

# Constructing a Geothermal Test Facility to Demonstrate and Scale Geothermal Technologies

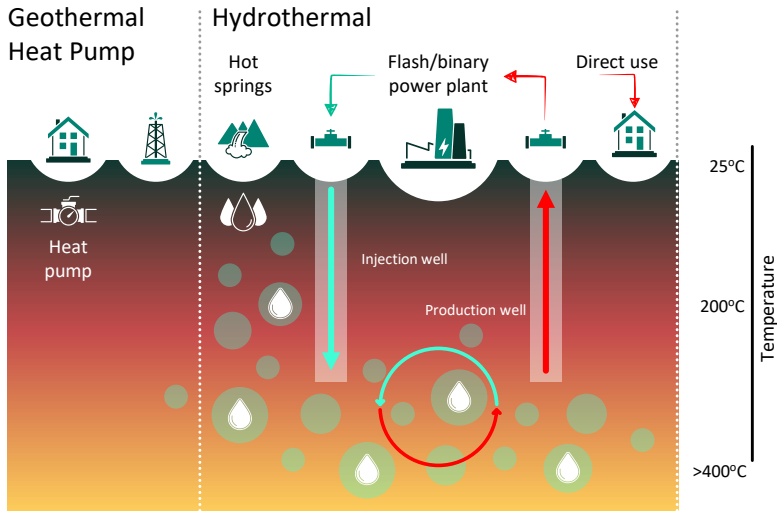
Wells2Watts

Rob Klenner – Director, Geothermal Technology & Innovation

Francesco di Credico – Geothermal Global Sales & Commercial Leader

# Geothermal is available anywhere with the right technology

## Conventional

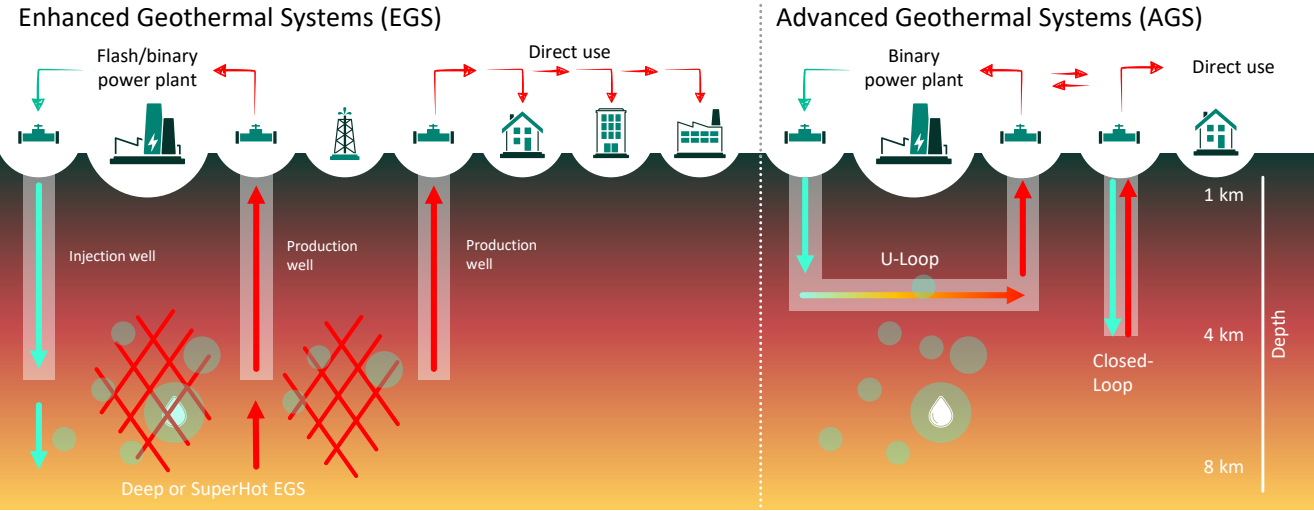


- ✓ Sufficient access to natural hot brine
- 🌐 Successful hydrothermal industry. Geographically limited to areas with natural underground reservoirs

Installed Power of ~16 GW  
(ThinkGeoEnergy, 2022)

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

## 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

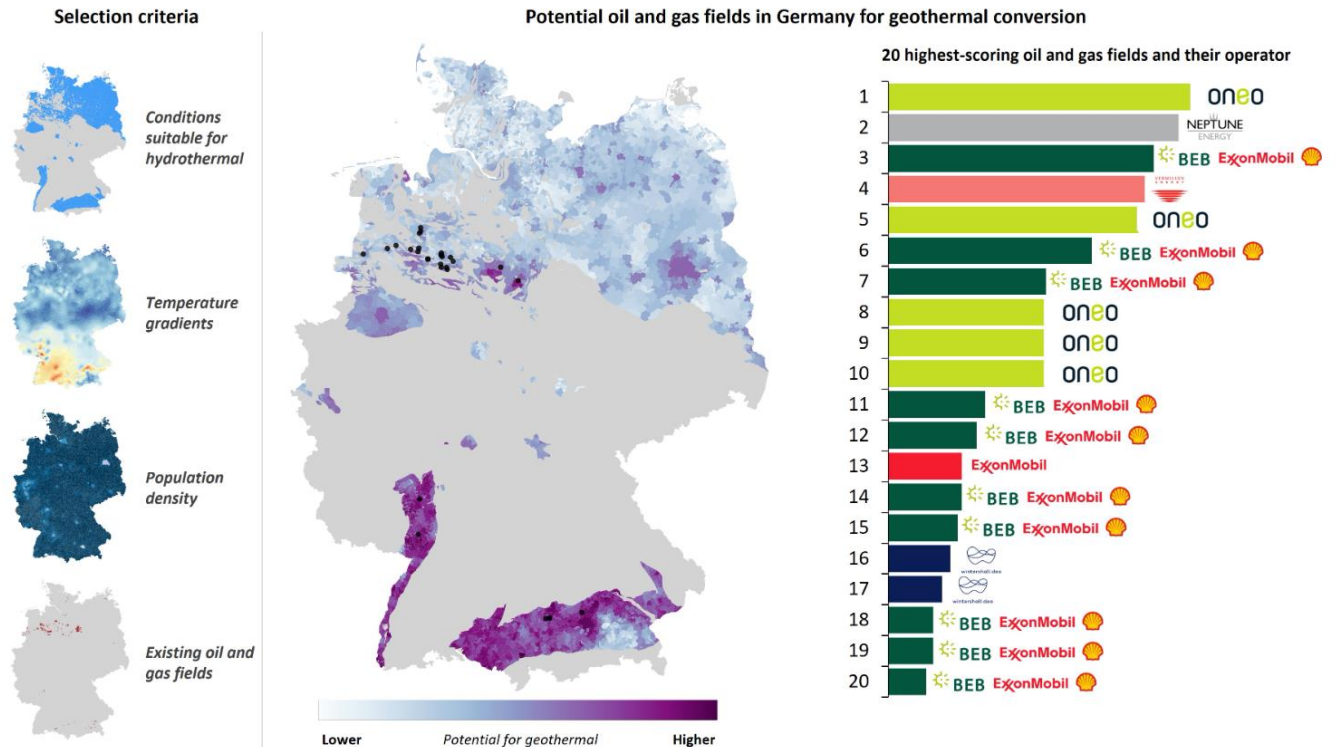
Unlimited Potential of Geothermal Anywhere

# 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

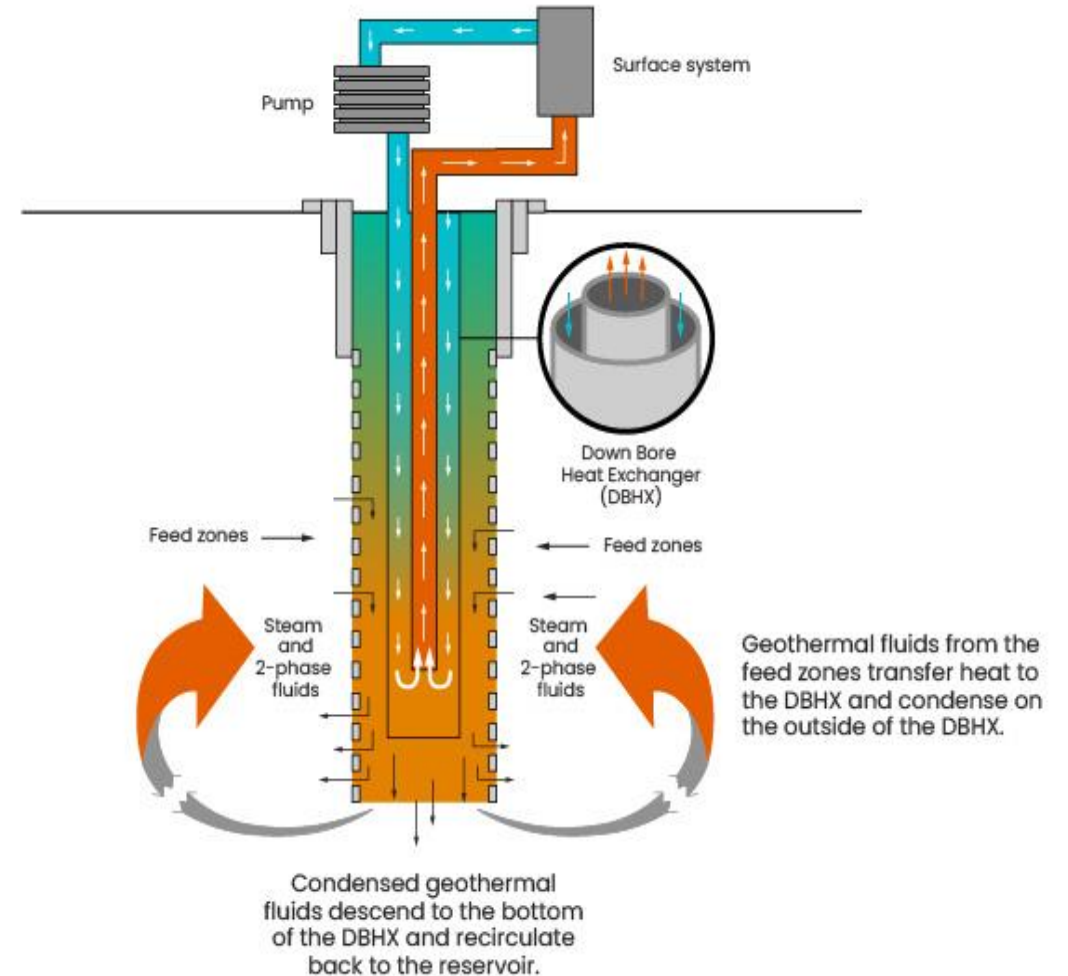
Figure 8: Growth area – geothermal built on the oil and gas legacy



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

## 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



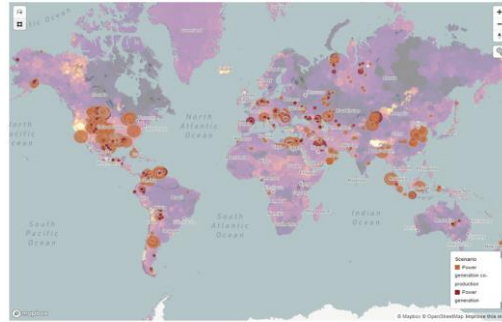
# De-risking and Deploying Closed-Loop Technology

## Existing Geothermal Wells



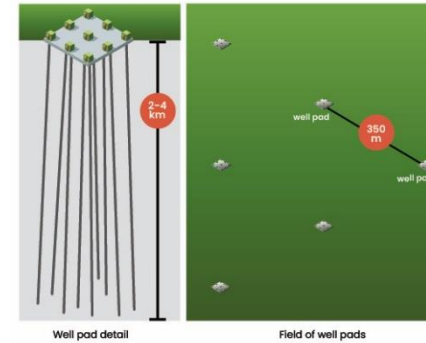
- California Energy Commission awards \$2.7 M Project to demonstrate steam and 2 phase GreenLoop (S2PGL)
- Produce heat (not water) to surface to ensure long-term sustainable electricity production without reservoir pressure decline
- Optimize the working fluid type to ensure minimum parasitic pumping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

## Oil and Gas Wells



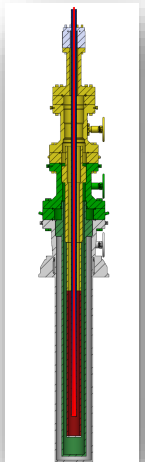
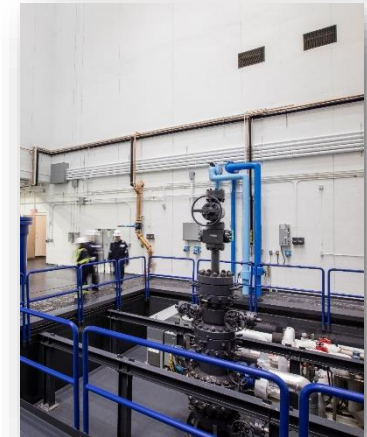
- Group exploring technology to convert and retrofit oil and gas wells for geothermal energy, revitalize dry non-productive geothermal wells and develop greenfield opportunities for geothermal renewable electricity production
- Retrofitting even a small portion of the tens of millions of abandoned O&G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



- 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

Baker Hughes

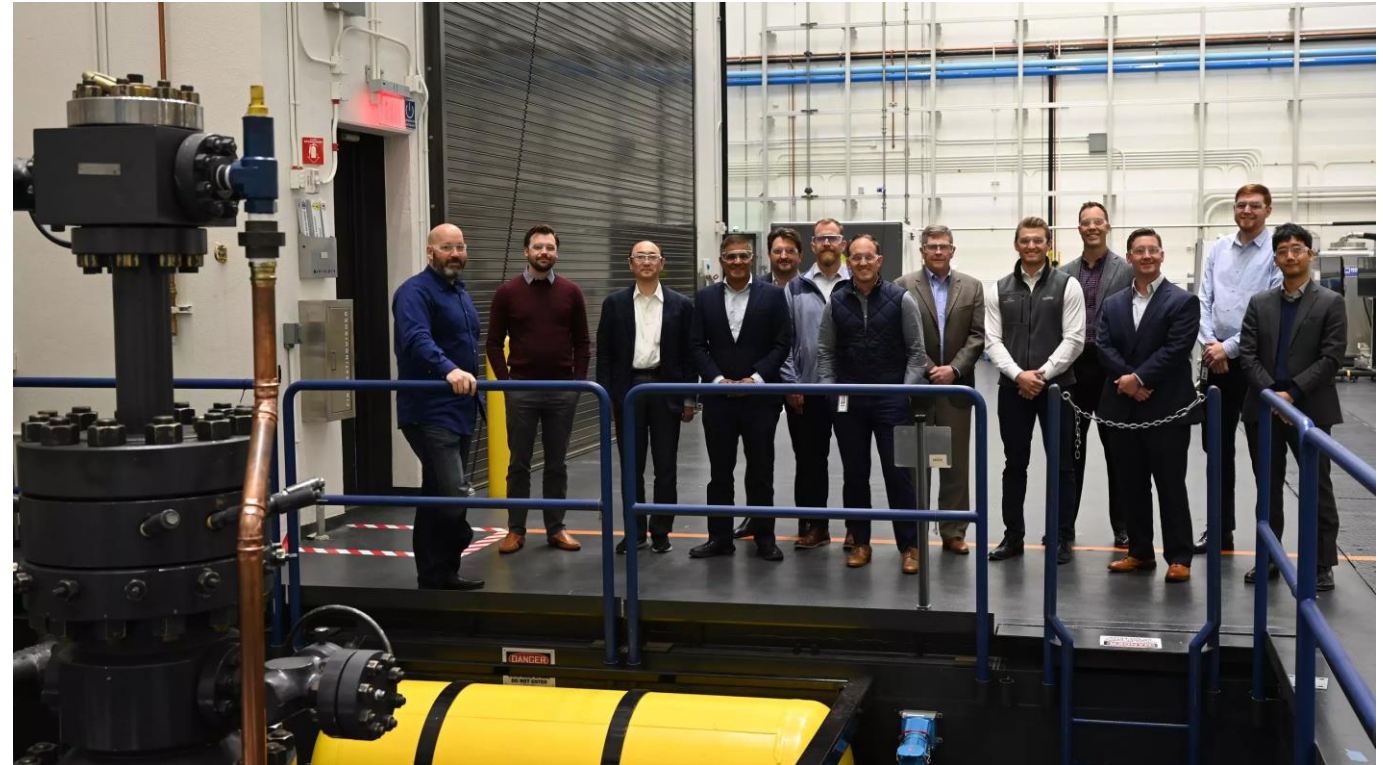
CALIFORNIA  
RESOURCES  
CORPORATION

Continental  
RESOURCES

INPEX

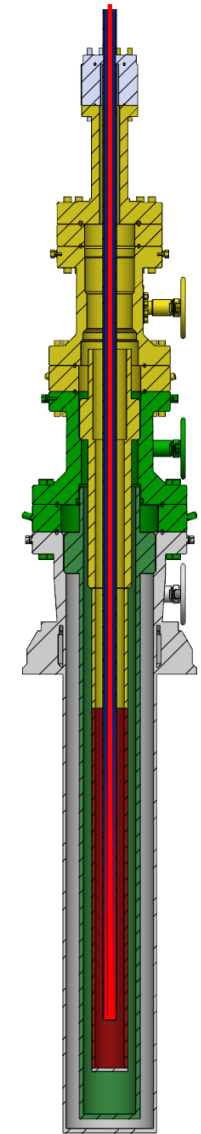
CHESAPEAKE  
ENERGY

- Wells2Watts consortium is a private industrial partnership between Baker Hughes, Continental Resources, INPEX and Chesapeake Energy Corporation
- 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

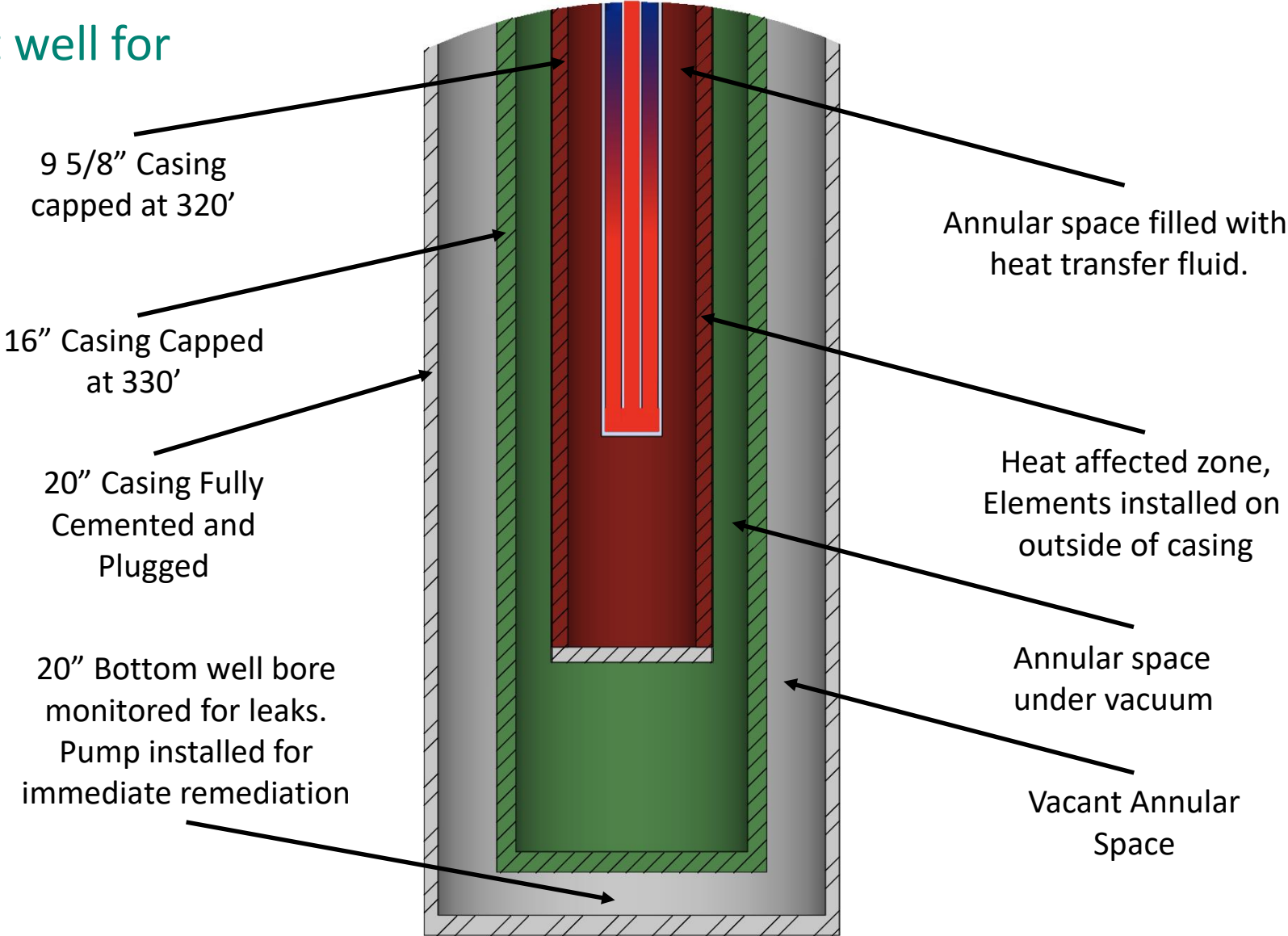
- Testing Parameters to measure
  - Flowrates, Pressure, Temperature, Working Fluid (Water and Hydrocarbon)
- Available Casing for Reservoir Testing
  - 9 5/8
  - 7 1/2
- Temperature
  - 350F at wellhead
  - 450F design downhole
- Pressure capacity of wellbore
  - 5000 psi
- Flowrates
  - variable gpm 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.

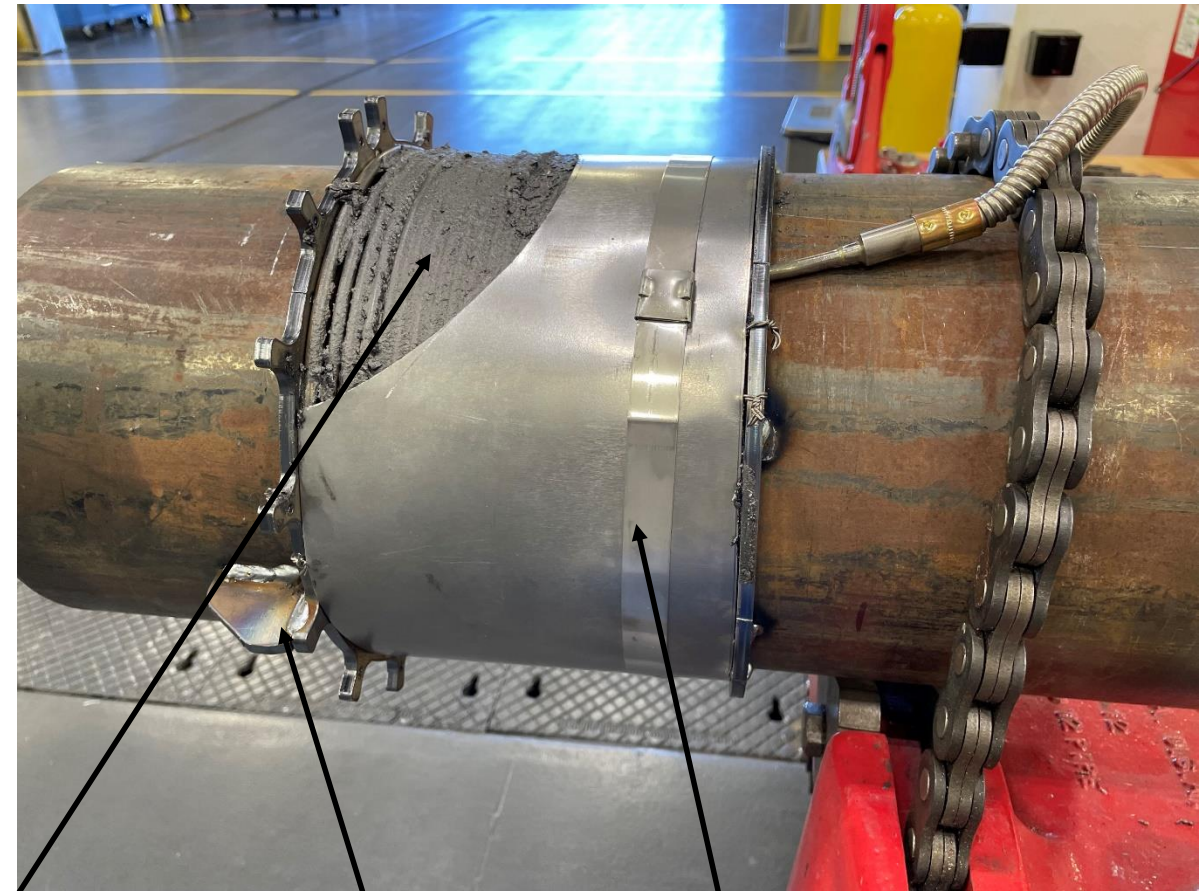
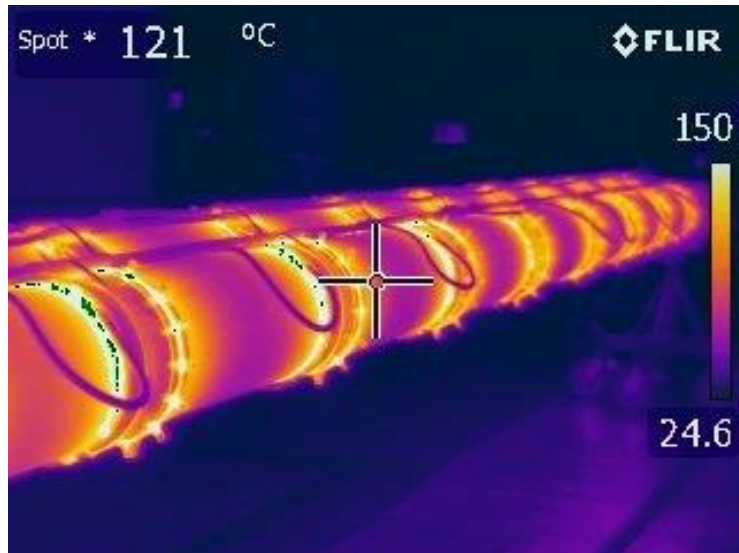




# Project 1: Creation of a 750kW Test well for Closed loop Geothermal Testing

## 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



Heat Transfer Grout      Integrated Spacer, Centralizer      Steel Containment Band

# 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 System
Operator:
Customer:
2/8/2024 10:51:50 AM

Baker Hughes Version 1.3.0.15 RT Version: 22
RT Connected
Test Well System
Recording Time: 00:00:26
Settings Account

### Control Valves

Water Valve	Oil Valve
<span style="border: 1px solid black; padding: 2px;">100.0 %</span>	<span style="border: 1px solid black; padding: 2px;">0.0 %</span>
Oil Tank	<span style="border: 1px solid black; padding: 2px;">Closed</span>
Water Tank	<span style="border: 1px solid black; padding: 2px;">Closed</span>
Main Iso.	<span style="border: 1px solid black; padding: 2px;">Closed</span>
Drain to Tanks	<span style="border: 1px solid black; padding: 2px;">Drain</span>
	<span style="border: 1px solid black; padding: 2px;">Drain</span>

### Pump Control

Transfer Pump	Transfer Pump CMD
<span style="border: 1px solid black; padding: 2px;">Activate</span>	<span style="border: 1px solid black; padding: 2px;">0.0 %</span>
Main Pump	Main Pump CMD
<span style="border: 1px solid black; padding: 2px;">Activate</span>	<span style="border: 1px solid black; padding: 2px;">50.0 %</span>
Main Pump PID Enable	Set Point
<span style="border: 1px solid black; padding: 2px;">Enable</span>	<span style="border: 1px solid black; padding: 2px;">0 GPM</span>
Transfer Pump Enable	Main Pump Enable
<span style="border: 1px solid black; padding: 2px;">Enable</span>	<span style="border: 1px solid black; padding: 2px;">Enable</span>

### Temp Control

Heater	Heater CMD
<span style="border: 1px solid black; padding: 2px;">Enable</span>	<span style="border: 1px solid black; padding: 2px;">0.0 %</span>
FB CH	Set Point
<span style="border: 1px solid black; padding: 2px;">139.5</span>	<span style="border: 1px solid black; padding: 2px;">33.0 F</span>
Bypass Valve	Cooler Valve
<span style="border: 1px solid black; padding: 2px;">85.0 %</span>	<span style="border: 1px solid black; padding: 2px;">15.0 %</span>
Cooler	Set Point
<span style="border: 1px solid black; padding: 2px;">Enable</span>	<span style="border: 1px solid black; padding: 2px;">33.0 F</span>

P&ID

Channel	Value	Units
TC19_String_1-Top	159.22	F
TC20_String_1-Bottom	158.09	F
TC21_VIT-Inner_Wall	190.08	F
TC22_VIT-Outter_Wall	182.83	F
TC23_7in_Outter_Wall	237.08	F
TC24_DBHX_Inlet	151.89	F
TC26_HTX_Inlet_Chilled_W	127.44	F
TC27_HTX_Outlet_Chilled_	136.21	F
TC28_Casing_Chiller_Inlet	52.21	F
TC29_Casing_Chiller_Outle	69.95	F
TC30_9_5/8_Casing_Temp	73.27	F
TC31_HTX_inlet_Working_I	178.63	F
TC32_HTX_Outlet_Working	153.87	F
T2_Pump2_Out	139.20	F
T3_Heater1_Int	139.74	F
T5_Cooler1_In	138.92	F
T6_Cooler1_Out	126.04	F
T7_Coolant_In	53.08	F
T8_Coolant_Out	54.45	F
T9_OilTank	77.38	F
T10_WaterTank	77.49	F
TC33_Circulating_Pump_B	102.37	F
PT3 7 x 9 5/8 Surface	11.51	psi
PT1 Pump Discharge	145.88	psi
PT4 Accumulator Static	125.19	psi
V5_OilTank_Closed	1.00	
V5_OilTank_Open	0.00	
V6_WaterTank_Closed	1.00	
V8_3Way2_Supplying	0.00	
V8_3Way2_Draining	1.00	
V9_MainIso_Closed	1.00	
Heater1_Contactor	1.00	

Safety Interlock ●
Heater 1 Contactor ●
Heater 1 Alarm ●
Leak Detection ●

Channel In Alarm List Errors
Din\_00 (V5\_OilTank\_Closed)

● Alarm
 ● IO Fault
 ● Limit Fault
 Reset E-STOP
Cool Down
Shutdown

Baker Hughes Confidential

# Test Well Up and Running!

Test Well System

Project/Job: \_\_\_\_\_ Operator: \_\_\_\_\_ Customer: \_\_\_\_\_ 2/8/2024 12:39:20 PM

Baker Hughes Version 1.3.0.15 RT Version: 22 **RT Connected** Test Well System Recording Time: 01:47:57 Settings Account

## Control Valves

Water Valve: 100.0 %  
Oil Valve: 0.0 %

Oil Tank: Closed  
Water Tank: Closed  
Main Iso.: Closed

Drain to Tanks: Drain  
Drain: Drain

## Pump Control

Transfer Pump: Activate 0.0 %  
Main Pump: Activate 50.0 %

Main Pump PID Enable: Set Point 0 GPM

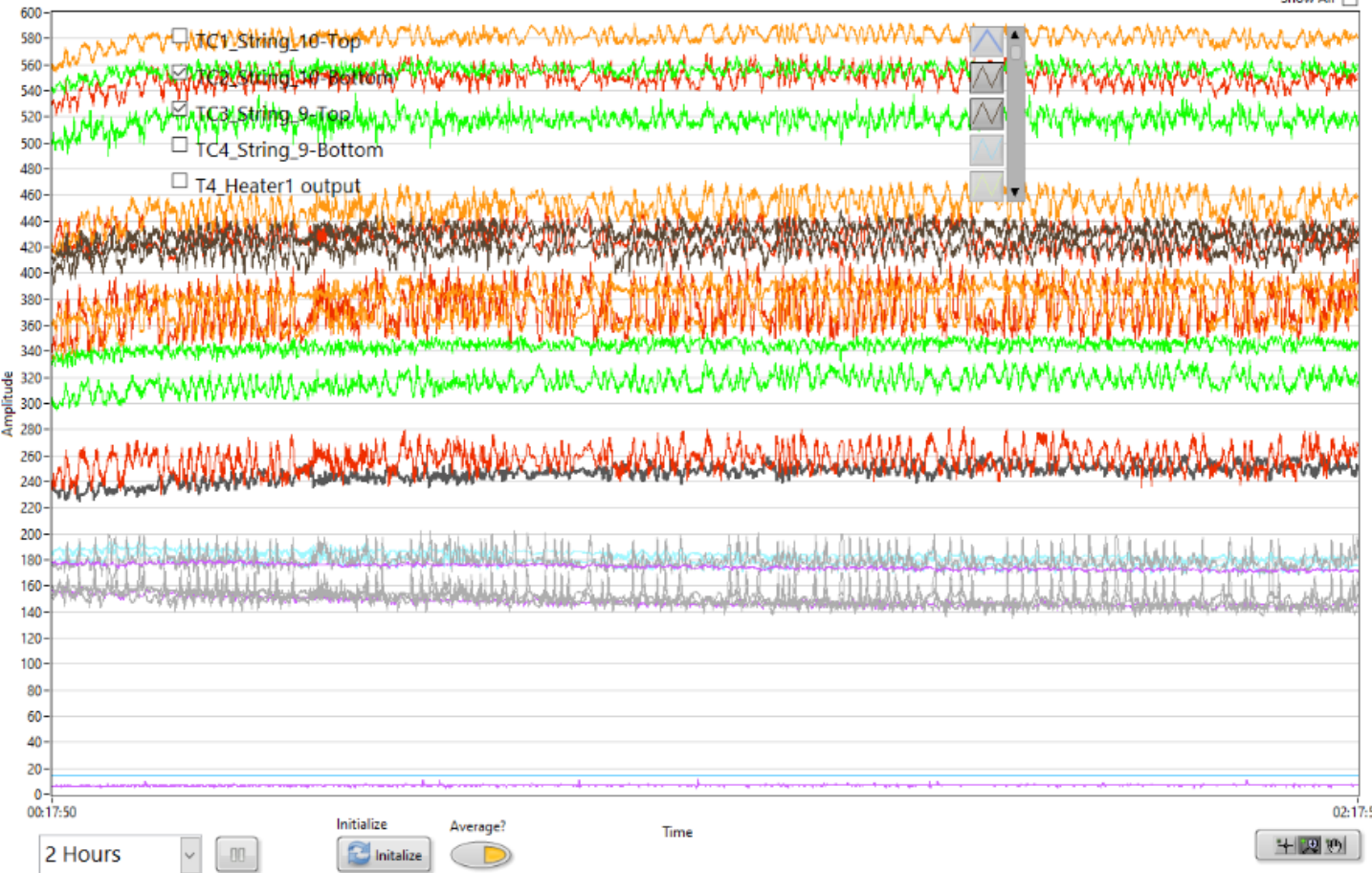
Transfer Pump Enable: Main Pump Enable

## Temp Control

Heater PID Enable: Heater CMD 0.0 %  
FB CH: 127.3 Set Point 33.0 F

Bypass Valve: 85.0 % Cooler Valve: 15.0 %  
Cooler PID Enable: Set Point 33.0 F

## Test Setup



## Graph Plot

Channel	Value	Units
TC19_String_1-Top	152.88	F
TC20_String_1-Bottom	144.75	F
TC21_VIT-Inner_Wall	182.69	F
TC22_VIT-Outter_Wall	175.83	F
TC23_7in_Outer_Wall	248.69	F
TC24_DBHX_Inlet	144.53	F
TC26_HTX_Inlet_Chilled_W	117.33	F
TC27_HTX_Outlet_Chilled_	126.14	F
TC28_Casing_Chiller_Inlet	52.35	F
TC29_Casing_Chiller_Outle	68.08	F
TC30_9_5/8_Casing_Temp	67.86	F
TC31_HTX_inlet_Working_I	172.57	F
TC32_HTX_Outlet_Working	145.37	F
T2_Pump2_Out	126.91	F
T3_Heater1_Int	126.93	F
T5_Cooler1_In	126.73	F
T6_Cooler1_Out	115.42	F
T7_Coolant_In	52.59	F
T8_Coolant_Out	53.75	F
T9_OilTank	76.25	F
T10_WaterTank	76.54	F
TC33_Circulating_Pump_B	101.95	F
PT3 7 x 9 5/8 Surface	25.94	psi
PT1 Pump Discharge	255.30	psi
PT4 Accumulator Static	89.14	psi
V5_OilTank_Closed	1.00	
V5_OilTank_Open	0.00	
V6_WaterTank_Closed	1.00	
V8_3Way2_Supplying	0.00	
V8_3Way2_Draining	1.00	
V9_MainIso_Closed	1.00	
Heater1_Contactor	1.00	

Safety Interlock: ● Heater 1 Contactor: ● Heater 1 Alarm: ● Leak Detection: ● Channel In Alarm: ● Din0\_00 (V5\_OilTank\_Closed) ● Alarm ● IO Fault ● Limit Fault

Reset E-STOP Cool Down Shutdown

# 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<sub>2</sub>
- 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

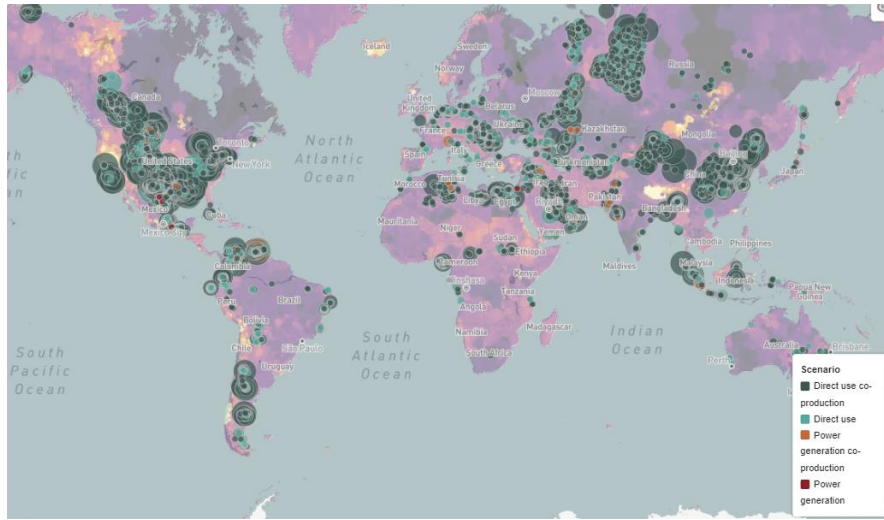
LCOH \$5-\$25 MWth

**Baker Hughes** 

# Retrofits will enable geothermal use in New Growth Markets

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

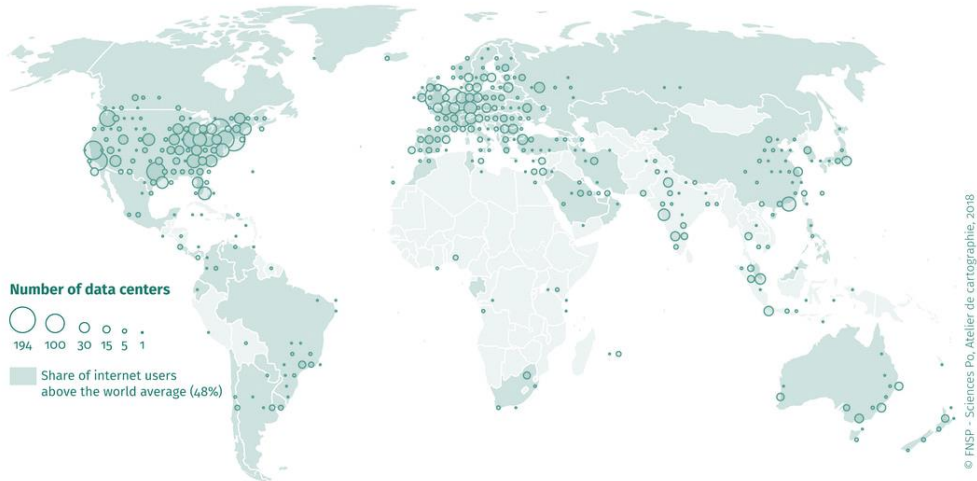
1M+ O&G Wells for Repurposing to Geothermal



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

