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CEMENT USE CASE

Stepwise Transition to High Alternative Fuel Substitution

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Executive Summary

This case study demonstrates how a data-driven, phased engineering approach can guide cement plants through the transition to significantly higher alternative fuel (AF) use in clinker production. By applying Computational Fluid Dynamics (CFD)-based process simulation and implementing targeted technical interventions, a clinker production line achieved up to 50% Thermal Substitution Rate (TSR) using Refuse-Derived Fuel (RDF) and other AFs. Throughout the project, process stability, emissions compliance, and clinker quality were maintained—highlighting the viability and impact of digital engineering in decarbonising cement production.

Introduction

Global cement producers are under growing pressure to reduce carbon emissions and improve energy efficiency. With traditional fossil fuels becoming more expensive and less sustainable, the adoption of alternative fuels (AF) like RDF has emerged as a practical and environmentally sound strategy. However, transitioning existing kiln systems to high levels of AF usage presents significant challenges—ranging from combustion instability and emissions control to fuel quality variability and equipment limitations.

This use case outlines a successful technical roadmap for achieving up to 50% TSR in an operational 3500 tpd clinker line, commissioned in the late 1980s and modernised in 2007. The multi-phase strategy was developed through a combination of advanced digital simulation, on-site diagnostics, and incremental implementation to ensure feasibility at every step.

Project Objective

To implement a phased strategy enabling up to 50% TSR via RDF and other alternative fuels, while maintaining clinker quality, kiln stability, and full emissions compliance.

Initial Plant Conditions

- Rated capacity: 3500 tpd clinker
- Design-specific heat consumption: ~920 kcal/kg clinker
- Limited infrastructure for AF co-processing

Key Technical Challenges

- CO Emissions Control: Excess CO from the calciner can cause kiln instability and pose risks to ESP operation.
- Pressure Drop Management: The plant's ID fan capacity is fixed, requiring any ducting modifications to avoid increasing pressure loss.
- Clinker Quality Assurance: Increased AF use must not impact phase composition or compressive strength.
- Fuel Specification Compliance: RDF needs to meet strict calorific and compositional standards to ensure reliable combustion.

Phased Implementation Plan

Phase 1: Operational Optimization with Current Setup

- Stabilise RDF feed to reduce fluctuations.
- Optimise control parameters:
    - Oxygen concentration to enhance combustion
    - Kiln speed for residence time adjustment
    - Calciner temperature for burnout reliability
- Incrementally increase TSR to ~15–20%.
- Establish emissions baseline via CO/NOx measurements.

Phase 2: Mechanical Upgrade with modification Package 1

- Scope:
    - Relocate and optimise meal feed boxes.
    - Reconfigure coal burners to improve flame shape and distribution.
    - Install precise, continuous RDF dosing system for calciner.
- Expected Impact:
    - Increase TSR to ~30–35%.
    - Improve burn consistency.
    - CO build-up may still pose operational limits.

Phase 3: Advanced Upgrade with Package 2:

- Scope:
    - Extend calciner for longer residence time.
    - Install Post-Combustion Chamber (PCC) for complete burnout.
    - Implement all Package 1 upgrades.
- Expected Impact:
    - Reach TSR levels up to 50%.
    - Reduce CO emissions and ensure ESP safety.
    - Achieve more stable and efficient calciner operation.

Outcomes and Strategic Gains

The CFD engineering resulted in the following KPI matrix.

Category	Phase 1	Phase 2	Phase 3
Modification	None	Pack 1	Pack 2
TSR	15–20%	30–35%	Up to 50%
Fuel Cost Savings	Moderate	Significant	Maximum
Emissions (CO/NOx)	Similar or slightly increased	Stable (risk of CO peaks)	Reduced CO, NOx (with SNCR)
Process Stability	Limited	Improved	Strong improvement
Fuel Flexibility	Low	Medium	High – can accept lower quality
CapEx Requirements	None	Medium	High

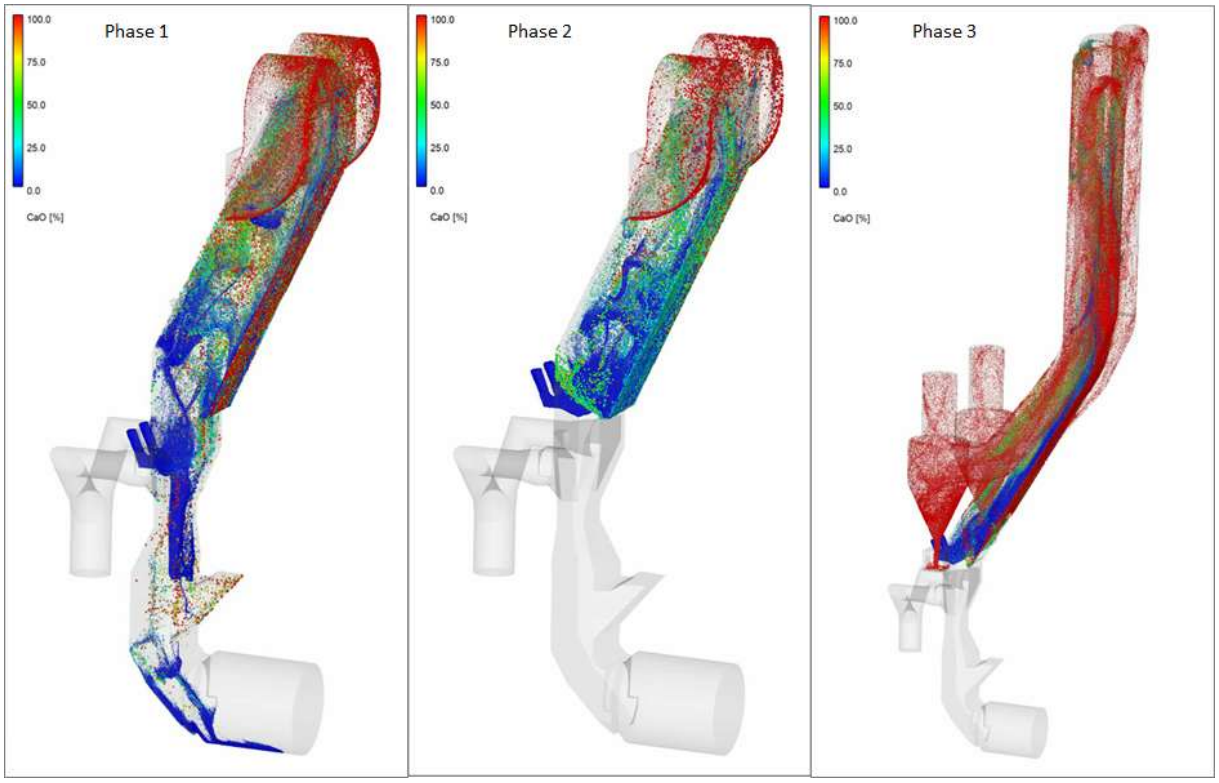

Figure 1 Meal motion and calcination improvement for the three phases of the stepwise TSR ramp-up

Conclusion

This use case illustrates the effectiveness of combining digital process engineering with phased technical upgrades in existing cement kilns. Through a rigorous audit and simulation-based roadmap, the plant achieved significant progress in alternative fuel usage. Each project phase was grounded in measurable data, enabling both environmental and economic benefits while laying the foundation for future digital integration.

From this project the successful application of CFD-Engineering for project de-risking and planning was demonstrated.