Digital Asistant for Clinker Kiln Operator

International SAP Conferences for Building Materials

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About Eurocement Group. Building in Harmony with Nature

Eurocement Group is an international industrial holding company, Russia's leading supplier of building materials and one of the **top five** biggest cement companies **in the world**. It has a total of 19 cement plants across CIS, as well as plants for ready-mix and prefabricated concrete manufacturing and aggregate mining quarries.

The **mission** of Eurocement is **Construction in Harmony with Nature** through continuous development as a goal:

- Supplying Russian construction industry with highest-quality building materials
- Enhancing green production and leveraging on environmental protection activities
- Transitioning to a new technological platform based on construction of state-of-the-art plants and upgrading existing facilities

60 mil. tons
Combined production capacity

5.5 bil. tons
Construction aggregates reserves

>300 mil.
Consumers of Eurocement products

42
Regional sales branches

Digital assistant for clinker kiln operator. Use case scope

Business Challenge

Quality and cost parameters majorly depend on equipment operation characteristics, specifically clinker kiln process times. Currently kiln operator controls the equipment based on target-set values and personal experience. As a result, operator concentrates on equipment operation and cannot thoroughly control its energy consumption. With energy costs making a substantial part of total manufacturing costs, it is crucial to increase energy efficiency in order to gain additional competitive edge.

Project goal

Develop **digital assistant for clinker kiln operator** to boost process energy efficiency without quality compromises based on data acquired from plant control system and input raw material laboratory as well as past quality level records.

Tasks

1

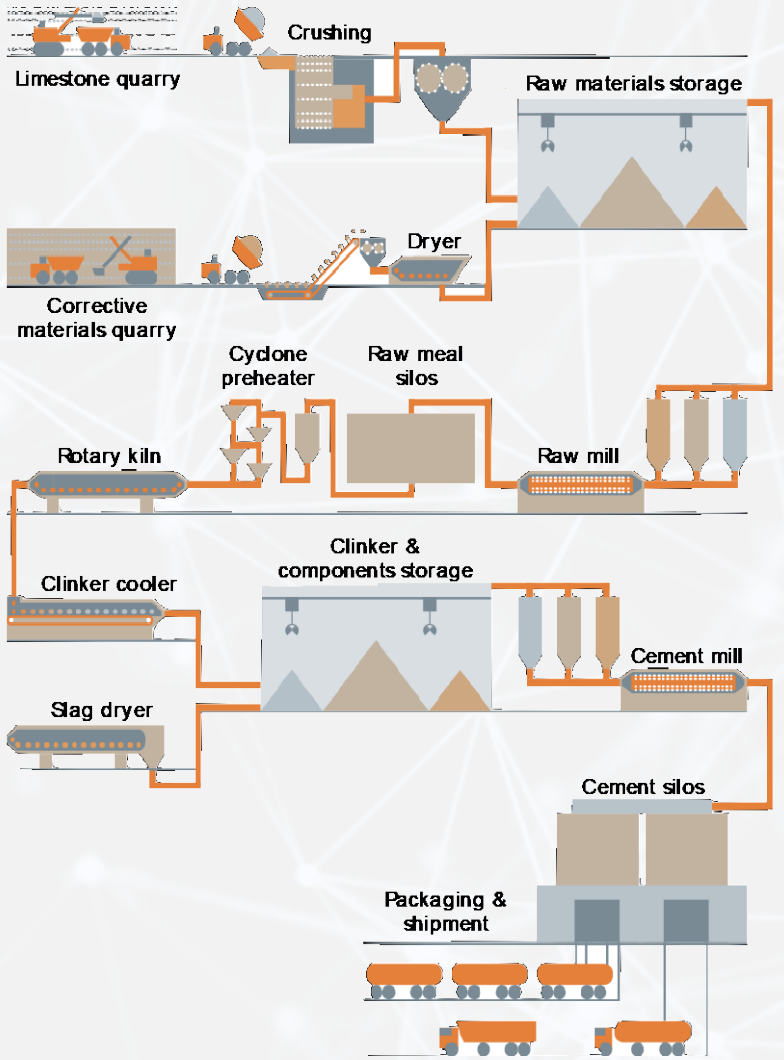
Predict clinker quality 2 hours ahead

2

Identify areas for energy efficiency optimization

3

Modelling of action recommendations for kiln operation



Digital assistant for clinker kiln operator. Project details

Project details

First, data collection from production systems, laboratory and raw materials records has been executed. The data volume in SAP HANA database increased 29 GB. 2061 parameters were deployed and for each visual and statistical analysis was performed. Window shifts were generated for verification purposes. Next, modelling of complex parameters for quality/energy consumption efficiency was performed in SAP HANA in order to determine target values for equipment operation.

Main steps

1. Data collection and preparation
2. Data analysis and definition of the target function
3. Detailed analysis of clinker kiln operation modes
4. Modeling the integrated quality/energy efficiency target parameter: defining target modes of operation
5. Completion and verification of mathematical model for kiln operation behavior

Fit-for-purpose solution – “going own way”

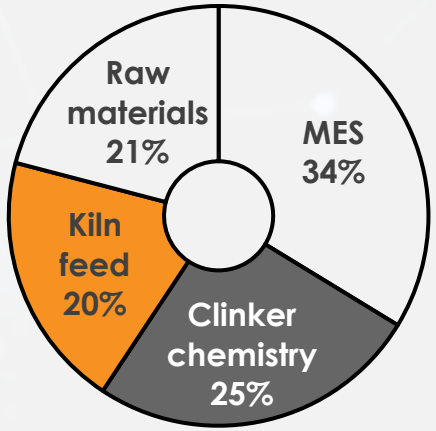
- Ready-made solutions (expert system, digital assistant) are not always transparent for the client – the function and logic are not clear. There are not existing products for some specific technologies (wet process kilns).
- Internal engineering experience.
- SAP experts (data scientists, business practitioners) – intellectual potential and competence.
- Synergy of implementation SAP S/4 HANA, MES and SAP MII and SCADA.

Data Analysis, Methods and Target Function Determination

Structure of data available

1. **Collected data series: 86 parameters и 529 962 values, distributed as follows:**

- 29 — data from MES
- 22 — clinker chemistry
- 17 — kiln feed
- 18 — raw materials



2. Generated window shifts for check:

- Statistics values – mean, standard deviation, min. value, max. value (window functions different length)
- Data fluctuation within 2, 4, 6, 8, 10 hours
- Parameters with defined limits and set points (from process engineers)

Set of data for processing & modelling

Necessity to improve quality and volume of collected data

- For the study the volume of data was 29 Gb. Created 2061 parameters
- For each parameter realized visual and statistical analysis, this allows correctly model process.
- There is necessity to improve quality (field instrumentation) and volume of data

Missing of data

Operations and control — change of parameters of equipment:

- ID fan rpm
- Booster fan rpm
- Tertiary air damper position
- Operator actions

Clinker cooler

- Thickness of clinker bed
- Grate strokes

Silos

- Allocation raw material to silo and its volume
- Raw materials homogenization

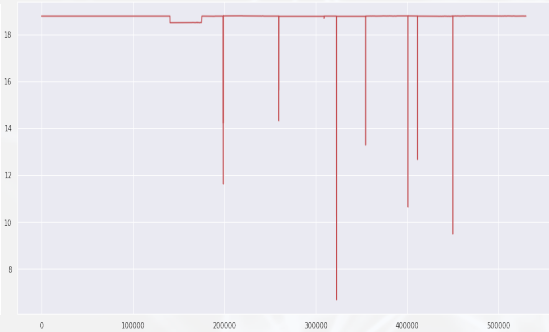
Quality and correctness of data

SCADA control system doesn't accumulate all necessary data:

- Trends of parameters and operations (influencing) in full scope
- There are gaps in trends

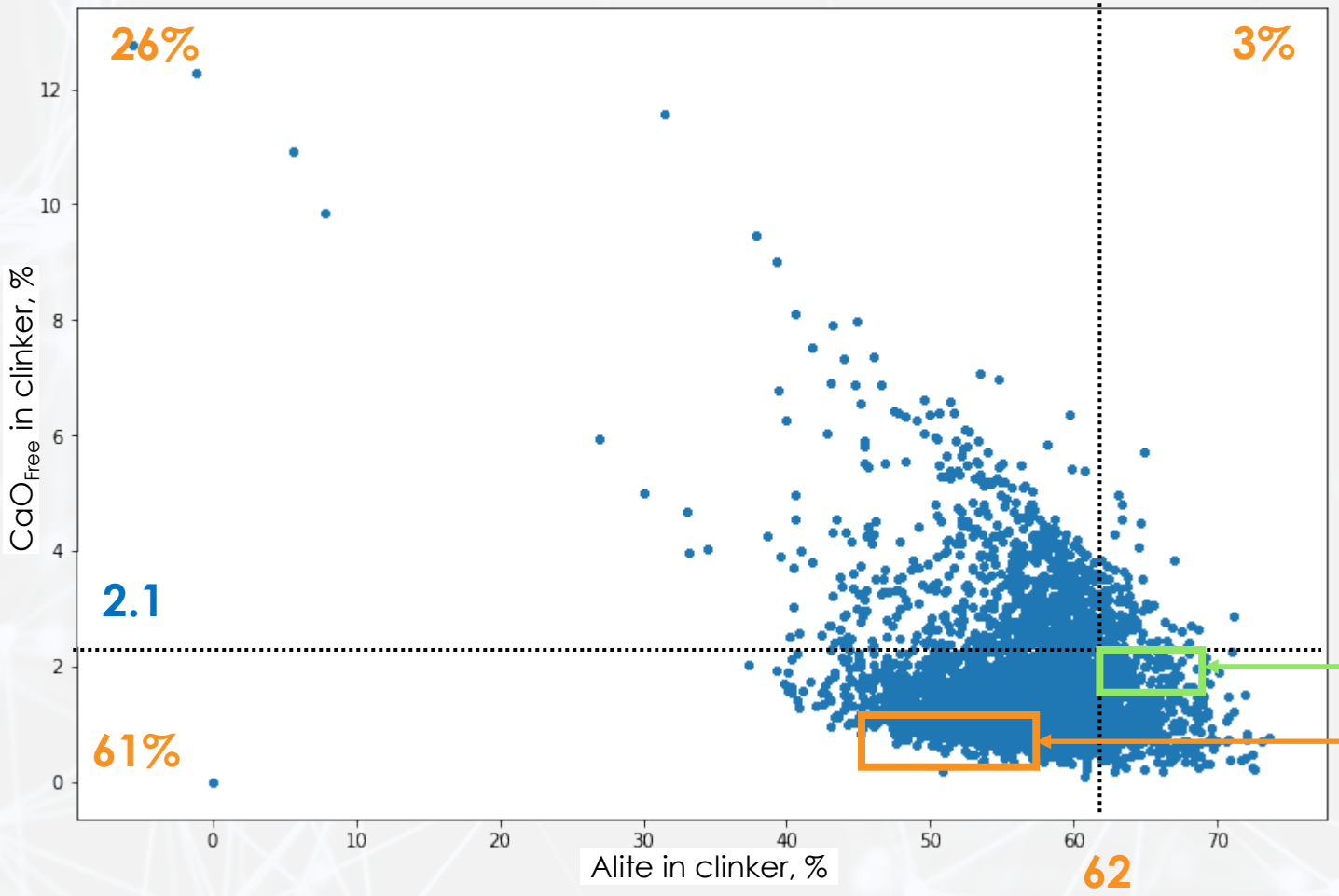
Trend NO_x since 08.06.2019 to 09.06.2020

Trend O_2 — kiln inlet



Only 10% results corresponds «targeted» values of clinker quality

Clinker quality analysis within 06.2019-06.2020



Significant part of clinker is out of «targeted» values of clinker quality

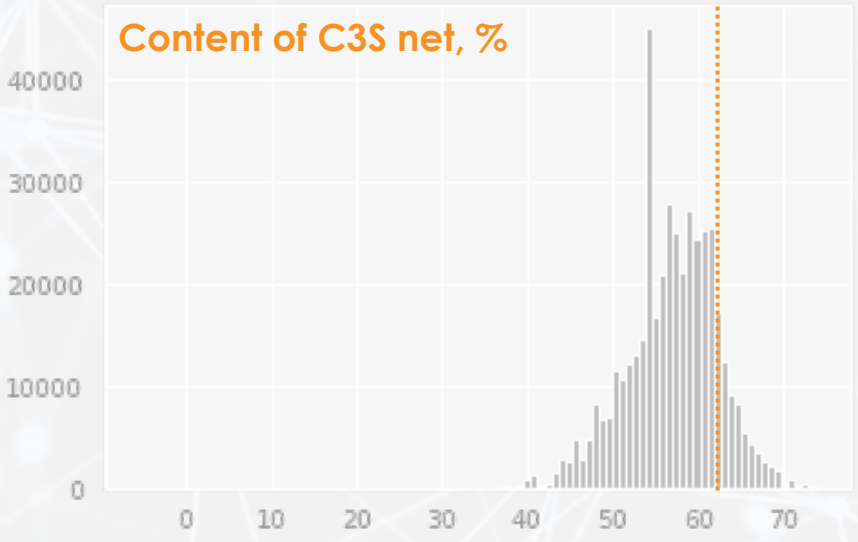
«Targeted» clinker quality

Alite 62-68, CaO_{Free} 1.9-2.1 – 0.8%

Alite 45-57, CaO_{Free} 0.5-1.5 – 27.0%

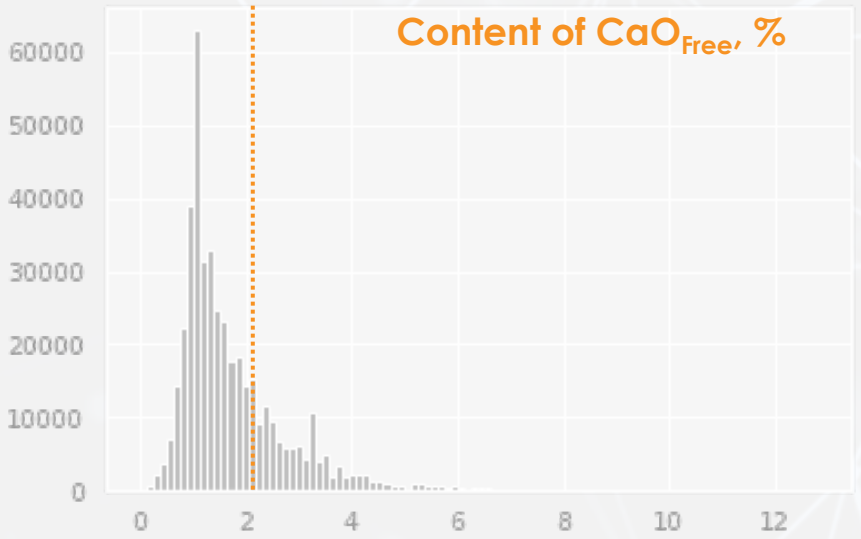
Clinker quality analysis. Alite content identified a main problem

Only in 14.4% cases Alite content in clinker exceeds 62%



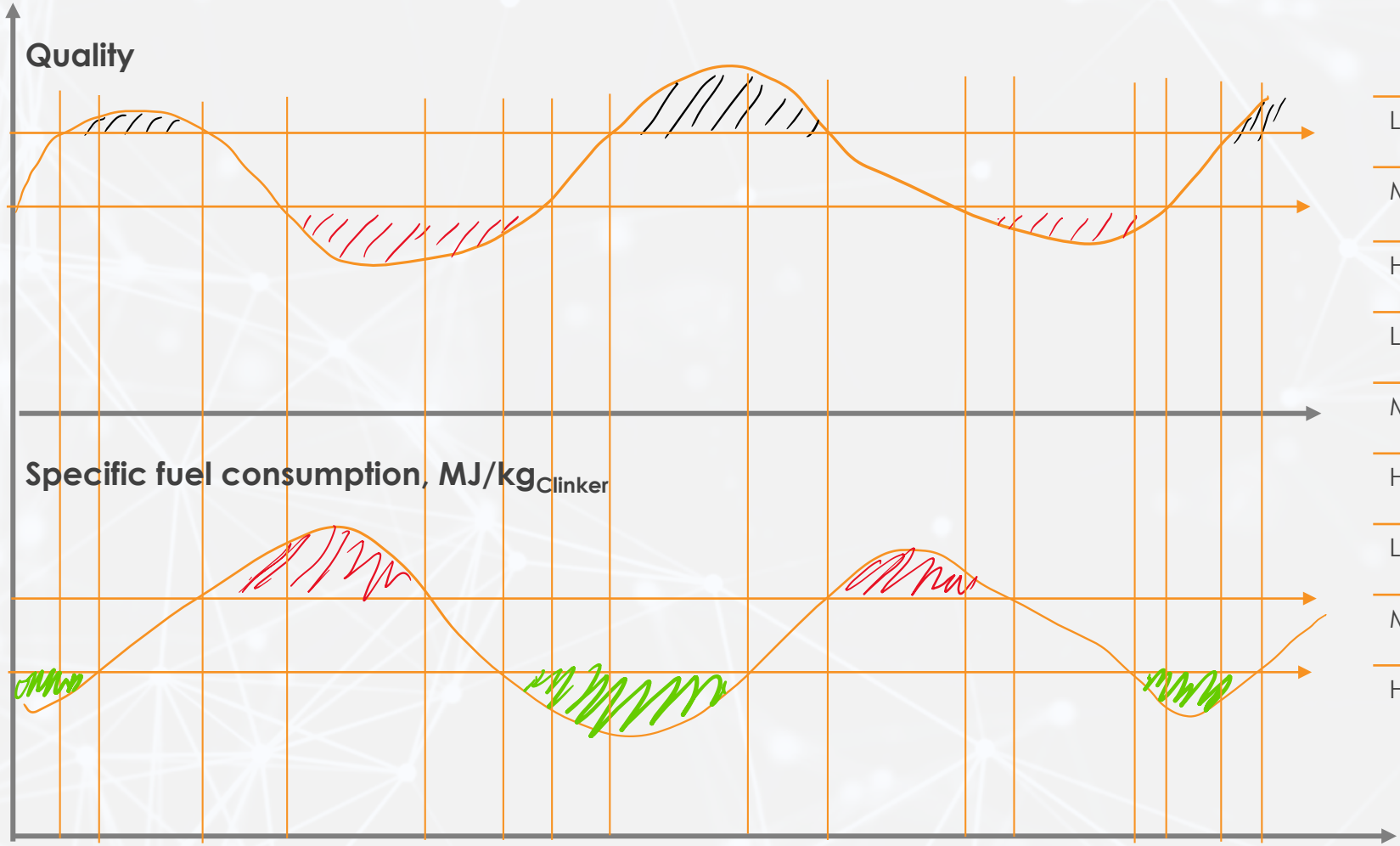
count	436521.000000
mean	56.709453
std	5.591680
min	-5.528430
25%	53.940550
50%	57.005490
75%	60.516970
max	73.656550

In 27% cases free lime content CaO_{Free} in clinker exceeds 2,1%



count	436521.000000
mean	1.765935
std	1.081888
min	0.000000
25%	1.110000
50%	1.410000
75%	2.150000
max	12.770000

Modelling of complex target parameter quality/fuel consumption efficiency. Identification target mode of operation

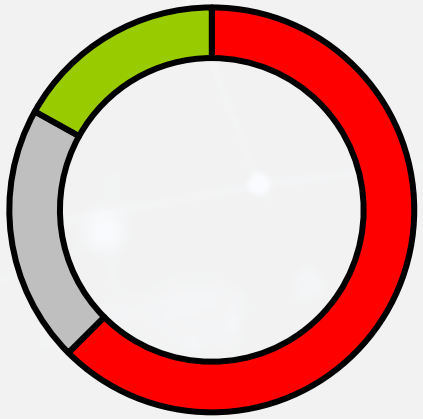


Quality	Fuel specific consumption	Markup class	Target value
Low	Low	1	0
Moderate	Low	2	1
High	Low	3	1
Low	Moderate	4	0
Moderate	Moderate	5	0
High	Moderate	6	1
Low	High	7	0
Moderate	High	8	0
High	High	9	0

Preliminary Results

Analysis of kiln modes of operation discovered high potential for optimization

Intense influencing*	62%
Shut down, repairs	21%
Stabilized operation**	17%



*Intense influencing — periods, when operator is driving the kiln manually to maintain operation and output

**Stabilized operation – periods, when operator can maintain kiln operation efficiency

- More than 20 accidental stoppages within period, total lost time 27 days
- Short-time stoppages more than 5 days

Zone	Specific fuel consumption MJ/$kg_{Clinker}$	Raw meal feed rate tph	Производство клинкера тонн в час
Red	3,381	364	233
Green	3,263	417	267

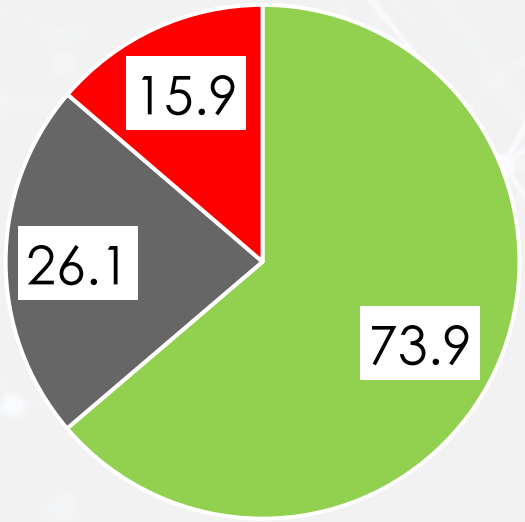
Increasing «green» zone on account of «red» by 20 % will result in additional:

- 48 days — period of stabilized operation
- 39700 т — extra clinker produced
- 42686 т — extra cement produced
- Extra sales
- Decrease of specific fuel consumption

Plant data analysis 2020

Operation and stoppages

- Operation – 73,9%
- Stoppge – 26,1%
- Accidental stoppage – 15,9%



- 69 accidental kiln stoppages within period
- Total period accidental stoppages - 58 days

KPI's

	PRI	GAI	NAI	NET OEE	MTBF
Achieved	90	73,9	74	67	94
Target	98	90	90	80	300

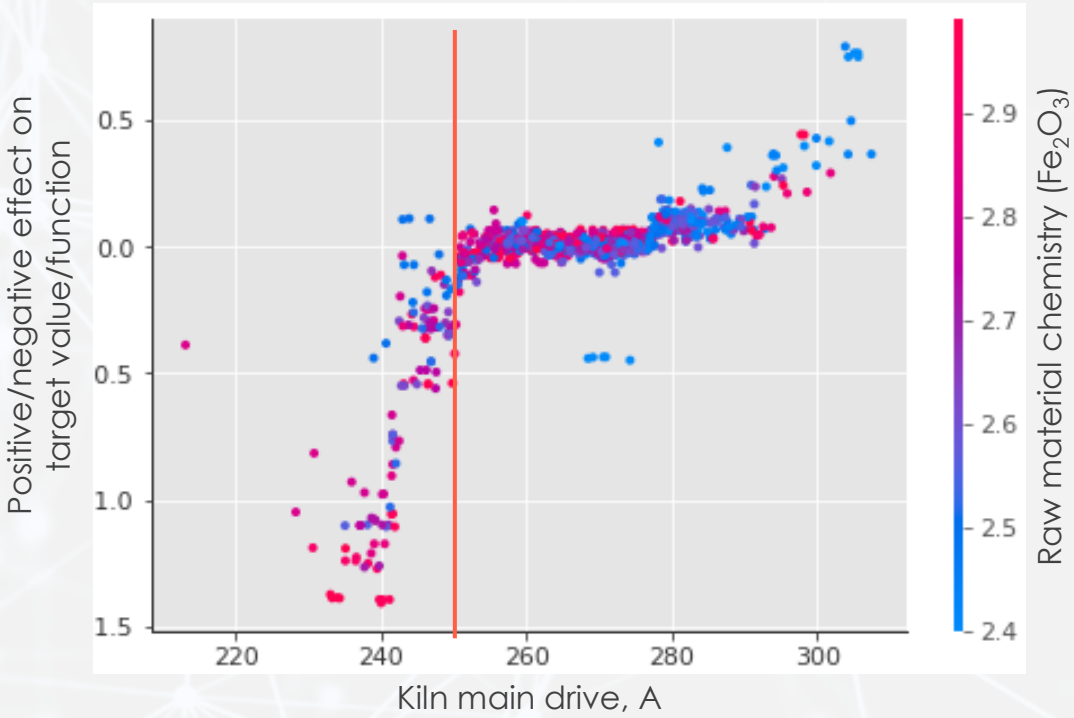
Due to the non-stable kiln operation and accidental stoppages – total operational efficiency of the kiln significantly decreased.
In this particular case, stabilization of kiln operation will result in PRI increase.

Stabilization of kiln operation and respective increasing PRI in 2,3% will result in:

- 35 874 т – extra clinker produced
- 39 461 т – extra cement produced
- Extra sales

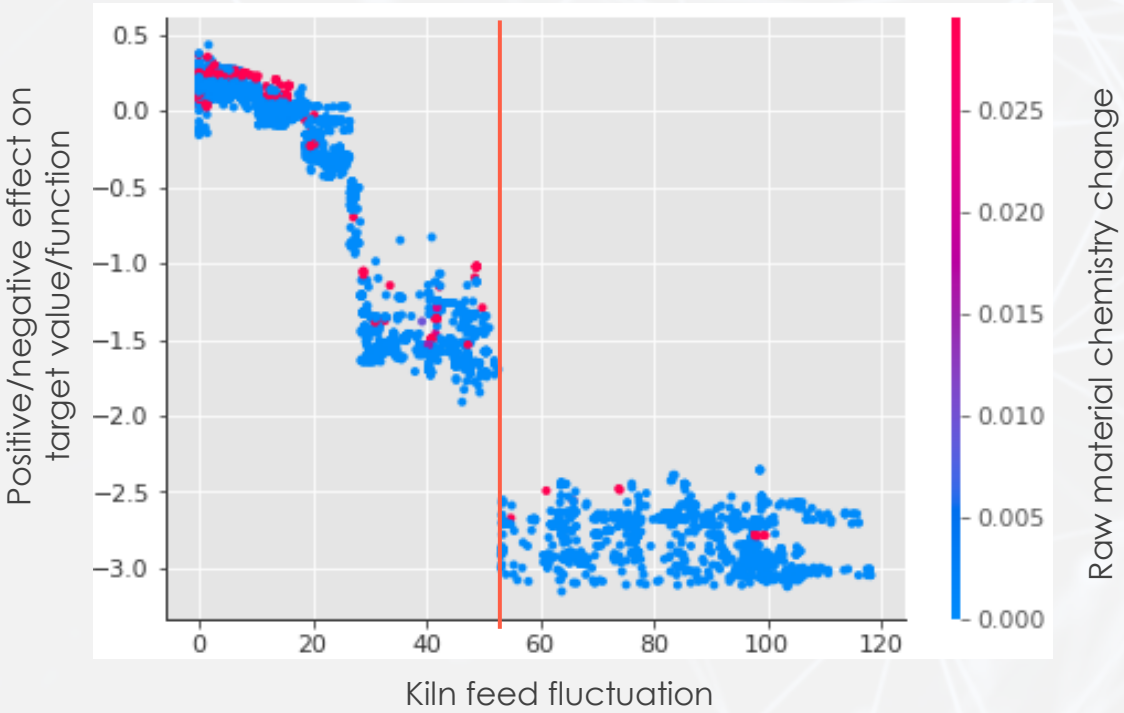
Stable kiln feed gives better quality clinker

Relation target function (quality + efficiency) on main drive load



In stable operation nominal current on the main drive to be not less 250A.

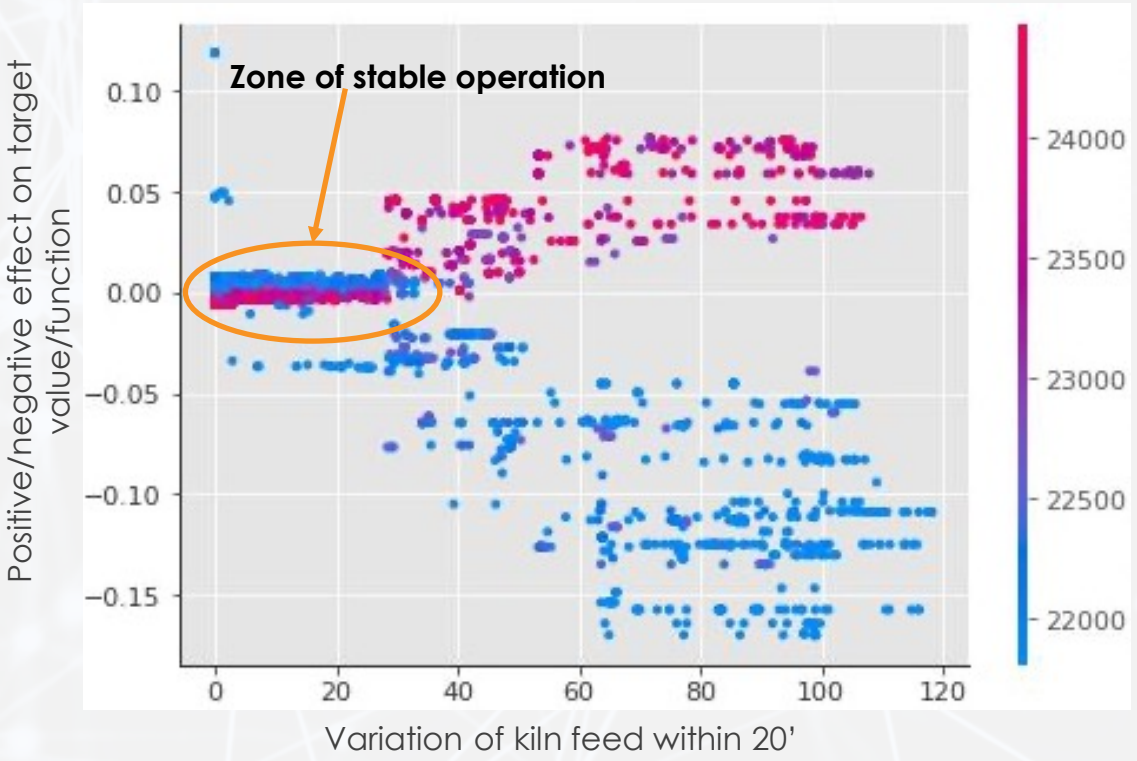
Relation target function (quality + efficiency) on change of raw materials chemistry



Identified significant relation target function on dispersion of kiln feed. The more the kiln feed fluctuates the worse target function.

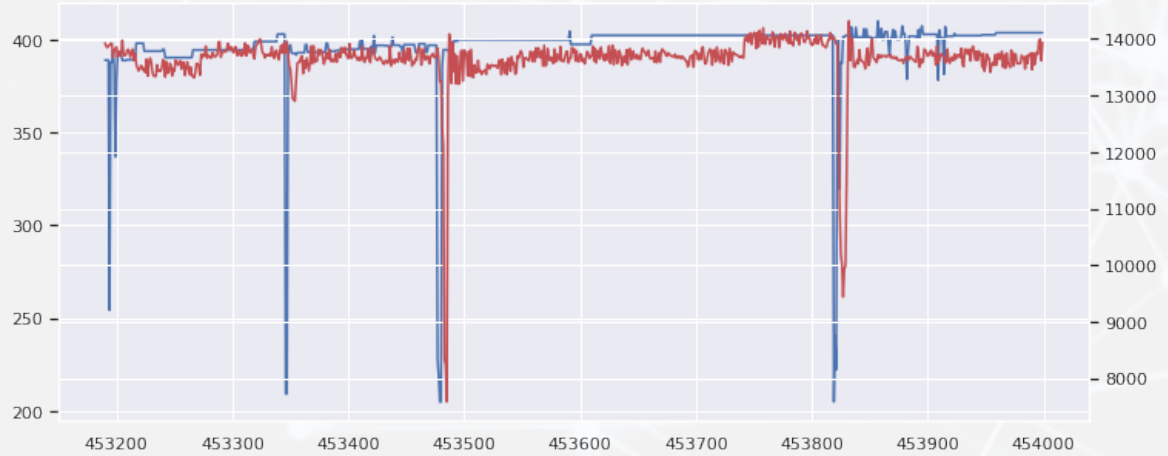
High fluctuation kiln feed demands maintaining fuel supply

Relation target function (quality + efficiency) on variation kiln feed and fuel consumption

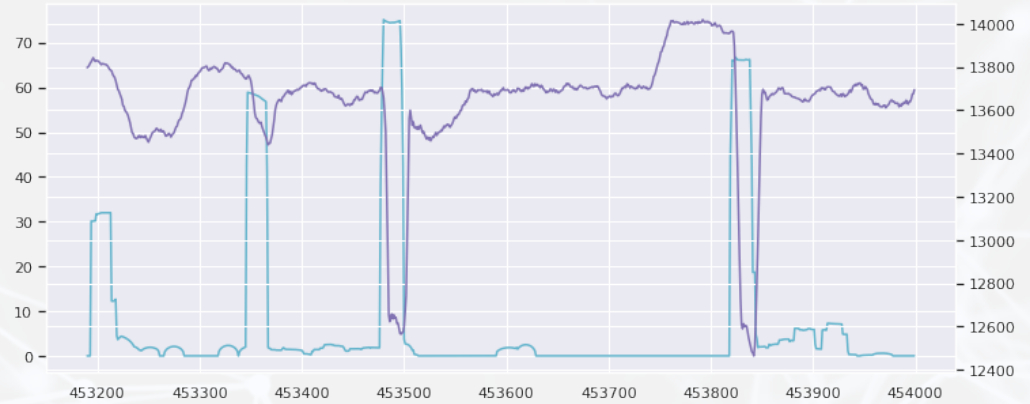


High kiln feed variation results in dispersion of entire kiln and attempts to balance it by maintaining fuel supply.

Trend from control system SCADA kiln feed and fuel consumption in calciner

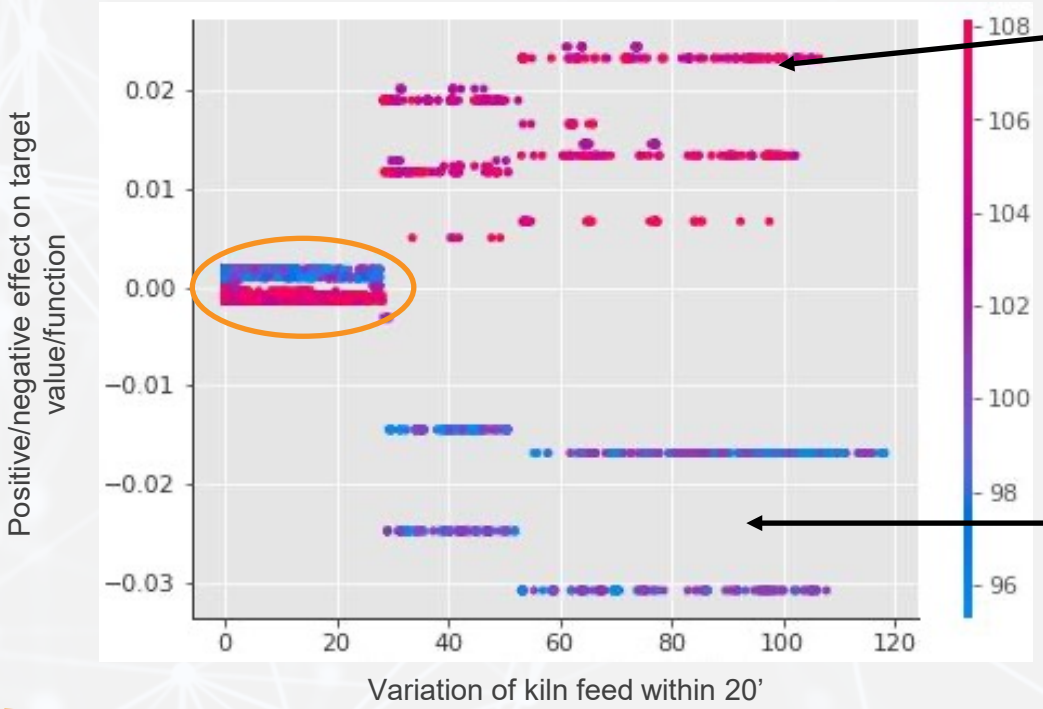


Trend from control system SCADA demonstrating variation of kiln feed and fuel consumption in calciner



Relation kiln feed composition and dispersion on quality

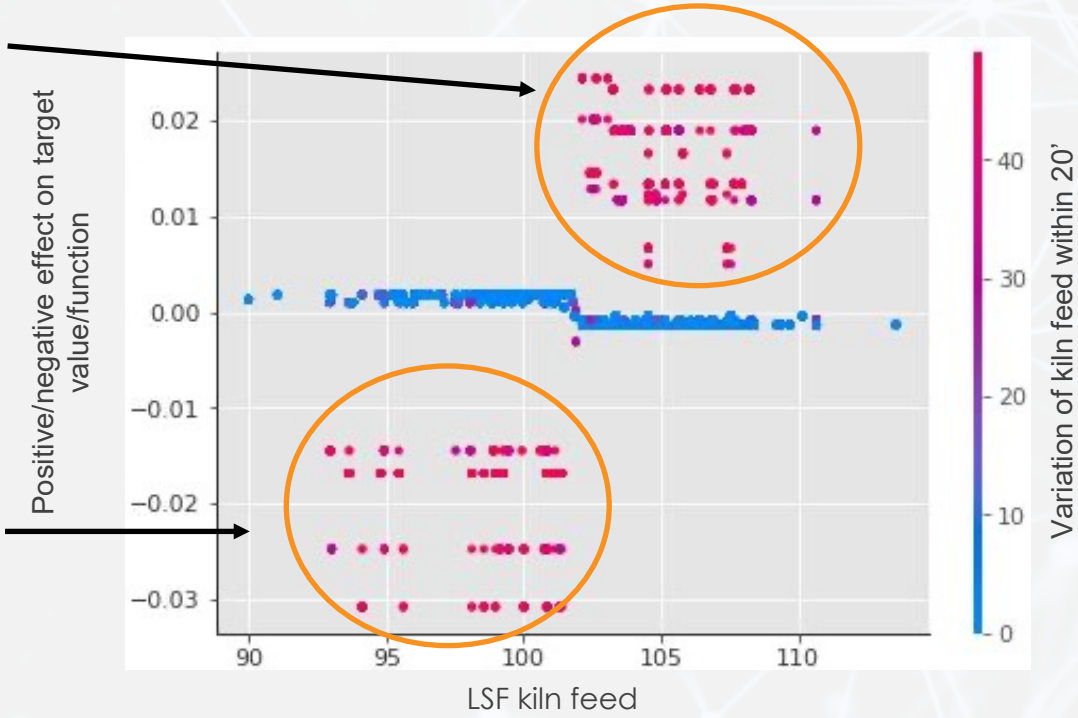
Relation target function on dispersion kiln feed and LSF



5.5 %

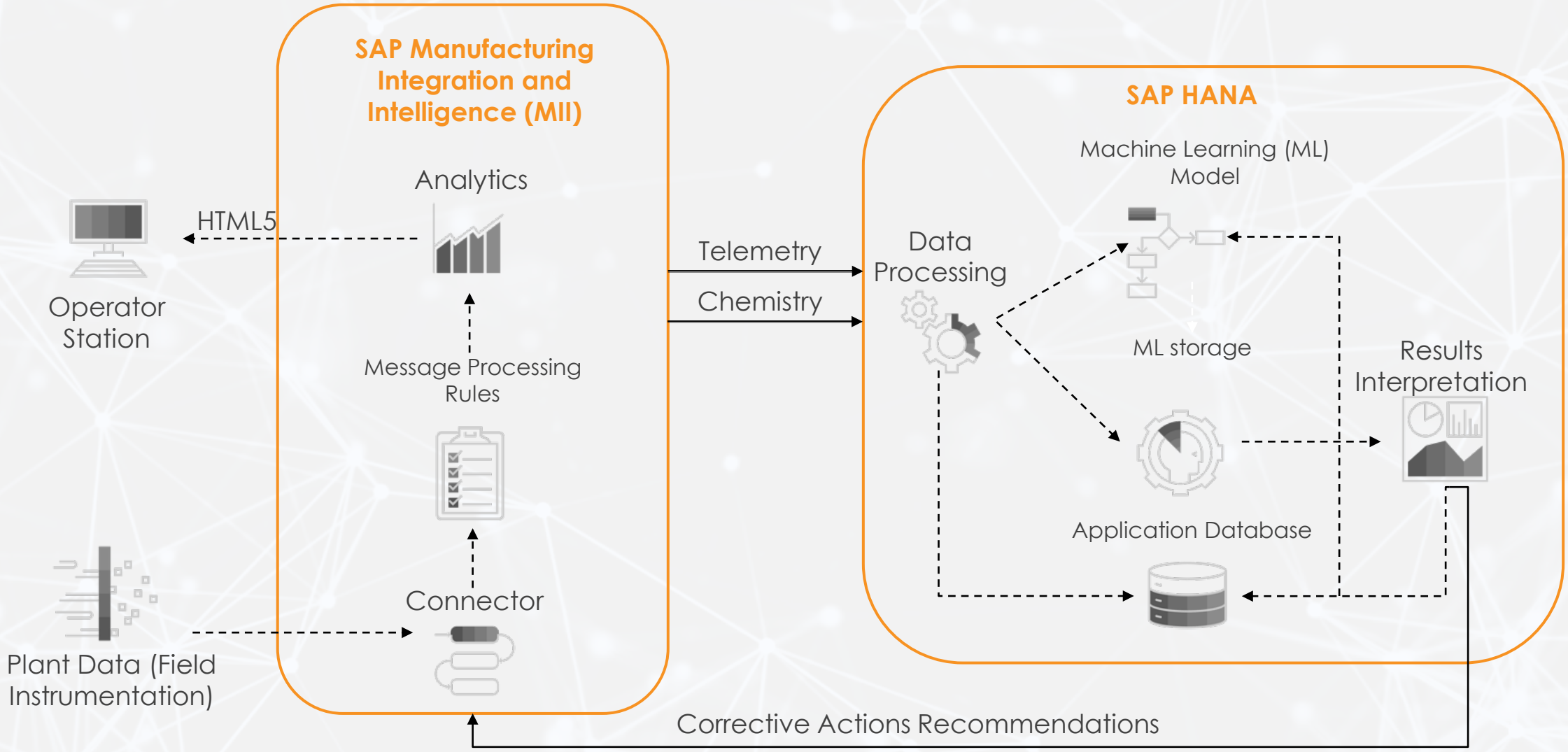
5.5 %

Relation target function on LSF and kiln feed dispersion



If stabilized kiln, the operator can maintain quality of clinker within different raw materials parameters.
In case of unstable kiln feed, fluctuating LSF demonstrates significant effect on the result.

Target architecture of clinker kiln operator assistant



Digital assistant for clinker kiln operator. Results

Main outcomes

- Mathematical model of kiln operation was successfully built
- Key areas of quality improvement were identified
- Potential effect of digital assistant application proved applicability of the model results in real-world operations

Conclusions

- Analysis of kiln operation characteristics outlined a substantial room for optimization
- Stable power supply allows for increase in output volume and quality improvement
- High variation of power supply causes the need for active gas input control
- Mutual influence of raw materials parameters and power supply variation on final product quality
- Creation of virtual quality sensor can help kiln operator as high degree of correlation between air pressure fed into the cooler and alite content in clinker was identified

2.3%
PRI increase and improvement of equipment operation stability

3%
reduction of gas specific consumption rate

48 days
increase of kiln stable operation period

Higher
quality of finished product

Increased
sales volume with higher output

Lessons learnt

The synergy of digital technologies, production competences and new capabilities in Data Science allows to find new ways for improvement of product quality characteristics, increase process energy efficiency and ensure the overall competitiveness of Eurocement Group products.

– E. Boychenko, Vice President of Digitalization & Transformation, Eurocement Group

Lessons learnt

- Correct concentration of alite in clinker as a major quality constraint
- Data quality and integrity is the key:
  - Increasing correctness of data and general quality
  - Minimization of missing data entries
- Intelligent scenarios as an indispensable building block of Eurocemnt digital transformation project

… and and next steps

- Full-scale project and scaling the solution for various plants of EUROCEMENT group
- In addition to main system users (operators and process engineers) the model will be used for employee education purposes
- Plans to use data for incident reporting and analysis
- Development of digital assistant for clinker kiln operator based on Artificial Intelligence
- Creating a model of raw material silos and mill operations
- Calculation of kiln supply composition will allow operator to better adapt to changes in raw material chemistry to further reduce unstable operation time
- Launch the initiative on the virtual quality sensor for alite contents
- Development of models for unstable kiln operation modes to reduce operators' errors
- Accumulation and monitoring the collection of available telemetry
- Accumulation and analysis of operators' actions, calculation of comparative metrics for operator performance

Thank you for attention!