World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Review Article)

Check for updates

Quantum driven innovations in emission profiling for drilling fluids

Muhammad Ahsan *

Baker Hughes, Sustainability and Energy Transition, Houston, United States of America.

World Journal of Advanced Research and Reviews, 2025, 26(03), 2312-2314

Publication History: Received on 20 January 2025, revised On 24 January 2025; accepted on 07 February 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.26.3.0940

Abstract

The oil and gas industry are under increasing pressure to minimize its environmental footprint, particularly in the area of drilling fluids, which contribute to greenhouse gas emissions across their lifecycle. Quantum computing represents a disruptive technology with the potential to redefine emission profiling by enabling unprecedented precision in life cycle analysis (LCA), optimizing formulations, and enhancing supply chain management. This paper explores how quantum computing can transform drilling fluid emissions profiling, review the current state of the industry, and propose a framework for integrating quantum-based methodologies. The discussion highlights key challenges and provides a way forward for adoption within the industry.

Keywords: Quantum; Sustainability; Life Cycle; Data Integration; Digital

1. Introduction

The sustainability of drilling fluids has become a focal point in efforts to reduce the carbon footprint of drilling operations. Traditional emission profiling methods rely on classical computing, which, while effective, is limited in handling the complexity and scale of modern supply chains, chemical reactions, and lifecycle assessments. Quantum computing, with its ability to process vast datasets and solve optimization problems exponentially faster, offers a revolutionary approach to understanding and reducing emissions.

This paper examines the potential applications of quantum computing in

- Conducting more accurate LCA for drilling fluids.
- Optimizing chemical formulations for lower emissions.
- Streamlining supply chains to reduce energy consumption and waste.
- Providing real-time decision-making tools for emissions management.

2. Methodology

2.1. Quantum Life Cycle Analysis (LCA) Framework

A quantum-enabled LCA approach involves

- Data Integration: Incorporating real-time operational data, such as drilling fluid consumption, mud losses, and seepage rates.
- Molecular-Level Simulation: Using quantum processors to simulate chemical interactions and predict emissions for various fluid formulations.

* Corresponding author: Muhammad Ahsan

- Comprehensive Emissions Profiling: Extending calculations to include Scope 3 emissions (e.g., raw material sourcing and transportation).

2.2. Optimization of Fluid Formulations

Quantum algorithms can identify eco-friendly drilling fluid formulations by

- Simulating millions of chemical combinations.
- Predicting their performance under high-pressure, high-temperature conditions.
- Prioritizing materials with lower carbon intensities.

2.3. Supply Chain Modeling

Quantum computing's ability to solve complex optimization problems enables:

- Route Optimization: Identifying energy-efficient transportation routes for drilling fluids.
- Demand Prediction: Minimizing waste by accurately forecasting fluid requirements for specific drilling campaigns.

2.4. Industry Benchmarking

To contextualize the potential of quantum computing, current industry practices were analyzed, including:

- Traditional LCA methodologies.
- Common challenges in emissions profiling, such as data gaps and assumptions.
- Case studies from operators and service companies.

---

3. Discussion

3.1. Current Industry Limitations

The oil and gas industry faces several challenges in drilling fluid emissions profiling

- Limited Scope: Most LCAs focus on production and disposal phases, often excluding Scope 3 emissions.
- Data Silos: Fragmented data across supply chains hinders comprehensive assessments.
- Static Models: Traditional methods lack the adaptability to integrate real-time operational changes.

3.2. Advantages of Quantum Computing

Quantum computing addresses these limitations by:

- Enhanced Accuracy: Modeling molecular interactions to predict emissions at an unprecedented level of detail.
- Dynamic Analysis: Continuously refining emission profiles using real-time data.
- Optimization Power: Solving large-scale supply chain and formulation problems faster and more effectively.

3.3. Challenges to Adoption

While promising, quantum computing faces several barriers:

- Technological Maturity: Quantum hardware and algorithms are still evolving.
- High Costs: Quantum systems require significant investment.
- Integration Complexity: Adapting quantum insights to existing workflows demands interdisciplinary collaboration.

---

4. Way Forward

To unlock the full potential of quantum computing for drilling fluid emissions profiling, the following steps are recommended

- Collaborative Research: Industry and academia should partner to develop quantum-based LCA tools tailored to oilfield operations.

- Pilot Projects: Test quantum algorithms on specific use cases, such as formulating lower-emission drilling fluids or optimizing logistics for fluid transportation.
- Data Standardization: Create industry-wide standards for data collection and sharing to support quantum applications.
- Training Programs: Equip industry professionals with the skills needed to understand and apply quantum technologies.

5. Conclusion

Quantum computing has the potential to transform the carbon footprint assessment of drilling fluids, enabling more accurate and comprehensive LCAs, optimizing formulations, and enhancing supply chain efficiency. By addressing the limitations of classical methods, quantum technologies can drive the industry toward a more sustainable future. However, realizing this potential requires overcoming technical, financial, and organizational challenges. With strategic investments and collaboration, the oil and gas industry can position itself at the forefront of quantum-enabled sustainability.

Compliance with ethical standards

Disclosure of conflict of interest

No Conflict of Interest to be disclosed. It has been presented at 2025 Winter Exploration and Production Standards API Meeting- San Antonio.

References

[1] Arute, F., Arya, K., Babbush, R., et al. (2019). Quantum supremacy using a programmable superconducting processor. Nature, 574(7779), 505–510.

[2] Aspuru-Guzik, A., and Perdomo-Ortiz, A. (2012). Quantum computers for computational chemistry. Chemical Society Reviews, 41(19), 5095–5106.

[3] Pasquali, F., Kitzinger, A., and Caldararo, G. (2023). Applications of quantum computing in life cycle analysis for energy-intensive industries. Journal of Cleaner Production, 385, 135927.

[4] ExxonMobil. (2023). Pathways to reduce emissions in drilling operations. Retrieved from www.exxonmobil.com.

[5] International Energy Agency (IEA). (2022). Energy Technology Perspectives 2022: Towards sustainable energy systems.