Indonesia or countries which have diplomatic relations with Indonesia.** Though the latter must bid to develop projects in consortium with reputable local companies. *Global Geothermal News.....*

Inside Geothermal

New PLN Subsidiary Plans 4,583 MW Geothermal Energy by 2027

Indonesian state-owned electricity firm **PT Perusahaan Listrik Negara (PLN)** is seeking to boost its geothermal power business through the establishment of a new subsidiary, **PLN Gas and Geothermal (PLN GG)**, to handle its geothermal projects.

The new entity will first develop eight geothermal working areas assigned by the government that could generate 300 MW of electricity. The government is reviewing PLN's proposal to develop another three geothermal working areas.

In its electricity procurement business plan for the 2018-2027 period, PLN envisions the development of **4,583 MW capacity** from geothermal power facilities. *Global Geothermal News.....*

15 MW First Phase of Sorik Marapi Geothermal Power Project Commences Commissioning

Eiríkur Bragason, CEO at **KS Orka** reports that his company has commenced commissioning of the first phase at the **Sorik Marapi geothermal power project** in Mandailing Natal Regency, **North Sumatra**, Indonesia **only 18 months after Spud-In. The first phase is 15 MW** but further phases will follow shortly. The project team aims to **produce close to 55 MW from pad C.** *Global Geothermal News.....*

ADB Funding for 86 MW Rantau Dedap Geothermal Project

The **Asian Development Bank (ADB)** has signed an agreement to provide a **USD 175.3 million loan** to **PT Supreme Energy Rantau Dadap (SERD)** to support the second phase development of the company's geothermal power project in **South Sumatra**, Indonesia.

The **86 MW Rantau Dedap** project is being developed by SERD, a joint venture between Indonesian geothermal power developer **PT Supreme Energy**, Japanese firms **Marubeni** and **Tohoku Electric Power,** as well as French utility **Engie**. *Global Geothermal News.....*

Joint Venture Formed to Develop Simbolon-Samosir Geothermal Project

Chinese company **Zhejiang Kaishan Compressor Co Ltd** has announced that the company's holding subsidiary, **KS Orka Renewables Pte Ltd**, has signed a Joint Venture agreement with **PT Optima Nusantara Energi (ONE)** to jointly develop the **Simbolan-Samosir geothermal power project** in **North Sumatra**, Indonesia. The project area indicates **a 110 MW resource.** *Global Geothermal News.....*

Turbine Being Installed at 5 MW Geothermal Power Plant in Iran

Iran has located three sites for the construction of geothermal power plants and is building the first such facility in the northwestern **province of Ardabil**.

According to *Fars News Agency*, the head of the Renewable Energy Department of Niroo Research Institute, **Shahriar Bozorgmehri** said that the **5 MW geothermal power plant** is under construction in **Meshkinshahr** and its turbine is being installed.

He elaborated that Iranian experts have identified three suitable sites, including **Meshkinshahr, Damavand** and **Sistan-Balouchestan**, for the construction of geothermal power plants. *Global Geothermal News.....*

Letter to the Editor

I enjoyed the article on Iran in *Global Geothermal News (Turbine Being Installed at 5 MW Geothermal Power Plant in NW Iran).* They've been a long time a-coming. I attach a picture of me working in Iran right before the Shah was asked to leave. I was contracted to conduct a geothermal appraisal of 2,500 square miles in the very northwest corner of Iran. I was in the field there for 31/2 months. I had to take age-date samples along the crest of volcanic vents forming the border with Turkey. - **Joe LaFleur**, Owner at Geologist Extraordinaire & Associates, LLC, Springfield, Oregon.

Joe LaFleur *and friends in northern Iran in the late 1970's*

AFRICA

USD 27 Million Loan Secured for 15 MW Djibouti Geothermal Power Project

A loan agreement has been signed between the **Republic of Djibouti** and **Kuwait Fund for Arab Economic Development**, whereby the fund will provide a Loan of Kuwaiti Dinars 8 million, equivalent to about **USD 27.2 million**, to the Republic of Djibouti to assist in the financing of **the 15 MW Jalla Koma Geothermal Power Project**, 120 km west of the capital, Djibouti, in the area of **Lake Assal.** *Global Geothermal News.....*

Plans to Replace Kenyan Feed-in-Tariff System With Energy Auction Tariff

Kenya plans to **scrap the current feed-in-tariff system** and replace it with an **energy auction tariff** that will see the government award energy contracts to companies' offering the lowest electricity tariffs.

Director of Renewable Energy at the Ministry of Energy **Isaac Kiva** says the auction model will replace the current feed-in-tariff system where investors identify potentially viable power projects and then acquire licenses to operate them at predetermined rates.

For the last ten years, Kenya has been using the feed-in-tariff model where investors interested in investing in wind power, geothermal, solar, hydropower and biomass energy sources are offered a *Power Purchase Agreement* to construct the power plant and sell the electricity to **Kenya Power**.

However, the model has been criticized as being responsible for making power tariffs expensive. *Global Geothermal News.....*

World Bank Loan Guarantee to Help KenGen Develop Geothermal Energy

The **World Bank** will provide up to **Sh18 billion (USD 180 million)** to **Kenya Electricity Generating Company (KenGen)** in the form of **risk guarantee** allowing it to attract long term capital for its renewable energy development projects.

KenGen said the World Bank's approval will also enable it raise up to **Sh30 billion (USD 300 million)** in long term commercial financing to refinance its existing commercial loans.

KenGen plans to **add 1,745 MW** of electricity **from geothermal** sources **by 2025**, part of a government push to end power generation from fossil fuels. *Global Geothermal News.....*

Consultants Confirm 105 MW Resource at Menengai Geothermal Power Project

Consultants from **West Japan Engineering Consultants (West Jec)** of Fukuoka, Japan have confirmed that Geothermal Development Company (GDC) has **enough steam for the set up of 105 MW** of geothermal power plants in **Menengai**.

In addition, **GDC has secured the lease** area for the Menengai project **for 40 years**.

The last hurdle was addressed after the **African Development Bank** offered credit guarantees to the three Independent Power Producers to each start the process of constructing a 35 MW capacity power plant and **start generating 105 MW to the national grid by end of next year.** *Global Geothermal News.....*

JICA Loan to Rehabilitate 51 MW at Olkaria I Geothermal Power Plant

The **Japan International Cooperation Agency (JICA)** has signed a loan agreement with the government of Kenya to provide a **Japanese Official Development Assistance (ODA)** loan of up to **JPY 10.077 billion** (USD 94 million) for the **Olkaria I Units 1, 2 and 3 Geothermal Power Plant Rehabilitation Project.**

JICA said in a statement that the project will rehabilitate units 1–3 (15 MW each) of the existing Olkaria I Geothermal Power Plant to **approximately 51 MW** (17 MW each) in the Olkaria geothermal field in Nakuru County in central Kenya. *Global Geothermal News.....*

Textile Plant to Take Advantage of Cheap Electricity at Olkaria Geothermal Industrial Park

A Dubai-based textiles company, **United Aryan (EPZ)**, plans to build a factory that could employ up to 10,000 workers at **Olkaria** geothermal fields in **Naivasha** to take advantage of lower electricity costs. *Global Geothermal News.....*

Toshiba Plans to Build 1 MW to 10 MW Geothermal Wellhead System in Malawi

Toshiba Energy Systems and Solutions has signed four *Memoranda of Understanding* (MoU) to cooperate with African countries to develop hydropower and geothermal energy systems.

One of the MoUs was concluded with Malawi's **Ministry of Natural Resources, Energy and Mining (MNREM)** for the development, supply of equipment, development of operational and management guidelines and to facilitate capacity building programs for **geothermal power in Malawi**.

Specifically, the agreement includes feasibility and geotechnical work, early construction and the supply of geothermal power generation equipment, including **a 1 MW to 10 MW geothermal wellhead system.**

Additionally, Toshiba will provide opportunities for local partners or subsidiary employees to complete master's and doctorate degrees at Japanese universities, specifically in geothermal sciences. *Global Geothermal News.....*

EUROPE

Construction of New 5 MW Bjarnarflag Geothermal Power Plant Begins

Deilir Technical Services of Iceland and **Green Energy Geothermal** of London, United Kingdom, have signed a construction contract for the **5 MW geothermal power plant** at **Bjarnarflag** in Iceland. The plant has been in operation since 1969 and is now being updated. Construction work is now underway.

While the old plant has seen a decrease in production, it has been a reliable and important source of power for the **Myvatn** region in the north of Iceland. *Global Geothermal News.....*

Bjarnarflag geothermal power plant (Courtesy Landsvirkjun)

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

Alexander Solberg, HSE & QA manager at **Rock Energy AS** of Oslo, reports on progress at a geothermal district heating project in Norway.

Rock Energy, in partnership with **Båsum Boring**, has of March 21 **reached 1,520 meters** - the deepest geothermal well in Norway. The work was carried out using **compressed air and hammer drilling technology**. Alexander reported up to **20 meters an hour** instant rate of penetration (ROP) in hard basement rock formation (6.5" hole). *Global Geothermal News.....*

Drilling at Finnish Geothermal District Heating Project Reaches Final Depth of 6,400 Meters

Mika Wiljanen, CEO at **St1 Oy Finland**, reports that the first well in the **40 MWth Espoo geothermal district heating project**, on the outskirts of **Helsinki**, has now been drilled to the **final depth of 6.4 km**. Mika claims that the well is the deepest well ever drilled for energy production. *Global Geothermal News.....*

Swedish Geothermal Energy Company Wins International Award

Bloomberg New Energy Finance (BNEF) has announced its selection of the **2018 New Energy Pioneers** – innovators that are revolutionizing the energy, transport, and technology sectors. A geothermal energy company is included.

According to the judges, **Climeon** of Sweden has commercialized the extraction of electricity from low-temperature heat (70-120°C), used in the context of waste heat or geothermal power. *Global Geothermal News.....*

See also " *Climeon Wins Order for First Geothermal Power Plant in Canada*" on page 14.

Company Awarded 6-Year Geothermal Exploration License in Denmark

Peter Veenhof, owner of **Nail Resources Denmark BV (NRDBV)**, has announced that his company has been awarded a 6-year geothermal license covering most of the **Lolland-Falster area** in Denmark. NRDBV will develop plans for geothermal projects in the license area with a view to develop low cost shallow geothermal projects. *Global Geothermal News.....*

Location of the Lolland-Falster area of Denmark.

Construction Starts of Geothermal District Heating Project for Historic Bath City Buildings

Construction will shortly begin on an under-floor heating system using the waters from the hot springs which supply the historic **Roman baths** in the **city of Bath** in south-west **England**.

The scheme, being funded by the **Heritage Lottery Fund**, envisages **1.5 MW**th of geothermal energy being produced, enough to heat the church and surrounding buildings, as well as the RomansBaths and **Pump Room** complex. *Global Geothermal News.....*

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

Inside Geothermal

149 MW of Dutch Geothermal Projects to Get Renewable Subsidy

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

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

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

63°C Geothermal Waters from 2,114 Meter Deep Well to Heat Dutch Greenhouses

Tests have been completed at the **Wayland Energy geothermal district heating project** near **Rotterdam** in southern Netherlands. Geothermal waters at temperatures of **60-63°C** from a **2,114 meter deep well** flowing at up to **400 m³/h** will provide heat for a total of **15 greenhouses** in **Bergschenhoek** and **Bleiswijk**. *Global Geothermal News.....*

Trias Westland Geothermal Project Drilling Nears Reservoir

The wellsite geologists of **T&A Survey/ AmsterdamPG** have established that the clay layers situated above the reservoir of the **Trias Westland geothermal project**, located in **Naaldwijk, Netherlands**, have been reached. Next, the borehole will be stabilized with a cement liner, in order to allow the drilling of the last trajectory, which will go through to the geothermal reservoir. *Global Geothermal News.....*

Second Well Completed at Paris Basin Geothermal District Heating Project

GRC Member **Miklos Antics** and his colleague **Pierre Ungemach** have reported a second **sub-horizontal well** has been successfully completed and tested at **Cachan** in the Paris suburbs, for its customer **Dalkia (EDF Group)**.

The well, which will serve as the injection unit of the local geothermal district heating doublet, is similar in design to the production well achieved in late December 2017, recorded as a world first in geothermal well engineering. **It features an open-hole drain, 8"1/2 in diameter and 1,005 meters long.**

The concept, pioneered by **GPC Instrumentation Process**, opens attractive perspectives for geothermal development in densely populated areas undergoing moderate to poor (by geothermal standards) reservoir performance. *Global Geothermal News.....*

200°C Geothermal Waters from 4,600 Meters to Heat Strasbourg

Fonroche has drilled the first production well for a geothermal district heating project in the **Eurometropolis** in **Strasbourg, France**. The first test results recorded over 80 liters of geothermal water per second at a temperature **over 200°C**. At **4,600 meters, the well is the deepest in France**. *Global Geothermal News.....*

Six More Wells to be Drilled at 50 MWth Munich Geothermal District Heating Project

Daldrup & Söhne AG has received an order for an **additional six wells** for a district geothermal heating project from Munich-based energy provider **Stadtwerke München**.

The plan is for the new geothermal power plant to produce approximately **50 MWth** of district heating for around **80,000 Munich households**. The new plant is **expected to go online in 2020**. *Global Geothermal News.....*

Taufkirchen Geothermal Power Plant Begins Electricity Generation

The **Taufkirchen geothermal power plant** in southern Germany has started electricity production. The plant is owned by **GeoEnergie Taufkirchen GmbH & Co. KG**, a subsidiary of the drilling technology and geothermal specialist **Daldrup & Söhne AG.**

For the first time, electricity and heating from a geothermal source, is being supplied to the communities of **Taufkirchen** and **Oberhaching**, located just south of Munich. *Global Geothermal News.....*

Enel Announces Award for Mercury and Sulphurized Hydrogen Reduction System for Geothermal Power Plants

Enel Green Power (EGP) has announced a winner of its challenge to identify innovative solutions for use at geothermal plants. The winner of the **EUR 15,000** prize is **Luigia Lona**, a researcher at **ENEA**, the **Italian National Agency for New Technologies, Energy and Sustainable Economic Development** in Rome, Italy.

Luigia won the challenge with a process to make **Mercury** and **Sulfurized Hydrogen Reduction (AMIS)** systems in EGP geothermal plants more effective by optimizing the amount of soda added to the scrubber. *Global Geothermal News.....*

4,000 MW of Geothermal Energy by 2030 is New Target for Turkey

Turkey has already passed its 2023 target for geothermal installed capacity prompting a revision upwards of the **2030 target to 4,000 MW**, according to General Directorate of Renewable Energy (YEGM) chief **Oguz Can**.

We, as the Ministry of Energy and Natural Resources, think that geothermal energy is a sector in which strategic and important developments need to continue," Can explained. He also recommended that geothermal energy be used not only for electricity production but for use in the agricultural sector. *Global Geothermal News.....*

165 MW Kizildere III Geothermal Power Plant Completed

Zorlu Dogal Elektrik, a subsidiary of Turkey's **Zorlu Enerji**, has commissioned the **65.5 MW second unit** of its USD 320 million **Kizildere III geothermal power plant** on the border between the southwestern provinces of Aydin and Denizli.

The plant now has an total installed **capacity of 165 MW – making it the largest in Turkey**. *Global Geothermal News.....*

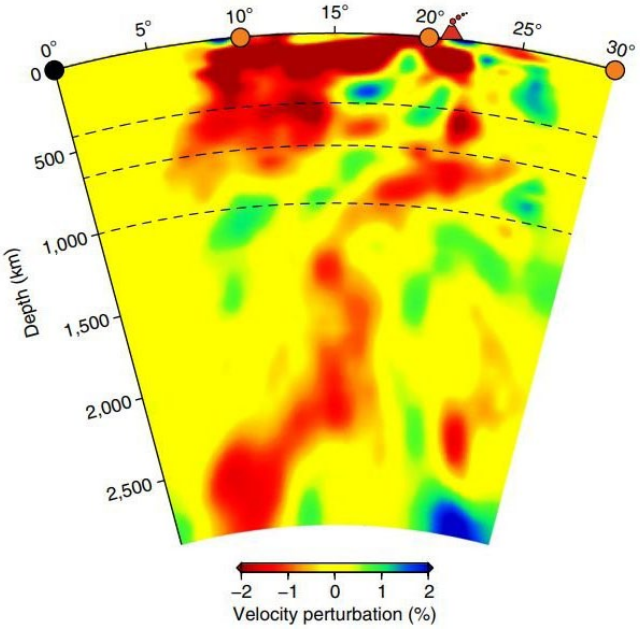
Somewhere Over The Rainbow: Kizildere Power Plant. By **Erdinc Senturk.** *GRC Photo Contest 2016.*

SCIENCE & TECHNOLOGY

New Research Supports a Deep Origin for the Yellowstone Hotspot

The **Yellowstone hotspot**, located in North America, is an intraplate source of magmatism the cause of which is hotly debated. Some argue that a deep mantle plume sourced at the base of the mantle supplies the heat beneath Yellowstone, whereas others claim shallower subduction or lithospheric-related processes can explain the anomalous magmatism.

A new **shear wave tomography model** for the deep mantle beneath the western United States, made using the travel times of core waves recorded by the dense **USArray seismic network**, seeks an answer.



The model reveals a single narrow, cylindrically shaped slow anomaly, approximately **350 km in diameter** that is interpreted as **a whole-mantle plume**. The anomaly is tilted to the north-east and extends from the core–mantle boundary to the surficial position of the Yellowstone hotspot. The structure gradually decreases in strength from the deepest mantle towards the surface and if it is purely a thermal anomaly this implies **an initial excess temperature of 650 to 850°C.**

The results strongly support a deep origin for the Yellowstone hotspot, and also provide evidence for the existence of thin thermal mantle plumes that are currently beyond the resolution of global tomography models. *Global Geothermal News.....*

Lower-mantle plume beneath the Yellowstone hotspot revealed by core waves, by **Stephen Grand** and **Peter Nelson**. *Nature Geoscience* (2018) DOI: 10.1038/s41561-018-0075-y

Discovery of Liquid Water Deep in Earth's Mantle has Implications for Geothermal Models

A new report published in *Science* suggests that **pockets of liquid water may exist up to 500 miles beneath Earth's surface**—far deeper than previous estimates. This conclusion was reached after scientists discovered a rare form of crystallized water known as **ice VII** in diamond samples recovered in **Africa** and **China**. These ice VII samples are the first time this form of crystallized water has been seen in nature and led the **International Mineralogical Association** to declare **ice VII as a new type of mineral**.

The discovery sheds new light on the how heat, rock, and water interact within the Earth's mantle, the 1,800 mile-thick crust that accounts for the bulk of our planet's volume. Scientists hope that a better understanding of the processes at work deep beneath Earth's surface will result in **more accurate geothermal models**, which, among other things, can help predict earthquakes with greater accuracy. *Global Geothermal News.....*

I*ce-VII inclusions in diamonds: Evidence for aqueous fluid in Earth's deep mantle.* **O. Tschauner**, et al. *Science* 9 Mar 2018: Vol. 359, Issue 6380, pp. 1136-1139 DOI: https://doi.org/10.1126/science.aao3030

New Drilling Technology Expands Engineered Geothermal Reservoirs in Hard Deep Rocks

A patent-pending technology developed at **ETH Zurich** could make for more efficient fracture networks in deep gas, oil and geothermal wells.

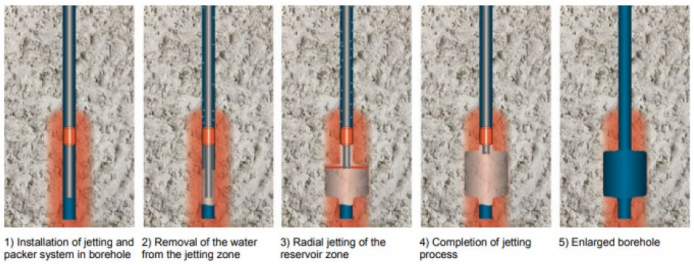
Thermal borehole enlargement through thermal spallation can be used to bore deep wells for gas, oil or geothermal exploration in hard rock. It could also boost the efficiency of new wells and recovery of abandoned wells.

The shape of the borehole can be optimized in order to enhance the subsequent stimulation process.

The Thermal spallation process excavates rock on the sidewalls of an existing borehole. One or more nozzles are placed on the circumference of a burner assembly, creating **a hot jet of combustion gases.**

When this hot jet impinges on the rock, high thermal stresses are induced, which lead to the disintegration of the rock surface. An adaptable packer system avoids water penetration during the jetting process and regulates the pressure in the jetting zone. *Global Geothermal News.....*

Demonstration of thermal borehole enlargement to facilitate controlled reservoir engineering for deep geothermal, oil or gas systems. **Kant, Michael & Rossi, Edoardo & Duss, Jonas & Amann, Florian & Saar, Martin & Rudolf Von Rohr, Philipp.** (2018). *Applied Energy.* 212. https://doi.org/10.1016/j.apenergy.2018.01.009 ■



Role of Geothermal in The Generation of Hydrogen and Its Use for Energy Storage

by Marcelo Lippmann, with significant input from Ronald DiPippo and Wilfred Elders.

Production of free hydrogen

Currently, fossil fuels (natural gas, oil and coal) are the dominant source for commercial, free hydrogen (H_2) production. Electrolysis is another way to generate the gas, but its contribution is minor. Specifically, bulk hydrogen is usually produced by steam reforming of methane or natural gas. The production from natural gas continues to be the cheapest source of hydrogen.

The gas is mainly used in industrial applications (e.g., in chemical and refining processes, in metallurgy, glass production and electronics) and/or, more recently, as a transportation fuel.

Interesting H_2 properties

Hydrogen has the highest energy per mass of any fuel; however, its low ambient temperature density results in a low energy per unit volume. It can be stored as either a gas or a liquid. Storage of hydrogen as a gas typically requires high-pressure tanks (350–700 bar [5,000–10,000 psi] tank pressure). Storage of hydrogen as a liquid requires cryogenic temperatures because the boiling point of hydrogen at one atmosphere pressure is −252.8°C. Hydrogen can also be stored on the surfaces of solids (by adsorption) or within solids (by absorption).

One of the interesting aspects of H_2 is that it can be stored and also transported along with natural gas in existing pipelines. That is, the gas can be delivered to consumer centers over long distances with the aid of compressor stations, which already exist, along the natural gas pipeline

Hydrogen production using geothermal resources

Concentration of free hydrogen in geothermal gases is quite low, i.e., below one percent by weight. "Geothermal hydrogen" can be generated using "geothermal electricity" to electrolyze water. There are a significant number of papers and reports about this methodology, many available in the GRC Library.

Two examples of the use of electrolysis in these geothermal projects are first the Carbon Recycling International (CRI) plant[1] at Svartsengi, Iceland, that uses 5 MW of geothermal and hydro-electricity and electrolysis to produce hydrogen. It manufactures methanol by combining the hydrogen with carbon dioxide from the HS Orka geothermal station.[2] Here, the CO_2 is collected from the gas extractors at the steam condensers of the geothermal power plant. The second example is the pilot geothermal-hydrogen project supported by Japan and New Zealand, in Taupo, NZ, that has been announced recently. In this particular case, the hydrogen (a CO_2-free fuel) would be used for transportation.

Shnell et al. (2016)[3] also discuss the production of hydrogen based on geothermal resources, typically from high-enthalpy geothermal fluids to generate the gas, a new and different concept. According to these authors the economics of generating geothermal hydrogen could be significantly improved if the fluids to produce electricity used in the electrolysis process come from deep, superhot, or supercritical, geothermal reservoirs. Currently there are a number of projects

Svartsengi geothermal power plant, Iceland. Courtesy Verkís Consulting Engineers.

in Japan, New Zealand, Mexico, and Iceland evaluating this new concept. Of these, the Iceland Deep Drilling Project is the most advanced (see for example, Friðleifsson et al., 2017.[4]

Importance of hydrogen to store excess renewable energy

Presently, renewable energies are competing in the electricity market against fossil fuels. Even a dramatic drop in production costs would still mean renewables would continue to struggle to displace oil and natural gas; coal is slowly and surely being displaced by renewables worldwide.

Because of the intermittent nature of wind and solar energies, i.e., they are not available at all times, (note that this is not the case for geothermal) there is a significant imbalance between supply and demand of the electricity being generated. This lack of reliability can be solved by storing excess power. For example, the surplus generated at off-peak times could be stored using rechargeable batteries, hydroelectricity (pumped storage), flywheels, as well as other technologies, and be used at periods of high demand.

In the particular case of geothermal, the generated electricity exceeding load demand could be used to produce hydrogen for direct applications or for temporarily storing the energy surplus. This would eliminate the practical difficulty of periodically curtailing flow from wells to reduce power output, such as at night when demand is low.

The idea of our geothermal research for hydrogen came after reading an article about how "to solve-renewable-energy-biggest-problem," i.e., their lack of reliability.[5] This article discussed new technology for using power to convert water to hydrogen gas, a process that is somewhat complex and may be slow to complete. Quoting the article, "Put in very simple terms, power-to-gas uses electrolysis to break water down into its constituent parts of oxygen and hydrogen. The hydrogen can be stored along with natural gas in pipelines, or used in fuel cell vehicles. An additional step called methanisation converts the hydrogen into renewable natural gas (RNG), which can be stored in those same pipelines to be used later in a variety of industrial and domestic applications." Note that methanisation has already been tested.[6]

As of April 2018, there are two new developments related to supercritical geothermal resources, and thus to "geothermal hydrogen," i.e., (1) the final meeting of the DESCRAMBLE project[7] was held in Florence, Italy in late March. The project is aimed at "developing new drilling technologies and concepts for geothermal

energy exploitation from deep and super-critical geothermal resources in continental Europe, and (2) Wilfred Elders and Jim Shnell are planning to submit two papers to the upcoming 2018 GRC Annual Meeting (Reno, Nevada, October 14-17, 2018). Their tentative titles are: "Improving Geothermal Economics by Utilizing Superhot and Supercritical Systems to Produce an Integrated Combination of Electricity, Hydrogen, and Minerals", and "Supercritical Geothermal Cogeneration: Bring Leading-Edge Technologies Online in a Combined, Flexible Energy Plant Powered by Highly-Efficient, Supercritical Geothermal Resources".

It is hoped that this short review might lead to an increase in the support of the concept of generating hydrogen based on "normal" and high-enthalpy geothermal resources, and might lead to the commercial implementation of the technology. It would be particularly appropriate for countries (or islands) rich in geothermal, but poor in fossil energy resources.

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Solar Thermal and Geothermal Hybrid Power Plant Study

by Kevin Kitz[1], Josh McTigue[2], Dan Wendt[3], Guangdong Zhu[2], Nick Kincaid[2], Josh Gunderson[4]

[1]KitzWorks LLC (formerly with U.S. Geothermal Inc.); [2]National Renewable Energy Laboratory; [3]Idaho National Laboratory; [4]POWER Engineers, Inc.

Over the past couple of decades, the concept of integrating solar thermal energy into a geothermal power plant has been studied and documented in various publications. A new concept, to use concentrated solar thermal energy first in a high pressure steam topping turbine, and then as an additional heat source to the Raft River geothermal binary power plant (GBPP) in Idaho, USA was investigated. The approach yielded an economically attractive design through lower capital cost, higher net output and higher efficiency. An unexpected result was the option to incorporate solar thermal storage into the hybrid cycle for 4 or 8 hours at a cost far below battery storage of electrical energy.

U.S. Geothermal Inc. (USGeo), the National Renewable Energy Laboratory (NREL), the Idaho National Laboratory (INL), and POWER Engineers (PEI) worked together to investigate the concept. The study was made possible through a 2017 Small Business Ventures Pilot Program grant, funded by the U.S. Department of Energy (DOE) Geothermal Technologies Office.

This article is a high-level summary of a detailed study that is pending publication by INL and NREL, and of a geothermal paper that will be presented at the forthcoming October 2018 GRC Annual Meeting in Reno, Nevada.

Conceptual Approach

Five principles comprised the approach to the integrated power cycle. These were:

- Use concentrated solar heat, not direct solar to electric panels (photovoltaic).
- Collecting solar thermal energy is very expensive, so high efficiency conversion is required. High efficiency means high temperature. High temperature means that a steam turbine must be installed between the solar collector and the geothermal power plant.
- Geothermal binary plants can convert low pressure steam at an efficiency similar to that of a steam turbine. Making use of existing capacity at geothermal power plants avoids the expense of a cooling tower system for the solar plant.
- When solar heat is added to the geo-solar hybrid power plant, avoid raising the temperature of the brine leaving the plant. It is not cost-effective to use solar energy to heat up injectate.
- Small high pressure steam turbines are not particularly expensive, nor are heat exchangers when there is clean fluid on both sides, especially when boiling or condensing is involved.

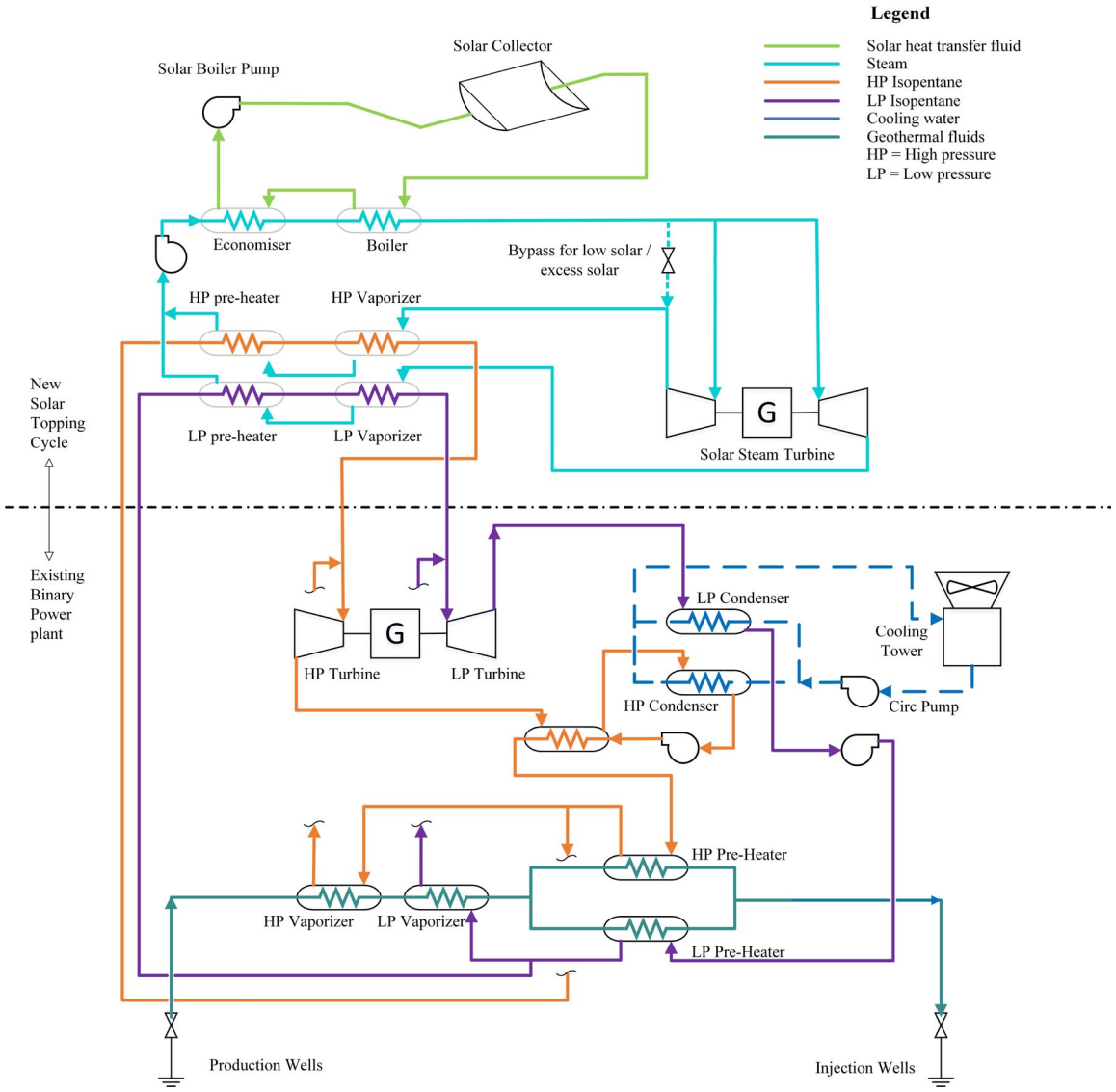

Figure 1: A Concept for a Geo-Solar Retrofit of the Raft River Geothermal Binary Power Plant.

These principles led to the development of a conceptual design of geo-solar hybrid power plant, as shown in Figure 1.

In Figure 1, several features are worth considering:

1. No changes to the Raft River GBPP were required other than pentane piping inlet and extraction connections. (The 4 orange and purple lines that cross the dashed dividing line.)
2. The pentane used in the solar heat cycle (purple and orange lines in upper half) is preheated by the geothermal brine. This extracts additional geothermal energy from the brine in the pre-heaters. Interestingly, adding solar energy increases the amount of geothermal energy that is extracted by the existing GBPP equipment.
3. The six heat exchangers shown in the upper half of the figure are only exposed to clean non-corrosive fluid, and all involve boiling and/or condensing which also reduces equipment cost. The small industrial steam turbine is also inexpensive.
4. The solar heat is collected using a heat transfer fluid (HTF), shown with green lines at the top of the diagram. Use of the HTF made plant performance and economic modeling easier using common software tools. It may be preferable to use direct solar steam boiling in actual practice.
5. The study was made using iso-pentane as the working fluid in the GBPP, but the results would be similar for any type of working fluid.

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Results and Comparison with Other Geo-Solar Hybrid Approaches

This cycle described in Figure 1 was screened against two of the most common actual or proposed Geo-Solar cycles, namely a) adding solar energy to either pre-heat the entire brine flow to the GBPP, or b) heating a small slip stream of cooled geothermal brine and returning it to the incoming flow to the GBPP.

The analysis showed that the cycle of Figure 1 has a conversion efficiency double that of the brine heating cycles efficiencies. The proposed geo-solar hybrid cycle also doubled the annual energy production (MWh/yr), and because of the high conversion efficiency, the size of the solar field was of a similar size, so solar field capital costs are similar.

The study also looked at several other configurations, which are listed in Table 1. Detailed results will be included in the pending NREL/INL study and the GRC Annual Meeting paper. The results are presented in approximate solar conversion efficiency ranking from best to worst.

Cycle Name	Brief Description	Comment
Two solar steam turbines	Solar steam exits turbines to HP and LP pentane boilers for the GBPP pentane turbine.	Initial focus of study
One solar steam turbine with steam cross-over	Some of steam from turbine exhaust is crossed-over to LP pentane boiler.	Low steam flow in second turbine, so eliminate it to reduce capital cost.
One solar turbine with geo-heat bypass of HP side of GBPP	All solar turbine steam is used on HP side. Transfer more geo heat to LP geo-boiler.	Use all solar energy in HP side of GBPP to have lower heat exchanger and turbine costs.
One solar turbine to reheat internal brine slip stream	Use one steam turbine, and then recirc and reheat brine after HP or LP vaporizers.	Good efficiency and simple process. Reduced solar heating of brine to injection.
One solar turbine to heat incoming brine	Captures solar turbine efficiency, but not as well.	Preheating may create chemistry problems. Simple cycle and lower cap costs.
One solar turbine to reheat brine slipstream from GBPP exit	Captures solar turbine efficiency in common geo-solar recirc approach.	Brine temperature still increases.
Directly heat incoming brine with solar energy. No solar turbine.	Heat all incoming brine with direct solar energy.	Low efficiency w/o solar turbine, and elevated brine exit temperature.
Directly heat brine from exit with solar energy. No solar turbine.	Heat exit brine slipstream with incoming solar energy, add back to plant inlet.	A common approach. Large solar field is expensive and efficiency is low.

Table 1: Description and Qualitative Comparison of Hybrid Geo-Solar Cycles Studied

In many of the cycles, efficiency can be improved by having multi-stage turbines with intermediate steam extraction, as used on many conventional fossil-fuel power plant designs.

Field Sizing and Thermal Storage

Since the solar resource varies hourly, daily, and especially seasonally, there are many factors that go into the "required" size of the solar field. The usual solar insolation value that is used to design the field is not the absolute maximum that can occur in the year. Consequently, some hours will have more solar energy than the design value. But using the normal design value, also means that there are many hours in which the solar field cannot produce the design heat flow. It is therefore quite common in the solar power industry to oversize the solar field. This means that even at the normal insolation value, there is greater than the design heat. The ratio of the size of the actual solar field to that required at the design solar insolation value is called the "solar multiple". How to handle this excess heat, especially with solar multiples greater than 1, was also examined.

One option to handle the excess solar heat is to allow greater steam flow into the solar turbine. In our study this was limited to 10% above the design value, although higher values could be specified. Above that point, we allowed excess solar steam to bypass directly to the pentane boiler. This is not efficient, but it is more efficient that tilting the collectors away from the sun. Steam was also directly sent to the petane boiler in the winter when the useable solar insolation is low, and the needed high pressure solar steam for the turbine could not be produced.

Another option for handling excess thermal energy was to store it at high temperature where it could be used at a later time and extend the hours of operation of the solar steam turbine and the hybrid plant. Storage enables a higher conversion efficiency of the excess solar heat than bypassing the steam turbine. Storing excess solar electrical energy in batteries is expensive, but storing solar thermal energy is much less costly. In initial investigations, the solar field size was only oversized by a small amount, with a small amount

of thermal storage. But as the study progressed, the results indicated that solar thermal storage could allow the size of the solar field to be more than doubled, and that the overall cost per kWh of generated power would be flat or reduced.

Results at Other Geothermal Locations in the U.S.

The Raft River GBPP is located in southern Idaho. The cool low-humidity weather (i.e. low wetbulb temperature) of this location results in the plant having a relatively small cooling system. However, there are geothermal plants located in areas with a much better solar energy resource. Therefore, one of the steam turbine options was re-run using the solar insolation and wetbulb temperatures for Reno, Nevada and Imperial, California. This was a hypothetical case involving moving the Raft River GBPP plant and the same resource and flow rates to another location. The higher wetbulb temperatures hurt the predicted benefit when using the small cooling system of the Raft River plant, especially at Imperial. In spite of the undersized cooling system, the improved solar resource had a large beneficial effect on the economics (lower LCOE).

There are binary power plants, near both Reno and Imperial, that may not be able to meet the maximum contract delivery limits. If so, this study indicates that they could benefit from using the results of this study to improve plant economics. The actual increase in generation at these warmer locations would likely be even higher, and the LCOE lower, if the cycle were modeled with the larger cooling systems that would have been part of the original design of these geothermal plants.

Economics

The Levelized Cost of Energy (LCOE) per kWh was calculated for all additional electricity generated by the hybrid plant for a variety of plant configuration options, solar field size, and storage amounts. Costs were based on estimates, but not hard quotes, for heat exchangers, turbines, ancillary equipment, the solar collectors, and the heat transfer fluid. Representative values for incremental operations and maintenance expenses were included. While these were reasonable for this level of study, it is likely that the costs could be reduced in some areas.

Figure 2 presents a typical result from the study. It shows the effect on the LCOE of additional power delivered from the hybrid system ($/kWh) of several of the study variables, including the solar multiple, inclusion of thermal energy storage (TES), and the beneficial effect of an improved solar resource (Imperial, California), compared with the Raft River location (Burley, Idaho).

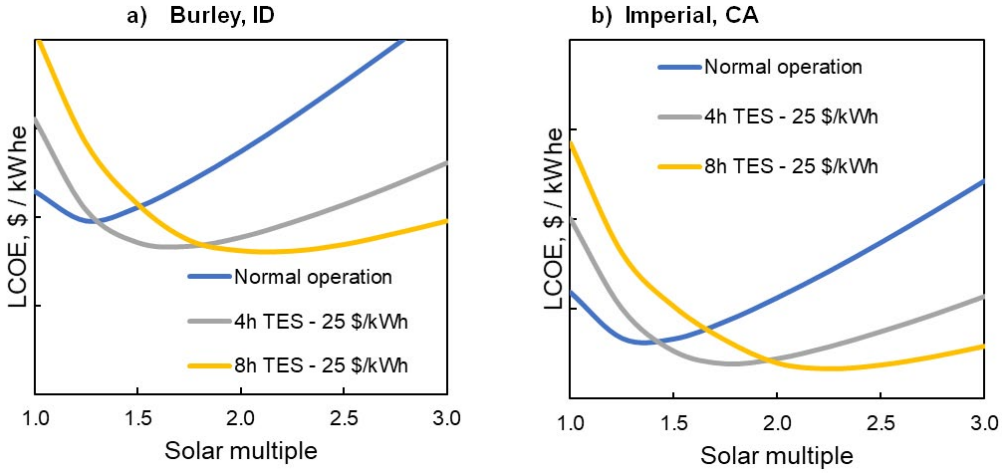

Figure 2: Thermal Energy Storage (TES) increases the optimal solar multiple for: **a)** The Raft River geo-solar hybrid plant at Burley, ID. **b)** The same hybrid plant with wetbulb temperature and solar insolation values, if located in Imperial, CA. Results are for a hybrid plant with one steam turbine.

Figure 2 provides several interesting and important lessons for geo-solar hybrid power plants.

1. Adding solar storage increases the optimal size of the solar field both by generating more power (bigger is better) and by lowering the cost of the power that is sold. This occurs because the solar turbine and solar pentane vaporizer are used for more hours of the day, without increasing the cost of that equipment. (Compare yellow and grey lines with blue lines.)
2. In spite of the undersized GBPP cooling system, the cost of a geo-solar hybrid is much less in a better solar location than Raft River. (Compare left and right graphs.)
3. In Imperial, the retrofit cost may be similar to the grassroots cost of a new geothermal power plant. (Right graph.)

4. Most interestingly, geo-solar hybrid with thermal energy storage may be a lower cost method than an installation of photovoltaics (PV) with batteries, especially in light of the high cost and replacement rate of batteries. This is a potentially important area for further study, especially if solar thermal retrofit and thermal storage provides a means to make geothermal "dispatchable and flexible" on the electric grid.
5. It is possible that the cost of geo-solar hybrid power can be delivered at a cost similar to that of conventional geothermal power plants, thus offering the potential to supplement existing power contracts at underperforming geothermal plants, or to increase the size and investment in grass roots plants while providing better electrical grid value and ancillary services.

Conclusion

Retrofit of solar thermal collectors into the Raft River Geothermal Power Plant was evaluated under a Small Business Ventures grant from the U.S. Department of Energy Geothermal Technologies Office. New approach identified that is more efficient to use a high temperature steam turbine between the solar field and the geothermal power plant. Doing so results in lower levelized cost of energy ($/kWh) than other geo-solar hybrid strategies. It also offers a very interesting opportunity to add solar thermal energy storage to the geo-solar hybrid plant at an incremental cost much lower than PV with batteries can deliver.

Photovoltaic (PV) panels, like these at the Stillwater geothermal power plant, are lower cost ($/MWh), but geo-solar hybrid also provides energy storage and grid support services at far lower cost than PV+Battery. (Photo courtesy Enel Green Power).

Multiple areas for potential further investigation were identified. These include:

- Strategies to optimize a new grassroots geo-solar hybrid plant, versus retrofit (the subject of another ongoing grant).
- Further evaluation of thermal storage as a means to lower the installed cost of geo-solar hybrid plants, including grid benefits such as plant flexibility and smoothing output.
- Application of this approach to geothermal power plants using geothermal steam, instead of a binary conversion. This could be especially valuable as a method to lower the installed cost of power plants at the Salton Sea in Southern California.

Raft River geothermal power plant (Photo by Ian Crawford).

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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 Geothermal Associated with Oil & Gas Operations.

The UND-CLR Binary Geothermal Power Plant

Will Gosnold, Michael Mann, and Hossein Salehfar
Institute for Energy Studies
University of North Dakota

Keywords
- Low-temperature geothermal
- binary power
- oil and gas setting

ABSTRACT

The UND-CLR Binary Geothermal Power Plant is a collaborative effort including the U.S. Department of Energy (DOE), Continental Resources, Inc. (CRL), Slope Electric Cooperative (SEC), Access Energy, LLC (AE), Basin Electric Cooperative (BEC), Olson Construction, the North Dakota Industrial Commission Renewable Energy Council (NDIC-REC), the North Dakota Department of Commerce Centers of Excellence Program (NDDC-COE), and the University of North Dakota (UND). The primary objective of project was to demonstrate/test the technical and economic feasibility of generating electricity from non-conventional, low-temperature (90°C to 150 °C) geothermal resources using binary technology. CLR provided access to 98°C water flowing at 51 l s^{-1} at the Davis Water Injection Plant in Bowman County, ND. Funding for the project was from DOE –GTO, NDIC-REC, NDD-COE, and BEC. Logistics, on-site construction, and power grid access were facilitated by Slope Electric Cooperative and Olson Construction. Access Energy supplied prototype organic Rankine Cycle engines for the project.

The potential power output from this project is 250 kW at a cost of $3,400 per kW. A key factor in the economics of this project is a significant advancement in the binary power technology by Access Energy, a spinoff of Calnetix, Inc. At the initiation of the project other commercially available ORC engines had efficiencies of 8 to 10 percent and could produce 50 to 250 kW per unit. The AE ORC units are designed to generate 125 kW with efficiencies up to 14 percent and they can be installed in arrays of tens of units to produce several MW of power where geothermal waters are available. This demonstration project is small scale but the potential for large-scale development in deeper, hotter formations is promising. The UND team's analysis of the entire Williston Basin using data on porosity, formation thicknesses, and fluid temperatures reveals that 4.0×10^{19} Joules of energy are available and that 1.36×10^{9} MWh of electric energy could be produced using ORC binary power plants.

Much of the infrastructure necessary to develop extensive geothermal power in the Williston Basin exists as abandoned oil and gas wells. Re-completing wells for water production could provide local power throughout the basin thus reducing power loss through transmission over long distances. Water production in normal oil and gas operations is relatively low by design, but it could be one to two orders of magnitude

greater in wells completed and pumped for water production. A promising method for geothermal power production recognized in this project is drilling horizontal open-hole wells in the permeable carbonate aquifers. Horizontal drilling in the aquifers increases borehole exposure to the resource and significantly increases the capacity for fluid production.

1. Introduction

In 2008, the University of North Dakota responded to DOE's FOA DE-FOA 0000109 with a proposal to demonstrate the technologic and economic feasibility of generating electricity from low-temperature (T≤ 100°C) resources using organic Rankine cycle (ORC) technology with air as the condensing medium. The geothermal resource selected for the project was the hot water stream from a secondary-recovery water-flood operated by Continental Resources, Inc. (CLR) in the Cedar Hills Red River-B oil field in the Williston Basin as shown in Figure 1. Two 7.75-inch diameter open-hole horizontal wells at 2,300 m and 2,400 m depths with lateral lengths of 1,290 m and 860 m produce water at a combined flow of 51 l s^{-1}. The two water supply wells, Davis 44-29, API No: 33-011-90121-00-00 and Homestead 43-33, API No: 33-011-90127-00-00 s are 570 m and 340 m from the power plant and the water flows through uninsulated pipes buried below the frost line. Water temperature is 103°C at the wellheads and 98°C at the ORC inlet. The source formation is the Lodgepole (Mississippian), the lower member of the predominately limestone Madison Group, and injection is into the Red River formation (Ordovician). The hydrostatic head for the Lodgepole is at ground surface and the pumps, which are set at 735 m and 967 m depths, have run continuously since 2008. Prior to installation of the binary power plant, CLR passed the water through two large air-cooled heat exchangers for reasons of safety and to minimize heat effects on the injection pumps. Thus installation of the ORC could benefit CLR by cooling the water and eliminating the electrical cost of running the fans on the air coolers in addition to generating power that CLR could use for pumping.

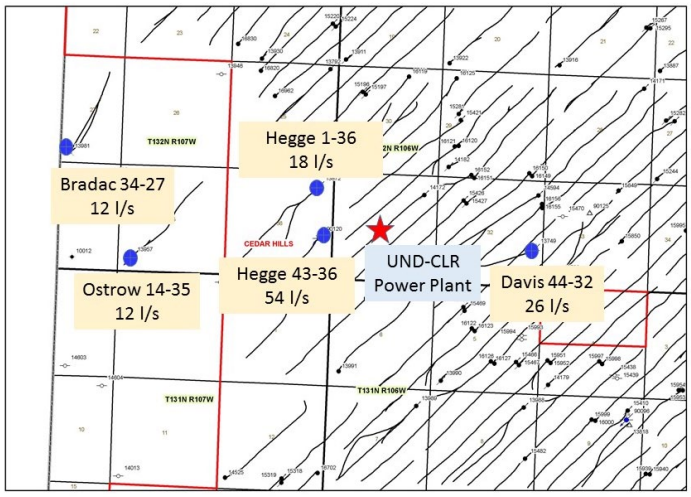

Figure 1. UND-CLR power plant in Williston Basin.

2. Selection Of Binary Power Equipment And System Operation

Selection of the power conversion system entailed a request for proposals from six binary power equipment manufacturers: Pratt & Whitney, Ormat, Recurrent, Calnetix (Access Energy), Electratherm, and Deluge. Given details on fluid temperature, flow rate, fluid composition, and annual and monthly temperatures at the site, the six suppliers were asked to respond to 27 separate items for the evaluation. After analysis of the responses and applying the CREST model on the relevant data, the Calnetix system was selected.

The CREST model showed that based upon the equivalent nominal levelized tariff rate, the Calnetix system offers the potential for the lowest rate at 4.45 ¢/kWh. The levelized rates for the other systems are compared in Figure 2, showing in rank order of Calnetix, Deluge, Recurrent, Pratt & Whitney, Ormat, and Electratherm. Based upon this preliminary analysis the Calnetix system was chosen for the demonstration project.

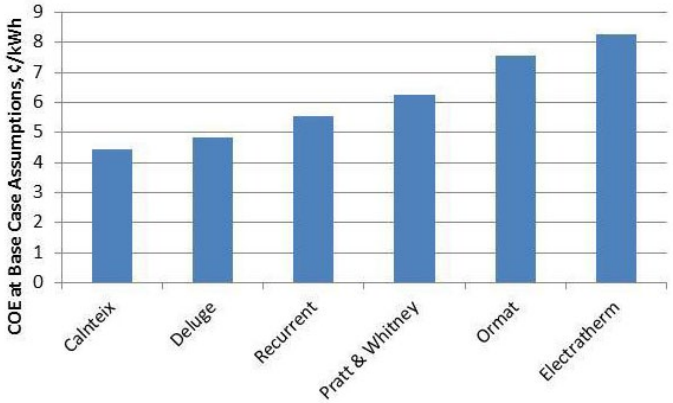

Figure 2. Comparison of equivalent nominal levelized tariff rate for evaluated systems

Two 125 kW Thermapower™ ORC 125 XLT units developed by Access Energy/Calnetix Technologies were installed on Continental

Resources, Inc. Davis Water Injection Plant. These units were specifically designed for this project and including modifying Calnetix's existing mid-temperature design (130°C the resource temperature) to efficiently recover heat from the lower temperature resources available in Williston Basin. Their new design is based upon a working/ geothermal resource of 105°C and access to a cooling tower. This system has a 95°C temperature with a custom designed air heat exchanger. Figure 3 is a Google Earth image of the site and the location of the ORC system. Figure 4 is a photo of the system as installed at the site.

Figure 3. Davis water injection plant – ORC located in northeast corner of the site.

Each of the two 125 kW ORC systems were constructed and installed in their own separate shipping containers. The shipping containers serve to house the system once installed on site. The two cooling systems, seen on the top of the shipping containers, were shipped separately and installed on site. Construction of the units including full installation in the shipping containers was performed by Calnetix. All site work including mounting the heat exchangers was performed on-site by a contractor (Olson Construction). If the installation is replicated at other sites, it is anticipated that similar site work would be needed to be performed by the host site.

Figure 4. ORC units as installed at the Davis Water Injection site.

The two units are designated as the north unit and the south unit. The south unit was operational briefly and demonstrated the viability of the system. The system generated 124 kW of electricity, meeting the design specifications. However, due to system failures that occurred shortly after startup, the unit did not operate for a long enough period of time to optimize the performance or collect data regarding long-term operation and maintenance costs. It was determined during the operation of the unit that the cooling system, as designed, did not have the capacity to adequately cool the working fluid of both units. Therefore, the unit was not able to run at its full rated capacity. Further troubleshooting indicated that refrigerant was being held up somewhere in the cooling loop. This shortcoming appeared to be related only to the cooling system, and was not reflective of the operation of the ORC itself.

Figure 5 shows a screen shot of the user interface for the system. As a remote site, UND was able to view the primary data, but did not have the ability to access any of the control screens. The screen shots show the system producing 115 kW of electricity.

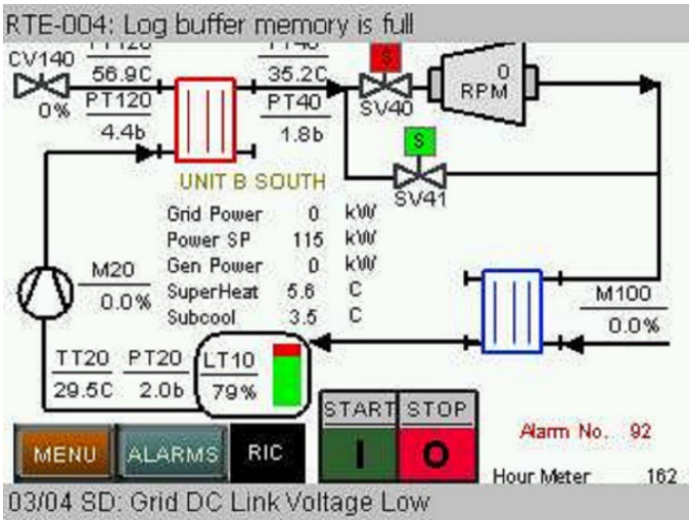

Figure 5. Screen shot of south unit during operation. (TT120 = Geothermal fluid temperature (°C), PT120 = Geothermal fluid pressure (bars); TT20 = Working fluid; TT40 = Working fluid inlet temperature (°C); PT40 = Working fluid inlet pressure (bars); TT50 = Working fluid exhaust temperature (°C)

After a review of the issues that were seen in implementing the Calnetix technology at the Davis Water Injection Site, several recommendations for future development were identified. First, and perhaps most important, it was determined that there were no issues identified with the ORC system itself. The south unit, when it was operational, produced the design amount of electricity. Operational issues were isolated to the cooling/condensing system. Therefore, the primary recommendation is a different configuration for the cooling system which would remove many of the issues/variables that were identified in the condensing system. Basically, the recommended design would have a container with a closed loop system inside, and would allow for a water/glycol loop to a condenser that can be mounted on ground level. A circulating pump for the cooling water would be included. Access Energy/Calnetix has some design ideas based upon other sites that use their technology.

3. Project Economics

Project economics were updated based upon the information obtained as a result of the installation and brief operating period. The DOE CREST model was used for this evaluation.

Based upon conversations with the Calnetix team, the budgetary price for a unit similar to the one delivered to the CRI site is $520,000. This equates to $2,080/kW. Olson Construction was contracted to perform the installation of the system, including the electrical interconnect. The cost to install the system, including all site preparation and interconnection was approximately $350,000. The total cost of the system used for the updated economic analysis therefore was $870,000 ($3,480/kW). The CREST model adds an increment for reserves and financing costs, for a total estimated project cost of $890,663. Other assumptions used in this model include: 50:50 debt: equity; 7% interest on debt; 15 yr. debt repayment; 12% after tax IRR; 35% federal tax rate; 6.5% state tax rate; 25 yr. project life; 90% C.F.; no ITC; 50% bonus depreciation in year 1; 5 yr. MACRS depreciation for the power plant and 15 yr. MACRS depreciation for the interconnect. There was no cost assigned to completing the wells since for this type of installation, the wells will be in place. There is no well-replacement allocated to the projects since the quality of the resource (the water flow rate) will increase over time rather than become depleted as is the case for conventional geothermal systems. The temperature of the water was assumed to remain constant over the life of the project, and this is valid for extraction of water from a deep formation with no injection of cold fluid. A summary of the CREST economic modeling is given in Table 1. Details can be found in the final report to DOE for this project.1 Based upon the above set of assumptions and the cost data generated during this project, the anticipated cost of electricity is 7.25 ¢/kWh. The cumulative cash flow of the project will be positive during the fifth year of the project. The pretax equity IRR for the project is estimated at 8.5% and the after tax equity IRR is 12.3%.

Table 1. CREST Model Summary

Outputs Summary	***units***	
Year-One Cost of Energy (COE)	*¢/kWh*	7.25
Annual Escalation of Year-One COE	*%*	0.0%
Equivalent Nominal Levelized Tariff Rate	*¢/kWh*	7.25
Inputs Summary		
Generator Nameplate Capacity	*MW*	0.25
Net Capacity Factor, Yr 1	*%*	90.0%
Annual Degradation of Thermal Resource	*%*	0.0%
Payment Duration for Cost-Based Incentive	*years*	25
Project Useful Life	*years*	25
Fixed O&M Expense	$/kW-yr	50
Variable O&M Expense	*¢/kWh*	1
Exploration / Wells	*$*	$0
Power Plant	*$*	$870,000
Interconnection (included in power plant costs)	*$*	$0
Reserves & Financing	*$*	$20,663
Net Project Cost	*$*	$890,663
Net Project Cost	*$/kW*	$3,563
% Equity (% hard costs) (soft costs also equity funded)	*%*	50%
Target After-Tax Equity IRR	*%*	12.00%
% Debt (% of hard costs) (mortgage-style amort.)	*%*	50%
Interest Rate on Term Debt	*%*	7.00%
Is owner a taxable entity?		Yes
Type of Federal Incentive Assumed		Cost-Based
Tax Credit Based or Cash Based?		Cash Grant
Other Grants or Rebates		No

4. Potential for Replication in Other Regions

As a part of this effort, temperature-depth profiles in the Williston Basin and were developed and are presented in several reports on temperature-depth relationships in all formations 2-15. In brief, there are six regional aquifer systems containing eleven different formations. Six of the aquifer systems have temperatures above 90°C and the waters contained in them could be developed for binary electrical power generation (see Figure 5).

T °C	km³ Rock	km³ Water	EJ Rock	EJ Water
90° -100°	192,467	10,486	3.2E+01	1.7E+00
100° -110°	255,799	12,430	3.2E+01	1.7E+00
110° - 120°	226,723	10,937	5.2E+01	9.9E-01
120° - 130°	204,628	10,166	5.7E+01	1.0E+00
130° - 140°	122,569	5,333	6.0E+01	1.1E+00
140° - 150°	60,806	1,766	4.1E+01	8.4E-01
T ≥ 150°	45,248	1,257	1.9E+01	5.3E-01

Table 2. Energy stored in the North Dakota portion of the Williston Basin grouped by 10°C temperature bins.

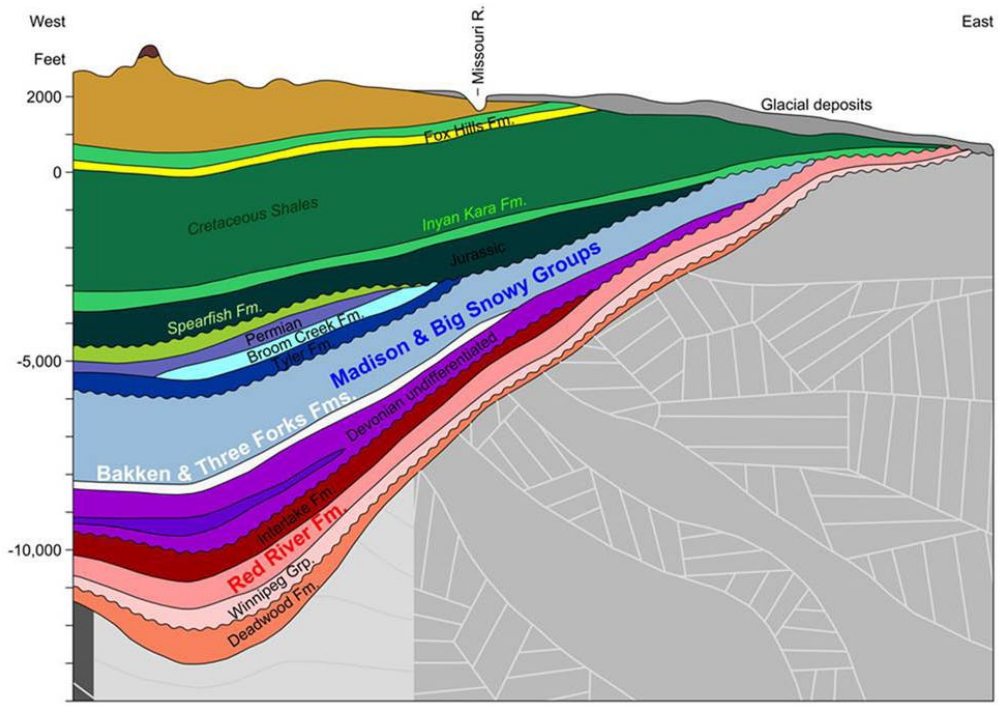

Figure 5. Cross section of Williston Basin in North Dakota and stratigraphic column.

Temperatures, depths to formations, and formation properties were determined from a variety of data. The result is that there is good potential for power production throughout the basin. At least eleven water-bearing formations with temperatures greater than 90°C extend over areas of several 100s of km^2. The total energy contained in the rock volume of those geothermal aquifers is 283.6 EJ (1 EJ = 10^{18} J). The total energy contained in the water volume, determined from porosities, which range from 2 percent to 8 percent, is 6.8 EJ. The aquifers grouped by 10°C temperature bins (Table 2) include one or more formations due to the bowl-shape structure of the basin.

The water flood operation at the CLR site adds a new perspective for geothermal development in a sedimentary basin. Conventional development would be vertical wells drilled into geothermal aquifers. Drilling open-hole lateral wells within a relatively flat or gently dipping geothermal aquifer greatly increases the volume of water that can be produced. An intriguing possibility would be to drill 6 to 8 laterals radially from a single pad. Three moderately high temperature aquifers in the Williston Basin, the Deadwood (Cambrian), Red River (Ordovician), and Madison (Mississippian), offer potential for this type of development. The rocks are competent and laterals can be open-hole, i.e., without lateral casing, and they are permeable enough to yield significant amounts of water. Figures 6, 7, and 8 were developed from the National Geothermal Data System (NGDS) bottom-hole temperature data for North Dakota and show the temperatures and depths for these formations.

5. Conclusion

This project demonstrated that generating electricity from non-conventional, low-temperature geothermal resources is technically and economically viable using binary technology. While this project showcased the Access Energy/ Calnetix technology, other binary machines are

available. Based upon the experience gained during this demonstration project, the following recommendations are made to others considering the implementation of binary engines for similar applications.

1.

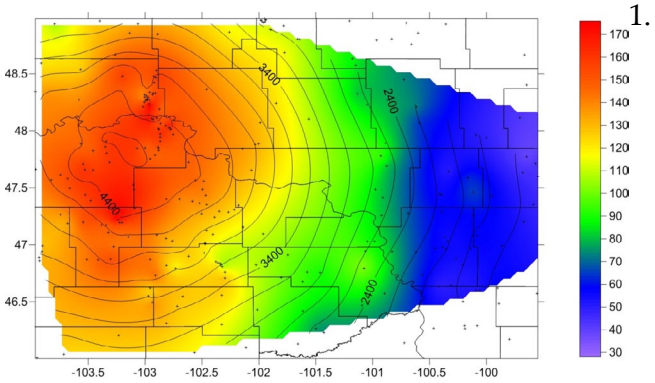

Figure 6. Temperature (colors) and depth (contours) for the Deadwood Formation.

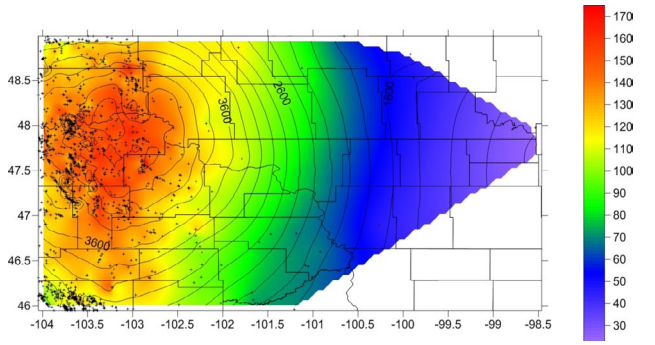

Figure 7. Temperature (colors) and depth (contours) for the Red River Formation.

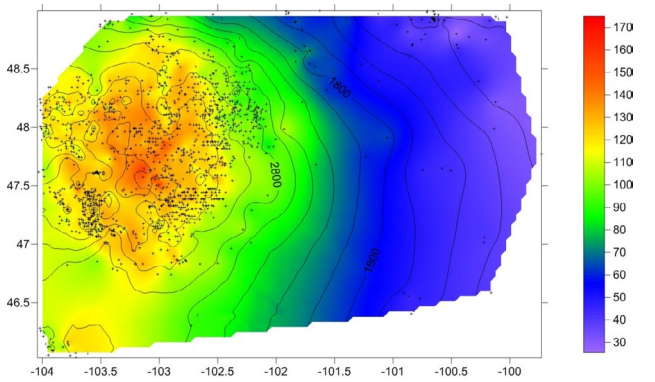

Figure 8. Temperature (colors) and depth (contours) for the Madison Formation.

Determine target formations. Data from oil and gas operators, state oil and gas regulatory agencies, and state geological surveys help to identify producing formations and their properties.

2. Determine the quantity of energy available in the target formations.
   a. A complete thermal analysis of the basin or region yields the most useful information.
   b. Critical data include bottom-hole temperatures, heat flow, stratigraphy, lithology, lithological properties, thermal conductivity, and subsurface structure.
3. Determine the potential for fluid production.
   a. State oil and gas regulatory agencies and state geological surveys have data on oil, gas, and water production. State water commission/ agencies have data on water quality, aquifers, and regulations.
   b. Consider single horizontal wells, multiple conventional wells, and unitized fields.
4. Calculate energy production capacity of each formation based on different well combinations and power-plant scenarios. This is a broad overview rather than a site-specific analysis.
5. Research and understand the local electrical power industry. Obtain the PPA before committing to the project.
6. Work with the high-level personnel in the oil company partner. Obtain a memorandum of understanding that addresses all issues in the project, including what to expect if the company goes out of business or changes management.
7. Be prepared for project delays.

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Corporate Focus

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

Eden GeoPower

The vision of Eden GeoPower is to develop new technologies to transform low-grade heat from depleted oil and gas reservoirs to sources of geothermal power. The power generated at these marginal well sites will be used to replace diesel generators during ongoing oil field operations, or sold to the grid in power purchase agreements.

Introducing the Future of Geothermal Energy

Utilizing abandoned oil wells for micropower generation

EDEN GEOPOWER

The Somerville, Massachusetts company is developing new technologies to use the latent heat in non-producing oil wells to operate a supercritical power cycle running within the wellbore. In this design, hot brine is pulled from deep within the reservoir and interacts with a secondary working fluid with a much lower boiling point in a down hole heat exchanger (DHE). As the working fluid changes phase, it passes through a turbine-generator assembly placed in the well, generating electricity on it's way to the surface. The increase of hydrostatic pressure with depth in the wellbore allows the system to run in a supercritical power cycle with a much higher efficiency than what can be achieved in a traditional, hot brine-to-surface binary cycle design.

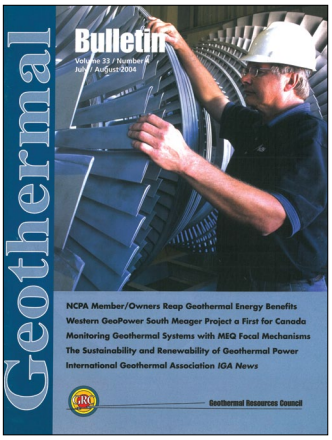
The patent-pending technology used in this system will avoid thermal depletion and provide a full retrievable system that can run up to 30 years.

Eden GeoPower was founded in April 2017 by **Paris Smalls** and **Ammar Alali** -a GRC Member. Both are in the process of earning their PhDs from Massachusetts Institute of Technology (MIT) in geophysics. They are currently working towards partnering with governments across the globe on retrofitting wells to provide sources of low cost and reliable electricity, as well as on projects to desalinate water in abandoned oil wells.

More information on the Eden GeoPower website at: https://www.edengeopower.com/ ■

Geothermal History in the Making

by Ian Crawford, Director of Communications



Steve Enedy *of Northern California Power Agency (NCPA) was on the cover of the July/August 2004 Bulletin. He was pictured inspecting a 55 MW low-pressure turbine rotor at NCPA Plant #1 at The Geysers.*

In 2020, the Geothermal Resources Council, the GRC, will be celebrating its 50-year anniversary. Our association was established in 1970 "to encourage development of geothermal resources worldwide." To mark our golden anniversary we are running a series of articles from the GRC Bulletin looking back on the history of geothermal energy around the world over these past decades.

In this issue we remember an article from 2004 on work being undertaken to confirm the potential for a geothermal power plant in British Columbia - a first for Canada.

A First for Canada?

(Written by a representative of Western GeoPower)

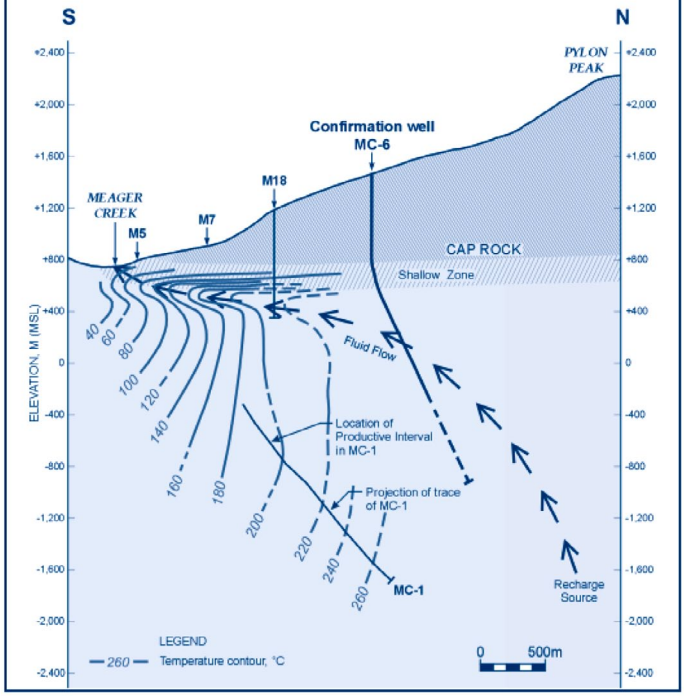
Drilling is underway at the Western GeoPower Corp. (WGP) site in southwestern British Columbia to confirm its potential to become Canada's first commercial geothermal power facility, with a capacity of 100 to 200 megawatts (MW) of electrical generation.

The geothermal power production potential of the South Meager Geothermal Field—located 90 miles north of Vancouver, B.C. —was recognized in the 1980s when B.C. Hydro drilled three production-size test wells and operated a 20-kilowatt demonstration plant for 21 months as part of an exploration program conducted with the Geological Survey of Canada. However, there was no immediate effort to confirm the potential for commercial geothermal power production because of the then-existing supply of low-cost hydroelectric power.

Exploratory drilling of three slimhole test wells in 2002 (M17-18-19) recorded temperatures between 200° to 224° C at relatively shallow depths of 1,500 to 2,700 ft. These are the highest temperatures at this depth ever reached by any well drilled in Canada [at that time].

Technical data assembled over 20 years of exploration were analyzed by GeothermEx, Inc. (Richmond, CA)—a global leader in geothermal assessments. Their work suggests that the South Meager Geothermal Field has an initial capacity of 100 MW and a potential capacity of 200 MW or more.

Figure 2 – Temperature cross-section of the South Meager Geothermal Project.



In their report summary, GeothermEx commented: "Upon the successful completion and testing of the confirmation wells, this geothermal field should become as attractive a development target as any available today in North America, particularly considering the recent commitment of the British Columbia Hydro and Power Authority to renewable energy, recent interest in geothermal energy resources, the trend of increasing natural gas prices, and the forecast of high power prices in the Pacific Northwest and California."

To confirm South Meager as a commercially viable geothermal resource, WGP initiated a drilling program in July 2004. Two production wells will be used to determine if the host rock is permeable enough to allow the free flow of hot water to the surface.

Of particular importance to the British Columbia government and public interest groups is the clear environmental advantage represented by geothermal over both large-scale hydroelectric facilities and fossil-fuel power production facilities. Though they provide renewable energy, hydroelectric dams require damming and flooding of thousands of acres of land to provide water storage.

Read the whole article from the GRC Bulletin *archives.....*

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What were the results of the drilling program? Was the host rock permeable enough to allow the free flow of hot water to the surface. Did the British Columbia government and public interest groups continue to be aware of the clear environmental advantage represented by geothermal over both large-scale hydroelectric facilities and fossil-fuel power production facilities? Did Canada ever get its first geothermal power plant?!! Whatever happened to Western GeoPower?

Bring us up-to date with your answers. We will publish your thoughts as a Letter to the Editor in the next Bulletin. *Contact Ian Crawford at icrawford@geothermal.org.* ■

In Memoriam

Professor Paul Younger 1962-2018

Professor Paul Younger, who held the University of Glasgow's Rankine Chair in the School of Engineering, has died peacefully at the age of 55. He was an internationally-renowned hydrogeologist, environmental engineer and pioneer in geothermal energy

Prior to 2012, Professor Younger spent just under 20 years at Newcastle University in north-east England, where, amongst other things, he founded and led the HERO research group, which went on to win the Queen's Anniversary Prize for the University for the first time (2005). He established what is now the Sir Joseph Swan Centre for Energy Research, founded and Directed the Newcastle Institute for Research on Sustainability (NIReS) and served as the University's Public Orator and its first-ever Pro-Vice-Chancellor for Engagement.

Latterly, his academic focus had been on geothermal and other aspects of water-related renewable energy, and the elimination of pollution and carbon emissions in the energy sector. During the construction of Glasgow University's district heating scheme in 2014/15, he was a member of the project board and championed the exploitation of the system as a teaching resource for engineering students.

Professor Younger was Director of BritGeothermal, a consortium established as a focus for deep geothermal energy research both in the UK and globally. He recently led the drilling and testing of the only three deep geothermal exploration boreholes to be drilled in the UK since the 1980s. ■
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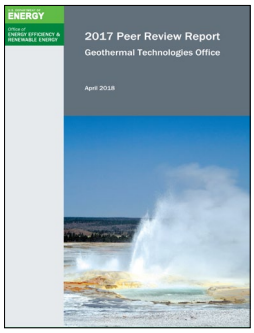
Publications, Websites, Videos & Maps

by Ian Crawford

Geothermal Technologies Office - 2017 Peer Review Report



The U.S. **Geothermal Technologies Office (GTO)** has announced the **2017 Peer Review Report**. This is a consolidated accounting of the *GTO 2017 Peer review*, held November 13-15, 2017. It amasses the independent, expert evaluation of the technical progress and merit of projects funded by GTO as well as the feedback and recommendations on future GTO strategic planning.

The GTO 2017 Peer Review offered geothermal stakeholders an opportunity to learn about the projects funded by the **Department of Energy** across a wide spectrum of technical complexities and funding magnitudes, from research and development to demonstration and analysis. As part of the GTO 2017 Peer Review, 60 projects in 12 technology panels were reviewed by 29 reviewers. *Download the Report.....*

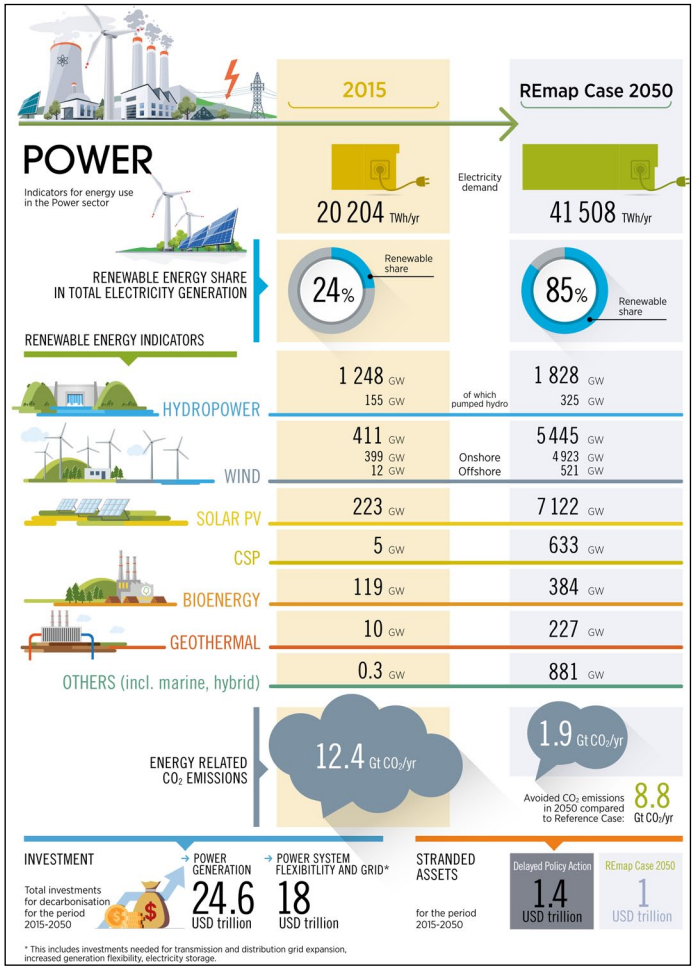
Vision for Deep Geothermal: Looking Towards 2050 (ETIP-DG)

The **European Technology & Innovation Platform on Deep Geothermal (ETIP-DG)** has presented its *Vision for Deep Geothermal* report looking at the future development of deep geothermal energy and highlighting the great potential of untapped geothermal resources across Europe.

"Our Vision is that by 2050 geothermal energy can cover a significant part of domestic heat and electricity demand," said **Ruggero Bertani**, Chairman of the ETIP-DG. "As a local and stable source of renewable energy, geothermal will be crucial in the future energy system, providing power, heat and thermal storage." *Download the Report.....*

Since geothermal energy is constantly provided, the Capacity Factor (i.e. actually produced energy with respect to the full capacity) is much higher than for other renewable energy sources (sources: Renewables 2017 Global Status Report, REN21; EUROSTAT), resulting in a total cost (LCoE) comparable or lower than for other energy sources (source: IRENA, 2017).

Global Energy Transformation: A Roadmap to 2050 (IRENA)



Renewable energy needs to be scaled up at least six times faster for the world to meet the decarbonization and climate mitigation goals set

out in the Paris Agreement, says the IRENA report *Global Energy Transformation: A Roadmap to 2050.*

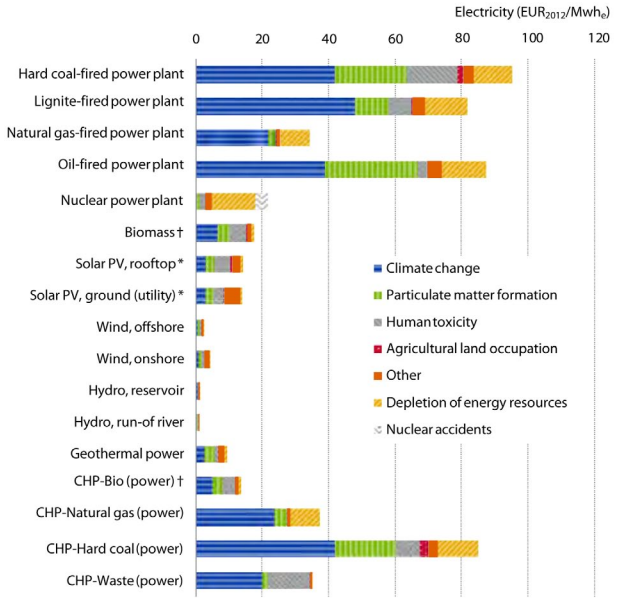
The total share of renewable energy must rise from around 18% of total final energy consumption (in 2015) to around two-thirds by 2050. Over the same period, the share of renewables in the power sector would increase from around one-quarter to 85%, mostly through growth in solar and wind power generation. **The REmap Case 2050 target for geothermal energy is 227 GW**. *Download the Report.....*

The Full Costs of Electricity Provision (OECD & NEA)

The market price of generating electricity doesn't necessarily account for the social and environmental impacts of its generation, says the **Organization for Economic Co Operation and Development (OECD)** and **Nuclear Energy Agency (NEA)** in a new report *The Full Costs of Electricity Provision.*

Figure 7.3: **External costs including resource depletion for different electricity generation technologies**

(Weighted average of EU countries, EUR/MWh)



Source: Ecofys, 2014, p. 37.

* Ecofys states that the values solar PV are likely to be an overestimation, because of the high pace of technological development for this technology improving efficiencies and reducing upstream impacts.

† Biomass is assumed to be sourced from agricultural/waste wood residues only, i.e. biomass from dedicated energy crops is not included.

"What this report reveals is that the notion of "electricity cost" that we often use today, the levelized costs of electricity (LCOE), is just a part of a much bigger picture. While LCOE is a useful tool to compare the costs of baseload technologies in regulated systems, it leaves out many decisive aspects of the costs of electricity. In particular, the grid level system costs and the social costs that are not captured by LCOE are too important to be ignored any longer" said NEA Director General **William D. Magwood, IV**, at the report's launch. *Download the Report.....*

Global Trends in Renewable Energy Investment Report 2018 (Frankfurt School-UNEP Collaborating Centre)

The *Global Trends in Renewable Energy Investment 2018 report*, published by **UN Environment, the Frankfurt School-UNEP Collaborating Centre**, and **Bloomberg New Energy Finance**, reported mixed results for the geothermal energy sector.

Geothermal project financing decreased by 36% between 2016 and 2017, with USD 1.4 billion invested, the lowest level for four years. Some 11 significant projects reached financial close last year, with Indonesia and the Netherlands accounting for three projects each.

Indonesia's Supreme Energy Muara Laboh Geothermal Plant Phase I, with 80 MW of capacity and costing USD 600 million, was the largest geothermal project in 2017, and the 55 MW ICE Borinquen I Geothermal Project in Costa Rica for USD 230 million came in second place. *Download the Report.....*

Renewables Readiness Assessment: Pakistan (IRENA)

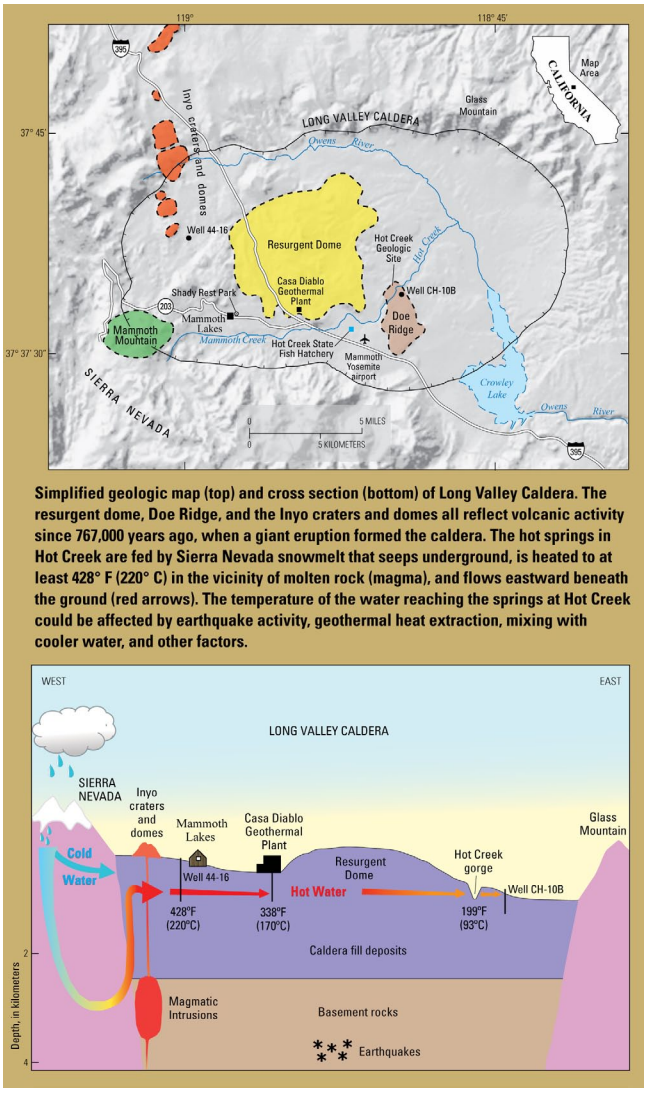
Pakistan's geothermal resources remain largely unexplored. No comprehensive assessment of the potential has been made nor does a policy framework exist to encourage private participation in the sector. Some scientific studies have located potential geothermal resource areas in the country.

Most of the world's high enthalpy geothermal resources are within the seismic belts associated with zones of crustal weakness. One example is the seismotectonic belt that passes through Pakistan, which has a long history of geotectonic events. Thus **the country in all probability has commercially exploitable geothermal resources.**

The sporadic efforts to assess the potential have all concentrated on identifying geothermal phenomena and locating production zones. However, assessors need to go further and integrate their efforts. They need to estimate the size of the resource base, determine heat content of fluids and compile a comprehensive database. *Download the Report.....*

New Fact Sheet on the Long Valley Caldera Geothermal System (USGS)

The volcanic processes that have shaped the **Long Valley Caldera** in eastern **California** have also created an abundant supply of natural hot water. This natural resource provides benefits to many users, including power generation at the **Casa Diablo Geothermal Plant**, warm water for a state fish hatchery, and beautiful scenic areas such as Hot Creek gorge for visitors.



Simplified geologic map (top) and cross section (bottom) of Long Valley Caldera. The resurgent dome, Doe Ridge, and the Inyo craters and domes all reflect volcanic activity since 767,000 years ago, when a giant eruption formed the caldera. The hot springs in Hot Creek are fed by Sierra Nevada snowmelt that seeps underground, is heated to at least 428° F (220° C) in the vicinity of molten rock (magma), and flows eastward beneath the ground (red arrows). The temperature of the water reaching the springs at Hot Creek could be affected by earthquake activity, geothermal heat extraction, mixing with cooler water, and other factors.

Courtesy USGS

However, some features can be dangerous because of sudden and unpredictable changes in the location and flow rate of boiling water. The U.S. Geological Survey monitors several aspects of the hydrothermal system in the Long Valley Caldera including temperature, flow rate, and water chemistry.

Evans, W.C., Hurwitz, S., Bergfeld, D., and Howle, J.F., 2018, *Hot water in the Long Valley Caldera—The benefits and hazards of this large natural resource:* U.S. Geological Survey Fact Sheet 2018–3009, 4 p., https://doi.org/10.3133/fs20183009. ISSN: 2327-6932 (online)

A GRC Fieldtrip will visit the Long Valley Caldera from the GRC Annual Meeting and Expo being held October 14-17 in Reno, Nevada, USA.

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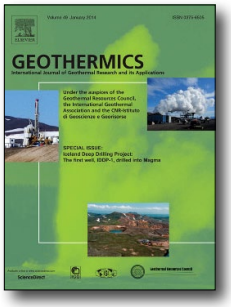
Geothermics



Through affiliation with the **International Geothermal Association (IGA)** the GRC offers a discount to the professional journal *Geothermics*, which publishes articles on the theory, exploration techniques and all aspects of utilizing geothermal resources.

Current, past as well as upcoming articles in *Geothermics* can be found by going to: http://www.elsevier.com/locate/geothermics

Members can contact the publisher Elsevier at mailto:JournalsCustomerServiceEMEA@elsevier.com in order to subscribe to the journal. Upon request Elsevier will send a *proforma* invoice to the member e-mail ID.

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The discounted price details for IGA/GRC members is $285. ■
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National Geothermal Academy 2018

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Geoscience focused geothermal training:

GEOL 457/657 - Module 1: Geothermal Exploration and Development Decisions Based on Resource Conceptual Models

Date: 18-22nd June 2018 (Monday to Friday, 8:00am - 5:00pm)
Location: University of Nevada, Reno, Redfield Campus (south Reno)
Instructors: William Cumming, Nicholas Hinz, Bridget Ayling, and others

- Open to outstanding undergraduate and graduate students, and professionals. International applicants welcomed.
- Offered to students for 2 academic credits at either the graduate or undergraduate level.

- Course cost: **Professionals: USD $1800, Current Students: USD $1000**
- Student applications due **4th June**, course registrations due **11th June**
- Professional registrations due by **11th June**
- All payment due by **15th June**

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

GREAT BASIN CENTER FOR
Geothermal Energy

University of Nevada, Reno

Calendar of Events

Resources for Future Generations
16-21 June, Vancouver Convention Center, Vancouver, BC, Canada
http://rfg2018.org/

Grand Renewable Energy 2018 - International Conference and Exhibition
17-22 June, Yokohama, Japan
www.grand-re2018.org/english/index.html

International Workshop on Geothermal Energy
19 June, University of Manchester, United Kingdom
https://www.eventbrite.com/e/international-workshop-on-geothermal-energy-tickets-45589846458

ICEM18 - the Eighteenth International Conference of Experimental Mechanics (EuraSEM) Session on "Experimental Methods in Geothermal Engineering"
1-5 July, Brussels, Belgium
www.icem18.org/

GeoEnergy Days (Pole-Avenia)
3-5 July, Pau, France
http://www.pole-avenia.com/eng/geo-energy-days/

Geothermal Energy: From Potential to Implementation (Cranfield University)
11-13 July, The Geological Society, London, U.K.
www.cranfield.ac.uk/Courses/Short/Energy%20And%20Power/Geothermal%20Energy

5th Geothermal Congress for Latin America and the Caribbean (GEOLAC)
17-18 July, Mexico City, Mexico
http://newenergyevents.com/geolac/

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

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

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

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

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

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

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

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GRC ANNUAL MEETING *& EXPO*

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