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European Technology
Deep Geothermal
& Innovation Platform

BHGE fullstream geothermal solutions

November 13, 2017

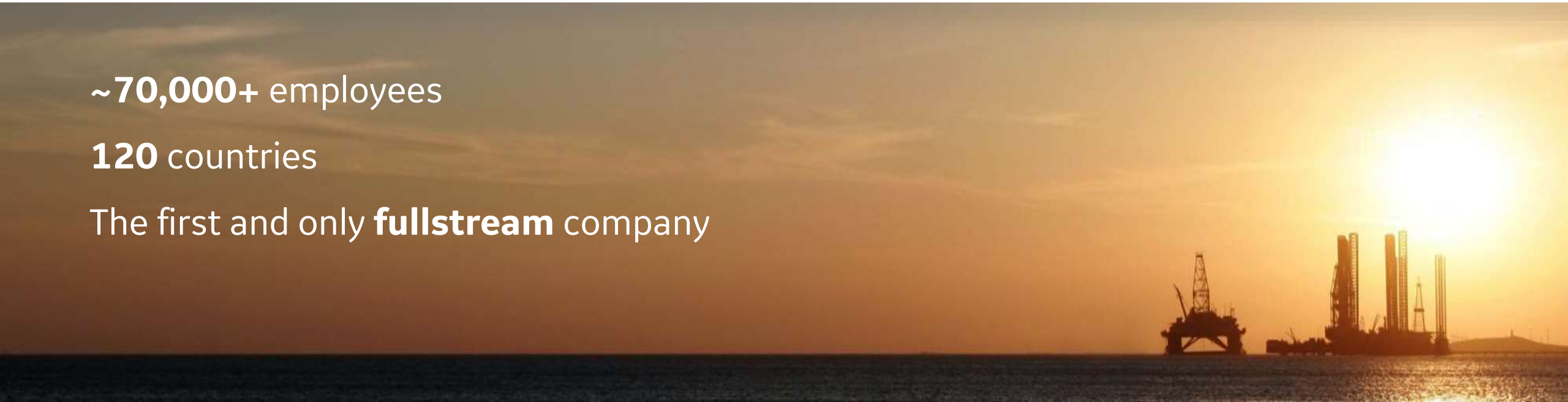
Since July 2017:

BAKER HUGHES + GE Oil & Gas = BAKER HUGHES a GE company

~70,000+ employees

120 countries

The first and only **fullstream** company

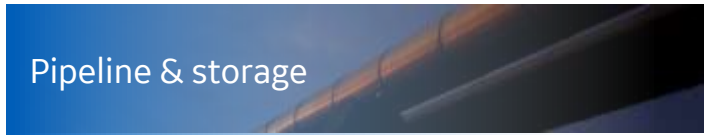


Fullstream

Rely on cutting-edge technology, digital solutions, and expert service across every segment

Upstream

Midstream



Downstream

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Technology Solutions across the Geothermal Fullstream

Key enablers from the underground system to the power production

Drilling

- **Drill-bits**
- **Drilling services**
- **Cementing services**
- Completion systems
- Fishing services
- Chemical services

Well

- **Submersible Pumps**
- Well Head Equipment
- Logging Technology

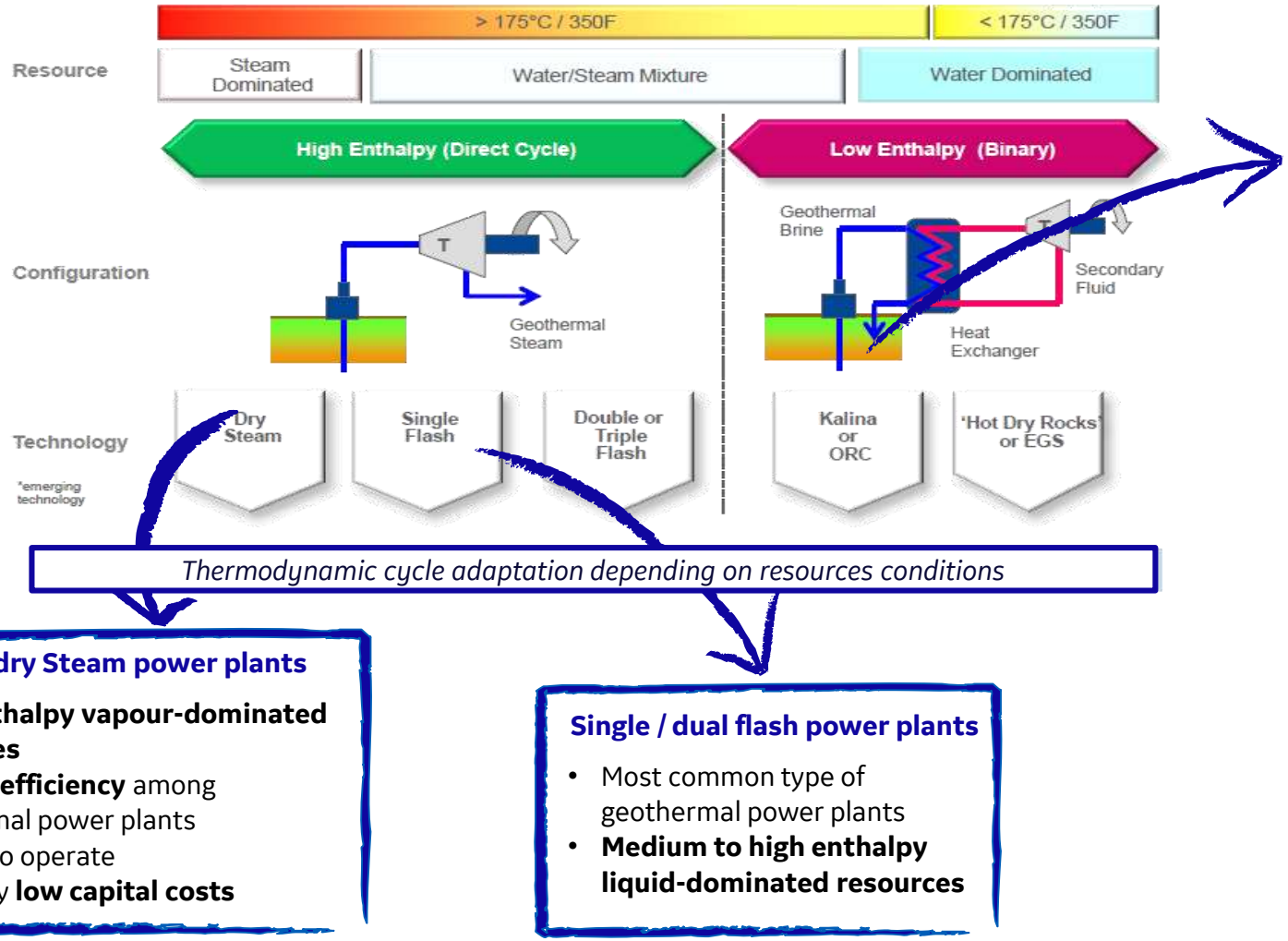
Power Island

- **Steam Turbine** & Generators
- **Expanders** for ORC systems
- Condensate & Re-injection Pumps
- Air Cooled Condensers
- Remote M&D

Power Delivery

- Primary Equipment
- Power Sensing & Quality
- Protection & Control
- Automation
- Remote M&D

BHGE Topside Geothermal Solutions



Binary / Organic Rankine Cycle:

- Operate at **lower water temperatures: 110-175 °C**
- The **organic compound with a low boiling point** uses the heat from the hot water to boil

Since 2012:
78% of new installed capacity are Binary cycles

EGEC GEOTHERMAL

Direct dry Steam power plants

- **High enthalpy vapour-dominated resources**
- **Highest efficiency** among geothermal power plants
- **Simple** to operate
- Relatively **low capital costs**

Single / dual flash power plants

- Most common type of geothermal power plants
- **Medium to high enthalpy liquid-dominated resources**

Underground systems- Drilling and Evaluation

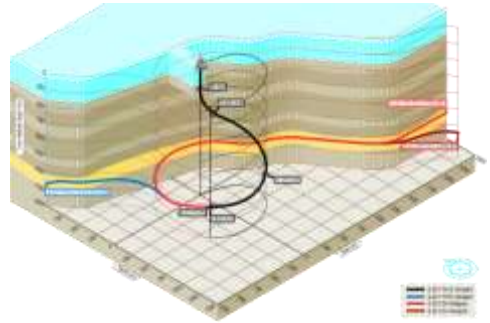
Cementing
X-treme set (312 Cº)

Drill Bits
Fixed PDC Quantec™
Hybrid Kymera™
Roller Vanguard™ (>288º C)

Motors
X-treme
(160- 200 Cº)

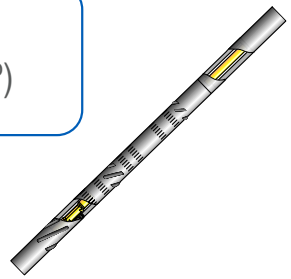
Fluids
PYRO-DRILL™ drilling fluids (340 Cº)

Automated drilling
RSM VertiTrak™,
RSS Auto-Trak™
(175 Cº)



Coring
HT™ core barrels and disposable steel inner barrels (>163 Cº)

MWD/LWD
(150 C - 175 Cº)



Wireline
NAUTILUS ULTRA™
(232 Cº)

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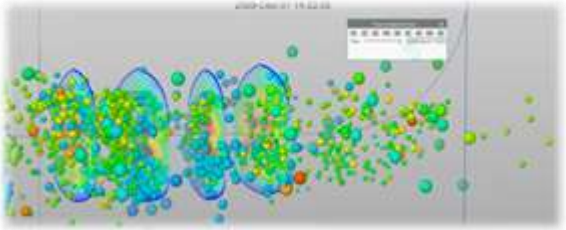
Underground systems- Completion and Production

Wellbore intervention
retrieving tools

Completion systems
External casing packers
Casing exit systems

Hydraulic fracturing/ stimulation
Planning, monitoring, evaluating



Specialty Chemical
FORSA™ Scale Control, corrosion inhibitors, biocide

ESP
CENetic™ Geothermal Pump (200 C°)

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Backup

BHGE Geothermal R&D

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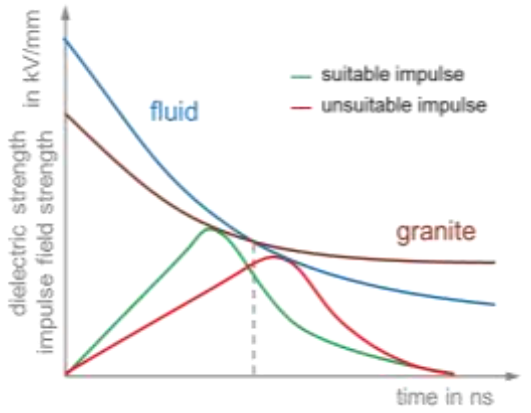
Alternative Drilling Technology

Electric Impulse Drilling for Deep Geothermal

First Real Size Low Pressure In-Situ Test with an 12 ¼" Electrode

TU BA Freiberg / TU Dresden
Field Lab

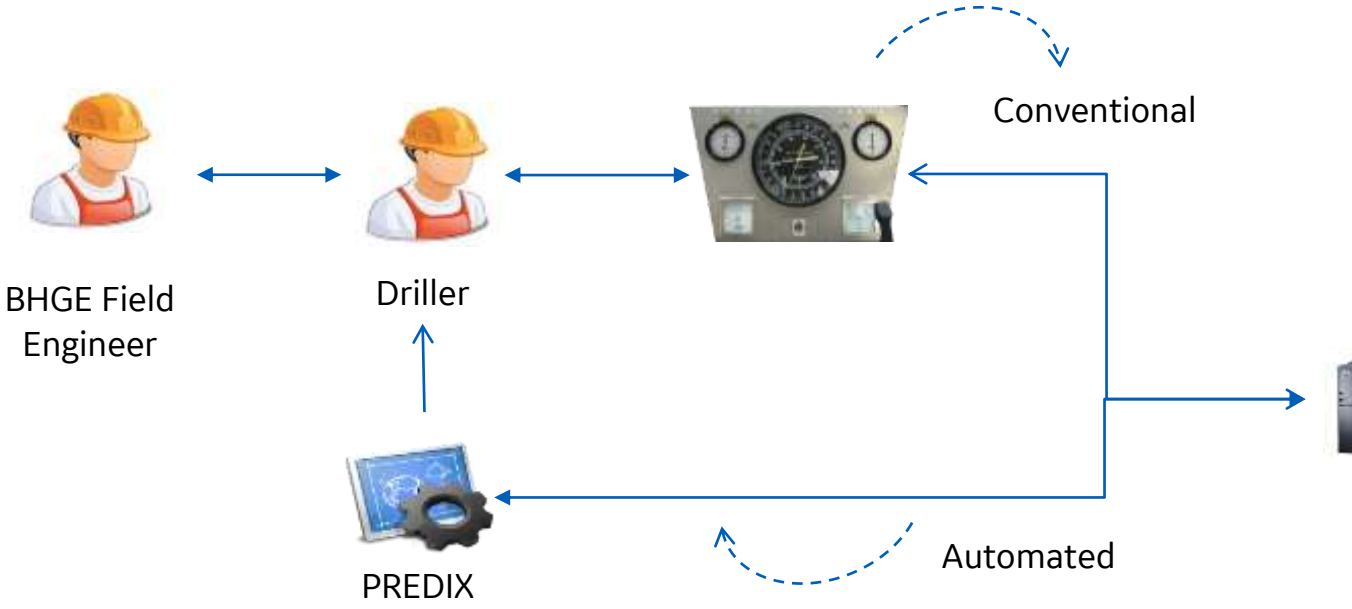
- High Voltage Generator (HVG) Module and Electrode tested in Water under low pressure drilling conditions
- Excavation of 50 mm of cement with a diameter of 12 ¼"
- Logging of wellbore revealed hole cleaning problem as reason for low ROP
- Alternative Deep Drilling EIT technology has the potential for reduction of bit exchange related NPT of more than 50%
- EIT potential enabling technology for ultra deep drilling

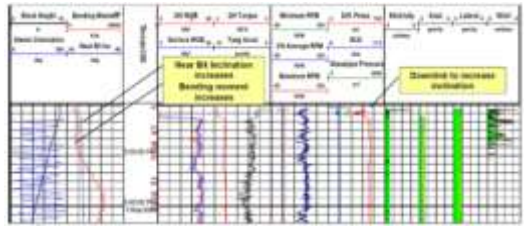


Surface Test Video

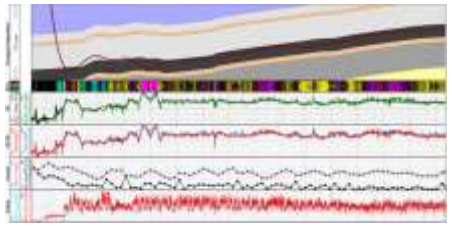
Virtualization and Automation

Automated Drilling Systems Control



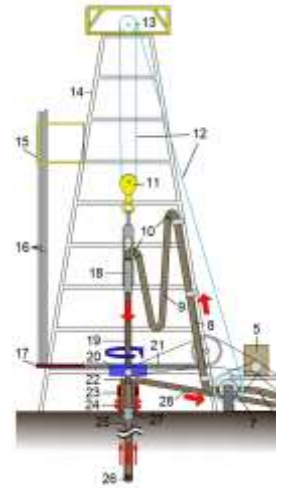


Real-time drilling performance plot



Real-time reservoir navigation plot

Controller (PLC)



Rig Actuators:
- Drawworks
- Top drive
- Mud pump

Rig Sensors: RPM, WOB...

Duerrnhaar and Kirchstockach project

- 80 % increased progress rate, saving of 16 days
- Additional 8 days saved for completion thanks to high quality of wellbore

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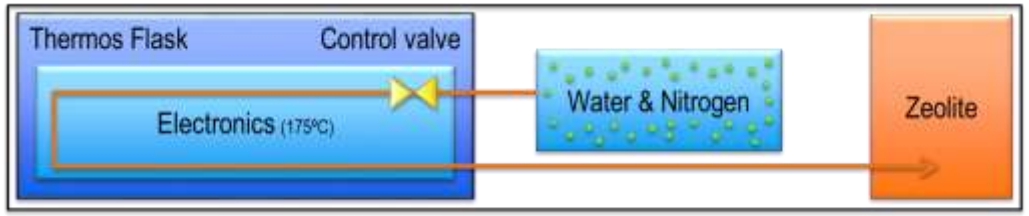
Drilling Systems Configuration

Optimized BHA

- Rotary Steerable Systems (AutoTrak ™)
- Rib Steered Motors (VertiTrak ™, CoilTrak ™)
- Innovative high temperature Drill Bits
- Drilling Dynamics Observation and Control

High Temperature Solutions

MWD System for 300 °C



Evaporative cooling of electronics within a flask, with power and telemetry at ambient temperature

Encapsulated and cooled electronics

Future BHGE Geothermal R&D roadmap

- Novel materials for geothermal steam turbines with increased corrosion resistance.
- New protection technologies for rotoric parts aimed to increase droplets resistance in low pressure steam turbine stages.
- Development of mixed power plant configurations with topping steam turbines and bottoming ORC.
- Hybrid geothermal power plants (with i.e. with biomass, solar) to increase the overall efficiency.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