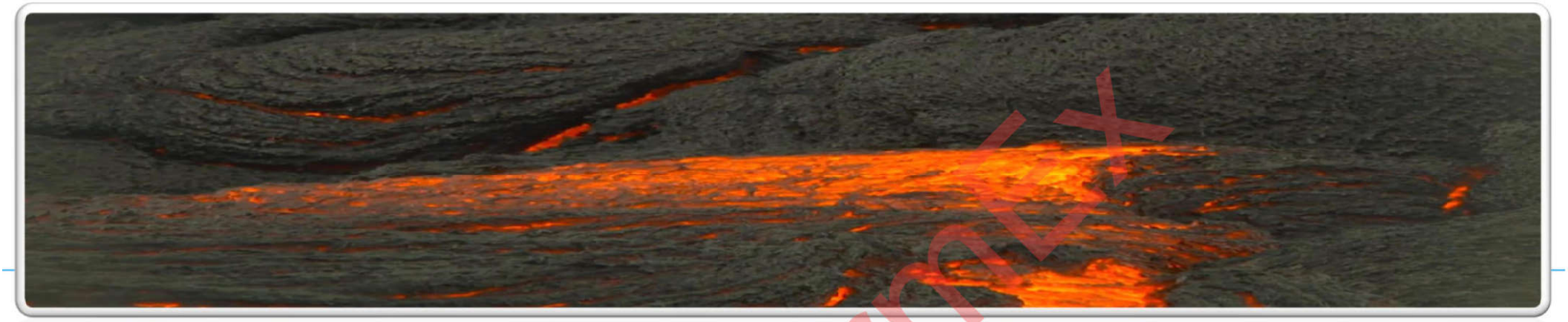


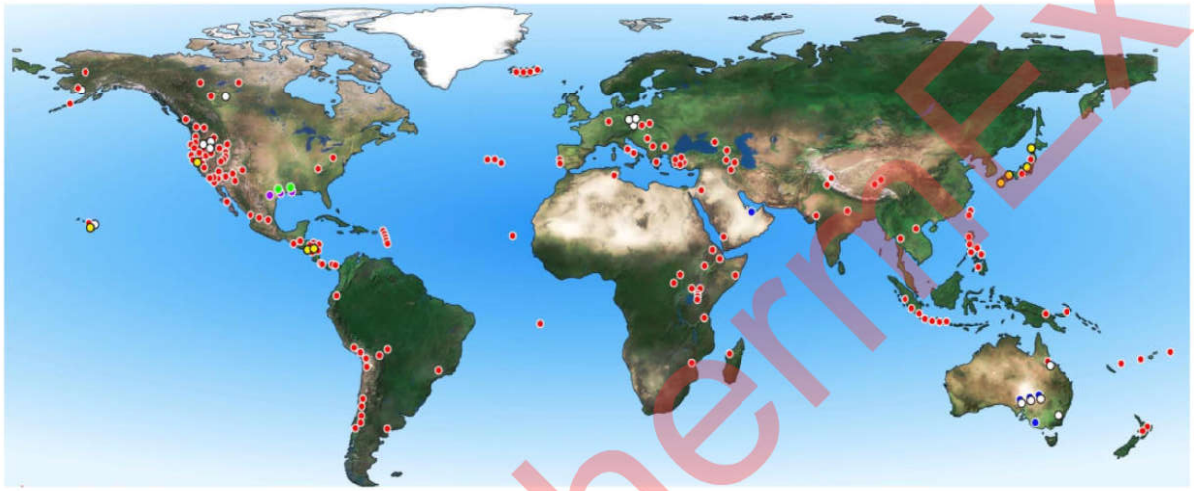
# Geothermal Wells and Drilling Challenges

GeothermEx
A Schlumberger Company

**Ozgur Balamir - Drilling Manager**

30 June 2021

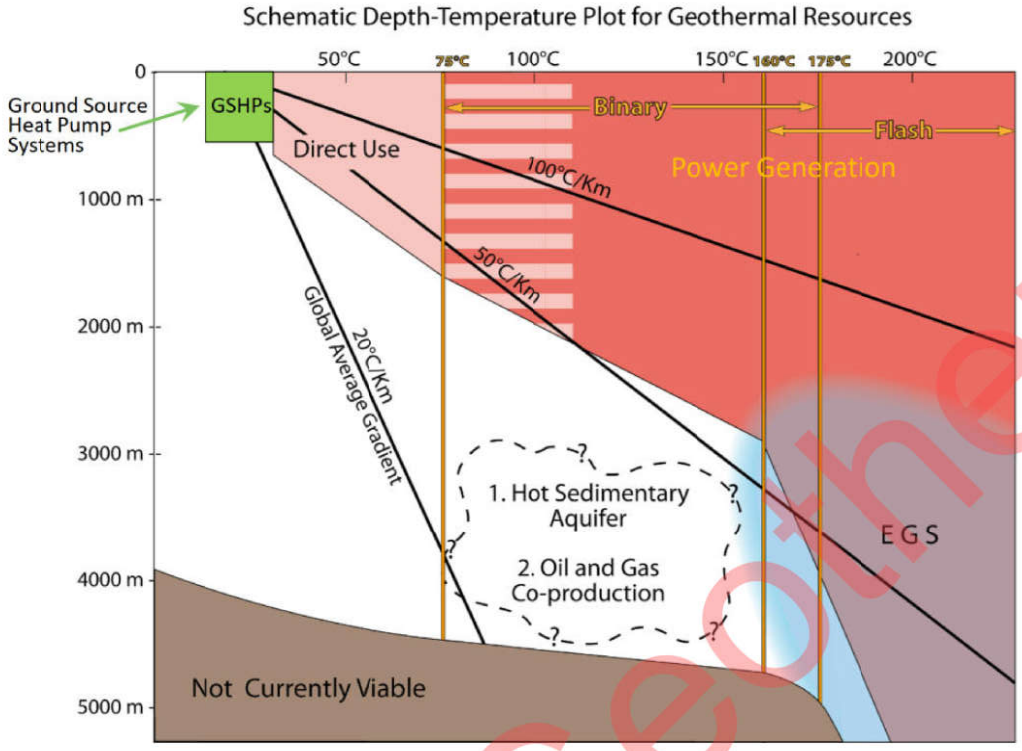
# GeothermEx is a global leader in geothermal consulting since 1973



- Worked in 56 countries and on 60% of all operating geothermal projects
- Modeled and optimized hundreds of (>90%) operating geothermal fields worldwide
- Hydrothermal resources, deep basin systems, EGS/AGS, and co-production
- Significant database of geothermal wells
- Expert Team with 25+ years each on average

# Geothermal

# Geothermal energy: a spectrum with many use cases

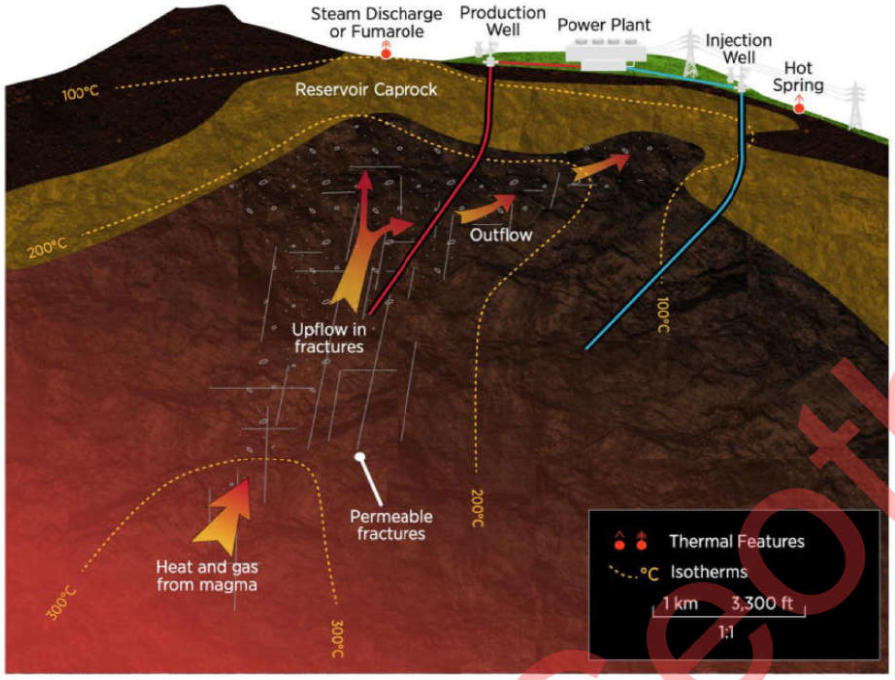



Modified from http://envgeo.com/publications/

| | Temperature Range (°C) | Produced Fluid Application | Product |
|---|---|---|---|
| Direct Use | 25 – 100 | Heating and cooling | District heating, process heat |
| Conventional Hydrothermal* | 100 – 175 | Binary generation | Heat + electricity |
| | 175 – 250+ | Flash generation, binary generation and direct use | Heat + electricity + mineral production |
| HSAs + Co-Production | 75 - 150 | Binary generation and direct use | Heat + electricity + mineral production |
| Enhanced Geothermal Systems | ~150 – 200+ | Binary generation and direct use | Heat + electricity + mineral production |

*Conventional Hydrothermal: Permeable reservoirs with natural recharge and convection as the primary heat transfer mechanisms

# Hydrothermal – ±16 GWe installed capacity



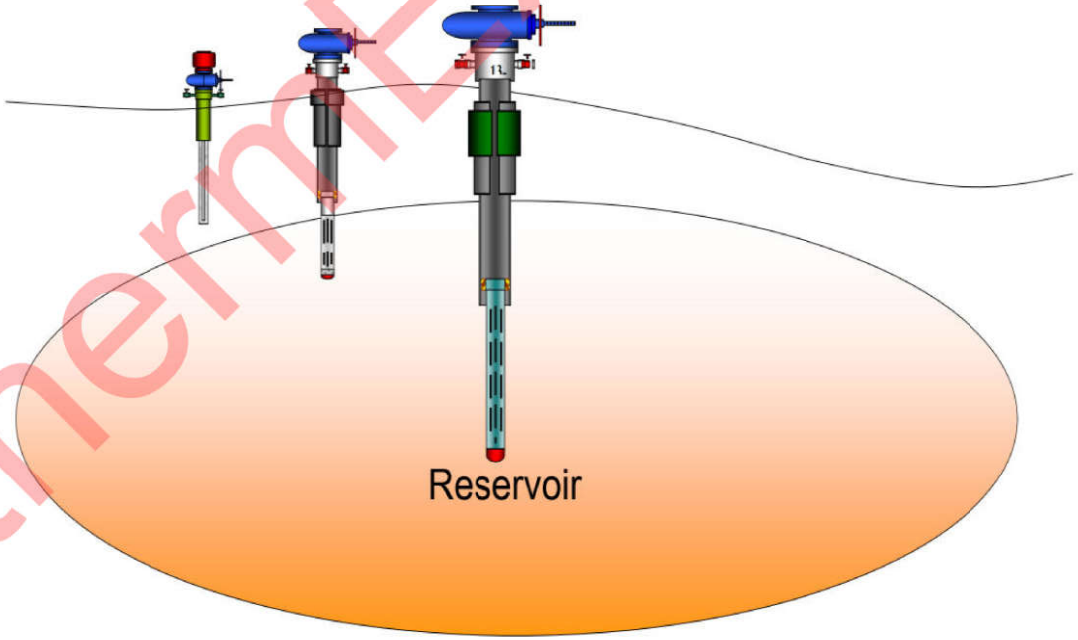

https://www.vox.com/energy-and-environment/2020/10/21/21515461/renewable-energy-geothermal-egs-ags-supercritical


https://www.thinkgeoenergy.com/thinkgeoenergys-top-10-geothermal-countries-2020-installed-power-generation-capacity-mwe/

# Wells

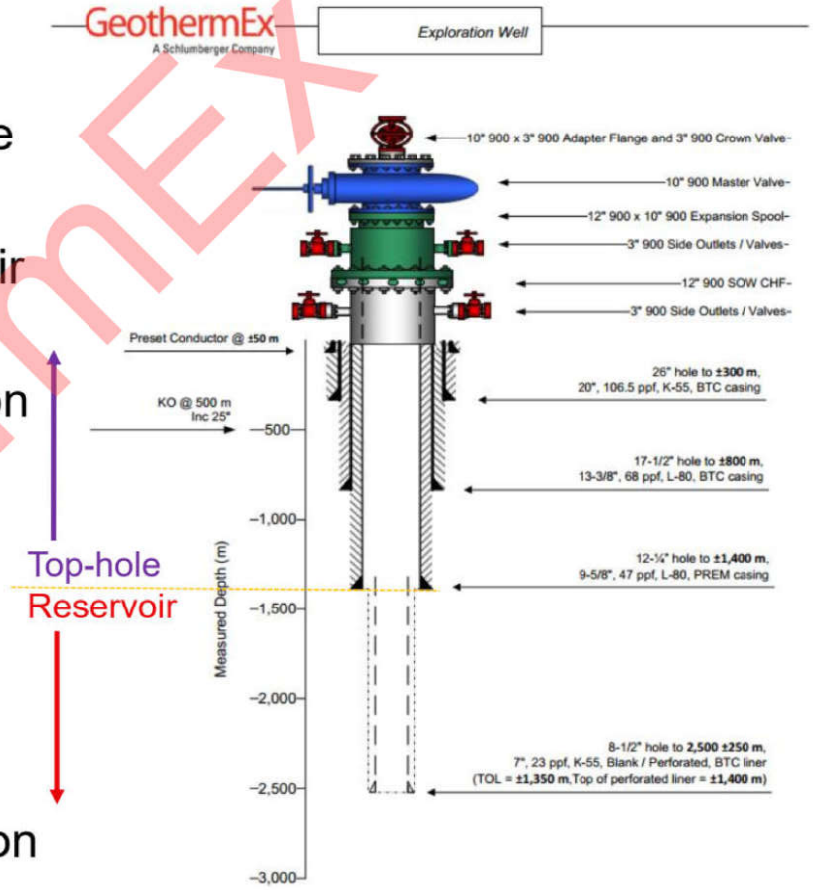
# Different wells for different reasons

- Temperature Gradient Wells
  - assess an important geophysical parameter (temperature)
  - integrate temperature into the early conceptual model
- Rotary or Core Drilled Slim Wells
  - encounter and test the resource
  - delineate the resource
- Full-Diameter
  - production and injection wells
  - create the resource supply
  - deliver a power project



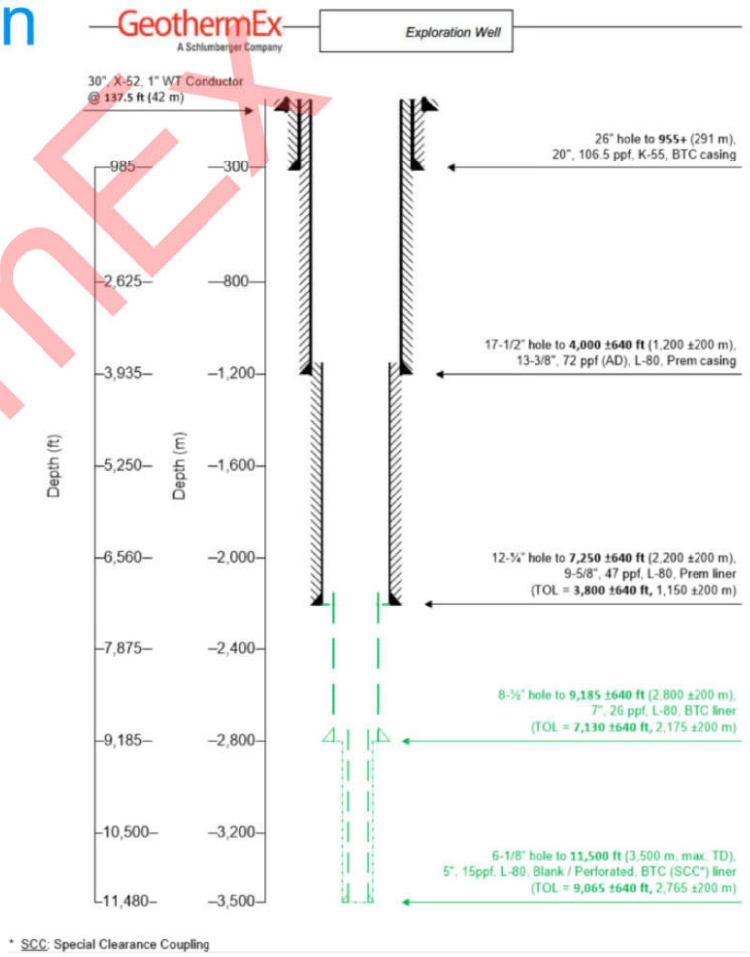
# Typical Full-Diameter well construction

- Surface casing in consolidated rock
- Intermediate casing to isolate problems in top-hole and provide kick tolerance
- Production casing to isolate top-hole from reservoir section. Directional 20-50°, 2-4°/30m DLS
- Slotted liner (one or nested) in the reservoir section (typically set on bottom with a liner adapter). Occasionally barefoot completions.
- Production through the slotted liner and last cemented casing string (no tubing – all loads on casing and wellhead)
- Permanent wellhead flange welded to first intermediate casing. Expansion spool nippled up on the permanent wellhead flange



# Typical Full-Diameter well construction

- Slotted liner (nested) in the reservoir section (typically set on bottom with a liner adapter)
- Production through the slotted liner and last cemented casing string (no tubing – all loads on casing and wellhead)
- No expansion spool needed when last cemented string is a liner. Master Valve nippled up on the permanent wellhead flange



# Root Causes and Challenges

# Top-hole section root causes -1

- Ambient to up to ± 200ºC formation temperature from surface to Top of Reservoir (circulating temperature varies)
- Shallow high-temperature zones – kicks from saturated steam pressure, sometimes charged with $CO_2$ and $H_2S$
- Igneous (volcanic / intrusive) and metamorphic formations vs. sedimentary
- Unstable and unconsolidated formations
- Increasingly harder, fractured, and sometimes abrasive formations
- Larger hole size requirement (much higher flow rates compared to oil/gas)
- Corrosion if air drilling

# Top-hole section root causes -2

- Must drill with significant to total losses – persistent from sub-hydrostatic formation pressure and varying size natural or induced fractures and vugular rock
- Cannot increase mud weight
- Must cement all casing strings over their entire length (thermal loads, zonal isolation, shallow $CO_2$)
- May need to start the directional work in the intermediate section (17-1/2")
- Cannot use high $ mud (or mix some others fast enough) if we have a lot of losses
- Need to drill with dumb iron when it gets too hot or stuck pipe is imminent

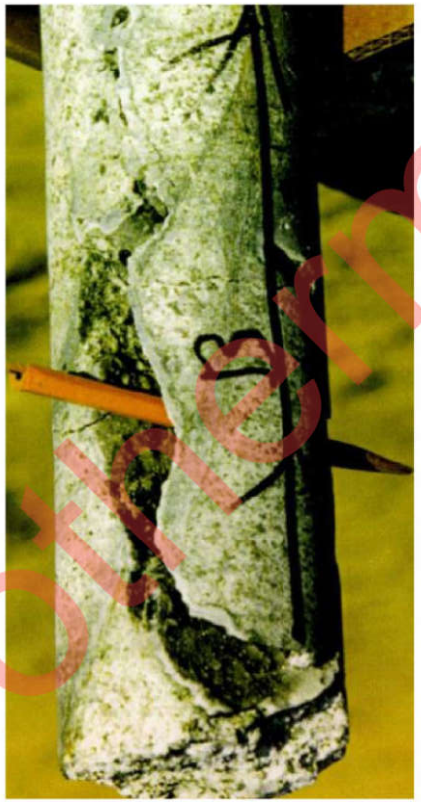
# Reservoir section root causes -1

- ±120ºC to ±320ºC formation temperature (circulating temperature varies)
- Ultra high temperature zones – kicks from saturated steam pressure, sometimes charged with $CO_2$ and/or $H_2S$
- Igneous (volcanic / intrusive) and metamorphic formations vs. sedimentary
- Unstable and unconsolidated formations
- Very hard and sometimes abrasive formations
- Severe to total losses – persistent from sub-hydrostatic formation pressure and varying size aperture and vuggy rock

# Reservoir section root causes -2

- Cannot use bentonite or other potentially reservoir damaging mud materials
- Cannot increase mud weight
- Cannot use high $ mud (or mix fast enough) if we have a lot of losses
- Mostly directional drilling (typically 20-50º INC @ 2-4º/30m DLS)
- Need to drill with dumb iron when it gets too hot or stuck pipe is imminent
- Corrosion if air drilling or $H_2S$ ppm is high
- Production casing damage during drilling can potentially compromise well integrity

# Reservoir section root causes



https://www.osti.gov/servlets/purl/1367577

# Geothermal drilling challenges -1

- Large Hole Sizes
  - Handling tools and tubulars
  - Hole cleaning
  - Cost (e.g., excess mud and cement, premium casing thread…)
- Losses
  - Plugs and LCM
  - High torque
  - Hole cleaning / Stuck pipe
  - Bad cement jobs / pumping and displacement issues
- High Temperature (ultra-extreme)
  - Kicks
  - BHT effects on downhole fluids
  - Downhole tool heat deformation
  - Downhole data collection
  - Surface equipment heat deformation (e.g. BOPE)
- Hard / Fractured / Abrasive
  - Low fracture gradient
  - Low ROP / High Torque
  - Prematurely worn-out
  - Drill string vibration
  - Directional control
  - Can't run casing to bottom

# Geothermal drilling challenges -2

- Wellbore instability
  - Shale (e.g., smectite)
  - Unconsolidated (e.g., boulders or paleosoil)
- Corrosion
  - Drill pipe and BHA when drilling
  - Casing, wellhead, and pumps during production
- Combinations within or between categories. e.g.,
  - e.g., losses and wellbore instability
  - e.g., different types of instabilities in the same well section

- Well Design
  - Casing seat selection (thermal kicks, low fracture gradient, cold zone isolation)
  - Casing design (temperature deration, low-cycle fatigue, corrosion)
- People!
  - Skill and training
  - Experience (geothermal specific)
  - Project management
  - Digital – the new frontier

# Scary photos

# Casing collapse


*Figure 8 Casing Collapse at 15~17m*

Leak at surface csg x csg annulus after collapsed casing

# Bit photos

- Granodiorite (4,000-7,000 ft depth)
- Runtime:  half a day to 1-2 days each

# Downhole tools suffer!




# Thank you

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# Agenda

**08.30-08.35** Welcome – **Dennis Moore**, DEC Chairman, **Roy Long and Robert Estes**, DEC Board members

**08.35-09.05** Geothermal Wells and Drilling Challenges, **Ozgur Balamirl**, GeothermEx

**09.05-09.35** Geothermal Drilling Challenges & Concerns, **Hani Ibrahim**, Drilling Performance SME

**09.35-10.05** Lessons Learned and Performance Improvement: Drilling Case Study from Sarulla Geothermal Operation, North Sumatra, **Hadi Permana**, Halliburton

**10.05-10.35** It's Just a Hole in the Ground (or is it?): Physics-based Practices Achieve Ground-breaking Performance In Geothermal Drilling Application, **Sam Noynaert**, Texas A&M University

**10.35-10.45** Break

**10.45-11.15** 3 Things I Wish I Knew Transitioning from O&G to Geothermal, **George Stutz**, US Department of Energy

**11.15-11.45** A Comprehensive Tubular Design and Materials Selection Approach for Geothermal Wells, **Suri Suryanarayana**, Blade Energy Partners

**11.45-12.15** Making 'Geothermal Anywhere' a Reality: Drilling Technology Capabilities, Gaps & Needs, **Eric van Oort**, UT Austin