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(Review Article)

Lifecycle carbon mapping of well construction- blockchain carbon footprint profiling

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Abstract

The construction of wells, particularly in the oil and gas sector, is a carbon-intensive process that contributes significantly to global greenhouse gas emissions. Traditional carbon footprint tracking methods often lack transparency and accuracy due to centralized data management systems. Blockchain technology, with its decentralized, immutable, and transparent nature, offers a promising solution for profiling and managing the carbon footprint of well construction. This paper examines how blockchain can enhance carbon tracking, reduce emissions, and support sustainability goals in well construction projects. Through a discussion of its application, case studies, and potential challenges, we highlight blockchain's role in revolutionizing environmental accountability in this industry. The findings suggest that blockchain can provide a reliable framework for carbon management, though its energy consumption remains a critical consideration.

Keywords: Well Construction; Carbon mapping; Emissions; Sustainability; Energy Transition

1. Introduction

Well construction, encompassing drilling, completion, and infrastructure development, is a cornerstone of the oil and gas industry. However, it is also a significant contributor to carbon dioxide (CO_2) and other greenhouse gas emissions due to energy-intensive machinery, material production, and transportation. As global pressure mounts to achieve net-zero emissions, industries are seeking innovative tools to monitor and mitigate their environmental impact. Blockchain technology, first introduced by Nakamoto (2008) for cryptocurrency transactions, has emerged as a transformative tool across various sectors due to its ability to securely record and share data in a decentralized manner. In the context of well construction, blockchain offers the potential to profile carbon footprints with unprecedented accuracy and transparency. This paper explores how blockchain can be applied to track emissions throughout the well construction lifecycle, discusses its benefits and limitations, and presents case studies to illustrate its practical implementation.

2. Discussion

Well construction involves multiple stages site preparation, drilling, casing, cementing, and completion each with distinct carbon emission sources. Diesel-powered drilling rigs, cement production, and steel manufacturing are among the largest contributors. Traditional carbon accounting relies on manual reporting and centralized databases, which are prone to errors, manipulation, and inefficiencies. Blockchain addresses these issues by providing a distributed ledger where all stakeholders operators, suppliers, regulators can record and access emission data in real time (World Economic Forum, 2021). Blockchain's key features immutability, transparency, and smart contract functionality make it ideal for carbon footprint profiling. For instance, emissions data from equipment usage, fuel consumption, and material sourcing can be logged as transactions on the blockchain, while smart contracts can automate carbon credit

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allocation or trigger penalties when emission thresholds are exceeded, incentivizing sustainable practices. Additionally, blockchain's traceability ensures that every ton of CO_2 emitted is accounted for, from raw material extraction to well completion. However, blockchain's environmental impact cannot be ignored. Many blockchain networks, particularly those using Proof-of-Work (PoW) consensus mechanisms like Bitcoin, consume vast amounts of electricity, often from fossil fuel sources (Sedlmeir et al., 2020). This raises a paradox: can a technology with its own carbon footprint effectively reduce emissions in well construction? Alternatives like Proof-of-Stake (PoS) blockchains, which use significantly less energy, offer a more sustainable option. Integrating renewable energy sources into blockchain operations could further align this technology with carbon reduction goals. The benefits of blockchain in well construction include enhanced accountability, streamlined regulatory compliance, and improved supply chain transparency. By linking carbon data to specific project phases, operators can identify high-emission activities and implement targeted mitigation strategies, such as optimizing drilling techniques or using low-carbon materials. Yet, challenges remain, including the high initial cost of implementation, the need for industry-wide adoption, and the technical complexity of integrating blockchain with existing systems.

3. Case studies

3.1. Hyperledger Fabric in Oilfield Operations

A consortium of oil and gas companies piloted a Hyperledger Fabric-based blockchain to track emissions during well construction in the North Sea (Hyperledger Foundation, 2023). Sensors on drilling rigs recorded fuel consumption and emissions, which were uploaded to the blockchain in real time. Smart contracts calculated the carbon footprint and allocated carbon credits to offset emissions. The project reduced reporting errors by 30% and enabled regulators to verify data instantly, demonstrating blockchain's potential for transparent carbon profiling.

3.2. Ethereum-Based Carbon Tracking in Texas

A Texas-based operator used an Ethereum blockchain with a PoS consensus mechanism, as outlined by the Ethereum Foundation (2022), to monitor emissions from a shale well construction project. The system tracked emissions from cement production, transportation, and drilling, linking data to a decentralized ledger. The operator reported a 15% reduction in emissions after identifying inefficiencies in cement mixing processes, showcasing how blockchain can drive operational improvements. However, the energy consumption of the blockchain itself was a noted concern, mitigated partially by using PoS.

3.3. BP and Shell's Blockchain Pilot

In 2023, BP and Shell collaborated on a blockchain platform to profile carbon footprints across their well construction supply chains (BP and Shell, 2024). Using a private blockchain, they tracked emissions from steel casing production to offshore drilling. The pilot revealed that 40% of emissions stemmed from material manufacturing, prompting a shift to lower-carbon suppliers. This case underscores blockchain's ability to enhance supply chain sustainability, though scalability remains a challenge.

4. Conclusion

Blockchain technology holds significant promise for profiling the carbon footprint of well construction, offering a transparent and reliable method to track emissions across complex operations. Its ability to integrate real-time data, enforce accountability, and support sustainability initiatives makes it a valuable tool for the oil and gas industry's transition to a low-carbon future (World Economic Forum, 2021). However, its effectiveness depends on addressing its own energy demands, likely through PoS mechanisms and renewable energy integration, as Sedlmeir et al. (2020) suggest. The case studies illustrate practical applications, highlighting both successes and hurdles. As the technology matures and adoption grows, blockchain could redefine environmental management in well construction, aligning economic interests with global climate goals. Future research should focus on optimizing blockchain's energy efficiency and developing standardized frameworks for industry-wide use.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed. It has been presented at Offshore Technology Conference (OTC) 2025..

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