KILN OPTIMIZATION

1-3%
Yield Improvement

15-30%
Natural Gas Reduction

6 months
Kick-off to closed loop

The Problem & Deep Learning Process Control® (DLPC) Scope

A client with a 175 kTa Petroleum Coke Calcination Rotary Kiln wanted to extract untapped value from their process by maximizing yield across various product grades while respecting unit constraints. In addition, the client wanted to minimize CO2 emissions through reduced natural gas usage. Prior to DLPC, the client manually controlled to a target Burn Zone Temperature to meet finished product specifications. This was extremely challenging to accomplish due to:

- Variable Time Dynamics. Long Kiln residence time made it challenging monitor and model the impact of key variables on finished product specifications.
- Feed Variability. Variable raw material quality, imperfect methods for mixing solid feedstock, and unreliable methods for measuring feed qualities.
- Non-Linear Process Relationships. Key variables, such as fuel and air supply, did not have direct relationships to Kiln temperature, making it challenging to find the optimal operating point.

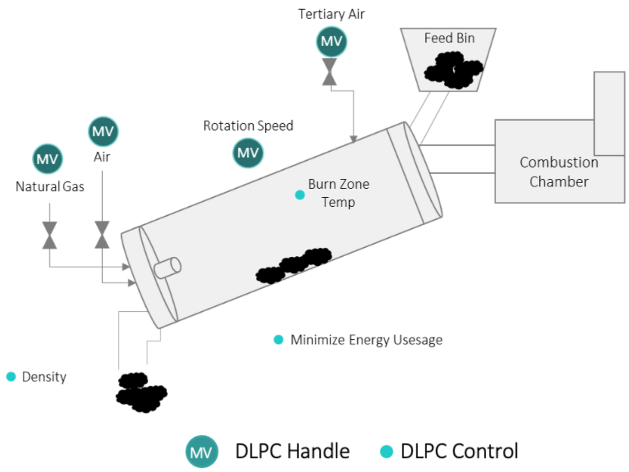
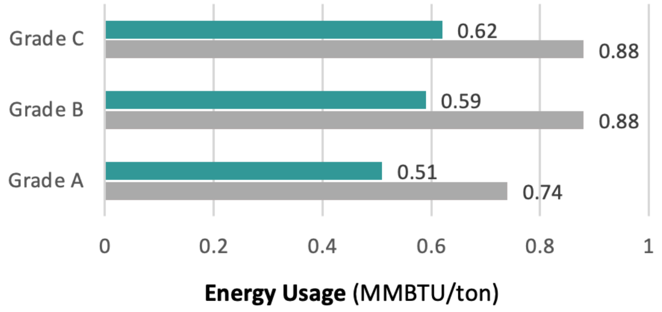


FIGURE 1 *Simplified system configuration and Rotary Kiln DLPC Design*

Value Generation



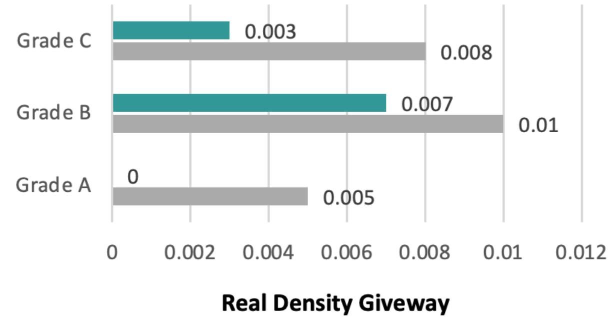


FIGURE 2 (Left) *6-month Energy Usage per ton product. DLPC consistently uses less 15-20% less energy across all product grades.*

FIGURE 3 (Right) *6-month Real Density Giveaway above requirement; DLPC reduces giveaway, thereby increasing yield.*

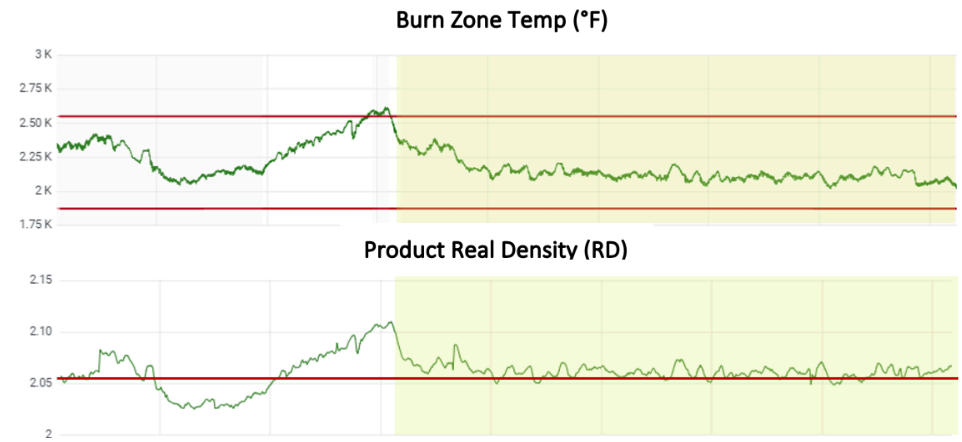
Over a 6-month period, DLPC was able to reduce kiln natural gas useage by 15-20% by using less energy per ton of petroleum coke while meeting product specificiation consistantly. This reduction in natural gas equates to approximately 15-30 kg of CO2 per ton of product. In addition, DLPC was also able to reduce Real Density giveaway by reducing the amount of coke burn in the Kiln. As a result, DLPC was able to accurately control to product specification, increasing product yields by 1-3%.

Realtime Performance

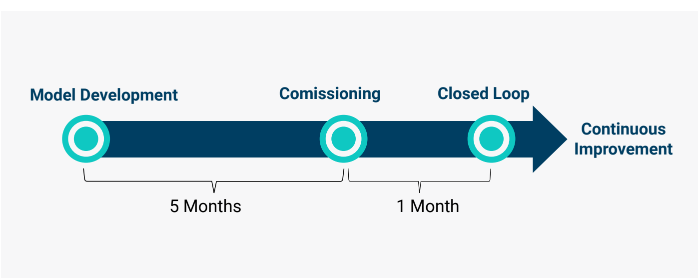
Without DLPC, there is a high degree of variability in operations, as operators struggle to manually optimize the dynamic operations of a Rotary Kiln to consistently optimize to product specification and energy utilization. In addition, the Burn Zone Temperature (kiln internal temperature) is run with high variability, leading to violation of Safe Operating Limits (SOLs) and product quality or giveaway on yield when operating well above Real Density (RD) limit.

With DLPC engaged, the Burn Zone Temperature is significantly reduced (~150°F) by dynamically adjusting air, natural gas, and kiln rotation speed as manipulated variables. DLPC also detects changes in feed quality and ambient conditions, constantly adjusting handles and controlling key variables. DLPC stabilizes Burn Zone Temperature to reduce natural gas usage, respect SOLs while significantly reducing Real Density giveaway. Finally, DLPC reduces violations in product quality limits. DLPC directly writes setpoints to the regulatory control layer, managing other key operating limits while maximizing yield and optimizing energy usage.

FIGURE 4 *Time series plot of Burn Zone Temperature (Kiln internal temperature) and Real Density (product specification) over a 2-day period. Both are critical operating limits. Without DLPC, both Burn Zone Temperature and RD have large variability and are violating limits. With DLPC, variability is significantly reduced. In addition, DLPC operates Kiln at lower temperature and consistently meet RD limit.*



Resources & Timeline



	Model Development	Commissioning	Continous Improvement
P&E	1-2 hrs/month	0-1 hr/day	1 hr/month
Ops	0-1 hr/week	4-8 hrs/day	1 hr/month
Process	1-2 hrs/week	2-4 hrs/day	1 hr/week
Controls	1-2 hrs/week	4-8 hrs/day	1 hr/week
IT	0-1 hr/week	per request	per request

DLPC Development, which includes Scoping, Data Cleaning, Model Training, and client approvals throughout the entire process, took 5 months. With 1 month of commissioning the model at the plant, the total timeline till Closed Loop was 6 months. Client resources throughout development include defining scope, sending data over to Imubit, and approving DLPC models during various milestones throughout Imubit's Project Workflow. Commissioning requires the most amount of support as it includes implementation, operations training, and building confidence with entire organization. Once model is Closed Loop and performing, Continuous Improvement effort requires minimal effort and can increase based on the desire of the client to be more involved in the process of developing DLPC models.