Constructing a Geothermal Test Facility to Demonstrate and Scale Geothermal Technologies

Wells2Watts

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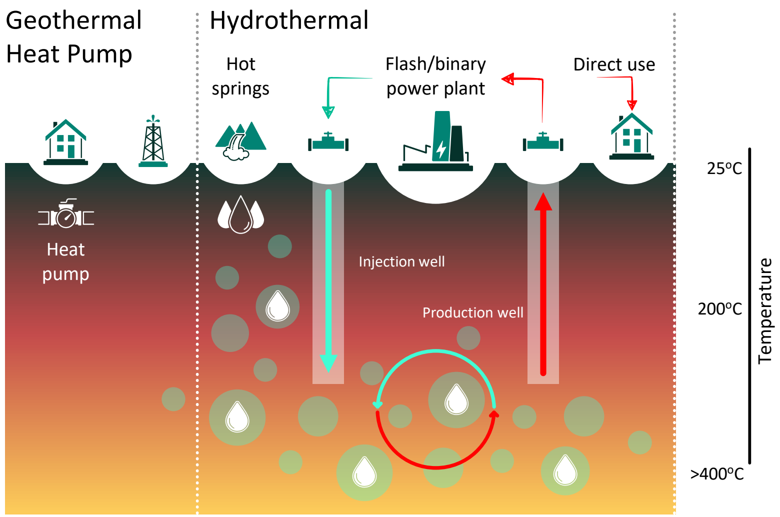
Geothermal is available anywhere with the right technology

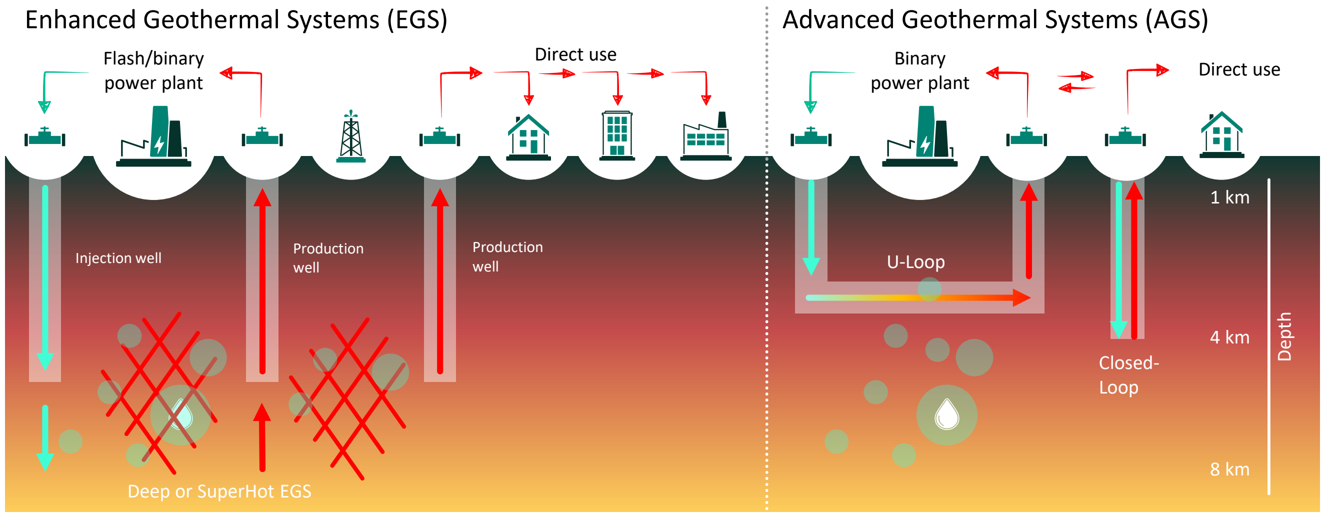
Conventional



✓ Sufficient access to natural hot brine

Successful hydrothermal industry. Geographically limited to areas with natural underground reservoirs

Unconventional



✓ Access to hot rock but insufficient permeability or fluid saturation. Engineered reservoirs, injecting fluid into the subsurface, or using closed-loop.

Less geographic restrictions allowing for geothermal expansion and growth – ultimately geothermal anywhere

Installed Power of ~16 GW (ThinkGeoEnergy, 2022)

Conventional Power Potential of ~200 GW (S&P 2022)

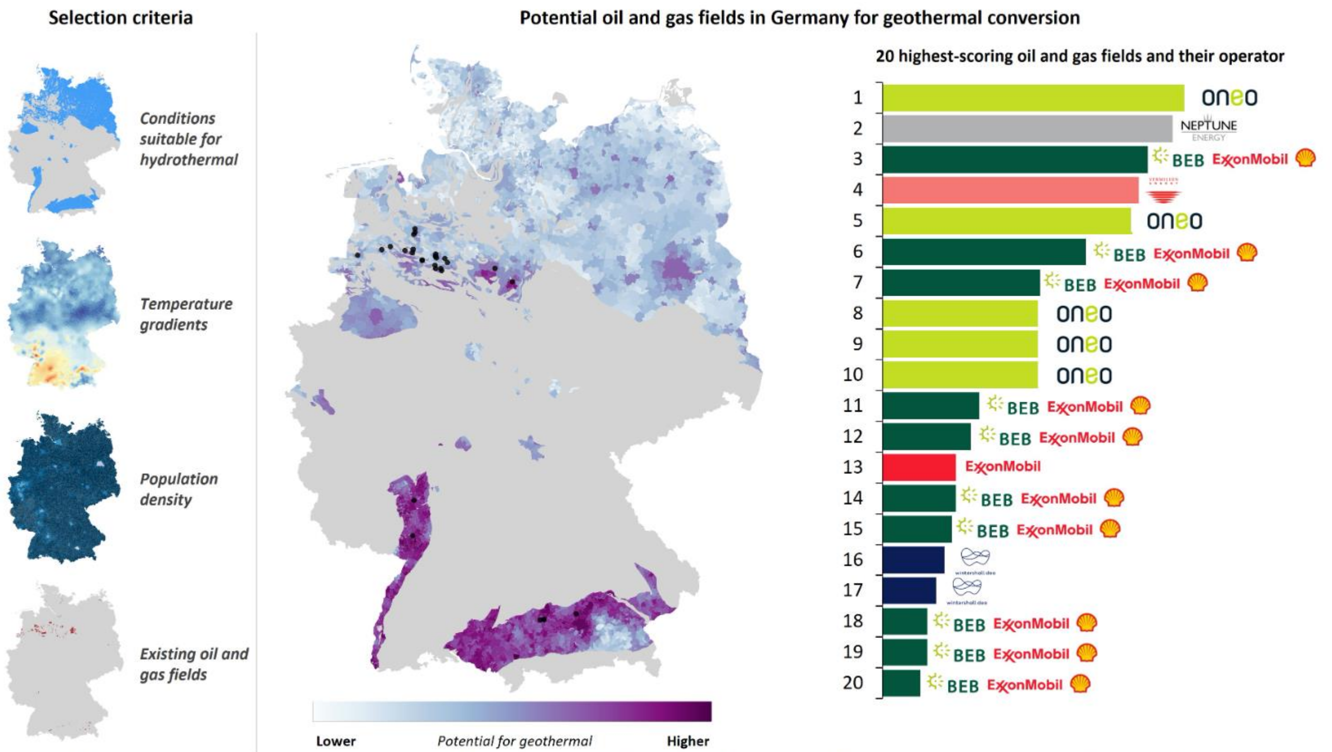
Unlimited Potential of Geothermal Anywhere

Leveraging O&G Infrastructure and AGS technology

- The heating market, primarily driven by district heating projects, accounts for close to 23 gigawatts thermal (GWt) of installed capacity today.
- Globally, we expect the active installed base of geothermal heating projects to exceed 25 GWt in 2024, with the heat being harnessed via close to 10,000 active production and injection wells.
- In certain locations around Europe existing O&G wells could serve a purpose to be reused for district heating demand using AGS technology. Saving $Millions without having to drill new wells for geothermal in these areas.

Source Rystad

Figure 8: Growth area – geothermal built on the oil and gas legacy

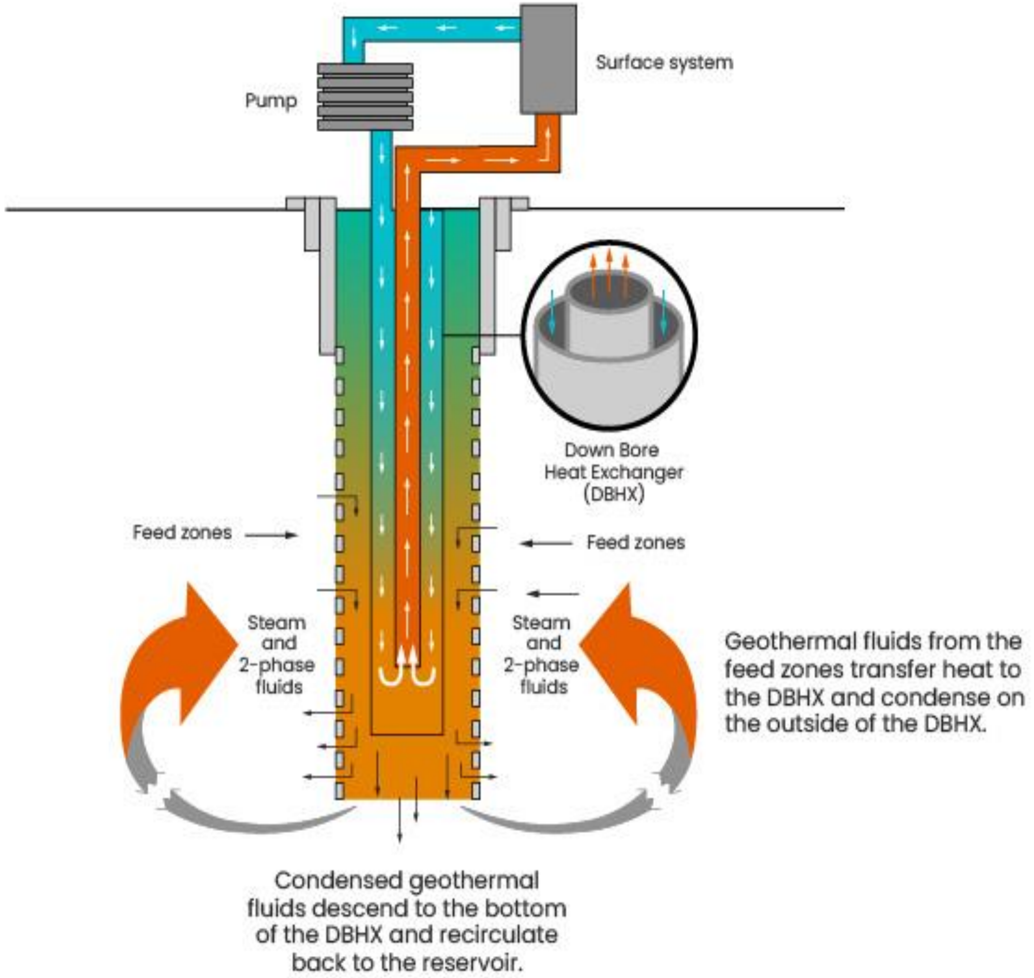


Source: Conditions suitable for geothermal from Schulz and Knopf (2013), gradients partially from Thorsten Agemar and LIAG; Rystad Energy Geothermal Solution; Rystad Energy

Baker Hughes

Steam and Two-Phase Green Loop example for pilot evaluation.

- Typically has a tube-in-tube Downbore Heat Exchanger (DBHX)
- Can use various working fluids (including ORC fluids)
- Hot working fluid to surface systems at targeted pressure to ORC or conventional surface systems
- Condensation occurs on the DBHX releasing the latent heat of vaporization, descends and returns to the reservoir
- Working fluid temp control sets saturation temp and pressure that can avoid deposition and scaling



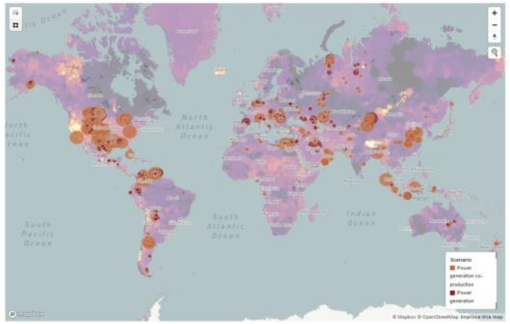
De-risking and Deploying Closed-Loop Technology

Existing Geothermal Wells

GreenFire Energy®

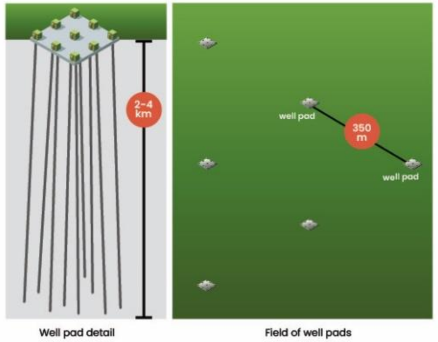
- California Energy Commission awards $2.7 M Project to demonstrate steam and 2 phase GreenLoop (S2PGL)
- Produce heat (not water) to surface to ensure long-term sustainable electricity production without reservoir pressure decline
- Optimize the working fluid type to ensure minimum parasitic pumping load to maximize net electric power
- Operate the DBHX so that working fluid flow to surface matches existing surface systems

Oil and Gas Wells



- Group exploring technology to convert and retrofit oil and gas wells for geothermal energy, revitalize dry non-productive geothermal wells and develop greenfield opportunities for geothermal renewable electricity production
- Retrofitting even a small portion of the tens of millions of abandoned O&G wells is a huge market and avoid plug & abandon costs

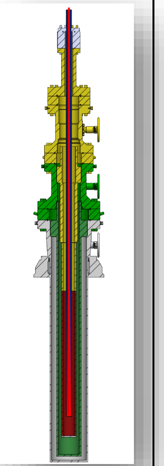
Greenfield Deployment



- No consumptive use of water, and ground water table is protected
- Dedicated On-Site (Zero Emission Load Following Renewable)
- Supply of base & peak load power
- Supply of heat to base if needed
- Micro Grid Enabled
- Island-Mode & Black-Start Capable
- Predictable & Competitive Electricity Pricing that includes Resiliency

Testing site in Oklahoma

WELLS 2 WATTS
A GEOTHERMAL CONSORTIUM



- Wells2Watts consortium is a private industrial partnership between Baker Hughes, Continental Resources, INPEX and Chesapeake Energy Corporation
- Additional support from technology providers includes Vallourec and GreenFire Energy to develop a first-ever closed loop geothermal test facility

Baker Hughes launches consortium exploring technologies to transform abandoned wells for geothermal energy production

December 8, 2022

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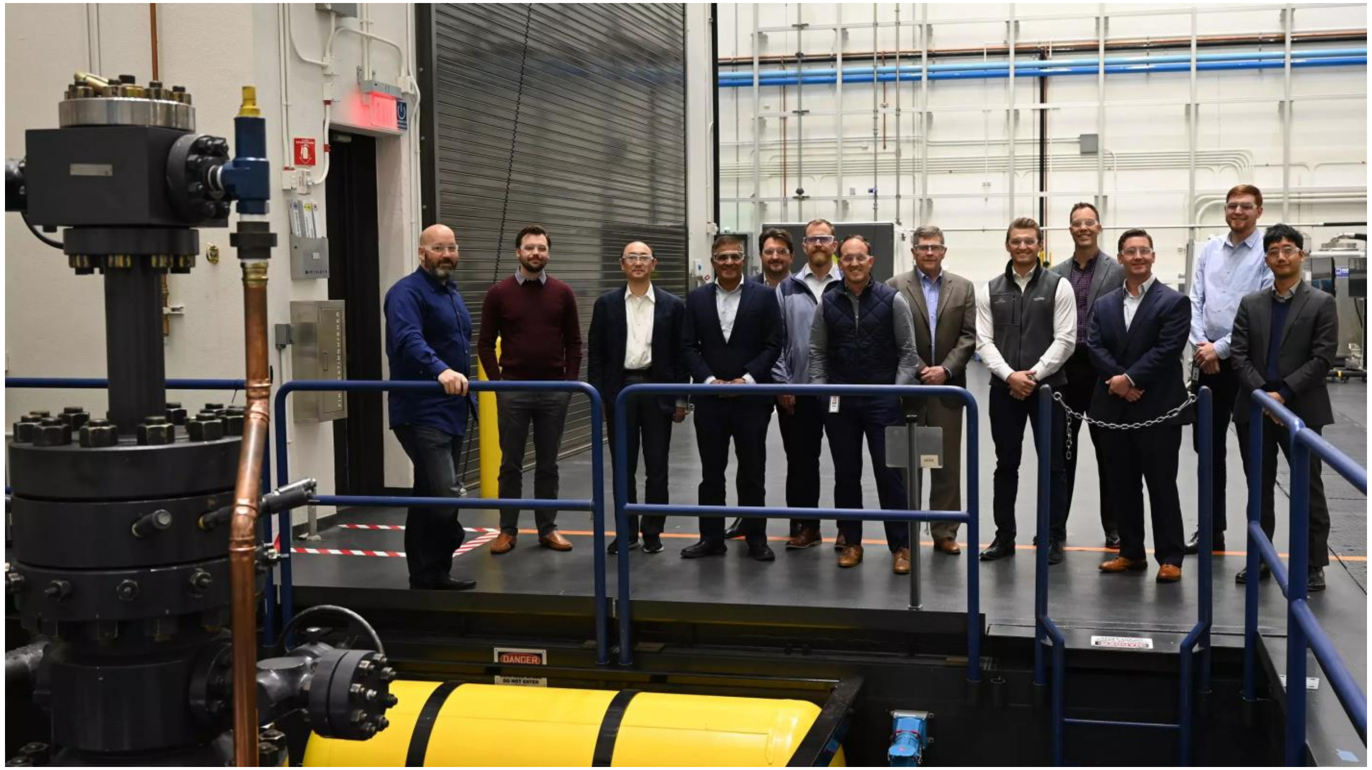
•Group exploring technology to convert and retrofit oil and gas wells for geothermal energy, revitalize dry non-productive geothermal wells and develop greenfield opportunities for geothermal renewable electricity production

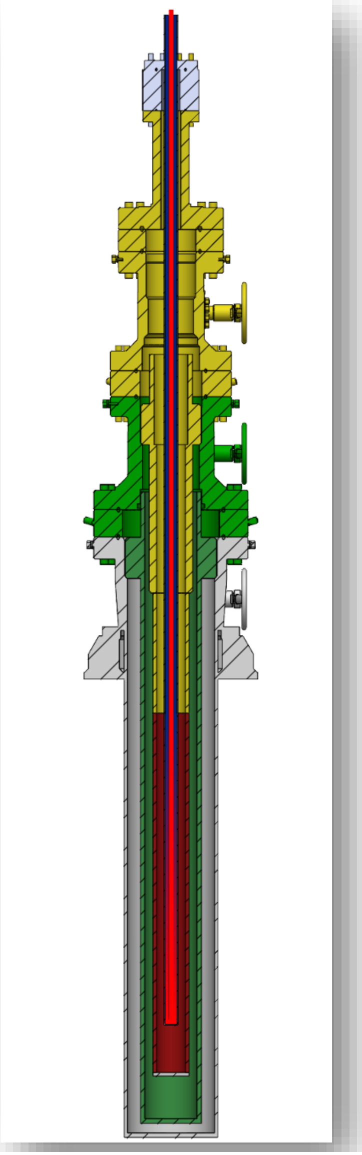
•Additional support from technology providers includes Vallourec and GreenFire Energy to develop a first-ever closed loop geothermal test facility in the world at the Hamm Institute for American Energy in Oklahoma City

•New Technology Members Advanced Thermovoltaic Systems and ICE Thermal Harvesting for Waste Heat Recovery.



Test set up for Design of Experiments

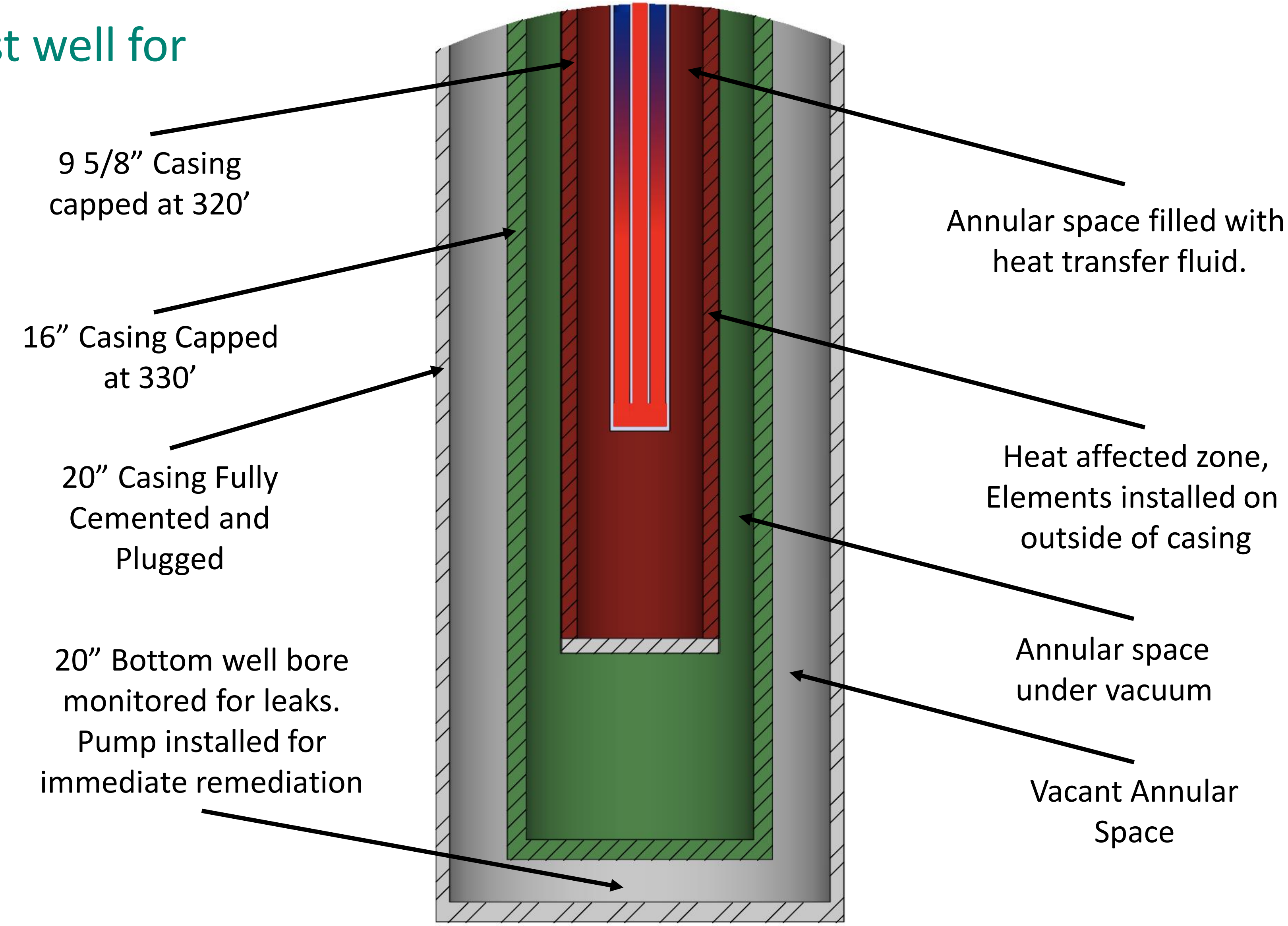
- Testing Parameters to measure
  - Flowrates, Pressure, Temperature, Working Fluid (Water and Hydrocarbon)
- Available Casing for Reservoir Testing
  - 9 5/8
  - 7 ½
- Temperature
  - 350F at wellhead
  - 450F design downhole
- Pressure capacity of wellbore
  - 5000 psi
- Flowrates
  - variable gpm of process fluid
- Power
  - Heating elements
- Cooling
  - Chilled water loop



Project 1: Creation of a 750kW Test well for Closed loop Geothermal Testing

Retrofit Well Designs

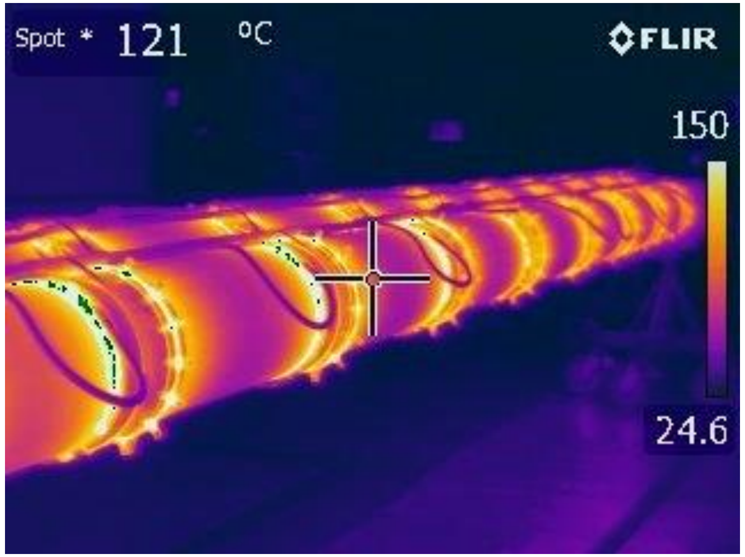
- 20” Casing is drilled out to 400’ deep, fully cemented, plugged and monitored to ensure no communication with water supply.
- 16’ casing is 330’ long and is capped. The annulus space inside of the casing is pulled under vacuum during the testing to prevent convective heat transfer
- 9 5/8” Casing is installed to 320’ with 90 coiled tube heaters installed every three feet to allow for heating. A heat transfer fluid will be installed into the annulus and its level monitored.

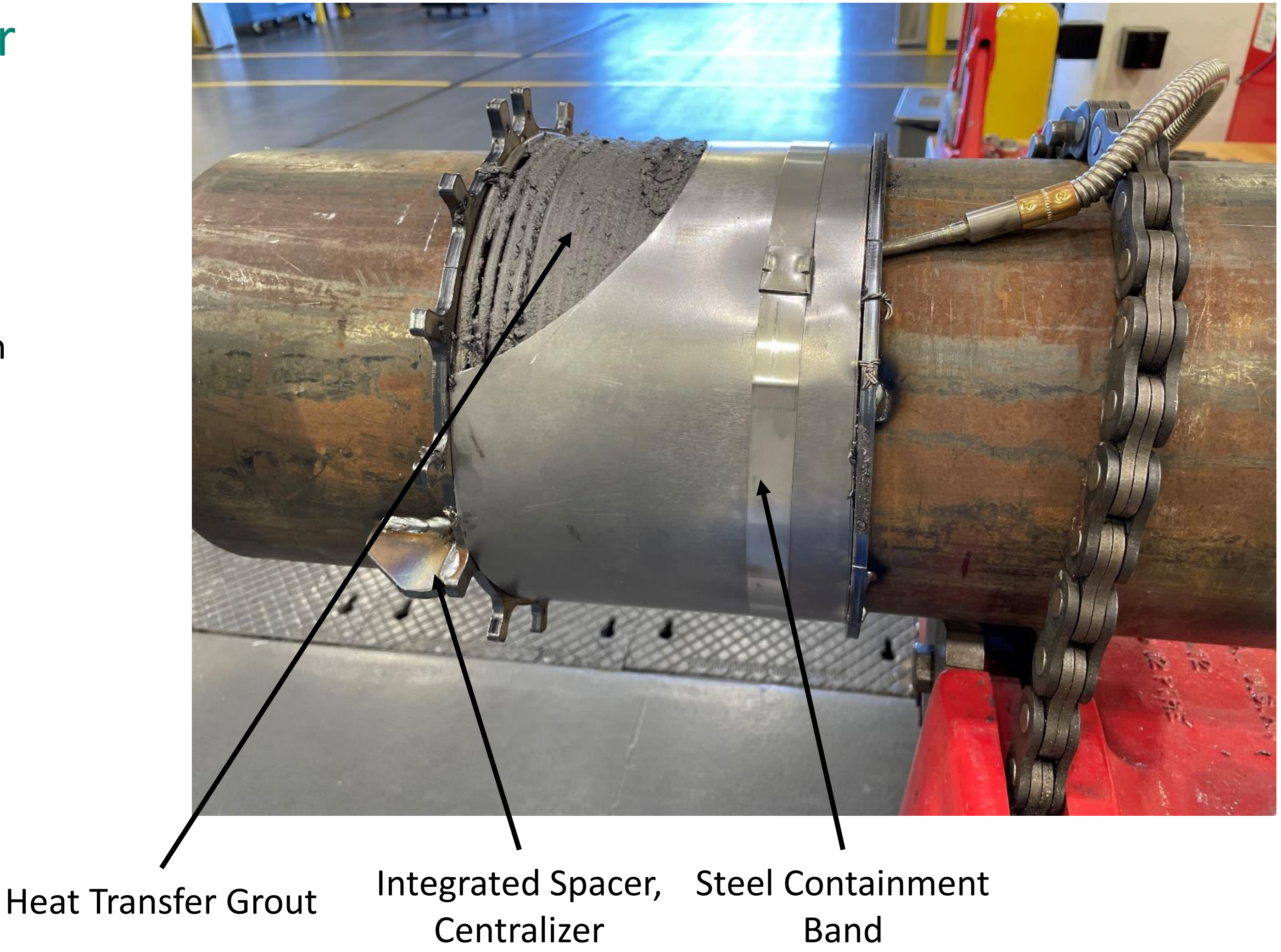


Project 1: Creation of a 750kW Test well for Closed loop Geothermal Testing

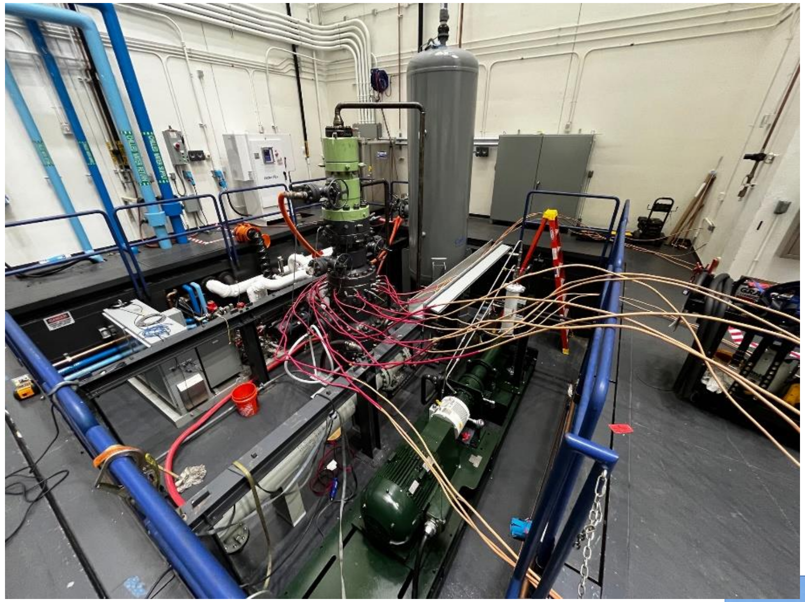
Heaters

- 90 x 8.3kW Stainless Steel Tube heaters
- Installed on 10 joints of 30’ 9 5/8 casing
- 18 heaters tied together in a three phase delta configuration to make up a control zone.
- 5 control zones in total for the well, each having 4 temperature measurements





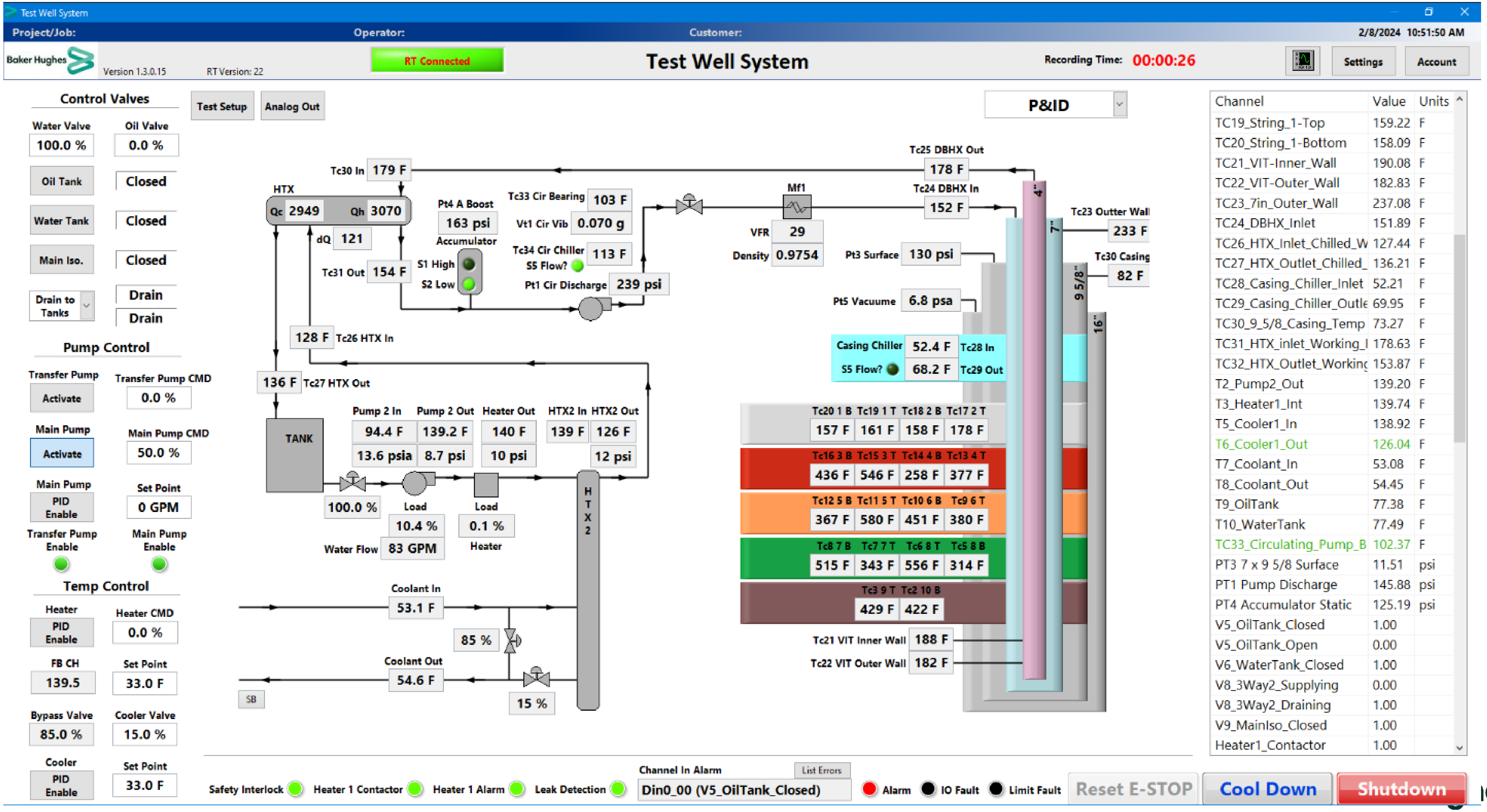
Testing of Organic Rankine Cycle with Closed Loop Well



GreenLoop Testing with ORC

- Installation requirements and guide
- ICE Thermal Harvesting to provide a half day workshop on ORC system to members and applications
- Performance Report and presentation
  - Processed Data including key insights or takeaways on performance from different Closed Loop Geothermal Tests with the ORC Equipment
  - Original Test Data upon request*
  - Operational Testing and Power curves report
- Engineering considerations at customer test sites for set up and installation (future considerations for lab testing)

Test Well Up and Running!



Test Well Up and Running!

2024 Pilot Opportunities

Direct Use for District Heating

250 kWth – 750 kWth

- Modeled retrofit of 9 5/8” Well
- Well depth 3000m
- Temperature is 125C
- Surface Temp is 5C
- Thermal Conductivity varies 2-3.5 W/m*K based on lithology
- Next to existing district Heating Plant and network
- Permeability and aquifer flow impact overall performance

LCOH $50-$85 MWth

Power Generation Opportunity

100 kWe – 200 kWe

- Next to warehouse unit that needs reliable offtake along with current solar at site
- Wells are up to 400F
- Well Depth of 2500ft-3000ft
- Field currently has 2000+ wells on site with long production history
- Use modular ORC units and distribution to site for behind the meter application

LCOE $0.12 kWe

Direct Use for Direct Air Capture

1 MWth -2 MWth

- Geothermal offers low carbon solution for DAC
- Electric load: ~2.06 MWh/tonne CO_2
- Electric load offset with heat
- Heat is directly used in the process for desorption
- Offers a viable solution when integrated with power from wind/solar
- Wells are 300F-400F

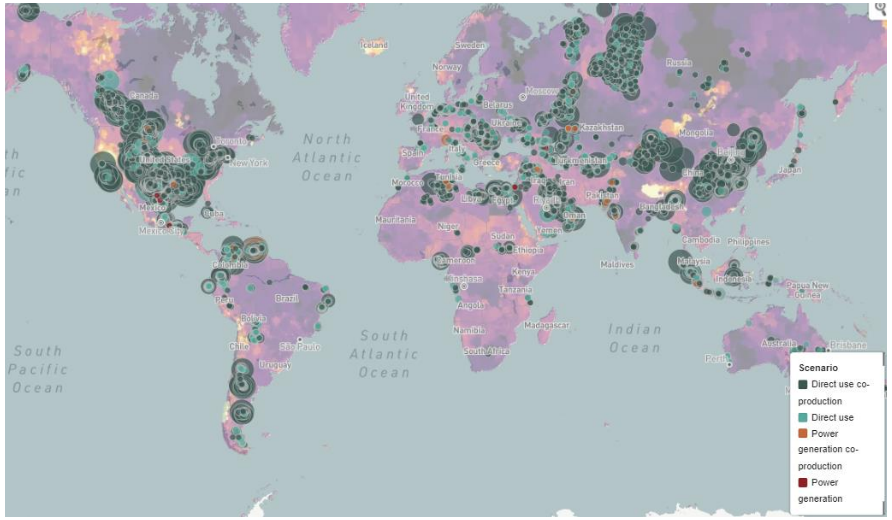
LCOH $5-$25 MWth

Baker Hughes

Retrofits will enable geothermal use in New Growth Markets

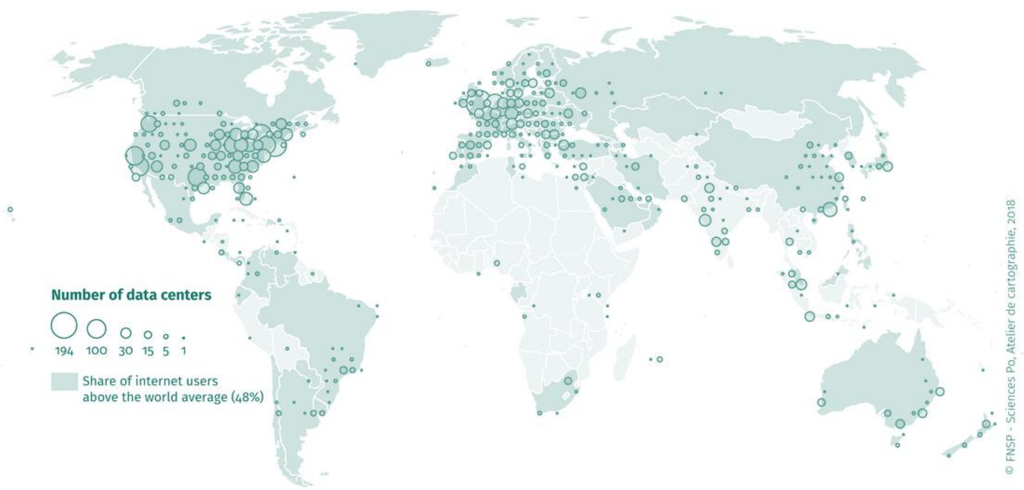
* Other Key Areas Include Hydrogen, Direct Air Capture, and Industrial Heating

1M+ O&G Wells for Repurposing to Geothermal



800+ US Military Bases for government contracts

4000+ Data Centers - consume 1-5MW (s) to 20-100+MW (large)



10,000+ Warehouses and Fulfillment Centers