Drilling the Limit
Increasing Efficiency in Geothermal Drilling

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Current Drilling Rates

Figure 3 Histogram of geothermal drilling rates determined for California and Nevada
Continuous Improvement

TECHNOLOGY IMPROVEMENT
• 6” PDCs instead of Impregs, 8.5” PDCs
• Rotary steerable instead of bent-motor BHAs
• EM-MWD

PROCESS IMPROVEMENT
• DWOPs, DTL, performance analysis/feedback, incentive pay
• UBD with OBM, Eliminated liners at 12, 500’
• Dual mud systems for WBM & OBM
• Mitigating drilling dysfunction

Source: de Wardt and Co 2018
Drilling as Manufacturing

**Lean Manufacturing** is a systematic method for *waste minimization* within a manufacturing system without sacrificing productivity.

1. **Map & Measure**
   - Document process “as is”

2. **Explore & Evaluate**
   - Identify Waste

3. **Define & Describe**
   - Design Improvements

4. **Implement & Improve**
   - Create Implementation Plan

5. **Monitor & Modify**
   - Monitor improvements for sustainability

Reported time savings of 20-50% - or more – translating to cost savings of 20-30%
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Review Available Data

For example ...

Drill Bit Performance

Drilling Log Time Distribution

Daily NPT Breakdown
Lean Manufacturing is a systematic method for waste minimization within a manufacturing system without sacrificing productivity.
Waste in Drilling

**ROOT CAUSES**

**TYPES OF WASTE**

- **Ignorance**
  - Not knowing something
  - Wrong Design

- **Operations**
  - Less than perfect actions
  - Right Design
  - Wrong Action

- **Technology**
  - Technology limitations

**Waste**
Less than perfect due to normal operations

- **Ignorance-based Waste**
  circulating bottoms up to check gas, conservative casing setting depth,

- **Operations-based Waste**
  new/inexperienced crew ‘always done it that way’ tripping slower than you could

- **Technology-based Waste**
  Multiple bits per hole section, circulating bottoms up,

**Loss**
Less than perfect due to failure

- **Ignorance-based Loss**
  Stuck because casing set in wrong place, Kicks, Geologic Side Tracks, Wrong mud type for formation

- **Operations-based Loss**
  Stuck because driller took wrong action, running the cone off a bit

- **Technology-based Loss**
  Stuck because no high-T downhole tools

Adapted from: Brett (PetroSkills) 2018
Lean Manufacturing is a systematic method for waste minimization within a manufacturing system without sacrificing productivity.
The Perfect Well time is the minimum time in which a well could possibly be drilled.
- Calculated from physical factors that constrain the drilling time (e.g. rock strength, equipment limits).
- Used to normalize differences between wells and create a purely objective indicator of well construction effectiveness.

The Technical Limit is the best possible well construction performance for a given set of design parameters.
- Estimated by a drilling team and therefore may not necessarily be an objective standard measurement.
- Estimate is that it takes about 15 minutes per well to calculate and define a non-ambiguous technical limit.

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Drilling The Limit* (DTL) represents an alternative planning methodology through which incredible gains can be made. Used to improve performance by working down from a point of perfection based on the current levels of technology, rather than from incremental improvements in today’s performance.

What is the current performance? → “Normal” average
What is possible? → Theoretical limit
What is needed to get there? → Resource investment

Applying the DTL methodology results in a **significant step change** in performance.
DTL requires a significant change in mindset and attitude, with full support from all levels within the company.

Reports indicate the engineers and rig personnel had fun. They enjoyed:
• the thrill of success,
• the peer competition (between rigs),
• the sense of achievement and professional pride.
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PDCA is a Lean problem solving method for continuous process improvement.
Hard-rock geothermal (with fewer wells per site) will be slower than soft rock oil and gas drilling, so the number of hours of drilling for both industries starts to look comparable in the millions-of-hours-per-year range. That’s an extra 1,000 wells per year in the U.S. every year for the next 30 years. That’s a huge increase over the current rate of <10 or so/year. But still is quite shy of the 15-20k U.S. oil and gas wells drilled each year. Since drilling makes up ~50% of project costs, faster drilling can significantly increase market competitiveness. Recent market deployment modeling suggests this could amount to an added 50 GW by 2050.

Faster drilling
Efficiency in drilling has been shown to decrease drilling time by 20-50% - and sometimes up to 60%

Cost Savings
Time savings equate to cost savings – both in drilling costs, as well as increase NPV. Additionally, costs savings reduce risk, which could equate to better loan rates.

Increased Market Competitiveness
Increased Drilling Market
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Significant Drilling Hours per Year
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THE “PERFECT GEOTHERMAL WELL”

DRILLING THE LIMITS – EQUINOR PERSPECTIVES
Drilling the Limits
“The Perfect Well” concept in Equinor

• PRINCIPLE:
  • Shorten
  • Execute in parallel
  • Delete

• ACHIEVEMENTS:
  • US onshore drilling time: from >50 days to <10 days!
  • NCS well cost: 2-for-1!

• SUCCESS FACTORS
  • Focus on **continuous improvement** in the drilling operation
  • Setting **stretch goals**, i.e. budget vs. “the perfect well”
  • Incentives for **competitive mindset** and **collaboration**
  • **Digitalization**
  • **HSE is non-negotiable!**
Drilling the Limits
«Perfect Geothermal Well» workshop

- Equinor expert facilitated IDDP-2 pre-drill workshop
- More than 100 improvement opportunities were identified
- Potential for reducing drilling time to 1/3 of current average?

- NEXT STEPS:
  - Capture O&G practices
  - Define the «perfect geothermal well»
  - Test potential in geothermal drilling
  - Joint industry initiative?
Thank you
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