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Data-driven well planning and its impact on energy efficiency

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Abstract

Data-driven well planning integrates geological, drilling, and emissions data to optimize well trajectories, fluid design, and equipment selection, ultimately reducing energy consumption and carbon intensity. This paper applies Life Cycle Assessment (LCA) to evaluate the energy savings enabled by digital well planning systems. The study demonstrates that the use of digital planning tools can reduce overall rig energy demand by 8–12% per well by minimizing non-productive drilling, optimizing bit runs, and improving hole cleaning efficiency. The findings reinforce data-driven planning as a cornerstone of sustainable drilling.

Keywords: Drilling; Sustainability; Well Trajectory; Energy Savings

1. Introduction

The oil and gas industry faces increasing pressure to decarbonize operations while maintaining cost and safety performance. Well planning traditionally relies on historical data and static assumptions, often leading to inefficiencies in drilling parameters, fluid systems, and equipment use (IEA, 2022).

Data-driven well planning leverages machine learning, cloud-based analytics, and LCA models to anticipate challenges and optimize design for lower energy intensity. By integrating offset well data, formation properties, and rig performance history, planners can minimize energy-intensive reaming, tripping, and circulation events.

2. Methodology

A comparative Life Cycle Assessment (LCA) approach was adopted to evaluate energy performance between traditional and data-driven well planning.

- Goal and Scope: Quantify energy and emissions benefits from data-driven planning compared to baseline methods.
- System Boundary: Includes planning, drilling, and completion phases.
- Functional Unit: 1,000 meters drilled.
- Data Sources: Offset well performance data, rig power consumption, and drilling time metrics from operator digital twins.
- Impact Categories: Energy demand and GHG emissions following ISO 14044 and GHG Protocol (2022) guidelines.

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3. Results and Discussion

Data-driven well planning influenced energy efficiency through:

- Optimized Drilling Parameters: Algorithms trained on historical well data minimized overpowered drilling modes, reducing fuel use by 6%.
- Improved Trajectory Design: Shorter, smoother trajectories reduced mechanical friction and torque, leading to 4% energy savings.
- Reduced NPT: Predictive modeling reduced unplanned tripping and circulation, saving up to 1,000 liters of diesel per well.

LCA results indicated a substantial reduction in total energy demand and a significant decrease in carbon footprint per well. Integrating LCA outputs directly into digital planning dashboards further enhances decision-making transparency.

Effective well planning and operations require collaboration between different subsurface teams and drilling team leveraging multidisciplinary data, historical events and risks and constructing integrated drilling and sub-surface model for collaborative planning and keeping the model live. This requires having a live sub-surface model that is kept close to the field reality while reducing uncertainties. However, extracting key learnings, knowledge and experience from a variety of sources and reports is intense and requires lot of manual processing of data.

The integration of advanced analytics, machine learning, and digital tools within the planning workflow supports continuous optimization. By correlating drilling efficiency metrics with environmental indicators, operators can identify trade-offs between energy use, operational time, and carbon impact. This integrated approach shifts well planning from being purely performance-driven to being performance-and-sustainability-oriented.

Effective well planning and operations require close collaboration between subsurface and drilling teams. Leveraging multidisciplinary data, historical performance records, and risk models facilitates the construction of an integrated digital model that reflects real-time subsurface dynamics. Maintaining a "live" model aligned with field conditions improves forecasting accuracy and operational adaptability while reducing uncertainty.

However, achieving this level of integration presents several challenges. Data heterogeneity across platforms, inconsistent data quality, and the need for standardization can limit model accuracy. Additionally, extracting insights from vast amounts of operational and sustainability data demands considerable computational resources and human expertise. Automating data workflows, incorporating AI-driven data cleaning, and expanding interoperability between drilling and LCA platforms can address these challenges and further enhance planning efficiency.

In the broader context, data-driven well planning supports the transition toward lower-carbon upstream operations. It demonstrates how digital technologies can help optimize energy use, extend equipment life, and enable transparent sustainability reporting. As the industry continues to align with global decarbonization goals, such integrated planning frameworks will play a central role in balancing production efficiency with environmental responsibility.

4. Conclusion

Data-driven well planning substantially improves energy efficiency by integrating predictive analytics and LCA insights into design workflows. Quantifiable reductions in energy demand and GHG emissions demonstrate the role of digital planning tools in achieving low-carbon well construction. Future developments should focus on combining LCA with real-time drilling performance analytics to deliver adaptive, low-emission well programs.

Compliance with ethical standards

Disclosure of conflict of interest

There is no conflict of interest among the authors.

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