Quantifying Asset Downtime in CCUS Value Chains: Impacts on Carbon Credit Generation and Strategies for Mitigation

P. Saini
Product Leader, Baker Hughes, Delft, Netherlands

U. Biradar
Technology Leader, Baker Hughes, Mumbai, India

K. Sonawane
Product Manager, Baker Hughes, Mumbai, India

A. Mehta
Software Architect, Baker Hughes, Mumbai, India

D. Chauhan
Software Architect, Baker Hughes, Mumbai, India

S. Bordoloi
Sr. Director, Baker Hughes, London, United Kingdom

Abstract

Carbon Capture Utilization and Storage (CCUS) systems are increasingly recognized as a critical pathway for achieving net-zero targets and enabling compliance with carbon reduction commitments. While significant research has focused on improving capture efficiency, optimizing transportation networks, and ensuring storage integrity, one operational dimension remains underexplored: asset downtime and its cascading impact on the CCUS value chain. Downtime events, whether planned or unplanned, directly influence the volume of carbon captured and stored, thereby affecting the generation of carbon credits and overall project economics. This paper examines the systemic implications of downtime across capture units, compression facilities, transportation infrastructure, and injection wells, highlighting how even short interruptions can lead to disproportionate financial and environmental consequences.

The study begins by establishing a framework for quantifying downtime in terms of lost carbon credits and associated revenue under varying carbon pricing scenarios. It then explores the operational interdependencies within the CCUS chain, demonstrating how localized failures propagate through connected assets, creating bottlenecks and reducing overall throughput. Using real-world case examples and simulation models, the paper illustrates the sensitivity of credit generation to uptime performance, emphasizing the need for robust monitoring and predictive maintenance strategies.

To address these challenges, the paper proposes a multi-pronged approach. First, it advocates for the integration of advanced digital technologies such as IoT-enabled sensors and SCADA systems for real-time asset health monitoring. Second, it introduces predictive analytics and machine learning models capable of forecasting potential failures and optimizing maintenance schedules to minimize disruptions. Third, it examines the role of digital twins in simulating operational scenarios and stress-testing mitigation strategies before implementation. Additionally, the paper considers emerging solutions such as blockchain-based credit assurance mechanisms to maintain transparency and trust in carbon accounting during downtime events.

Beyond technical interventions, the paper discusses regulatory and market implications, including how downtime reporting could evolve into a compliance requirement under future carbon credit standards. It also evaluates cost-benefit trade-offs for redundancy and modularization strategies, offering practical recommendations for operators seeking to balance reliability with economic efficiency.

By framing asset downtime as a critical determinant of CCUS performance and credit generation, this research contributes a novel perspective to the discourse on carbon management. It underscores the importance of proactive risk mitigation and digital transformation in safeguarding the financial viability and environmental integrity of CCUS projects. Ultimately, the paper aims to provide actionable insights for industry stakeholders, policymakers, and technology developers committed to accelerating the deployment of resilient and economically sustainable CCUS systems.

Keywords

CCUS, Asset Downtime, Carbon Credits, Predictive Maintenance, Digitalization.