NEW TECHNICAL, EFFICIENT AND ECONOMICAL SOLUTION FOR GEOTHERMAL DRILLING

“THE HURDLES OF THE GEOTHERMAL INDUSTRY”
GEOTHERMAL HURDLES

- We’re currently in the transition from an hydrocarbon based society towards a sustainable energy based society

- The promising geothermal industry is relatively young and going through a very dynamic development

- Much of the needed experience is used from the drilling industry which was primarily developed for the oil & gas industry

- Due the many similarities with the hydrocarbon industry, the differences cause a series of hurdles to be taken to make the geothermal industry successful
THE GEOTHERMAL BUSINESS CASE

- Energy content:
  - Burning 1 m³ of diesel ~36000 MJ/m³
  - Harvesting of 60 Celsius heat out of salt water ~260 MJ/m³ (140 times less!)
    - Source: Binas / Wikipedia

- Burning of 1 m³ of diesel produces ~2,7 tonnes or 1550 m³ of CO₂ while geothermal energy can be harvested CO₂ neutral
  - Source: http://www.icbe.com

- Hydrocarbons are so profitable that a global market of users and producers exist while geothermal energy can only be used in the direct vicinity of its production location

An hydrocarbon business case is easy to make profitable when CO₂ impact is ignored &
Geothermal energy market is very local
OIL & GAS DRILLING LEGACY

- Oil & gas are over-pressured, relative easy to produce but geothermal energy needs to be pumped out in 1 well and back in the ground in a 2nd well.

- Oil capacity limited by production rate of viscous oil or amount of gas trapped while geothermal production limited by heat demand, pump pressures and financing.

- Most geothermal drilling hazards are not related to the reservoir opposed to hydrocarbon drilling in overpressured reservoirs.

Legislation, drilling & production technology and geological knowledge are based on the oil & gas industry.
URBAN GEOTHERMAL DRILLING FOR CITY HEATING

- Urban drilling areas often require special attention to minimize environmental disturbance due to noise, light, logistics.

- Drilling risk contours more relevant in populated areas.

- Directional drilling in relative large sizes is needed to ensure sufficient distance between producer and injector well.

- Innovative technical solutions to reduce drilling risks and environmental disturbance available but expensive due to niche oil and gas applications.

Drilling technology specifically for urban drilling is needed.
DRILLING RISKS AND COSTS

- Geothermal budgets are tight and risks need to be mitigated by expensive insurances or pushed down to suppliers.
- Risk-related costs and learnings are often limited to a single project.
- Lumpsum drilling is easier to finance but in general, not cheaper if not well performed due to poor risk control.
- Currently, lumpsum suppliers are often drilling contractors because they account for the largest share of time-based costs, even though they have limited control on the operations.
- Capex budget strain results in sub-optimal wells with respect to their full life cycle, for example, corrosion in single wall wells without production tubing.

Crucial to spread risk-related costs over multiple projects & to build a learning curve.

Total life cycle to be considered when constructing wells.

Fit for purpose rigs with better risk control are key for lumpsum drilling.
Huisman LOC400 returned to NL for geothermal drilling is used as base to develop geothermal drilling technology.

Geothermal rig for lumpsum drilling needs to be:
- Highly productive to drill more wells per year
- Have strong focus on NPT avoidance
- Capable to offer additional services

Purpose built geothermal rig under development:
- AC driven for reliability
- Compact
- Silent
- Fast moving with minimum of logistics
- Highly automated for high performance and safety
- Integrated services making niche and risk reducing technology affordable
REDUCING RISK AND TIME WITH RIG INTEGRATED TECHNOLOGY

- Enhanced Casing Installation system:
  - Less critical steps
  - Minimum of geological impact
  - Higher productivity
  - Less pipe handling

- Managed Pressure Drilling:
  - Significantly safer drilling for urban areas (500 times!)
  - Higher drilling rates
  - Produce & test reservoir while drilling to minimize skin
ECI FIELD TRIAL IN KOHLENKALK: HARD ROCK ‘INTERBEDDED’ WITH CAVERNS

Multiple bit runs & severe losses expected
RISK AND TIME REDUCING INTEGRATED TECHNOLOGY

- Automated directional drilling:
  - Minimum of people onsite monitored remotely
  - Less electronics for higher reliability
  - Expensive service provided under control of contractor

- Composite casing (drilling):
  - Eliminate corrosion and prolong well life
  - Alternative for double walled well designs
  - Use smaller rigs on smaller locations
Installation of 7” HSCC on Rig in Oman
**Vertical weight comparison**

**Load for 1000m well with 9-5/8” casing:**

<table>
<thead>
<tr>
<th>Material</th>
<th>Specific Weight</th>
<th>Buoyancy in mud</th>
<th>Hook load (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel casing</td>
<td>70 kg/m</td>
<td>0.85</td>
<td>60</td>
</tr>
<tr>
<td>5” drill pipe</td>
<td>29 kg/m</td>
<td>0.85</td>
<td>25</td>
</tr>
<tr>
<td>HSCC / ECCI</td>
<td>20 kg/m</td>
<td>0.45</td>
<td><strong>9</strong></td>
</tr>
</tbody>
</table>

Conventional rig | Super single rig | Mini rig
TECHNICAL HURDLES ARE “THE EASY PART”
WITH THE SAME PASSION WE CAN OVERCOME THE “NON TECHNICAL ISSUES”

- High level support, governmental commitment needed regarding geothermal specific drilling and production technology development and implementation roadmap

- Reduce drilling and reservoir related risks by promoting geological knowledge sharing and reprocessing/shooting of seismic data

- Until geothermal industry has matured sufficiently, a rolling fund is needed to spread risks over the various projects instead of pushing risks down to contractors or paying expensive insurance fees

- Pre-drilling phase to be simplified & shortened to reduce project uncertainties resulting in larger scale industry with continuous multiple rigs drilling

A significantly more sustainable energy industry will rise if these hurdles are taken successfully

Taken the hurdles successfully will create opportunities