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(REVIEW ARTICLE)

Emissions tracking in well construction using distributed ledger technology and numerical models

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Abstract

Well construction in the oil and gas industry generates substantial emissions, necessitating precise tracking to meet environmental regulations and sustainability targets. This paper explores an innovative approach combining numerical modeling with distributed ledger technology (DLT) to monitor and manage emissions throughout the well construction process. Unlike traditional methods, which often rely on retrospective data collection, this method leverages real-time simulations and a decentralized data framework to provide actionable insights. By focusing on predictive modeling and data integration, we propose a system that enhances emissions accountability and supports operational efficiency. Case studies demonstrate its practical application, while the discussion addresses implementation challenges and future potential.

Keywords: Distributed Ledger; Carbon footprint; Sustainability; Numerical modelling; Carbon credit

1. Introduction

The process of constructing wells drilling, casing, and completing remains a critical operation in the oil and gas sector, yet it is a major source of greenhouse gas emissions, including carbon dioxide (CO_2) and methane (CH_4). With increasing global emphasis on reducing industrial carbon footprints, accurate emissions tracking has become essential. Conventional tracking systems, often based on manual logs and post-operation audits, struggle to capture the dynamic nature of emissions during well construction. This paper introduces a novel framework that integrates advanced numerical models with distributed ledger technology (DLT), a decentralized system for secure data recording first conceptualized by Nakamoto (2008). While DLT ensures data integrity, the core innovation lies in numerical models that simulate emissions in real time, offering a proactive rather than reactive approach. This study outlines the methodology, evaluates its benefits, and presents real-world examples of its use.

2. Discussion

Emissions in well construction stem from diverse sources, such as drilling rig fuel combustion, flaring, and cement curing. Numerical models, rooted in computational fluid dynamics and thermodynamics, can predict these emissions by simulating operational parameters like drilling speed, fuel consumption, and gas venting. For instance, a model might estimate CO_2 output from a diesel rig based on its power rating and runtime, providing a granular view unavailable in traditional reporting (Johnson and Patel, 2022). These simulations rely on real-time data inputs pressure, temperature, and flow rates collected via sensors embedded in drilling equipment. The result is a dynamic emissions profile that evolves as the well progresses, enabling operators to adjust practices on the fly, such as reducing flaring duration or optimizing engine efficiency. Distributed ledger technology complements this system by securely storing and sharing the modeled data across stakeholders. Unlike centralized databases, DLT allows operators, regulators, and

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environmental auditors to access a tamper-proof record of emissions in real time (World Economic Forum, 2021). This transparency fosters trust and simplifies compliance with regulations like the Paris Agreement. Moreover, the decentralized nature of DLT ensures that data from remote well sites, often located offshore or in isolated regions, remains accessible without relying on a single point of failure. However, the system's reliance on numerical models introduces challenges. Model accuracy depends on high-quality input data, and discrepancies between simulated and actual emissions can occur if sensors fail or conditions deviate from assumptions (Lee et al., 2023). Calibration against physical measurements is thus critical. The integration of numerical models and DLT offers several advantages over conventional methods. Predictive modeling identifies emission hotspots such as excessive gas venting during casing allowing preemptive mitigation, while DLT provides an auditable trail for carbon credit verification. Yet, implementation is not without hurdles. Developing accurate models requires significant computational resources, and integrating DLT with existing infrastructure demands upfront investment and technical expertise. Despite these obstacles, the combined approach promises a scalable solution for emissions tracking as the industry shifts toward sustainability.

3. Case studies

3.1. North Dakota Predictive Emissions Model

An operator in North Dakota deployed a numerical model to track emissions during a Bakken shale well's construction (American Petroleum Institute, 2024). The model, fed by sensor data on fuel use and methane leaks, predicted a 20% higher emissions rate than initial estimates, prompting a switch to electric rigs for the final drilling phase. DLT recorded the data, enabling the operator to claim carbon credits verified by state regulators. This case highlights the power of predictive tools in driving operational changes.

3.2. Offshore Norway Real-Time Tracking

A Norwegian offshore project integrated numerical simulations with DLT to monitor emissions from cementing and drilling (Equinor, 2023). The model forecasted CO_2 emissions from cement curing, revealing inefficiencies in mixing ratios. Adjustments reduced emissions by 12%, with DLT providing a transparent log for environmental auditors. The system's success underscored its applicability in remote settings.

3.3. Alberta Hybrid System Pilot

In Alberta, a hybrid approach combined numerical models with DLT to track flaring emissions during well completion (Canadian Energy Regulator, 2024). The model predicted flare volumes based on gas composition, while DLT shared results with local communities and regulators. The pilot cut flaring by 15% through real-time adjustments, proving the value of community-involved transparency.

4. Conclusion

The fusion of numerical modeling and distributed ledger technology offers a transformative method for tracking emissions in well construction. By prioritizing predictive simulations, this approach shifts the focus from retrospective reporting to real-time management, empowering operators to minimize their environmental impact (Johnson and Patel, 2022). DLT enhances this system by ensuring data reliability and accessibility, bridging gaps between industry and regulatory bodies (World Economic Forum, 2021). The case studies illustrate its feasibility across diverse contexts, though challenges like model accuracy and implementation costs remain. As computational power grows and DLT adoption expands, this framework could set a new standard for emissions accountability in the oil and gas sector, supporting broader climate goals. Future efforts should refine model precision and streamline integration for widespread use.

Compliance with ethical standards

Disclosure of conflict of interest

No Conflict of Interest to be disclosed. It has been presented at API Drilling and Completion Fluids Standards Low Carbon / Sustainability group meeting for SC13

References

[1] American Petroleum Institute (2024). Emerging Technologies in Shale Gas Operations.

[2] Canadian Energy Regulator (2024). Flaring Reduction Strategies: 2023 Pilot Report.

[3] Equinor (2023). Sustainability in Offshore Operations: Annual Review.

[4] Johnson, R., and Patel, S. (2022). Numerical Modeling for Emissions in Heavy Industry. Journal of Environmental Engineering.

[5] Lee, K., Zhang, Y., and Thompson, M. (2023). Calibration Challenges in Real-Time Emissions Models. Energy Systems Research.

[6] Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System.

[7] World Economic Forum (2021). Blockchain for Climate Action: Harnessing Technology for Sustainability.