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CEMENT WHITE PAPER

Process Stability as a Precondition for CCUS in Cement Plants

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Executive Summary

As the cement industry faces increasing pressure to reduce its carbon footprint, Carbon Capture, Utilisation, and Storage (CCUS) is gaining traction as a key technology. Yet its implementation remains complex. One core barrier: unstable cement production processes. This whitepaper by aixprocess explores how digital twin technology, advanced engineering, and predictive process control lay the essential foundation for effective CCUS deployment. The result? Higher availability, fewer failures, and stable gas conditions - exactly what CCUS systems need to work reliably.

Introduction

With roughly 2.3 gigatonnes of CO_2 emissions annually, the cement industry plays a central role in global climate action. CCUS technologies promise to capture up to 90% of process emissions, offering a realistic decarbonisation pathway. However, these systems are susceptible to unstable operating conditions - something the cement process is notoriously prone to.

This paper shares practical experience from aixprocess and outlines a strategic pathway to stabilise plant operations using engineering best practices, real-time monitoring, and digital twin solutions.

Understanding Process Instabilities

Common Failures

Several recurring failure modes disrupt reliable kiln operation:

- Cyclone blockages interrupt feed flow.
- Meal flushing causes pressure surges and shutdowns.
- Refractory damage leads to unscheduled outages.
- Kiln rings interfere with heat transfer and burner performance.

Why Instability Is a Problem

Instability is not only operationally disruptive but also financially and environmentally costly:

- A cold restart after a complete shutdown can cost ~€500,000 if a CCUS unit is installed.
- Variable gas conditions reduce CCUS separation efficiency and component lifetime.
- Downtime increases energy intensity and CO_2 emissions per ton of clinker.

Case Study: Data from a European Plant

- 495 kiln stops per year
- 3034 hours of downtime
- Only 65% kiln availability
- MTBF (mean time between failures): 11.5 hours

This level of instability makes CCUS integration technically unviable without first addressing operational variability.

Root Causes: Malfunctions vs. Disturbances

- **Malfunctions** are equipment or control failures (e.g., fuel spills, partial combustion).
- **Disturbances** arise from natural process variability (e.g., RDF moisture, raw meal fluctuations).

Mechanical upgrades can fix malfunctions, but disturbances require data-driven process control and real-time monitoring.

Strategic Pathway to Stabilisation

1. Engineering Foundations

- Regular maintenance to avoid blockages and mechanical issues
- Optimisation of burners and fuel supply systems
- Better combustion design for variable fuels

2. Digital Twin Integration

- Use digital twins to track KPIs like pressure, temperature, and emissions
- Apply AI to anticipate instabilities and prevent failures
- Move toward closed-loop automation for better control

3. Organisational Enablement

- Train teams in using AI tools and interpreting sensor data
- Build data infrastructures for real-time and historical analysis
- Focus investment on scalable, digital-ready process components

Conclusion: Stability Enables Sustainability

CCUS is only effective when processes are stable. Through digital transformation and smart process engineering, cement producers can:

- Increase availability and reduce failure rates
- Ensure stable conditions for CCUS
- Cut emissions while maintaining profitability

The future of cement decarbonisation depends not just on new technologies - but on reliable, optimised process performance.



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