

GEOTHERMAL RESOURCES COUNCIL

# Bulletin

Vol. 46, No.2  
March/April 2017

**The Iceland Deep Drilling Project - A Geothermal Milestone**

***GRC Annual Meeting -  
Workshops and Fieldtrips  
Announced***



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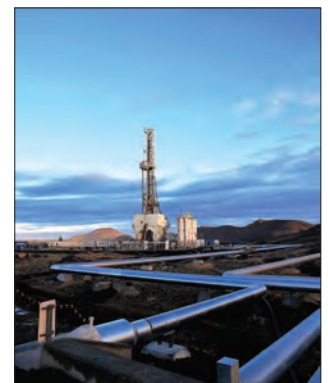
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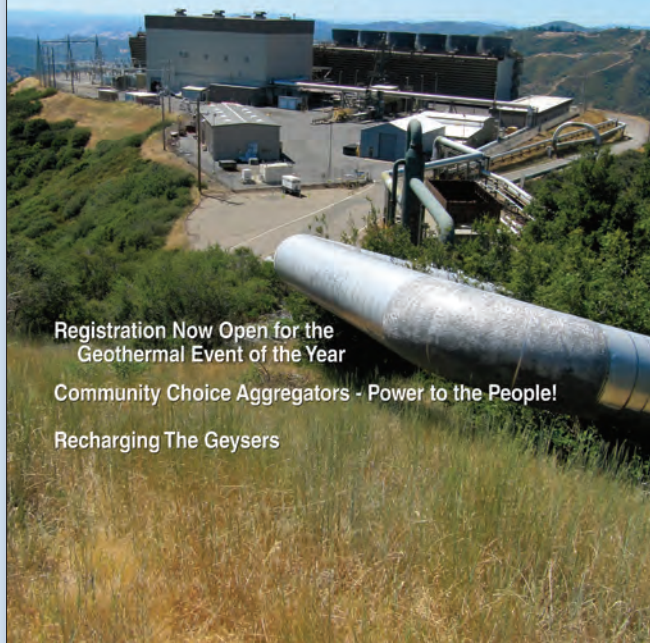


COVER: The rig Thor drilling the supercritical well IDDP-2 at Reykjanes, Iceland (COURTESY WILFRED A. ELDERS)

GEOTHERMAL RESOURCES COUNCIL

# Bulletin

Vol. 45, No. 4  
July/August 2016



Registration Now Open for the  
Geothermal Event of the Year

Community Choice Aggregators - Power to the People!

Recharging The Geysers

## The GRC Bulletin

### The premier geothermal energy magazine

The Geothermal Resources Council (GRC) *Bulletin* is a periodic publication (6 issues per year) that reaches the association's worldwide membership and paid subscribers. Current circulation is 1,200.

The GRC *Bulletin* provides a technology and issues forum for professionals involved in geothermal resource research, exploration, development and utilization. The GRC *Bulletin* also provides news and information that highlights the environmental and economic benefits of geothermal resource development.

Keep up-to-date with news from the global geothermal community by becoming a member of the GRC and receive your GRC *Bulletin* free, or subscribe for six issues a year.

### Annual Subscription rates are:

Domestic - \$90

International - \$140 (includes additional cost to cover postage)

Back issues are available for \$10 per issue.



## GRC Member Benefits

### Two Memberships for the Price of One

- ▶ International Geothermal Association (IGA) membership comes with GRC membership.

### Free Subscription to the GRC Bulletin

- ▶ Find out what's new in the community with the bi-monthly GRC *Bulletin*.
- ▶ The official, worldwide industry trade publication of the GRC, the *Bulletin* is the definitive voice on geothermal energy development and production.



### Free Annual Membership Roster & Registry

- ▶ Contact information for GRC members around the world—members in more than 40 countries and still growing!
- ▶ The GRC *Membership Roster & Registry* plus the *Yellow Pages* is also available online to members only.



### Full Access to the World's Largest Online and Onsite Geothermal Library

- ▶ Online access to tens of thousands of technical reports, journal articles and other resources; members receive free access to featured content.
- ▶ Convenient physical access to the GRC Library by appointment.
  - The GRC Library holds rare, one-of-a-kind geothermal publications, records, and maps—some not available online or anywhere else in the world.



### Discount to GRC-Sponsored Events

- ▶ Webinars
- ▶ Workshops
- ▶ GRC Annual Meeting
  - Largest meeting of its kind in the industry.
  - Great way to socialize and meet new people in the geothermal community.
  - Three days of technical sessions by geothermal experts on a broad range of topics.

### Discount on Advertising in GRC Publications

- ▶ Discount on advertising in the GRC *Bulletin*, mailed to members worldwide government offices, libraries, etc.
- ▶ Exclusive first access to advertising spaces in all GRC publications, including the GRC *Bulletin*, *Membership Roster & Registry*, and the Annual Meeting *Final Program*.

[www.geothermal.org](http://www.geothermal.org)



The GRC Library can be accessed at:  
[www.geothermal-library.org](http://www.geothermal-library.org)



## President's Message

by Maria Richards

### *Salt Lake City, Here we come!*

Attending conferences is a wonderful opportunity for me to meet more GRC members. In March, I flew to Salt Lake City (SLC) to attend the SedHeat-Unlocking the Energy Elephant workshop, funded by the National Science Foundation through John Holbrook's SedHeat program within the Texas Christian University's Energy Institute. This meeting showcased how many different ways we can use geothermal resources in sedimentary basins. The presentations are online at [www.itascacg.com/about-us/training-events/unlocking-the-energy-elephant/presentations](http://www.itascacg.com/about-us/training-events/unlocking-the-energy-elephant/presentations).

Many of the workshop attendees were GRC members, including Joe Moore, the Chair of this year's Annual Meeting in SLC. The selection of a city for the GRC Annual Meeting and GEA GeoExpo+ was always a mystery to me. Now I know the process begins more than three years out with GRC Board members suggesting cities. GRC Conference Manager Estela Smith, GRC Executive Director Steve Ponder, consultant Paul Miller, and the GRC Board Annual Meeting Advisory Committee (chair, Andy Sabin, US Navy), then get bids from all the cities. Factors taken into consideration when deciding on a meeting date/location include religious holidays, competing events, availability and cost of hotel rooms and convention centers, ease of travel for attendees, workshop themes, opportunities for field trips to points of interest and even possible government shut-downs (let's hope not this year!). The GRC Executive Committee voted unanimously for SLC in early December 2015, desiring a new location further east than we had been in decades. Plus this location brings exciting opportunities for field trips and workshops. In addition we're near the location of the FORGE and Play Fairway projects, and Utah's sedimentary basins with oil and gas exploration and potential for deep direct use. Joe Moore (University of Utah) stepped-up quickly to be Annual Meeting Chair and has put together a fantastic planning team (of about 20 members) embracing our 2017 GRC Board focus on innovation. The meeting theme is "Geothermal Energy: Power to Do More".

There are already plans on visiting Yellowstone National Park for a pre-meeting field trip. For the geothermal community, Yellowstone is part of our DNA. Providing an opportunity for attendees to take a few days to visit this magnificent park went into our location decision. I remember my first time walking through the Yellowstone geysers fields in September 2004, my senses exploding as I experienced Fall colors, a snowstorm, the rising of the mystical heat, set to the sound of noisy elk calls, all in just a weekend!

An example of the innovation being introduced this Annual Meeting is the work of Technical Program Chair Rob Podgorney (Idaho National Lab), working with GRC staff members Anh Lay and Brian Schmidt, to develop a new GRC Annual Meeting paper template and online submission system making the process easier, plus saving time and money. Anh Lay is willing to happily assist anyone with questions about the process.

Did you know that we review every paper submitted? This year the process is changing from a group of us meeting for a few days to review the papers in person, to a brand new electronic system. This allows more people to be involved and cuts down on individual reviewer travel expenses and time away from their offices. It also provides us with the ability to assign multiple reviewers to a paper to give you a stronger review and it improves the GRC Transaction publication ratings. Please let Rob Podgorney ([robert.podgorney@inl.gov](mailto:robert.podgorney@inl.gov)) know if you want to be a reviewer.

Other innovations include expanding on the success of last year's Annual Meeting Opening Session panels by including a broader mix of industry discussions, and if possible, to include sessions where panels are held rather than just papers presented. The goal is to be more inclusive of current industry needs and for researchers to discuss with industry what topics can assist them and vice versa. Then as a WING (Women in Geothermal) member, I'm looking forward to their presentation on changes in the gender of attendees at different meetings over the past decade. More details about WING are available online at [www.geothermal-energy.org/wing](http://www.geothermal-energy.org/wing). By the way – you don't have to be female to join WING, we love our WING men!

As I fly home from this week's SedHeat workshop, my enthusiasm continues for holding our Annual Meeting in SLC. It is a city that heightens your thinking, welcomes you with warm hospitality, and offers you plenty to explore. Keep reading, this Bulletin for plenty more on the fieldtrips, workshops and other information on the GRC Annual Meeting. If you haven't already started to write your paper, join me in getting it done by April 28th. My topic is on temperature change over decades. We've found wells Dave Blackwell logged 40 years ago! Don't forget to invite your coworkers and colleagues to join us too!

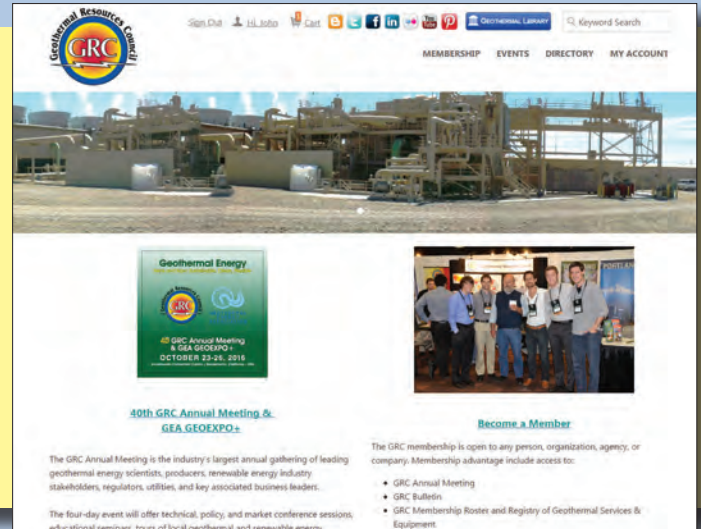
I'm one who enjoys a "cup of coffee" with colleagues and am known for Friday socials, so call me (214-768-1975), or send me an email at [grcpres@geothermal.org](mailto:grcpres@geothermal.org). This month, tell me what you value most about your GRC membership. ■

# The New GRC Membership Website

## [www.my.geothermal.org](http://www.my.geothermal.org)

### Highlights Include:

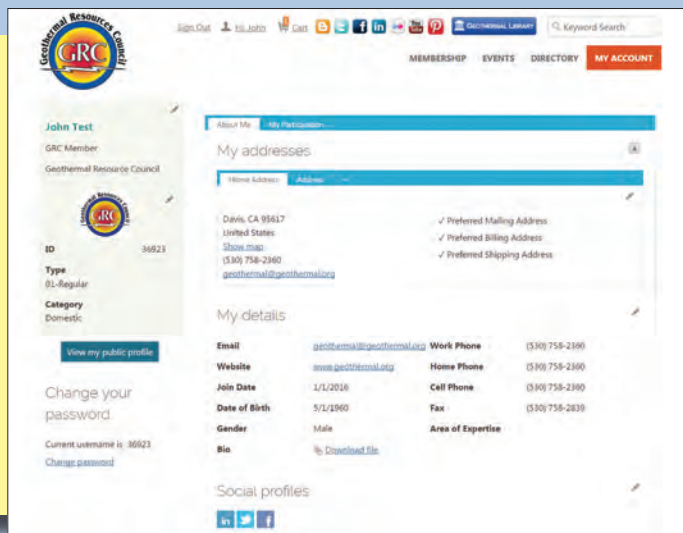
- **Events:** Allows you to register for GRC Events such as the GRC Annual Meeting.
- **Directory:** Allows you to search and view other GRC members' public profile. Only available to current members.
- **My Account:** Allows you view your profile, update your information, renew your membership and pay invoices.
- **Shopping Cart:** You can now pay all your dues and invoices together.



### My Account:

- **Photo:** You can now upload a headshot of yourself
- **Bio:** Allows you to upload your bio or resume that can be viewed and downloaded by other GRC members.
- **Social Media Links:** You can now link your personal social media sites to your profile for other members to view.

Update Your Profile Today!



### Public Profile:

- **Exclusive Access:** Restricted to current GRC Members only.
- **Advertise Your Services:** Members can find your information and download your bio/resume.
- **Stay Connected:** Allow members to follow you on your social media links.





## Executive Director's Message

by Steve Ponder

I have often reflected over the last four years about the duties that define an "Executive Director" (ED). Recently, I read a very good analogy that I will here paraphrase.

"The ED is not just a director but is like a conductor of an orchestra who plays not a note, but must be musician, teacher, administrator, psychologist and public relations person and do all these things superlatively well."

We direct or cajole others to do things we cannot do ourselves. All I have to do is close my eyes and think of math or computer problems and I quickly ask for help. I find the most important and enjoyable part of my job is its creative opportunities.

All this is intended to make the GRC a more beautiful place.

Speaking of beautiful places, our January Board meeting, for the first time in several decades, was held in Davis, California. This is significant because Davis is the home of the GRC office. Downtown Davis is a very welcoming place with lots of restaurants, hotels and shops.

However, there was little time for any diversions. Our meeting was held in a cozy conference room (after we got the heat working and coffee delivered), so small that it did not require audio equipment to amplify our voices. This Board is very serious about staying financially fit as required by our Strategic Plan. The best part of the meeting was that the Board members had enough time to squeeze in a quick tour of our nearby office and visit our renowned world class geothermal library. Everyone enjoyed the experience so much that the Board plans to return to Davis for our next Board meeting in May.

Let's move on to future geothermal events.

The SPE/GRC Drilling Corrosion Workshop in San Diego from March 21-22. SPE is the Society of Petroleum Engineers with over 100,000 members. They put on conferences all over the world. We have learned from each other in preparing for this meeting. I am pleased to

report that the GRC members and staff have more than carried our load in arranging for speakers and organizing the program. It has been a pleasure to work with the SPE staff on our joint marketing efforts. The GRC wants to sponsor other joint workshops with the SPE. This relationship could expand anywhere in the world where you have geothermal and/or oil and gas activities. More information on the SPE website at: [www.spe.org](http://www.spe.org).

### GRC Membership Survey

The GRC Board and staff are always looking for ways to improve services for GRC members. Decisions are often based on limited available information from the feedback the members provide. We would like to see many more members contribute to our understanding of which items are of most importance to the community. Your support and a few minutes of your time can make a great difference.

A Membership Survey will be emailed to all GRC members in the near future (make sure your email address is current in our database!). Although this survey asks for some of your personal and work related data, all results will be held confidential. You will also be asked to quantify the importance and quality of the GRC's existing membership services, such as this Bulletin. For sure let us know your thoughts about our most important event of the year, the Annual Meeting and Expo. Did you find the meeting app useful, do you prefer printed or electronic items, do you have suggestions for improvements? By participating, you'll support the Board in making decisions that impact you and the geothermal community directly.

You will soon receive an email containing the survey. We strongly encourage you take some time out of your busy day to complete it, knowing that your time is appreciated.

Please call or email if you would like to talk. My door is always open to suggestions or input. ■

# Communication from the GRC

by Ian Crawford, Director of Communications



The GRC Board of Directors for 2017-2018 met for the first time in January in Davis, California. From left to right: Standing - Joe Moore, Gene Suemnicht, Paul Brophy, Steve Ponder, Jeff Witter, Kevin Wallace, Dave Boden, Bridget Ayling, Tim Conant, Patrick Hanson, Kate Young, Patrick Walsh, Jim Lovekin, Dennis Kaspereit, Marcelo DeCamargo, Louis Capuano III.  
Sitting - Karl Urbank, Warren Dewhurst, Kevin Kitz, Bill Rickard, Danielle Matthews-Seperas, Maria Richards, Louis Capuano, Jr., Elaine Sison-Lebrilla, Andrew Sabin and Jon Trujillo. (Not in attendance: Roy L. Mink, Richard Campbell, Dan Hoyer, Stuart Johnson, Shigeto Yamada)



President Maria Richards presents Past President Paul Brophy with a plaque recognizing his service at the helm of the GRC for the last two years.



The new members of the Board of Directors: Warren Dewhurst, Jeff Witter, Tim Conant, Jon Trujillo and Bridget Ayling (Dan Hoyer did not attend)

## GRC Scholarships 2017

The Geothermal Resources Council (GRC) has announced the availability of the 2017 GRC Scholarship Awards.

To qualify for one of these awards a student must be a GRC member (student memberships

are only \$5 per year) as well as a student in an accredited academic institution. Selection of recipients will be based upon a variety of factors, including the individual's academic record, student activities, geothermal industry experience, and career goals.

The following awards are available:

- **Two (2) GRC Undergraduate Scholarship Awards of \$1,500**
- **Three (3) GRC Graduate Scholarship Awards of \$2,500**
- **One (1) Student Geothermal Project Award of \$4,500**

Applications must be received by 5 May, 2017 to be considered.



# GRC ANNUAL MEETING & GEA GEOEXPO+

**OCTOBER 1-4, 2017**  
**Salt Lake City, Utah · USA**

*"Geothermal Energy: Power to do More"*

For application instructions and other details see the announcement on the GRC website at: [www.geothermal.org/students.html](http://www.geothermal.org/students.html). Please direct questions regarding the scholarship awards to: **Brian Schmidt**, [bschmidt@geothermal.org](mailto:bschmidt@geothermal.org) or 530-758-2360, ext. 107

## Call for Papers

The GRC invites you to present your latest technical work in geothermal research, exploration, development and utilization at the **2017 GRC Annual Meeting** to be held in **Salt Lake City, Utah, USA, October 1-4**.

Authors may submit an oral technical presentation and/or poster at the 2017 GRC's Annual Meeting. **The Draft Paper submission deadline is April 28.**



All of the events of the GRC Annual Meeting and GEA GeoExpo+ are under the one roof of the Calvin L. Rampton Salt Palace Convention Center. COURTESY VISIT SALT LAKE

More information can be found on the GRC Annual Meeting webpage at: [www.geothermal.org/meet-new.html](http://www.geothermal.org/meet-new.html).

## Workshops and Fieldtrips

**Two GRC Workshops** have been confirmed just before the GRC Annual Meeting in Salt Lake City, Utah, USA. They will be held on Friday & Saturday, September 29 & 30 at the Salt Palace Convention Center. *Conceptual Modeling II* will be led by **Pete Stelling and Bill Cumming**; *Operations & Maintenance* will be led by **Kevin Kitz**.

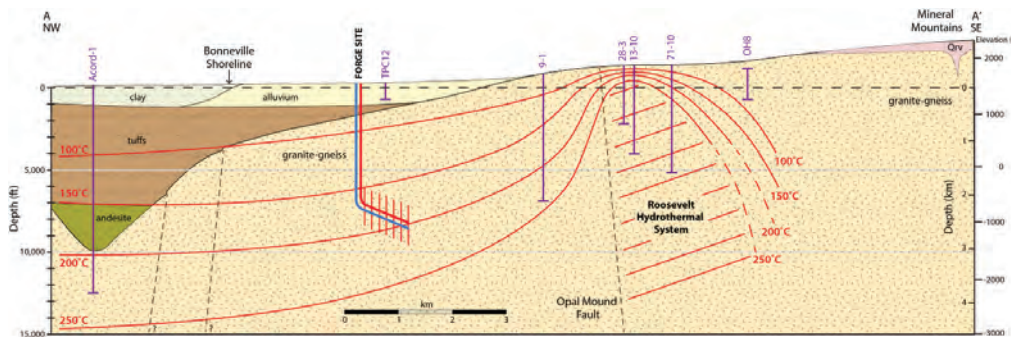
In addition, **two GRC Fieldtrips** have been organized: A tour of **Yellowstone and Grand Teton National Parks** will offer a guide to the greatest concentration of geothermal features in the world. The fieldtrip will leave Salt Lake City on Thursday September 29 and return on Sunday October 1, in time for the start of the GRC Annual Meeting. The trip guides will be **Duncan Foley and Roy Mink**.



Excelsior Geyser in the Midway Geyser Basin in Yellowstone National Park. Taken on a GRC Fieldtrip in June 2015 by Ian Crawford.

## Communication from the GRC

After the GRC Annual Meeting, a **Southern Utah Geology & Geothermal Power Plants** fieldtrip will depart on Wednesday October 4 for an overnight tour of the fascinating geology and geothermal sites in the south of Utah, including Cove Fort, Thermo No. 1 and Blundell geothermal power plants and the Milford FORGE site. The trip guide will be **Rick Allis**.

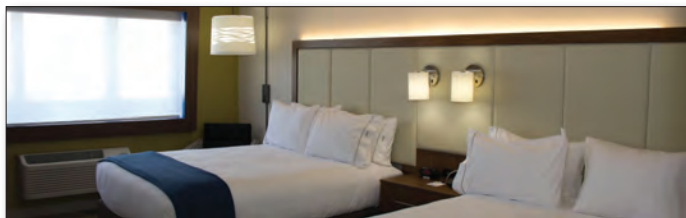


Geologic map of the FORGE deep well site, Milford, Utah (Hintze et al., 2003; Rowley et al., 2005; Kirby, 2012)

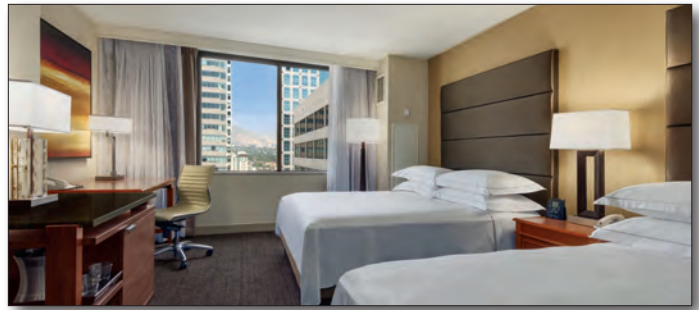
More information can be found on the GRC Annual Meeting webpage at: [www.geothermal.org/meet-new.html](http://www.geothermal.org/meet-new.html).

## Reserve Your Hotel Room for the 2017 GRC Annual Meeting & GEA GeoExpo+

Reservations can now be made for hotel rooms for the GRC Annual Meeting & GEA GeoExpo+, being held in Salt Lake City, Utah, USA, October 1-4, 2017. All the events and accommodation are in one central location, at the **Calvin L. Rampton Salt Palace Convention Center** and neighboring **Holiday Inn Express Salt Lake City Downtown** and **Hilton Salt Lake City Center** hotels, a short 4 minute walk from the event space.



A double queen bed guest room at the Holiday Inn. COURTESY HOLIDAY INN HOTEL



A double queen bed guest room at the Hilton. COURTESY HILTON HOTEL

The GRC has contracted with the hotels for a discounted block of rooms. At both hotels there is a choice of rooms with either two double beds or a king bed starting at \$149 a night excluding taxes and fees. The discount ends September 5.

Attendees can make their reservations on secure

websites prepared specially for the GRC. The links are available from the GRC Annual Meeting website at: [www.geothermal.org/meet-new.html](http://www.geothermal.org/meet-new.html). ■

### 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](mailto:icrawford@geothermal.org) or mail to Geothermal Resources Council, P.O. Box 1350, Davis, CA 95617-1350.



**WE WANT YOUR OPINION!**

**Look out for a GRC Membership Survey in your email inbox.**

**Shape the Future of the GRC**

# Electric Youth:

## THE GRC STUDENT COMMITTEE

*As part of a regular series of columns the members the GRC Student Committee updates readers on the good work of the committee and news for the young and aspiring members of the global geothermal community.*

### Students and the Stanford Geothermal Workshop

by Cari Covell and Owen Callahan

GRC Student Committee members and former GRC student scholarship winners Cari Covell and Owen Callahan, recently attended the 42nd Annual Stanford Geothermal Workshop to present portions of their geothermal-related graduate research.

The Stanford Geothermal Workshop is a mainstay in the geothermal community, occurring every year in late January or early February. Like the GRC Annual Meeting, the Stanford Geothermal Workshop is a great venue for staying up to date with practices and policies affecting the geothermal community. As a student presenter, the meeting provides the chance to get insightful feedback about ongoing projects from some of the leaders in the field.

The two meetings differ in some ways that might be of interest to students. Talks at the Stanford Geothermal Workshop often have a more academic feel, with topics geared toward reservoir engineering and cutting edge technology, while the GRC Annual Meeting has a bit more industry focus, which is usually on display in the associated vendor and exhibitor hall. The Stanford Geothermal Workshop does not usually include separate short courses or field trips, as the GRC does, but the smaller venue provides ample opportunity for students to network



*The venue for the Stanford Workshop provides great opportunities for networking.*

with peers and professionals from government agencies and national labs, universities, and private industry, active in the geothermal sector.

Overall, both meetings are great networking opportunities, and provide deep discounts for student participants.

For more about the GRC Student Committee members and activities please visit: <https://geothermal.org/students.html>. ■



*From left to right: Susan Petty, Tony Batchelor, Roland Horne, Jeff Tester and Kewen Li enjoy networking at the Stanford Workshop.*

# Inside Geothermal

## NORTH AMERICA

### The Cleanest Refinery In The World, Powered By Geothermal

A Texas company is moving ahead with plans to build what it says will be the **cleanest oil refinery in the world, thanks to the use of geothermal energy.**

**Raven Petroleum** has chosen Austin-based geothermal company **Thermal Energy Partners** to provide 100% renewable power and carbon sequestration capabilities using geothermal technology.

**Christopher Moore**, Raven Petroleum's managing director, said geothermal technology used at the plant is expected to **generate about 20 megawatts.** Any electricity it produces but doesn't use for refining would be shared with local power grids, he said.

Thermal Energy Partners CEO **Bruce Cutright** told the *San Antonio Business Journal* that the proposed refinery's site is in a "sweet spot" for geothermal energy. Cutright said early cycles of geothermal power will rely on **high-temperature brackish water from deep underground** while later cycles will rely on the refinery's own **carbon dioxide emissions** for power.

Cutright's company has designed a system where the refinery's emissions are captured and pumped deep underground where carbon dioxide will become "supercritical" from the pressure and heat. The supercritical carbon dioxide will then be used as fuel source for the geothermal power plant's turbines.

"We're excited that this is going to be in Texas to show that carbon dioxide is not a problem," Cutright said. **"It's going to revolutionize the production of geothermal energy."**

According to their website, Thermal Energy Partners' model utilizes **Deep Sedimentary Basins** with a proprietary database of geothermal resources. The engineering process leverages resource reservoirs to emulate the characteristics of today's commercial hydrothermal systems. Through this process Thermal Energy Partners claim they can circulate fluids for a long period of time and

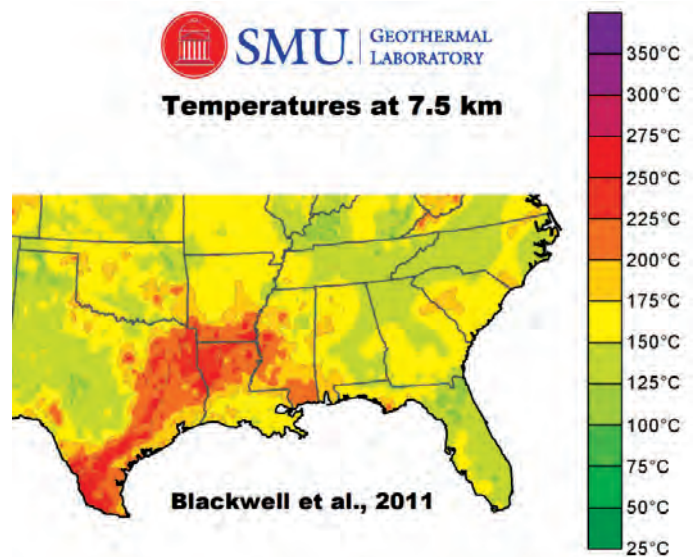
generate the heat flow required for reliable base-load power.

Texas Railroad Commission Chair **Christi Craddick** said that the agency has prepared its staff to receive what could be their first geothermal permit application in years.

"We are excited about the opportunity to have geothermal as a part of our energy portfolio in this state," Craddick said. "I think it's a good opportunity for Texas."



From Left to right: **Thomas Balke**, President and CEO of Basic Equipment, **Christopher Moore**, managing director of Raven Petroleum LLC and **James Jackson**, chief business development officer for Thermal Energy Partners. COURTESY THERMAL ENERGY PARTNERS AND SAN ANTONIO BUSINESS JOURNAL



Detail from temperature at depth (7.5 km) map showing geothermal resources in SE USA. This ground-breaking map of geothermal resources was produced by the Geothermal Laboratory at Southern Methodist University (SMU), then led by past president of the GRC **David Blackwell** and including the current President of the GRC, **Maria Richards**. Professor Blackwell is advising Thermal Energy Partners. COURTESY SMU

**THERMAL**  
ENERGY PARTNERS, LLC



## Drilling at Hell's Kitchen Geothermal Power Project Could Begin in June

**Sammy Roth** of the *Desert Sun* reports that Australian company **Controlled Thermal Resources** has signed a development agreement with **Alger Alternative Energy**, which acquired **Simbol's** lithium extraction technology after the startup landed in receivership, a process similar to bankruptcy. Under their deal, Alger would **extract lithium** and other minerals from the geothermal brine that Controlled Thermal will use to generate electricity, then sell those minerals to third parties.

Critically, Alger officials say they've **secured financing to build a full-scale lithium plant** — and a **10-year contract to sell the lithium** in huge quantities that would reshape global lithium markets.

Together, the companies **hope to start producing** geothermal energy - and lithium - **as soon as 2021**.

"This year's actually the year we get down and dirty and covered in hydraulic fluid," said **Rod Colwell**, CEO of **Controlled Thermal Resources** and **GRC Member**. "It's exciting to actually get on site."

Last year, Colwell's firm leased 1,880 acres from the **Imperial Irrigation District**, which owns the land where their project would be built. Some of the land used to be covered in water, **but the lake is receding fast**.

Colwell originally planned to drill exploratory wells last fall, but the government approval process has taken longer than expected. Company officials now say they **hope to start drilling in June**, after getting their conditional use permit from **Imperial County**.

"We're **95 percent done**, we're just waiting on some final archaeological reports," said **Jason Czapla**, the firm's chief engineer, who moved from Australia to El Centro to oversee operations last year.



**Rod Colwell**, CEO of *Controlled Thermal Resources* at the Salton Sea. COURTESY CTR

## California Energy Commission Funds Two Berkeley Lab Geothermal Projects

Scientists at the Department of Energy's **Lawrence Berkeley National Laboratory (Berkeley Lab)** have launched two **California Energy Commission**-funded projects aimed at making geothermal energy more cost-effective to deploy and operate.

The first project will test deployment of a dense array of seismic sensors to improve the ability to image where and how fluids are moving underground. The second project will develop and apply modeling tools to enable geothermal plants to safely run in flexible (or variable) production mode, allowing for better integration with other renewable energy sources.

The California Energy Commission's **Electric Program Investment Charge (EPIC)** program has awarded Berkeley Lab a total of **USD 2.7 million** for the two projects.

In a project led by Berkeley Lab scientist **Kurt Nihei**, a dense network of portable seismic recorders (about 100 recorders over a 5 square kilometer area) will be installed at **The Geysers** to demonstrate the ability to perform **high-resolution tomographic imaging**. "The goal is to image where steam and fluids are going using geophysics," Nihei said. "We will improve the spatial resolution of the imaging using a dense array and demonstrate that this can be done cost-effectively in an operating geothermal field."

In the second project, led by Berkeley Lab scientist **Jonny Rutqvist**, the goal is to enable the **conversion of geothermal production from baseload or steady production to flexible or variable mode**. Flexible-mode geothermal production could then be used as a supplement to intermittent renewable energy sources such as wind and solar, which are not available around the clock, thus significantly reducing the costs of storing that energy.

## Lithium Extraction Pilot Plant Planned for an Existing Geothermal Facility

**6th Wave Innovations Corp.** of Salt Lake City, Utah, has teamed up with **TriLateral Energy, LLC** of Jackson, Wyoming, to form **Geolithic Corp.**, a joint venture for the **extraction of lithium** and other minerals **from geothermal brine**, at locations **adjacent to existing geothermal power plants**.

6th Wave has already commenced laboratory testing of the proprietary lithium extraction technology, which could **significantly reduce the cost of producing lithium** and other minerals compared to traditional mining and mineral extraction techniques. Such minerals are naturally present in the brine utilized by many existing geothermal power plants in the U.S. and worldwide.

Geolithic Corp. plans to construct a **pilot project extraction plant at one or more U.S. geothermal energy facilities**, with a design that will seamlessly integrate with the facility's existing brine handling facilities, to extract the lithium and other minerals prior to reinjection of the brine into the geothermal reservoir.

### Organic Rankine Cycle Generator Company Sold

German company **Bitzer**, the world's largest independent manufacturer of refrigeration compressors, has announced the acquisition of **ElectraTherm** of Reno, Nevada, USA, a leader in distributed, waste heat and geothermal resource to power generation and a regular exhibitor at the GRC Annual Meeting & Expo.

### Coal Plant Closure Could be Opportunity for Geothermal Energy

Four utilities led by plant operator **Salt River Project** have decided to shutter the coal-fired **Navajo Generating Station (NGS)** near **Page, Arizona**, by 2019. The **2,250 MW plant** is the largest coal generator in the western United States, reports *Utility Dive*.

Competition from inexpensive natural gas generators means **electricity from NGS is already more expensive than wholesale power prices**, the utilities said in a news release, a trend that's not expected to reverse in coming years.

**The retirement of over 2 GW of polluting baseload energy should be an opportunity for a clean, reliable renewable energy to take up the slack.**

### Another Deep Drilling Project Could Benefit Geothermal Energy Research

A new **5 km borehole project** in New Mexico will hopefully provide new drilling and testing techniques for geothermal energy applications.

**DOSECC Exploration Services**, a drilling company and subsurface technology firm based in Salt Lake City, Utah, has announced that, as part of a team led by **Enercon Federal Services, Inc.**, they were awarded a contract by the **US Department of Energy** to evaluate the scientific and technical aspects of drilling deep, large diameter boreholes in crystalline rock for the **safe and effective disposal of waste**. The project will be conducted near the town of **Nara Visa, New Mexico**.

When the drilling portion **begins, likely in 2018**, the scientific drilling team will be tasked with drilling a **5,000-meter deep borehole 8-3/4" in diameter**. If successful, a **second borehole, 17" in diameter**, would be drilled to the same depth at the same site. The data gathered will allow scientists to study the type and **temperature of the rock** as well as the nature and chemistry of the fluids encountered.

**Marc Eckels**, DOSECC Program Director for this project, explains that the data gained from this uniquely deep geological research has potential for other local and societal benefits, such as **providing new drilling and testing techniques for geothermal energy applications**.

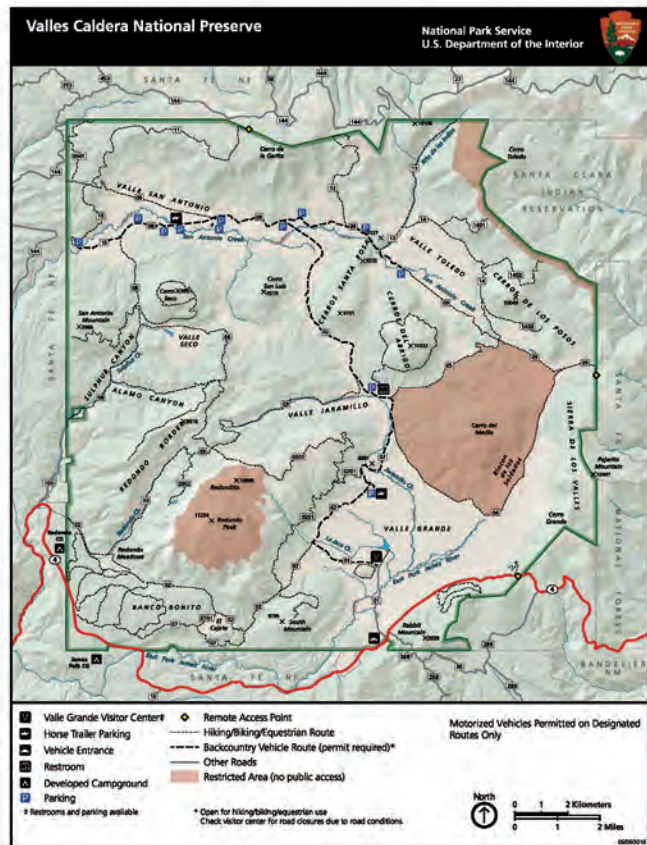
*DOSECC Exploration Services will be exhibiting at the GRC Annual Meeting & GEA GeoExpo+ in Salt Lake City, Utah, USA from October 1-4.*

### New Mexico Geothermal Resources Could be Put Off Limits

Because of the wealth of geothermal resources in **Valles Caldera National Preserve** in New Mexico, the U.S. **National Park Service** has nominated the preserve to the **Geothermal Steam Act** list of "significant thermal features" within the U.S. national park system. If the **Department of the Interior** approves the nomination, Valles Caldera would be one of only 18 parks units within the 400-plus national park system with that designation, reports *Los Alamos Monitor*.

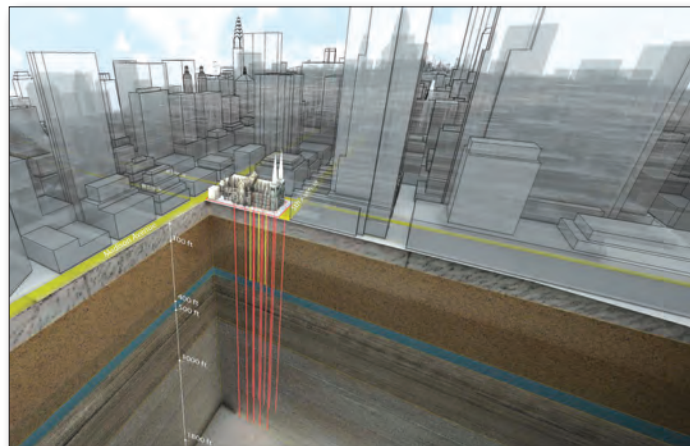
The geothermal resources within the preserves boundaries have been protected from development since the early 2000s. This designation would add protection from negative influences outside the park's boundaries.

While Valles Caldera doesn't have anything as spectacular as Yellowstone's "Old Faithful" geyser, it does have some boiling and acidic calling cards to show off that highlight its volcanic past. Valles Caldera does have a number of pungent smelling sulfur springs with fanciful names like **Stomach Trouble Spring** and **Laxative Spring**.



### New Geothermal Plant Uses Heat from 2,200 Feet Deep Below New York Cathedral

The **Archdiocese of New York** has announced that the historic **St. Patrick's Cathedral** in **Manhattan** has activated a geothermal plant -



St Patrick's Cathedral – rendering of the new geothermal heating system for the church. COURTESY MURPHY BURNHAM & BUTTRICK ARCHITECTS

comprised of **10 wells drilled up to 2,200 feet deep**, reports *US News & Report*.

The system is designed to harness clean, renewable geothermal power to regulate the temperature of the cathedral and adjoining buildings.

The archdiocese and cathedral said they want to "**lead by example**" in choosing the **cost-effective, eco-friendly** power option.

The cathedral's rector, **Monsignor Robert T. Ritchie**, says the church's mission includes "**responsible stewardship of our natural resources.**"

### Challenges to Geothermal Energy Development in Eastern Caribbean

A survey conducted by the Energy Unit of the **Organization of Eastern Caribbean States (OECS) Commission** gathered the views of 86 persons involved in geothermal energy, half of whom were based in the OECS Region.

There was clear consensus amongst all survey participants that **finance** and **government policy** are the main challenges to geothermal energy development in the region. These were followed closely by **competition from other energy sources**, and **technological issues**.

The majority of survey participants would like to see the establishment of a regional mechanism to support geothermal development in the region. The geothermal stakeholders are convinced that such a mechanism would be beneficial to the industry, especially as it relates to policy, legislation, and regulations.

The full report on the survey can be downloaded from the OECS website at: [www.oecs.org](http://www.oecs.org).

### Funding Provided for Dominica Geothermal Project

The Hon. Prime Minister and Minister for Finance of the **Commonwealth of Dominica**, **Dr. Roosevelt Skerrit** has announced that his



## Inside Geothermal

government will inject **45M East Caribbean Dollars** into Dominica's **7 MW geothermal project**.

**Three test wells have been drilled** in Trafalgar, Wotten Waven and Morne Prosper parishes followed by **four flow tests** to determine the generation capacity of the wells.

### New Funds Made Available for Caribbean Renewable Energy Projects

As reported by *Trade Arabia*, the **UAE** has announced a landmark new **USD 50 million fund** for renewable energy projects in Caribbean island countries.

Launched by **Reem Al Hashimy**, Minister of State for International Cooperation, the **UAE-Caribbean Renewable Energy Fund** represents one of the largest single investments in the region's clean energy sector, as well as a significant deepening of bilateral relationships between the UAE and Caribbean countries.

Grant funding is provided by the **Abu Dhabi Fund for Development (ADFD)**, with the **UAE Ministry of Foreign Affairs** managing the initiative and **Masdar**, Abu Dhabi's renewable energy company, leading implementation.

The new fund will seek to conclude project agreements with several countries per year. Designed for flexibility, it can **support renewable energy projects** both as a minority or full financier, as well as engage with both the public and private sectors. With Masdar as the technical lead, all sources of renewable energy can be considered, including solar, wind, **geothermal** and waste-to-energy.



صندوق أبوظبي للتنمية  
ABU DHABI FUND FOR DEVELOPMENT

### Geothermal Resources Confirmed on Both St. Kitts and Nevis

The *Times Caribbean* reports that **St. Kitts & Nevis** Minister of Public Infrastructure with responsibility for Energy, the **Honorable Ian Patches Liburd**, said that having now established that there is a geothermal resource on both islands, "the situation is now ripe for discussion on inter-connectivity, for the discussion on the export of energy, as we on St. Kitts move now to finalize a geothermal agreement."

Five geoscientists have been conducting geophysics, geology and geochemistry feasibility studies. President of exploration company **Teranov**, **Jacques Chouraki**, said that the prospects for geothermal energy on St. Kitts were promising.

## CENTRAL AND SOUTH AMERICA

### Possible Commercial Operation of Platanares Geothermal Power Plant by the End of the Year

Construction of the **35 MW Geotérmica Platanares power plant** in Honduras is at an advanced stage, according to the advisor to the Honduran Council of Private Enterprise (COHEP), **Solomon Ordonez**, and as reported by Honduran newspaper *La Tribuna* (continued on page 20).



*Rig Sky* by **Steven Fercho**. Taken as a storm approaches while drilling Ormat's Platanares, Honduras project. GRC PHOTO CONTEST 2016

# Geothermal and other renewable energy sources used to generate electricity in Central America

by Marcelo Lippmann, Staff Scientist (retired) at Lawrence Berkeley National Laboratory

Every year, the Economic Commission for Latin America and the Caribbean (ECLAC, or CEPAL in Spanish) publishes reports (in Spanish) on the electricity market in Central America. The first one available on the Internet is from 2010: <http://repositorio.cepal.org/handle/11362/25935>. The report for 2016 is not available yet, but the one for 2015 is at: <http://repositorio.cepal.org/handle/11362/40325>.

This note is based on these reports and focuses on the renewable energy sources used to produce electricity in Central America. The installed capacities and net generations for the period 1980-2015 are given in Table 1, while Table 2 lists the capacities and generations for the year 2015 for each country in the region\*.

Looking at Table 1, in 1980, power production in this part of Latin America was mainly from hydro (5,657.8 GWh or 66.8%) and fossil fuels (2,443.5 GWh or 28.9%). Geothermal – the only

Table 2  
Central America – Electricity Sector – Installed Capacity and Net Generation by Countries  
Year 2015

	Installed Capacity (MW)						
	Total	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama
Geothermal	625.5	217.4	204.4	49.2	-	154.5	-
Hydro	6,008.6	1,935.4	490.2	1,087.0	636.9	137.2	1,721.9
Thermal *	7,075.9	635.7	938.5	2,504.6	1,130.4	851.3	1,015.4
Wind	897.2	278.1	-	75.9	152.0	186.2	205.0
Solar	441.6	1.0	-	8.5	588.0	1.4	42.7
<b>Totals</b>	<b>15,048.8</b>	<b>3,067.6</b>	<b>1,633.1</b>	<b>3,725.2</b>	<b>2,307.3</b>	<b>1,330.6</b>	<b>2,985.0</b>

	Net Generation (GWh)						
	Total	Costa Rica	El Salvador	Guatemala	Honduras	Nicaragua	Panama
Geothermal	3,664.6	1,375.6	1,432.4	251.5	-	605.0	-
Hydro	22,235.8	8,066.6	1,419.4	3,851.8	2,340.1	289.7	6,268.2
Thermal *	19,416.8	190.4	2,773.5	5,942.0	5,037.8	2,419.4	3,053.7
Wind	2,869.8	1,079.5	-	107.3	664.6	852.8	165.6
Solar	586.4	1.5	-	149.3	417.2	2.1	16.3
<b>Totals</b>	<b>48,773.4</b>	<b>10,713.6</b>	<b>5,625.3</b>	<b>10,301.9</b>	<b>8,459.7</b>	<b>4,169.0</b>	<b>9,503.8</b>

\* Plants burning fossil fuels, biomass/biogas + cogeneration

other renewable source of energy developed at that time - provided the rest (365.3 GWh or 4.3%).

In 2015, the situation had changed; cogeneration (7.6%), wind (5.9%), solar (1.2%) and biomass + biogas (0.1%) were added to the energy mix. Geothermal plants produced 7.5% of the total, while hydro (45.6%) and fossil fuels (32.2%) remained the predominant energy sources for electricity generation.

Over the period from 1980 to 2015, the amount of fossil fuels (oil, natural gas and coal) being burned, as indicated by the net generation numbers, has continuously increased as the electricity market has grown; the year 1990 was an exception (Table 1). However, the rate of growth varied from year to year, mainly because of the variable levels of hydro and the rise of other renewable generation. For example, between 2012 and 2013 the power produced using fossil fuels

Table 1  
Central America – Electricity Sector – Installed Capacity and Net Generation  
Totals for 1980-2015

Year	Installed Capacity (MW)							
	GEO	HYDRO	WIND	SOLAR	BIO	COGEN	FOSSIL	Total
1980	95.0	1,231.9	-	-	-	-	1,093.7	2,420.7
1990	165.0	2,708.6	-	-	-	-	1,255.7	4,129.3
2000	405.4	3,252.7	42.5	-	-	193.3	3,209.7	7,103.5
2010	506.8	4,490.8	182.6	-	3.7	735.8	5,237.6	11,237.3
2011	558.6	4,967.6	297.8	-	10.1	797.8	5,279.7	11,911.5
2012	635.6	5,284.3	395.8	1.0	10.1	894.3	5,226.7	12,447.7
2013	625.6	5,380.7	416.7	1.0	10.1	1,034.9	5,408.8	12,877.8
2014	625.6	5,724.6	589.7	8.4	6.4	1,172.0	5,376.8	13,503.4
2015	625.5	6,008.6	897.2	441.6	8.7	1,393.9	5,673.3	15,048.8

Year	Net Generation (GWh)							
	GEO	HYDRO	WIND	SOLAR	BIO	COGEN	FOSSIL	Total
1980	365.3	5,657.8	-	-	-	-	2,443.5	8,466.7
1990	747.6	12,165.9	-	-	-	-	1,261.7	14,175.2
2000	1,999.3	15,120.6	182.7	-	-	709.9	8,490.7	26,503.2
2010	3,131.1	20,974.4	519.0	-	0.1	1,775.9	14,267.5	40,668.0
2011	3,188.2	20,626.0	737.7	-	19.5	1,717.3	16,003.2	42,291.9
2012	3,542.4	22,143.6	1,191.5	0.3	23.1	1,729.9	15,650.9	44,281.6
2013	3,778.8	21,671.4	1,351.4	1.4	32.8	2,305.9	16,665.9	45,807.7
2014	3,819.0	21,341.6	2,079.9	10.1	33.0	2,530.6	17,044.9	46,859.1
2015	3,664.6	22,235.7	2,869.8	586.4	37.1	3,698.1	15,681.7	48,773.4

Note: BIO = Biomass + Biogas; COGEN = Cogeneration; FOSSIL = Oil + Diesel + Natural Gas + Coal; GEO = Geothermal; HYDRO = Hydroelectric.

increased from 35.3% to 36.4% and then to 36.7% in 2014. However, in 2015 it dropped to 32.2%. The return of rains after a drought that hit some parts of Central America and the rapid growth of solar, would explain such a decrease.

Note that renewables, mainly hydro, accounted for 54.8% (or 1,326.9 MW) of the total installed capacity in 1980, decreasing to 53.0% (or 7,981.6 MW) in 2015 (Table 1) . That rather small percentage change does not reflect the recent growth in installed renewable capacity, especially in solar. Just one renewable energy source has not increased in installed capacity since 2013 - geothermal . However, this should change in the future when new geothermal plants come on line in Costa Rica (Las Pailas II, Boriquen), El Salvador (Chinameca and San Vicente), Guatemala (El Ceibillo), Honduras (Platanares), Nicaragua (San Jacinto-Tizate) and Panama (Barú-Colorado).

For more information about plans for geothermal energy development in the region see Paul Moya's presentation from the International Session at the 2016 GRC Annual Meeting: *Central America Region – Added generation and future plans*, at [https://geothermal.org/Annual\\_Meeting/past\\_presentations.html](https://geothermal.org/Annual_Meeting/past_presentations.html).

*\* Note: Belize, even though it is in Central America, was not included in this note because its electricity market is very small . In 2015, the country's total installed generating capacity was only 142.6 MW. The total electricity generated was 345.9 GWh, of which 68.4% (or 236.5 GWh) was renewable, mostly hydro (235.9 GWh) and a little solar (0.6 GWh). ■*

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*Continued from page 18...* This will be the first geothermal power plant to operate in Honduras. It is expected to start operating this year. The **USD 200 million** geothermal project – inclusive of Honduran and foreign capital – is located in the municipality of **La Union**, department of **Copán**, in western Honduras.

In 2013, **Ormat** signed a **Build, Operate, and Transfer (BOT)** contract for the Platanares geothermal project with ELCOSA, a privately owned Honduran energy company, for **approximately 15 years** from commercial operation date (COD).

### Construction of Las Pailas II Geothermal Project is Currently at 54%

The **Costa Rica Electricity Institute (ICE)** has said that the **Las Pailas II Geothermal project**, currently under development and expected to be ready by 2019, will be the most modern geothermal plant in Central America and the Caribbean, reports the *Costa Rica Star*.

“It is the first geothermal plant in the region that will have a **cooling tower made of reinforced fiberglass**, all its wells will be drilled by directional technique and it will produce electricity with just one latest generation Japanese turbine” stated the press release.

According to the construction coordinator of Las Pailas II, **Didier Ugalde**, in previous projects the cooling towers have been built of concrete and wood, but never in fiberglass; this new element reduces the costs of operation and benefits the environment, explained Ugalde.



*Pipeline in Las Pailas I, by Paul Moya. Two phase pipeline coming to the separation station at Las Pailas I, Costa Rica. Photo was taken in July 2011. GRC PHOTO CONTEST 2016*

The project is currently at a 54% completion, with the construction of the five cooling towers having started in January. The machine room will take up less space than usual using a light concrete panel system to improve the sound isolation of the equipment.

## AUSTRALASIA

### A New Australian Geothermal Association



Graeme Beardsmore, President of the new Australian Geothermal Association.

Graeme Beardsmore, Technical Director, Hot Dry Rocks Pty Ltd, Australia, has issued an invitation for interested parties to join a new **Australian Geothermal Association (AGA)**.

The AGA will continue the work of the **Australian Geothermal Energy Group (AGEG)** and the **Australian**

**Geothermal Energy Association (AGEA)**, both of which are now deregistered. Residual funds from AGEA have been transferred to AGA, as approved by the outgoing AGEA Executive.

The inaugural Board of AGA comprises **Graeme Beardsmore** (President), **Adrian Larking** (Secretary) and **Betina Bendall** (Public Officer), with **Ludovic Ricard** performing the role of Treasurer. The **South Australian Department of State Development** is providing Secretariat services.

The membership fee for the 2017 calendar year is set at AUD 25. Fees will contribute towards the running costs of the association and support the development of an AGA website to provide information about geothermal energy and all its benefits and uses, including ground source heat pumps, direct uses of geothermal heat, and power generation.

For more information about joining the new association, contact the Secretary, **Adrian Larking** [adrian.larking@gmail.com], or **Graeme Beardsmore** [Graeme.beardsmore@hotdryrocks.com].

## ASIA

### Liability Guarantee Allows 7 MW Iwate Geothermal Power to Proceed

The geothermal resource exploration project in the **Matsuo-Hachimantai** area of **Iwate Prefecture**, on the northeastern coast

of **Honshu**, being developed by **Iwate Geothermal Power Co., Ltd.**, has been awarded a **liability guarantee** by **Japan Oil, Gas and Metals National Corporation (JOGMEC)**, which covers finance raised for future development activities.

As a result, parent company **Mitsui & Co., Ltd** will proceed toward commercialization of the **7 MW geothermal power plant** in collaboration with the other shareholders of Iwate Geothermal.

### 5 MW Takigami Geothermal Plant Starts Up

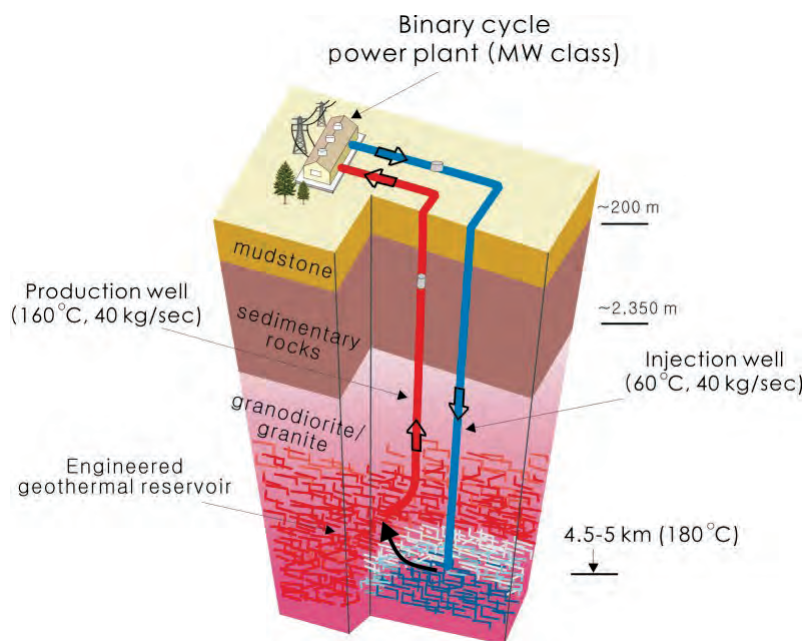
**Idemitsu Kosan Co.,Ltd** has announced through its subsidiary **Idemitsu Oita Geothermal Co., Ltd.**, that the **5 MW Idemitsu Oita geothermal binary power plant** in Takigami, Oita Province has achieved commercial operation.

### First Geothermal Power Plant in South Korea

A **1.2 MW geothermal power plant**, the first in South Korea, could be ready by April, reports *The Korea Bizwire*.

The South Korean government launched the Enhanced Geothermal System (EGS) geothermal power generation project in **Pohang**, in the south-east of the peninsula, at the end of 2010. The EGS pilot plant project is the first attempt to realize geothermal power generation in the country.

Officials said optimal conditions for generating geothermal electricity have been found, with **temperatures reaching 180°C at a depth of five kilometers**.



Conceptual model of the Korean EGS pilot plant project. Background and Progress of the Korean EGS Pilot Project, Yoonho Song, Tae Jong Lee, Jaesoo Jeon and Woon Sang Yoon. Proceedings World Geothermal Congress 2015.

Once running successfully officials will raise an additional 80 billion Won in investment through a power plant consortium to expand the capacity to **6.2 MW by 2019**.

### Philippines Update

Philippines company **Aboitiz Power Corp.** has announced **it has withdrawn** from the geothermal exploration and development project in **Ijen, East Java, Indonesia**, reports *The Standard*.

"Aboitiz Power has decided that it will focus and allocate its resources to other ongoing and pipeline projects and has agreed to step aside to allow its partner to proceed with the project," Aboitiz Power said in a disclosure to the Philippines stock exchange.

Aboitiz Power International had earlier signed an agreement with **PT Medco Power Indonesia** to participate in the exploration and development of a potential 110 MW geothermal power plant, which **would have been the company's first international venture**.

~~~~~  
According to *Philippine Star*, **Basic Energy Corp.** will sell unissued shares to **Thailand-based Vintage Engineering Public Co. Ltd. (VTE)** in line with their joint development of domestic and international renewable energy projects.

Also under the deal, both parties agreed VTE has the right to invest in the **Mabini geothermal project** and other projects.

Currently, Basic Energy has five geothermal service contracts, namely the **Mabini** Geothermal Service Contract in Batangas, **East Mankayan** Geothermal Prospect in Ifugao, **Mt. Mariveles** Geothermal Project in Bataan, **Mt. Iriga** Geothermal Project in Albay and **West Bulusan** Geothermal Prospect in Sorsogon.

~~~~~  
**Basic Energy Corp.** and **Phinma Energy Corp.** have announced that the target depth of 1,679 meters has been reached at the **Mabini geothermal**

**project** in Batangas, and **perforated liners will soon be put in place**.

"Testing of the well aimed at obtaining temperature, pressure, and permeability data, to be performed by its contractor, **Scientific Drilling International (SDI)**, shall commence shortly," the firm said.

Basic Energy Senior Vice President and General Manager **Anthony Cuaycong** said completion tests will last up to three days and are intended to set baselines that will allow Basic Energy to assess the resources.

"After the completion test, there is a heat-up period of up to one and a half months, during which time surveys will be conducted to check well response after specific 'rest' periods," Cuaycong said.

Pre-feasibility studies show that **the capacity of the resource could be between 20 to 60 MW**.

~~~~~  
**Ayala Corp.** will depend on foreign financing to fund the acquisition of the geothermal operations of **Chevron Global Energy, Inc.** in Indonesia and the Philippines, reports *BusinessWorld*.

Ayala announced that its subsidiary **AC Energy** had signed agreements with Chevron and their relevant affiliates for the acquisition of the geothermal assets at an undisclosed price.

"Chevron is actually quite interesting because, while it looks big on the surface, we have been able to get financing but, of course, we have partners - that's not all ours. Our share in Indonesian and Philippine assets is a manageable amount for us," said Ayala Corp. Chief Sustainability Officer and Finance Group Head **Jose Teodoro K. Limcaoco**.

**Star Energy Geothermal** has enlisted three lenders for a USD 660m dual tranche loan that will go partly towards funding the company's purchase of its stake in Chevron's Indonesian assets, reports *GlobalCapital*.

**Credit Suisse, DBS** and **Maybank** are arranging the facility and have pre-funded a portion of the money ahead of senior syndication. The mandated lead arranger and bookrunner title is also available to new lenders for commitments of USD 100m or more.

~~~~~  
**Biliran Geothermal Inc.** has disclosed it has found a way to address the excessive acidity of its geothermal power project in **Leyte**, making the field fit for the generation of geothermal power.

The company said the **49 MW Biliran geothermal power project** had not been completed due to the acidity of the geothermal brine. The solution involves **regular injection of chemicals** into the wells to treat the acidity and ongoing careful and rigid monitoring of the well geochemistry.

The chemical treatment had previously been used in the **Miravelles geothermal field** in **Costa Rica**, where the geothermal brine also required treatment for acidity.

## Indonesia Update



The World Bank has announced it will extend Indonesia a **USD 55.25 million grant** to facilitate geothermal energy power plant

development in the country.

The bank said the grant will support Indonesia's **Geothermal Energy Upstream Development Project** and will mostly be used to fund infrastructure development and drilling exploration.

Production capacity in Indonesia is targeted to **increase in stages from the current 1.6 GW to 7.2 GW by 2025**, according to the Ministry of Energy and Mineral Resources.

The Indonesian **Ministry of Energy and Mineral Resources** has issued **Regulation No. 10/2017** on Principles of *Power Purchase Agreements* (PPA) (**MEMR Reg. 10**), which, for the first time in any material way, seeks to impose certain requirements as to what provisions must be built into PPAs in the power sector.

*Lexology* reports that all projects must now be on a **Build-Own-Operate-Transfer (BOOT) model** and transferred to **PLN for a nominal amount** at the end of the term of the PPA. Developers complain that all potential "upside" in negotiations has been taken off the table.

The **Indonesian Geothermal Association (INAGA)** is also disappointed with the Energy Ministry's **Regulation No.12/2017** and believes the rule will hamper efforts to discover geothermal reserves.

"The clauses are so biased, they could hamper geothermal exploration," INAGA chairman **Abadi Purnomo** said. The 11 clauses govern that a geothermal SPA can only be signed once the

developer has proven reserves, which requires exploration that costs USD 8 million-USD 10 million per well, reports *Tempo*.

"Who would want to pay for the explorations? And businesses will not take risks of drilling wells if there is no guarantee someone will buy the electricity," he said.

**Supreme Energy, Engie and Sumitomo Corporation** have signed the financing documents for the **80 MW Muara Laboh geothermal power plant** in **West Sumatra**, allowing the project to break ground.

The project is being built by **Supreme Energy Muara Laboh (SEML)**, an Indonesian subsidiary of Engie, the French power company making a debut in geothermal energy. **Construction started in March**, and **commercial operations are planned for 2019**.



**Fuji Electric** will supply the plant's steam turbines and power generators. Sumitomo will handle surveying of the project area, as well as operations and maintenance after construction is completed. It is the first time that Sumitomo, a trading house, will run a geothermal power plant.

The plant is backed by a **USD 440 million finance agreement** coordinated in part by the **Asian Development Bank** and other regional lenders.

The electricity will be sold to the state-owned power utility **PT PLN over a 30-year period**.

The Indonesian Energy and Mineral Resources Ministry has **scrapped plans to auction the Ciremai Mountain geothermal working area** in West Java. The government will instead appoint state-owned oil and gas company **PT Pertamina** to become the **sole operator** of the area. The estimated **capacity ranges between 110 and 150 MW**.

“They [local residents] at the vicinity of Ciremai Block suggested it be operated by Pertamina,” Energy Ministry Geothermal director **Yunus Saefulhak** told *Tempo*.

Australian company **Xped Limited**, formerly Raya Group, has announced the completion of the *Conditional Sale and Purchase Agreement* (CSPA) with Singapore based **KS Orka Renewables Pte Ltd.** to acquire the company's 45% shareholding in **PT Sokoria Geothermal Indonesia (SGI)**.

The Sokoria project, located on **Flores Island**, was planned for **30 MW capacity** with the first 5 MW unit expected to come online in December 2018, and the whole plant to reach commercial operations between 2023 and 2024.

KS Orka Renewables reports on its website that **road and wellpad construction has begun** and the drilling contractor **ABS Drilling** has mobilized their rig.

## AFRICA

### Japan Joins Power Africa, with a Focus on Geothermal Technology

Japan has joined the **Power Africa Consortium**, committing to bring 1,200 MW of power online. As part of its agreement, Japan will work with African governments to **develop renewable geothermal power**, reports the *Young African Leaders* initiative.

More than 100 private-sector partners, host governments and multilateral organizations are participating in Power Africa. The goal is to help the estimated two out of three people in sub-Saharan Africa who currently lack electricity.

### Kenya Update

**President Uhuru Kenyatta's** government has announced plans for spending in the latest national budget.

One of the key items in the energy sector expenditure is **Sh16.4 billion to go to geothermal development**.

In December 2016, the Treasury had proposed the allocation for geothermal development should be reduced to Sh10.5 billion, down from Sh21.9 billion budgeted last year. A reduction to Sh16.4 billion is not so severe.

**Kenya Electricity Generating Company (KenGen)** has entered into a deal that could see it complete the **sale of the 4.4 billion shares** that were on offer during its rights issue offer in 2016, reports *Citizen TV*.

Also, South African pension fund **Public Investment Corporation** has entered into talks with KenGen to buy the remaining 351.2 million shares that were not taken up during the offer.

The deal is valued at Sh2.3 billion, meaning KenGen has hit its initial target to raise Sh28.7 billion.

KenGen had indicated it plans to spend Sh20.1 billion to pay off its expensive debt while the **remaining Sh8.6 billion** would be sunk into its ongoing projects including **developing the Olkaria geothermal fields**.

**Mitsubishi Hitachi Power Systems (MHPS)** has secured the contract to deliver two sets of geothermal power generation equipment for the **Olkaria V geothermal power plant**. At the time of writing construction was about to begin.

According to *Energy Business Review*, the order includes supply of **two 70 MW class steam turbines**, condensers, generators and other key auxiliaries.

As part of the contract, MHPS will also be responsible for the design aspects of the geothermal facilities, **slated to be commissioned in 2019**.

*Mitsubishi Hitachi Power Systems will be exhibiting at the GRC Annual Meeting & GEA GeoExpo+, October 1-4 in Salt Lake City, Utah, USA.*

**Maasai** elders, who for two months have opposed **KenGen's Olkaria projects** in Naivasha, **now support them**.

After many demonstrations, the elders have decided to back the **Stakeholders' Coordination Committee** that will oversee the work.

The elders said they will end the differences between two rival groups over control of the committee. Their spokesman **Lila ole Mututwa** said the committee in charge of the new **260**



The Maasai locals show their support for the geothermal energy development at Olkaria. COURTESY THE STAR

MW geothermal project has the interests of the community at heart.

The port city of **Mombasa** will soon enjoy geothermal energy from **Olkaria**. *Business Daily Africa* reports that the Kenyan High Court has lifted orders that had stopped work on the **Nairobi–Mombasa electricity transmission line**.

Upon completion of the line, residents in Mombasa will for the first time get connection to cheaper steam power from the Olkaria complex, and **cut dependence on thermal power**.

The Kenyan Energy Regulatory Commission has stated that some of the steam power generated at Olkaria is lying idle because there are no transmission lines to Western Kenya and the coast, areas which experience constant system disturbances and instability.

## EUROPE

### New Regional Group to Develop Geothermal Energy Projects

A new European geothermal consortium was announced at the recent **GeoTHERM Expo** in Germany.

The objective of **Geothermica** is to combine the financial resources and know-how of 16 geothermal energy research and innovation program owners and managers from 13 countries: **Iceland, Netherland, Switzerland, Italy, Germany, France, Turkey, Slovenia, Portugal, Spain, Denmark, Romania, and Belgium**.



Together with financial support from the **European Commission**, Geothermica will launch joint projects that demonstrate and validate novel concepts of geothermal energy deployment within the energy system, and that identify paths to commercial large-scale implementation.

**In April, Geothermica will publish a joint call for projects.** The budget for the call is about **EUR 32 million** and the call will ask for large projects with strong industry participation that accelerate the deployment of geothermal energy in Europe. More information can be found at: [www.geothermica.eu](http://www.geothermica.eu)

### German Company Wins European Geothermal Innovation Award



The **European Geothermal Energy Council (EGEC)** has announced the **European Geothermal Innovation Award** for 2017 during

the opening session of **GeoTHERM** exhibition and Congress in **Offenburg, Germany**.

**enOware GmbH**, based in **Karlsruhe**, won for their **GEOsniff®** miniaturized sensor which allows the monitoring and measurement of near-surface geothermal probes.



**GEOsniff®**

German company enOware GmbH won for their GEOsniff® miniaturized sensor.

The four other nominations for this year's European Geothermal Innovation Award were:

- **HakaGerodur AG** (Switzerland), for a pressure-resistant borehole heat exchanger (BHE) for difficult geological conditions and applications up to 300m depth.
- **Huisman Well Technology BV** (The Netherlands), for the application of the Enhanced

Casing Installation (ECI) system in a geothermal well.

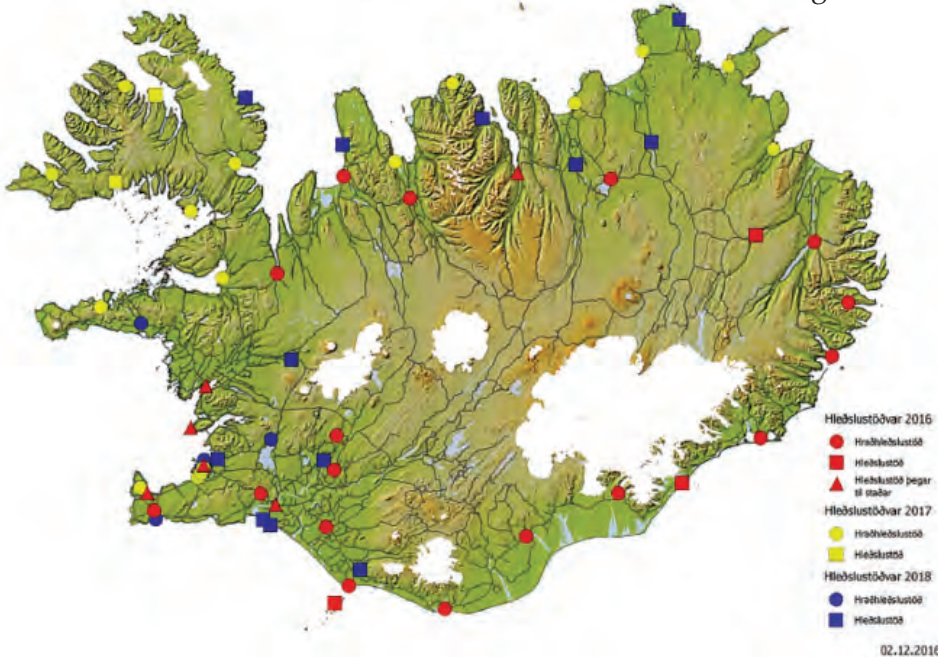
## Inside Geothermal

- **Jansen AG** (Switzerland), for the JANSEN shark technology, which reduces the flow resistance in pipes resulting in less power needed for pumping.
- **SWM Services GmbH** (Germany), for a project to provide 100% renewable energy for district heating in Munich, including a major contribution from geothermal energy.

### Geothermal Energy Will Make it Possible to Drive Around Iceland

Plans have been announced for about **200 charging stations for electric cars** to be built in Iceland in the next three years. A lack of charging stations has prevented electric cars from becoming popular in the country, reports *Iceland Review*.

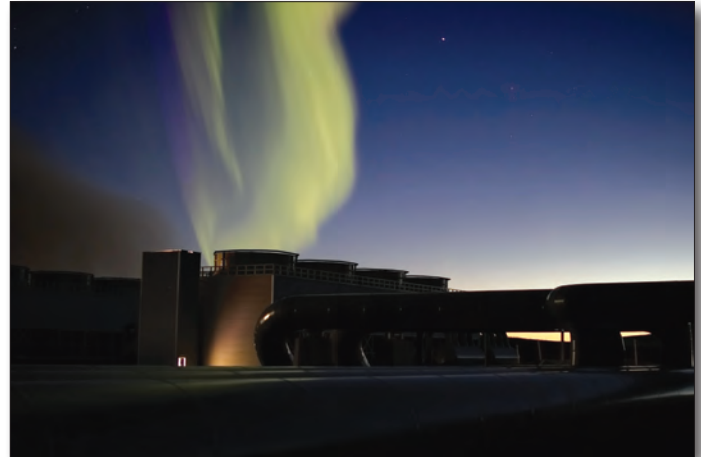
Today, there are 13 charging stations in Iceland, all of them operated by **Orka Náttúrunnar**. Six of those are in the capital area, the others in Reykjanesbær, Akranes, Borgarnes, Selfoss and by **Hellisheiði geothermal plant**.



Within the next two years it will be possible to drive all the way around the wild and scenic Icelandic coastline, charging your electric car on clean renewable energy mostly produced by geothermal power.

### 303 MW Hellisheiði Geothermal Plant Could be Sold

According to *Askja Energy*, a firm called **MJDB** has made offer to buy the **Hellisheiði geothermal plant** in southwest Iceland. According to Icelandic media, MJDB is mostly owned by **Magnús B. Jóhannesson**, who is director of a firm with the name of **America Renewables**, in Rolling Hills in California. No public information is available about the offering price for the geothermal plant.



*The power and the light no. 1, by Christopher Mathews. Aurora borealis and cooling towers at Hellisheiði Power Station, Iceland. August 31, 2016. GRC PHOTO CONTEST*

The Hellisheiði plant is the largest and most recent geothermal plant in Iceland, starting operation in 2003. It has a **generation capacity of 303 MW** and 130 MW in thermal energy. It is owned and operated by the energy firm **Orka Náttúrunnar (ON)**, which is a subsidiary of **Orkuveita Reykjavíkur (OR)**, sometimes referred to as **Reykjavík Energy**.

According to Iceland's public service broadcasting organization **Ríkisútvarpið (RÚV)**, an investment of **ISK 13 billion (USD 119 million, EUR 112 million)** will be needed to **ensure adequate steam** for Hellisheiði geothermal plant.

After the plant entered full operation in September of 2011, it became apparent that the production area used at the time would not be sufficient for full operation indefinitely. In 2013, the decision was made to connect the Hverahlíðarsvæði area to Hellisheiði Geothermal Plant in order to obtain more steam

and spread out the production. That connection was made at the beginning of 2016, after which it became possible to reduce production in older areas closer to the Hellisheiði plant, giving them a chance to recover, reports RÚV.

In the next ten years, **15 new boreholes are planned to maintain the production capability** of the Hellisheiði plant.

### New Lithium/ Geothermal Energy Project Proposed in Cornwall

Mining company **Cornish Lithium** has announced that it has secured a mineral rights agreement with Canada's **Strongbow Exploration and Mineral Exploration** to carry out exploration for lithium from deep reservoirs of geothermal brine contained in granite in **Cornwall** in south-west England, reports the *Daily Mail*.

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

### Balmatt Geothermal Energy Plant to be Built By End of Year

According to *Flanders Today*, the Flemish institute for technological research (**Vito**) has **completed the first two phases** of a geothermal district heating project. The third phase will install a power station at the **Balmatt site in Mol, Antwerp province**. **A geothermal power plant could be completed by the end of the year.**

**Drilling of a production well has reached 3,610 meters to a limestone layer where the temperature reaches 138°C.** When pumped to the surface, the water retains a temperature of 126-128°C, which allows it to be used for heating.

In the second phase of testing, it was found that water could also be returned to the limestone layer in order to be reheated and pumped back out, creating a closed water

loop. **A second re-injection well, reaching a depth of 3,830m, was completed in September last year.**

### Drilling at Alsace Geothermal Project to Begin in June

French company **Vallourec** has won a contract to deliver tubular products for a geothermal power project in eastern France. Vallourec will assist **Fonroche Géothermie** in the exploration phase for underground reserves in **Alsace**.

The project will consist of **two to four wells drilled in doublets** (one injection well and one production well) with between 1,700 and 3,400 tons of semi-premium and premium tubes and connections. **The drilling of the first well is expected to begin in June 2017.** If results are positive, **production will start soon thereafter.**

### 5 MW Swiss EGS Project Gets Risk Guarantee

According to **Geo-Energie Suisse**, a consortium of Swiss energy supply companies promoting geothermal energy for electricity and heat generation in **Switzerland**, the **Haute-Sorne Enhanced Geothermal Systems (EGS) project** has taken another important step in securing the Swiss Confederation's risk guarantee.

The project has been granted a maximum sum of **CHF 47 million** in case of partial success or failure if the temperatures or flow rates required for successful geothermal utilization are not achieved.



The Haute-Sorne EGS Project site in NW Switzerland

## Inside Geothermal

### Poland to Clean Air With Geothermal Energy

The Polish government is to use geothermal energy to try and clean up its air quality problem, reports *PennEnergy*.

Both Warsaw and the **European Union** are to help fund a USD 2.4bn program to tackle the problem, of which **USD 120m** is to be designated towards geothermal energy projects.

### Combined Geothermal Heat and Power Plant in Hungary About to Launch

**KS Orka Renewables** reports that commissioning for a combined 3 MWe and 7 MWth geothermal power plant near **Budapest, Hungary**, is planned for early May.

## EDUCATION

### National Geothermal Academy



19-30 June, University of Nevada, Reno, Nevada, USA

The National Geothermal Academy is an intensive summer course this year with a focus on engineering. The course is

offered through the University of Nevada, Reno.

- *Module 1: Geothermal drilling engineering* 19th - 23rd June 2017. Instructor: **Bill Rickard**, Geothermal Resource Group
- *Module 2: Geothermal reservoir engineering* 26th - 30th June 2017. Instructor: **Prof. Roland Horne**, Stanford University

These training modules are intended for outstanding undergraduates, graduate students, and professionals with strong backgrounds in science, math, and/or engineering. All classes will be held at the University of Nevada, Reno's Redfield campus in south Reno. International and USA applicants welcome.

**Course cost: USD 2,000/module.** Optional campus accommodation option: ~USD 500/week.

**Applications from students** (2 credits per module) **due in April 2017.**

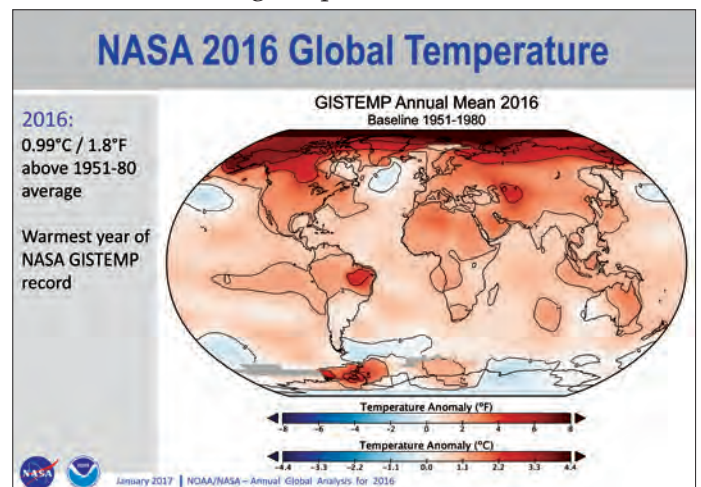
**Applications from professionals** (certificate) **due in May 2017.** Applications accepted only until course is filled.

More information can be found on the **Great Basin Center for Geothermal Energy** website at: [www.gbcge.org/education-NGA.php](http://www.gbcge.org/education-NGA.php)

## CLIMATE CHANGE

### Human Activity Causes Record Warm Temperatures - Scientists

**2016 was the hottest year on record**, setting a new high for the third year in a row, with **scientists firmly putting the blame on human activities** that drive climate change, reports *The Guardian*.



COURTESY NASA

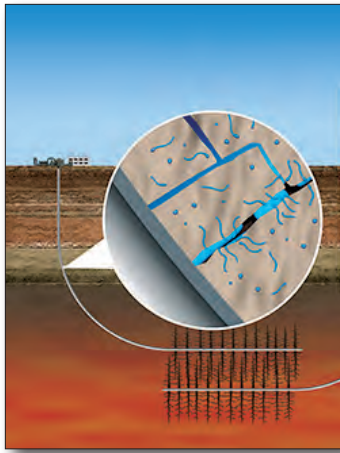
The final data for 2016 was released by the three key agencies – the **UK Met Office** and **NASA** and **NOAA** in the US – and showed **16 of the 17 hottest years on record have been this century.**

Direct temperature measurements stretch back to 1880, but scientific research indicates the world was last this warm about 115,000 years ago and that **the planet has not experienced such high levels of carbon dioxide in the atmosphere for 4m years.**

## SCIENCE & TECHNOLOGY

### Using Self-Healing Cement for Geothermal Wells

With an average life span of 30-40 years, **the cement around geothermal production wells eventually cracks over time.** Because wells with cracked cement are vulnerable to leakage, reduced strength, and corrosion, it's important to repair them in a timely fashion. However, repairs can easily top USD 1.5 million; the cost of new materials,



COURTESY PNNL

excavation, installation, and halting power production adds up fast.

Researchers at **Pacific Northwest National Laboratory (PNNL)** have developed cement that **can heal itself** when cracks occur. Using self-healing cement for geothermal wells would save geothermal plants millions of dollars and

would reduce the amount of downtime necessary for repairs.

PNNL chemist **Carlos Fernandez** and his team discovered that by adding a strong and flexible and powerful ingredient, called **polymers**, they could create self-healing cement. Naturally found in the human body, plant structures, and more, these large, chain-like molecules work to hold substances together. The team discovered by **mixing in 5 to 20 percent of man-made polymers** into typical cement before it is poured and cured, the cement can repair itself when cracks occur. PNNL's research team has successfully proven **this cement can repair itself in a few days**, and they predict it has the **potential to heal itself in just a matter of hours**. Just as impressive, is the cement's projected ability for continuous self-healing, meaning it can **repair itself many times over** and maintain the rheological and mechanical properties necessary for geothermal wells.

*This work is part of a collaborative project between PNNL, Brookhaven National Laboratory, and National Energy Technology Laboratory funded by the U.S. DOE's Geothermal Technology Office.*

### Project to Use Geothermal Heat to Grow "Food of the Gods"

**Enel Green Power** has signed an "Agreement of collaboration for experimentation on geothermal resources applied to the cultivation of algae" with the **Consortium for the Development of Geothermal Areas (CoSviG)**.

The two sides will put up **EUR 100,000 each** towards the construction of a pilot plant, which will be built next to the **Chiusdino geothermal plant** in Larderello, Tuscany, Italy, for the production of *spirulina algae* using geothermal energy.

*Spirulina* is a biomass of cyanobacteria (**blue-green algae**) that can be consumed by humans and other animals. There are two species, *Arthrospira platensis* and *Arthrospira maxima*.

**Arthrospira** is cultivated worldwide; used as a dietary supplement as well as a whole food; and is also available in tablet, flake and powder form. It is also used as a feed supplement in the aquaculture, aquarium and poultry industries. The Mayans and Aztecs called it the "food of the gods". ■

### This Just In....

#### 110 MW Sarulla Geothermal Power Plant Unit I Starts Operation

**Toshiba Corporation** and **Ormat Technologies Inc.** have announced that the first unit of the **Sarulla geothermal power plant**, located in Indonesia's North Sumatra province, has commenced commercial operation.

The approximately **110 MW power plant**, which combines flash and binary technologies, is operated by **Sarulla Operations Ltd. (SOL)**.

As participants in the project, Toshiba supplied the geothermal steam turbines and generators (STGs) for the flash systems, while Ormat provided the conceptual design of the Geothermal Combined Cycle Unit (GCCU) power plant and supplied its Ormat Energy Converter (OEC), which serve as the condensing units for the steam turbines and utilize the separated brine for maximum resource exploitation and maximum power output.

**Isaac Angel**, Ormat's CEO, commented, "The commencement of commercial operation at Sarulla is a significant milestone for Ormat, both as an owner of SOL and as a supplier of our 25-year-proven binary technology. **The Sarulla supply contract is the largest single contract that Ormat has signed to date.** We continue to share our expertise as work continues on the **second and third units of the Sarulla project** that are expected to **come on line by 2017 and 2018**, respectively." ■



COURTESY SARULLA OPERATIONS LTD.



View from the MAR (Mid Atlantic Ridge), by Robert Zierenberg GRC PHOTO CONTEST

# The Iceland Deep Drilling Project geothermal well at Reykjanes successfully reaches its supercritical target

Guðmundur Ó. Friðleifsson and Wilfred A. Elders  
IDDP-Principal Investigators  
HS Orka, Iceland, and University of California, Riverside, USA



**The Iceland Deep Drilling Project passed a significant milestone in the geothermal industry when its IDDP-2 well at the Reykjanes Peninsula in Iceland reached the depth**

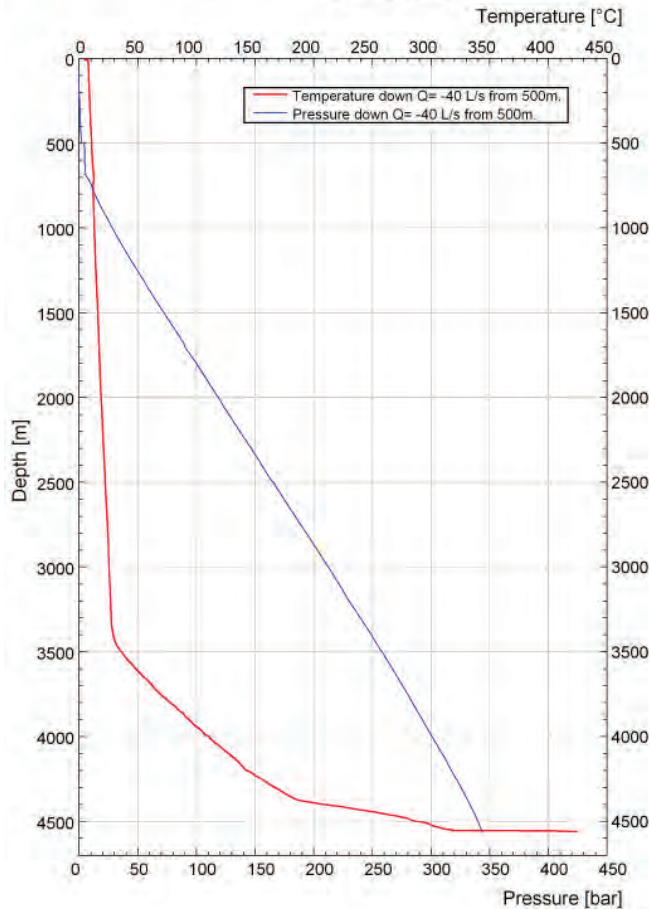
**of 4,659 meters on the 25th of January 2017, after 168 days of drilling.** The IDDP-2 achieved its initial targets, (a) to drill deep enough to reach supercritical conditions (4 to 5 km), (b) to measure the fluid temperature and pressure, (c) to search for permeability, and (d) to recover drill cores. After only 6 days of heating, the temperature measured at the bottom of the well was ~427°C, with fluid pressure of 340 bars, and indications of permeability at depth (Figure 1), and drill cores were retrieved. It's clear that the bottom of the well reached fluids at supercritical conditions, so that the main objective of the drilling phase of the project had been achieved.

The critical point of fresh water occurs at 374°C and 221 bars. The reservoir fluids currently produced from the Reykjanes field have the salinity of seawater which has a critical point of 406°C at 298 bars. The fluids at the bottom of the IDDP-2 well when the PT log shown in Figure 1 was measured were a mixture of injected surface water and formation fluid. Although we do not yet know the salinity of this mixture, it is hard to argue that it was not at supercritical conditions during the logging operation.

## The Iceland Deep Drilling Project (IDDP)

The IDDP is a long-term project by a consortium of Icelandic energy companies aimed at greatly increasing the production of usable geothermal energy by drilling deep enough to reach the supercritical conditions believed to exist beneath existing high-temperature geothermal fields in Iceland. Modeling indicates that a well producing from a supercritical geothermal

## Reykjanes Well IDDP-2



**Figure 1.** Temperature and pressure log to 4,560 m depth in IDDP-2 after only 6 days of heating. As can be seen from the temperature profile, because of cold water injection, the well is far from thermal equilibrium. When thermal recovery is complete, it is likely that temperatures will exceed the estimated 427° measured at the bottom of the hole. The PT logging was done with a K-10 logging tool, which was calibrated to only 380°C. (Source ISOR logging group).

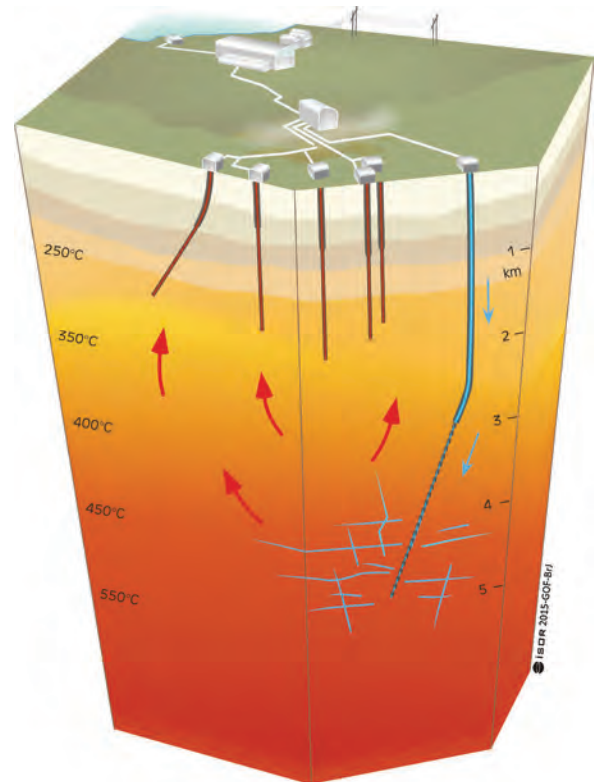
reservoir could produce an order of magnitude more usable energy than that produced by a conventional high-temperature (~300°C) geothermal well. This is because of both the higher enthalpy of supercritical fluid and its more favorable flow properties, due to its very low viscosity.

When the IDDP consortium was formed, three geothermal fields in Iceland were chosen as suitable to search for supercritical resources, Krafla in the north-east of Iceland, and Hellisheidi and Reykjanes in the south-west (Figure 3). The first attempt to drill into a super critical reservoir was made in 2009 in the Krafla caldera, but the IDDP-1 well did not reach supercritical fluid pressures because drilling had to be suspended at a too shallow depth. This is because 900°C rhyolite

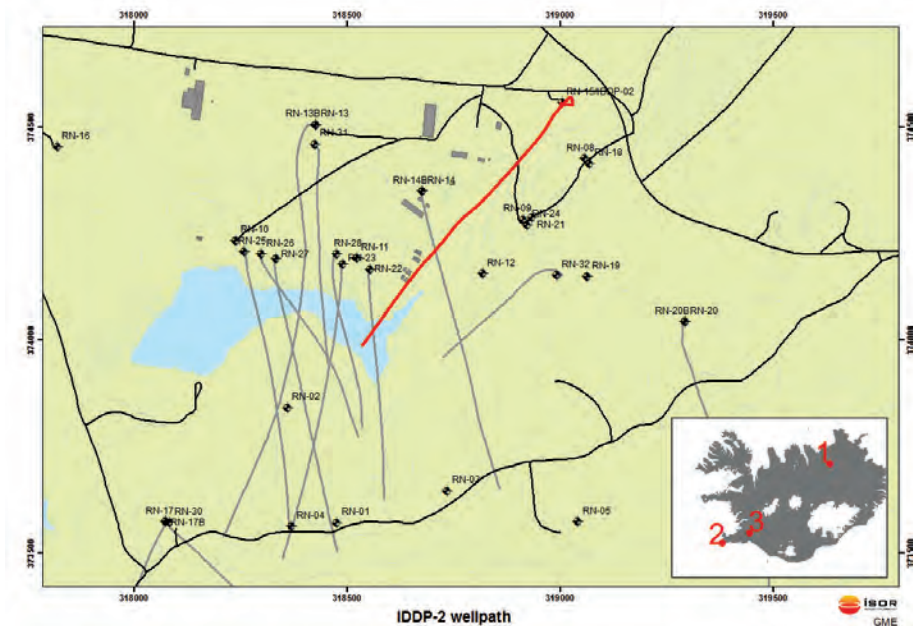
magma flowed into the well at only 2,100 m depth. However, the IDDP-1 was completed with a liner set above the rhyolite intrusion. When the well was tested, it produced superheated steam at 452°C at a flow rate and pressure sufficient to generate about 35 MWe. After two years of flow testing, unfortunately repair of the surface installations was necessary, and the well had to be quenched due to failure of the master valves. This caused collapse of the well casing and abandonment of the well.

## The IDDP-2

The IDDP consortium then decided to make the Reykjanes geothermal system the focus of its next attempt at drilling to supercritical conditions. HS Orka, the field operator at Reykjanes, led the drilling of the IDDP-2 well, in close collaboration with other project partners, Landsvirkjun, Orkuveita Reykjavíkur, and the National Energy Authority in Iceland, together with Statoil, the Norwegian oil and gas company. The IDDP has also received funding from the EU H2020 (DEEPEGs), and science funding from International Continental Drilling Program (ICDP) and US National Science Foundation (NSF). The drilling contractor was the Iceland Drilling Company.



**Figure 2.** Conceptual model of the roots of the Reykjanes Geothermal field indicating existing wells (brown) and the planned track of the IDDP-2 well (blue) to intersect the supercritical zone beneath the producing reservoir.



**Figure 3.** The locations and tracks of wells in the Reykjanes geothermal field. The red line shows the track of well RN-15/IDDP-2. The map insert at the lower right shows the location of the three geothermal fields being investigated by the IDDP where 1 = Krafla, 2 = Reykjanes, and 3 = Helisheiði.

The Reykjanes geothermal field lies near the southern tip of the Reykjanes Peninsula, which is the landward extension of the Mid-Atlantic Ridge. Some 34 production, injection, and observation wells supply steam to a 100 MWe power plant, from a 300°C reservoir at 1 to 2.5 km depth. It is unique among Icelandic geothermal systems in that its reservoir fluid is modified seawater, and that seawater is used to cool its steam condensers. Figure 2 shows a conceptual model of the drilling target of the IDDP-2 well, based on the existing extensive well and geophysical data. The IDDP-2 well took advantage of an existing production well, the RN-15, which was 2,500 meters deep. This well was deepened and cased to 3,000 m depth and then deepened to the total depth of 4,659 m. The deepest existing geothermal wells at Reykjanes are about 2.5 km deep. The IDDP-2 has the deepest casing and is also the deepest well in Iceland. Figure 3 is a map showing the track of the well as actually drilled, together with the tracks of existing wells.

The IDDP-2 was drilled vertically down to 2,750 meters and below that drilled directionally to the southwest to intersect the main upflow zone of the Reykjanes system as indicated by geophysical surveys. The bottom of the well has a vertical depth of about 4,500 meters, and is situated 738 meters southwest of the well head.

Various challenges arose as the drilling progressed, there were weather delays, problems with hole stability that required frequent reaming, and the drilling assembly becoming stuck several times. Each instance was successfully solved as it happened. However, the major unsolved problem was a complete loss of circulation below 3,060 m depth, that could not be cured with lost circulation materials, or by multiple attempts to seal the loss zone with cement. As cementing was not successful, below 3180 m, drilling continued without any return of drill cuttings to the surface. Consequently, the drill

cores were the only deep rock samples recovered. In the beginning, we had difficulties recovering drill cores and overall only a total of 27.3 meters of core were retrieved in 13 attempts. These cores indicate that the IDDP-2 drilled through a basaltic sheeted dike complex that shows progressive metamorphism from greenschist, to lower amphibolite facies, consistent with hydrothermal alteration at temperatures of up to 450°C, with low water/rock ratios. The deepest core, returned from the bottom of the well is quite fresh dolerite, with minor intrusions of felsite. The main indications of hydrothermal alteration in this rock are quartz + biotite + hematite mineralization on fracture surfaces.

Another interesting aspect of the temperature log in Figure 1 is that, in addition to the major loss zone at 3,400 m, there are lesser permeable loss zones at 4,450 m and just below 4,500 m depths. After that PT logging run, a 7" perforated hanging liner was inserted to the bottom. Subsequently a 7" sacrificial casing was lowered from surface down to 1,300 m, and cemented up to the surface. Casing shoes were then drilled out and the well deepened by 6" bits, ending with 3 successive coring runs to the 4,659 m final depth. After the deepest coring run, a 3 1/2" drill string was lowered to the bottom of the hole. The aim is to enhance the permeability

deep in the hole by pumping in cold water for several months through the 3 ½" drill string. There are already some positive indications of enhancement of injectivity. Tests made after the last coring runs showed that cold water injection increased the injectivity index from 1.7 (l/s)/bar to 3.1 (l/s)/bar. We expect that continued deep stimulation with cold water is likely to further improve the fracture permeability at depth.

While this "soft" stimulation is going on, a surface test bed, with two parallel flow lines, will be designed and constructed ready for long term flow testing. Only after these fluid handling and flow tests are concluded can we determine the nature of the formation fluids, their enthalpy and flow characteristics, and hence estimate their engineering and economic potential. The total loss of circulation below 3 km depth was unexpected, but the existence of large permeability, a kilometer deeper than the current production zones at Reykjanes, may have implications for the future development of the geothermal resource that are independent of supercritical production.



*Drilling rig Thor at IDDP-2 site at Reykjanes (Guðmundur Ó. Friðleifsson)*

## Significance of the IDDP-2

The geological environment of the Reykjanes geothermal field is of great interest to the scientific community, situated as it is on the landward extension of the Mid-Atlantic Ridge that forms part of the world-encircling system of divergent plate boundaries, or oceanic spreading centres. These are regions of frequent volcanic eruption, high heat flow, and submarine hot springs. The IDDP-2 is a unique opportunity to examine the roots of a black smoker.

In future, our demonstration that it is possible to drill into a supercritical zone could have a large impact on the economics of high-temperature geothermal resources worldwide. By extending the available economic reservoir downwards we can extend the lifetimes of existing producing fields. As higher enthalpy fluids have greater power conversion efficiencies, fewer turbines are required for a given power output. Similarly, as fewer

wells are need for a given output, we can increase the productivity of a geothermal field without increasing its environmental footprint.

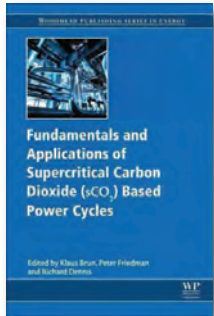
Iceland is fortunate in having several likely sites for such developments. Planning for drilling the IDDP-3 well at Hellisheidi is already underway, and, subject to the availability of funding, drilling could begin in 2020. However supercritical conditions are not restricted to Iceland, but should occur deep in any young volcanic-hosted geothermal system. Deep wells drilled in geothermal fields such as Kakkonda in Japan, Larderello in Italy, Los Humeros in Mexico, and The Geysers and Salton Sea in USA, have encountered temperatures above 374°C. Development of supercritical geothermal resources could be possible there and in many other volcanic areas worldwide.

More information on the IDDP can be found at [www.iddp.is](http://www.iddp.is) and [www.deepegs.eu](http://www.deepegs.eu). ■

# Publications, Websites, Videos & Maps

by Ian Crawford

## New Book on Properties of Supercritical Carbon Dioxide Relevant to Power Cycles



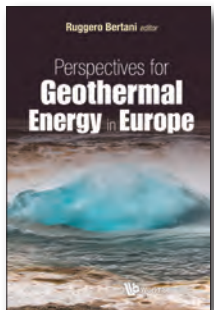
*Fundamentals and Applications of Supercritical Carbon Dioxide (SCO<sub>2</sub>) Based Power Cycles*

Editors: **Klaus Brun, Peter Friedman, Richard Dennis.**  
Hardcover ISBN: 9780081008041,  
eBook ISBN: 9780081008058.  
Imprint: Woodhead Publishing

This book aims to provide engineers and researchers with an authoritative overview of research and technology in this area. Part One introduces the technology and reviews the properties of SCO<sub>2</sub> relevant to power cycles.

Other sections of the book address components for SCO<sub>2</sub> power cycles, such as turbo-machinery expanders, compressors, recuperators, and design challenges, such as the need for high-temperature materials. Chapters on key applications, including waste heat, nuclear power, fossil energy, geothermal and concentrated solar power are also included. The final section addresses major international research programs.

## Review of Practicalities of Geothermal Extraction and Use in Europe



*Perspectives for Geothermal Energy in Europe*  
Edited by: **Ruggiero Bertani**  
(Enel Green Power, Italy)

- Introduction (**Ruggiero Bertani**)
- Geothermal Energy in Europe (**Philippe Dumas**)
- Binary Plants for Continental European Electricity Development (**Joseph Bonafin**)

- The Icelandic Experience on Integrated Geothermal Utilization (**Olafur Flovenz & Brynja Jónsdóttir**)
- The Italian Challenge for Geothermal Energy (**Adele Manzella, Assunta Donato, Gianluca Gola & Eugenio Trumpy**)
- The Turkish Geothermal Experience (**Sakir Simsek**)
- Unlocking Geothermal Energy from Mature Oil and Gas Basins: A Success Story from the Netherlands (**Jan Diederik Van Wees, Maarten Pluymaekers, Damien Bonté, Serge Van Gessel & Hans Veldkamp**)
- Geothermal Heat Pumps (**Ladsi Rybach & Burkhard Sanner**)
- Policy and Regulation in Europe (**Luca Angelino**)

## Legal Frameworks Governing Exploration, Exploitation and Production of Geothermal Energy

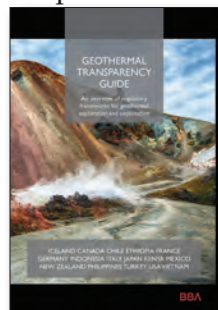
*Geothermal Transparency Guide* - BBA

Reykjavik law firm BBA, has published a guide to legal frameworks in geothermal energy around the world.

The handbook is intended to provide an insight into the legal frameworks governing exploration, exploitation and production of electricity from geothermal resources, in countries where geothermal capacity is being harnessed or is available for harnessing.

The hope is that the handbook will increase transparency and awareness of some of the rights and obligations governing applications for licenses for geothermal development and will serve as a first step in an eventual international cooperation for the purposes of creating industry standards in this field.

The *Geothermal Transparency Guide* features chapters on Iceland, Canada, Chile, Ethiopia, France, Germany, Indonesia, Italy, Japan, Kenya, Mexico, New Zealand, Philippines, USA and Vietnam.



A PDF of the publication can be downloaded from: [https://issuu.com/bba3/docs/geothermal-transparency-guide\\_web](https://issuu.com/bba3/docs/geothermal-transparency-guide_web)

## Guide to Successful Outreach for Geothermal Power Projects



*Communication concept for deep geothermal energy* (BINE Information Service)

Technical innovations can only be successful if they are supported by the general public. Early, comprehensive and transparent communication with the public is also indispensable for planning, constructing and operating plants for utilizing renewable energies.

The new **BINE Projektinfo** brochure entitled *Communication concept for deep geothermal energy* presents successful public relations theory and practice for geothermal energy plants. It provides operators and participating companies with numerous practical ideas and suggestions.

The brochure can be downloaded at: [http://www.bine.info/fileadmin/content/Presse/Projektinfos\\_2016/PM\\_17\\_2016/ProjektInfo\\_1716\\_engl\\_internetx.pdf](http://www.bine.info/fileadmin/content/Presse/Projektinfos_2016/PM_17_2016/ProjektInfo_1716_engl_internetx.pdf)

## Report Suggests Potential for 690 MW Geothermal in Romania, Bulgaria, Croatia and Slovenia

*Cost-competitive renewable power generation: Potential across South East Europe* - International Renewable Energy Agency (IRENA)

This report from the International Renewable Energy Agency (IRENA), prepared in collaboration

with regional researchers, aims to support South East European governments in preparing long-term renewable energy strategies.

The geothermal energy potential of the region is primarily characterized by a relatively low-enthalpy resource base, which is more appropriate for non-power applications. Binary plants that allow cooler geothermal reservoirs to be used for electricity generation are the only feasible option, which offer a potential of up to 690 megawatts (MW) at an average LCOE of EUR 86/MWh in the medium cost of capital scenario.

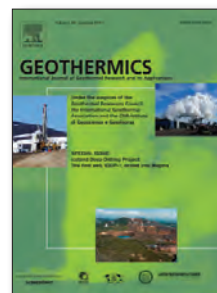
This renewable could be deployed mainly in Romania and, to a lesser extent, in Bulgaria, Croatia and Slovenia. In the rest of the region, the geothermal electricity potential is often marginal and uncertain.

The report can be downloaded at: [http://www.irena.org/DocumentDownloads/Publications/IRENA\\_Cost-competitive\\_power\\_potential\\_SEE\\_2017.pdf](http://www.irena.org/DocumentDownloads/Publications/IRENA_Cost-competitive_power_potential_SEE_2017.pdf)

Table 7.17: Cost-competitive geothermal potential in 2016

2016	Low cost of capital scenario				Medium cost of capital scenario				High cost of capital scenario				Full technical potential		
	No CO <sub>2</sub>		With CO <sub>2</sub>		No CO <sub>2</sub>		With CO <sub>2</sub>		No CO <sub>2</sub>		With CO <sub>2</sub>				
	88	90	88	90	88	90	88	90	88	90					
LCOE EUR/MWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	MW	GWh	
Albania	1	10	1	10	0	0	0	0	0	0	0	0	0	1	10
Bosnia and Herzegovina	7	50	7	50	0	0	0	0	0	0	0	0	0	7	50
Bulgaria	200	1,400	200	1,400	200	1,400	200	1,400	0	0	0	0	0	200	1,400
Croatia	64	450	64	450	64	450	64	450	0	0	0	0	0	64	450
Kosovo	n.a.	n.a.	n.a.	n.a.	0	0	0	0	0	0	0	0	0	n.a.	n.a.
Montenegro	1	10	1	10	0	0	0	0	0	0	0	0	0	1	10
Republic of Moldova	n.a.	n.a.	n.a.	n.a.	0	0	0	0	0	0	0	0	0	n.a.	n.a.
Romania	357	2,500	357	2,500	357	2,500	357	2,500	0	0	0	0	0	400	2,800
Serbia	10	70	10	70	0	0	0	0	0	0	0	0	0	10	70
Slovenia	70	540	70	540	70	540	70	540	0	0	0	0	0	70	540
The former Yugoslav Republic of Macedonia	10	70	10	70	0	0	0	0	0	0	0	0	0	10	70
Ukraine	0	0	0	0	0	0	0	0	0	0	0	0	0	n.a.	n.a.
SEE Region	721	5,100	721	5,100	692	4,890	692	4,890	0	0	0	0	0	763	5,400

COURTESY IRENA



## Geothermics, March and May 2017

The Table of Contents for Geothermics Volume 66 follows:

"Thermal conductivity estimation model considering the effect of water saturation

explaining the heterogeneity of rock thermal conductivity", by K. Albert et al., pp. 1-12.

"Value of MT inversions for geothermal exploration: Accounting for multiple interpretations of field data & determining new drilling locations", by W.J. Trainor-Guitton et al., pp. 13-22.

"Magnetotelluric monitoring of permeability enhancement at enhanced geothermal system project", by Y.L. Didana et al., pp. 23-38.

"Numerical analysis on the impact of the flow field of hydrothermal jet drilling for geothermal wells in a confined cooling environment", by X. Song et al., pp. 39-49.

"Assessment of heat mining and hydrogeochemical reactions with data from a former geothermal injection well in the Malm Aquifer, Bavarian Molasse Basin, Germany", by T. Baumann et al., pp. 50-60.

"Using seismic data to estimate the spatial distribution of rock thermal conductivity at reservoir scale", by Y. Gu et al., pp. 61-72.

"Early exploration of the Aluto geothermal field, Ethiopia (History of discovery well LA-3)", by M.P. Hochstein et al., pp. 73-84.

"Conceptual and 3D simulation modeling of the Sorgun hydrothermal reservoir (Yozgat, Turkey)", by E.Y. Turali and S. Simsek, pp. 85-100.

"Thermal geological model of the city of Guayaquil, Ecuador", by G. Soriano et al., pp. 101-109.

"Borehole thermal energy storage systems under the influence of groundwater flow and time-varying surface temperature", by A. Nguyen et al., pp. 110-118.

"On the impact of spatially heterogeneous permeability on free convection in the Perth Basin, Australia", by J. Niederau et al., pp. 119-133.

"System performance optimization of ORC-based geo-plant with R245fa under different geothermal water inlet temperatures, by X. Liu et al., pp. 134-142.

"Thermal conductivity and porosity maps for different materials: A combined case study of granite and sandstone", by S. Haffen et al., pp. 143-150.

"Calculations of environmental benefits from using geothermal energy must include the rebound effect", by R.S. Atlason and R. Unnthorsson, pp. 151-155.

"Fault-controlled development of shallow hydrothermal systems: Structural and mineralogical insights from the Southern Andes", by T. Roquer et al., pp. 156-173.

"Determination of vertical borehole and geological formation properties using the Crossed Contour Method", by B.P. Leyde et al., pp. 174-182.

"Corrigendum to 'Evaluation of common mixing models for calculating bulk thermal conductivity of sedimentary rocks: Correction charts and new conversion equations' [Geothermics 47 (2013) 40–52]", by S. Fuchs et al., pp. 183.

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*The Table of Contents for Geothermics Volume 67 follows:*

"Subsurface stratigraphy and its correlation with the surficial geology at Los Humeros geothermal field, eastern Trans-Mexican Volcanic Belt", by G. Carrasco-Núñez et al., pp. 1-17.

"A GIS-based multi criteria decision analysis approach for exploring geothermal resources: Akarcay basin (Afyonkarahisar)", by M. Yalcin and F.K. Gul, pp. 18-28.

"Short-term fluid temperature variations in either a coaxial or U-tube borehole heat exchanger", by D. Gordon et al., pp. 29-39.

"Use of tracers and temperature to estimate fracture surface area for EGS reservoirs", by G.M. Shook and A. Suzuki, pp. 40-47.

"Geothermal state of the deep Western Alpine Molasse Basin, France-Switzerland", by C. Chelle-Michou et al., pp. 48-65.

"Geothermal sea water desalination system (GSWDS) using abandoned oil/gas wells", by Y. Noorollahi et al., pp. 66-75.

"Evaluation of effective thermal conductivity of unsaturated granular materials using random network model", by C. Lee et al., pp. 76-85.

"Evaluation of inert tracers in a bedrock fracture using ground penetrating radar and thermal sensors", by A.J. Hawkins et al., pp. 86-94.

"Development of a new borehole probe for thermal conductivity scanning", by D. Saueret et al., pp. 95-101.

"Quantifying the variability of paleotemperature fluctuations on heat flow measurements", by A. Suman and D. White, pp. 102-113.

"A porothermoelastic solution for the inclined borehole in a transversely isotropic medium subjected to thermal osmosis and thermal filtration effects", by J. Gao et al., pp. 114-134.

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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.

Members can contact the publisher Elsevier at [JournalsCustomerServiceEMEA@elsevier.com](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.

Members can make their payment via bank transfer, fax their card details or call Elsevier with the information provided in their invoice.

The discounted price details for IGA/GRC members is \$285. ■



The GRC Library can be accessed at:  
[www.geothermal-library.org](http://www.geothermal-library.org)

## Transitions

### Letter from Jack Frost, President of Frost Consulting Group, Inc.



Greetings Everyone,  
Many people in the geothermal community are unaware that I have been battling an aggressive form of skin cancer since May 2016. I've elected to have a high risk surgery, but it will be several weeks before I can read and several months of recovery after that. The long term prognosis is a 25% survival rate after 5 years.

While my days of running rigs or commissioning downhole pumps and power plants are likely over, I intend to continue working as much as possible. We have been preparing for this worst case scenario for some time and Frost Consulting will continue to operate seamlessly. Tony Quevedo and Ricardo Paredes will oversee bids, field work, and engineering, and Wende Frost will continue in her role as CFO. In the event of my death, Wende will assume the role of CEO.

I would also be remiss if I didn't acknowledge the hard work and highly responsive support we receive from ITT Goulds -LA PRO shop, especially Todd Gerstenberger, Martha Fair, and Gary Jordan who collectively are responsible for building our geothermal pumps and products.

Please do not shed any tears over my current predicament. The geothermal industry has provided me with a rich and rewarding career for which I have always been grateful. This job has given me the opportunity to work with many people who I respect and consider not only colleagues, but lifelong friends and even family. I had an opportunity to be a pioneer in the industry and have no regrets. My only wish is that my family continue to be provided and that the business continues to thrive. It is still my wish to attend the upcoming GRC Annual Meeting and GEA tradeshow so I can personally thank my many friends in the industry.

P.S. For business inquiries or questions about installed equipment, please contact Ricardo and Tony directly:

Ricardo Paredes, Cell Phone (951) 202-2251, Email: [rparedes@frostconsultinggroup.net](mailto:rparedes@frostconsultinggroup.net)

Tony Quevedo, Cell Phone (909) 257-9186, Email: [tquevedo@frostconsultinggroup.net](mailto:tquevedo@frostconsultinggroup.net) ■

## This Just In...

### Late breaking news from the global geothermal community

by Ian Crawford, GRC Director of Communications

#### A Successful Meeting for Geothermal at Renewable Energy Conference



From left to right: GRC Board member **Kate Young**, GRC Executive Director **Steve Ponder** and GRC Board member **Dennis Kaspereit** at the GRC booth at the summit.

The GRC represented the global geothermal community at the **10th Annual Imperial Valley Renewable Energy and Water Summit** from March 15-17. Much of the discussions among renewable energy experts was focused on geothermal and how it can be utilized to save the shrinking Salton Sea and reduce carbon emissions in the Golden State.

**James H. Caldwell Jr.**, Project Manager for the Low Carbon Grid 2030 Study for the state of California stated that **Salton Sea geothermal is more valuable than solar PV** even if the transmission grid is made more flexible. More geothermal energy will need to be added to a diverse mix of renewables if the target of a 50% reduction of carbon emissions is to be met by 2030.

**Rod Colwell**, CEO, Controlled Thermal Resources (CTR) was much in demand at the summit, with attendees eager to hear of his plans for what could be a game-changing geothermal power project next to the Salton Sea. The CTR **Hell's Kitchen geothermal energy plant** would be located just 2.3 miles north-west of the John L. Featherstone plant on Mullet Island - no longer surrounded by



From left to right: **Jason Czapl** and **Jim Turner** of Controlled Thermal Resources joined GRC Board member **Dennis Kaspereit**, Vice President - Resource Management at Geothermal Resource Group, Inc., for a Geothermal 101 workshop for attendees.

water as the Salton Sea continues to shrink. Rod announced that **drilling will start for the triple-flash 2X140 MW project** in June and **commercial operation is expected by 2021**. CTR also hopes to partner with **Alger Alternative Energy** to mine **lithium** and other rare minerals from the geothermal brine.



**Rod Colwell**, CEO, Controlled Thermal Resources addresses the summit whilst (from right to left) moderator **Charlene Wardlow**, Geothermal Program Manager, CA Division of Oil, Gas and Geothermal Resources, **James H. Caldwell Jr.**, Project Manager for the Low Carbon Grid 2030 Study and **Martin Hermann**, CEO, 8minutenergy listen.

The summit was chosen as the venue for an important announcement concerning the plans for restoration of the Salton Sea. **Secretary John Laird**, California Secretary for Natural Resources, **Senator Ben Hueso** and **Assemblymember Eduardo Garcia**, both representing local districts, led a delegation on a day-trip from Sacramento to see at first hand the shrinking inland sea and hear about the health concerns of locals.

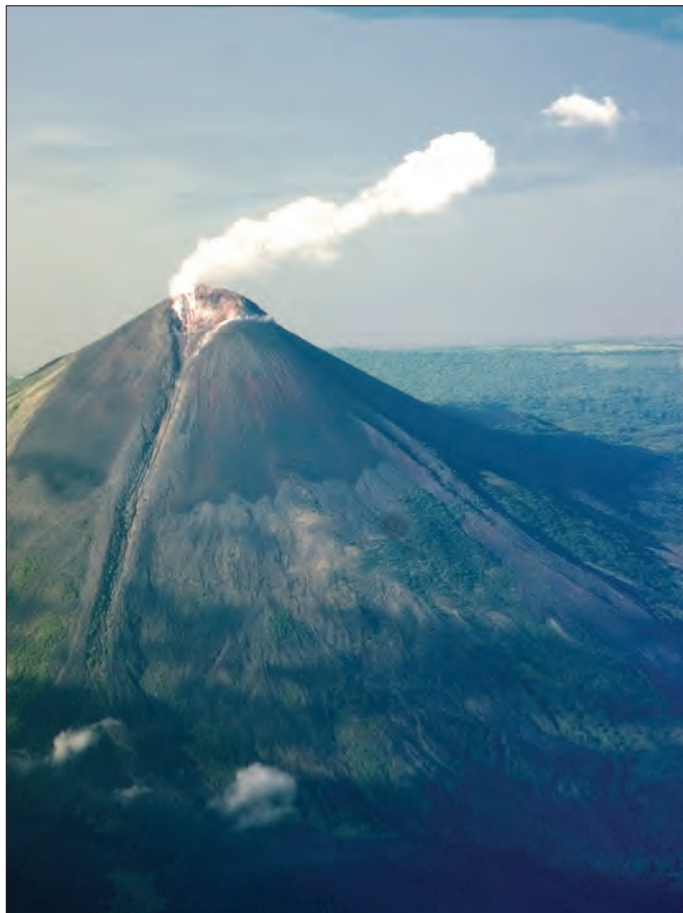


*This photo was taken from the EnergySource 55 MW John L. Featherstone geothermal power plant looking across the Niland mud volcanoes to the CalEnergy 38 MW Elmore geothermal power plant in the distance. Many more geothermal power plants could be seen from the Hudson Ranch I site. Vince Signorotti, Vice President, Resource & Real Estate Assets at EnergySource hosted a tour of the facility and said that a new 85 MW plant is in the works, together with a minerals extraction plant that would include valuable lithium.*

A USD 383 million plan was presented that lays out a schedule for building thousands of acres of ponds and wetlands that will cover up stretches of dusty lakebed and create habitat for birds as the lake recedes.

Assemblyman Eduardo Garcia, praised the plan but said questions remain to be answered about

the funding after the first four years and what role geothermal energy development could play as a funding source. ■



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# Calendar of Events

## 6th Annual Conference for the Development and Utilization of Geothermal Energy

26-29 March, Beijing, China

<https://geothermal.org/PDFs/CUGB-Call-for-Paper-2017.pdf>

## 24th Annual Congress of the Mexican Geothermal Association (AGM)

29-31 March, Morelia, Michoacán, Mexico

[www.geotermia.org.mx/geotermia/?page\\_id=1131](http://www.geotermia.org.mx/geotermia/?page_id=1131)

## Mexican Geothermal Opportunities Workshop

4 April, Institute of the Americas, La Jolla, California, USA

[www.iamericas.org](http://www.iamericas.org)

## Geothermal Cross Over Technology Workshop (AAPG)

25-26 April, Durham, United Kingdom

[www.aapg.org/global/europe/events/](http://www.aapg.org/global/europe/events/)

## Geothermal Congress For Latin America and the Caribbean - GEOLAC 2017

25-26 April, Mexico City, Mexico

<http://newenergyevents.com/geolac/>

## Euroheat & Power Congress

14-17 May, Glasgow, United Kingdom

[www.ehpcongress.org](http://www.ehpcongress.org)

## Geothermal Reservoir Engineering Short Course (IGA)

15-19 May, Bochum, Germany

[www.geothermal-energy.org/iga\\_academy/courses\\_and\\_workshops.html](http://www.geothermal-energy.org/iga_academy/courses_and_workshops.html)

## 1st EFG EuroWorkshop: Geothermal - the Energy of the Future (EFG/AGG)

18-19 May, Santorini, Greece

<http://eurogeologists.eu/santorini-2017>

## GeoEnergi 2017

22-23 May, Bergen, Norway

<http://cmr.no/courses-and-events/10688/geoenergi-2017/>

## IGC Turkey 2017

22-24 May, Izmir, Turkey

<http://igc-turkey.com>

## National Geothermal Academy - Module 1: Geothermal drilling engineering

19-23 June, Reno, Nevada, USA

[www.gbcge.org/education-NGA.php](http://www.gbcge.org/education-NGA.php)

## National Geothermal Academy - Module 2: Geothermal reservoir engineering

26-30 June, Reno, Nevada, USA

[www.gbcge.org/education-NGA.php](http://www.gbcge.org/education-NGA.php)

## Clean Power for the South Pacific Conference 2017

7-11 August, Vanua Levu, Fiji

[www.geothermalcities.com/en](http://www.geothermalcities.com/en)

## Praxisforum Geothermie

11-12 September, Munich, Germany

[www.praxisforum-geothermie.bayern/en](http://www.praxisforum-geothermie.bayern/en)

## DGK 2017 - Der Geothermiekongress 2017

12-14 September, Munich, Germany

[www.geothermie.de](http://www.geothermie.de)

## GRC Annual Meeting & GEA GeoExpo+

1-4 October, Salt Lake City, Utah, USA

[www.geothermal.org/meet-new.html](http://www.geothermal.org/meet-new.html) ■

# In Memoriam

## John H. Sass

20 July 1937 – 16 January 2017



John H Sass, who spent his life working in heat flow and geothermal energy, a friend and colleague (USGS) of many in the United States, Canada and throughout the world, passed away on January 16, 2017, at the age of 79.

A memorial celebration will be held in the spring at John's Canadian residence, details later in *The London Free Press* (Canada). Please consider a donation reflecting John's concerns to Doctors Without Borders (MSF), climate change control, animal welfare and nature conservancy. Memories and condolences may be shared with the family at [www.pollockrandall.com](http://www.pollockrandall.com).

(Thanks to Paul Morgan, Ph.D. of the Colorado Geological Survey, Colorado School of Mines for the information) ■



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## GEA GEOEXPO+

Entry to the trade show is free with GRC Annual Meeting registration.

More information at [www.geothermalenergy2017.org](http://www.geothermalenergy2017.org)

**Note:** All events are a work in progress and may change at any time.

**Get the latest news on the geothermal event of the year at [www.geothermal.org](http://www.geothermal.org)**

## DEADLINES

**April 28** – Draft Paper Submission

**August 18** – GRC Amateur Photo Contest

**September 5** – Discounted hotel room block expires



# 41st GRC ANNUAL MEETING & GEA GEOEXPO+

Salt Lake City, Utah • USA  
October 1-4, 2017

# National Geothermal Academy 2017

## Module 1: Geothermal drilling engineering

19th – 23rd June 2017 (M - F, 8:30 – 4:30pm)

Instructor: Bill Rickard, Geothermal Resource Group

## Module 2: Geothermal reservoir engineering

26th – 30th June 2017 (M - F, 8:30 – 4:30pm)

Instructor: Prof. Roland Horne, Stanford University

- Open to outstanding undergraduate and graduate students, and professionals. International applicants welcomed.
- All classes to be held at the University of Nevada, Reno (UNR) Redfield Campus  
Course cost: USD\$2000 per module
- UNR campus accomodation option ~USD\$500 per week
- For more information, see: [www.gbcge.org/education-NGA.php](http://www.gbcge.org/education-NGA.php)  
or email [geothermal@unr.edu](mailto:geothermal@unr.edu)

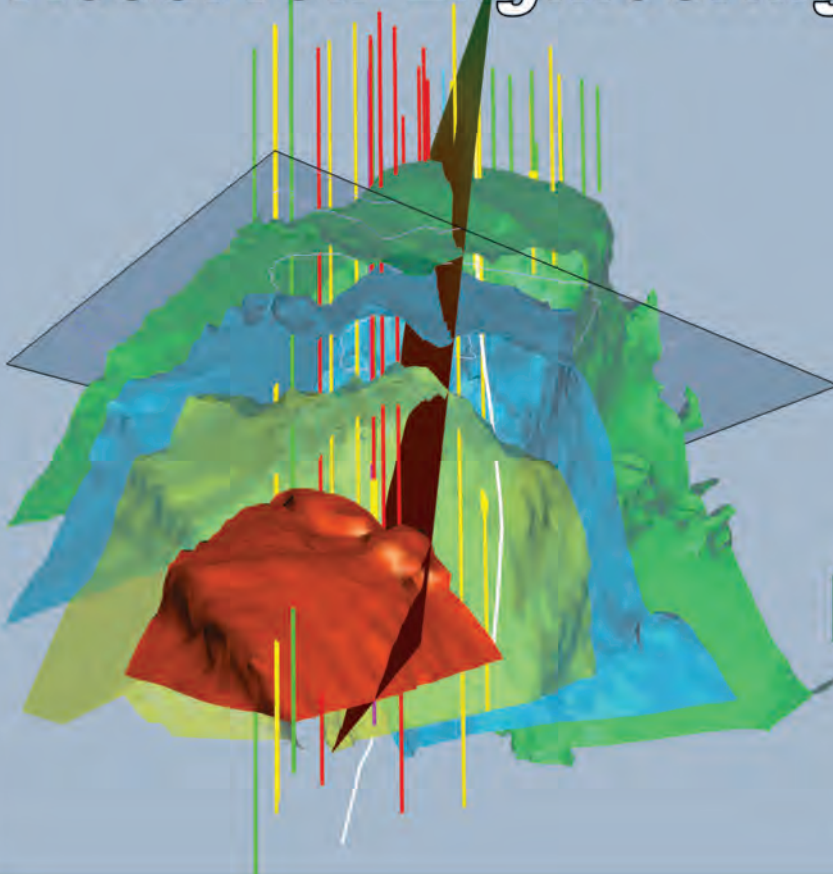


National Geothermal Academy  
University of Nevada, Reno



University of Nevada, Reno

## *Reservoir Engineering*



- Conceptual Modeling
- Numerical Simulation
- Well Bore Modeling
- Resource Assessment
- Development Economics
- Bank Feasibility



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