



 Nergyflux

 **SteelSense™**

**AI System Advisor for
Sustainable Steel**

The Steel Imperative: Compete on Carbon, Not Just Cost

Every 1 % efficiency gain =
\$10 million saved per year (5 Mtpa plant)

Steel = 8% of global CO₂ emissions

EU CBAM* adds €80-100/tCO₂e impact on exports

OEMs now prefer “Green Steel” suppliers

Green steel premiums up to 10-20%

**CBAM: Carbon Border Adjustment Mechanism - EU's carbon tariff.*

1. 40+ nations introducing carbon border taxes (CBAM, ETS, IRA) - unverified steel will lose export competitiveness by 2027.
2. Energy cost volatility (30-60 % of OpEx) demands continuous AI optimization, not manual tuning.
3. \$1 trillion global green-steel market by 2030 - plants with verified carbon data will access premium pricing, credits, and ESG capital.

“The top 20 steelmakers will control 70 % of low-carbon production by 2030.”
IEA Green Steel Outlook 2025

AI and Carbon Intelligence will decide who leads the Green Steel transition.

Data Silos → Delayed Decisions → Wasted Energy → Higher CO₂ → Lost Profit

Challenge

Disconnected systems

Manual furnace tuning

Reactive maintenance

Spreadsheet reporting

Impact

Slow decisions

Inconsistent quality

Unplanned downtime

Poor audit trail

Lost Value

Fuel waste

+3-5% SEC *

Higher OpEx

Green funding risk

* **SEC**: Specific Energy Consumption (kWh or Gcal per ton of steel).

Future Plant Playbook

Re-imagine → Improve → Automate

REIMAGINE : Core Business (Focus on Value)

Transform the way value is created across the steelmaking chain

Reimagine furnace optimization, yield control, and energy efficiency

Shift from “operator-led tuning” to “data-driven precision”

Use digital twins to redesign heat-to-heat stability

Build green-steel readiness (CBAM/SBTi)

Create new value pools: CO₂ reduction, energy savings, quality uplift

Outcome:

✓ Leaner operations, better product quality, lower energy cost

IMPROVE : Digital Platform (Engineer Data Flow)

Build a unified intelligence backbone for the plant

Integrate PLC/DCS, SCADA, MES, lab, and utility data

Create a Operations Feature Store foundation

Establish AI & BI Workbench

Standardize KPIs & heat-level analytics

Launch modular apps (Furnace, PM, Quality, Carbon, Investment Planning)

Outcome:

✓ Single source of truth powering all decisions & AI models

AUTOMATE : Streamline Operations (Grow Margins)

Move toward autonomous, self-optimizing steel operations

AI recommendations → semi-auto control → closed-loop optimization

Predict failures before downtime hits

Optimize O₂, zone temperature, speed, dwell time in real-time

Automate carbon reporting and abatement planning

Use simulation & forecasting to stabilize production and cost

Outcome:

✓ Higher throughput, lower fuel/CO₂, and improved profitability

System Advisor for Sustainable Steel

A unified, self-learning platform that:

Detect → **Explain** → **Prescribe** → **Simulate** → **Verify**

Modules:

1. Energy & Furnace Optimizer
2. Predictive Maintenance Advisor
3. Quality & Yield Advisor
4. Carbon & Compliance Reporting
5. Investment & Abatement Planner

Function	Outcomes
Detect	Anomalies in energy, quality or equipment
Explain	Root causes of loss in real time
Prescribe	Optimal setpoints & maintenance actions
Simulate	What-if scenarios to quantify ROI & CO ₂ impact
Verify	Auditable savings & reports for CBAM/SBTi

Module 1

Energy and Furnace Optimizer

- Learns ideal O₂ and temperature balance to cut fuel waste
- Predicts and optimizes combustion efficiency in real time
- Delivers 2-5 % fuel savings and 1-2 % throughput gain

Module 2

Predictive Maintenance Advisor

- Monitors motors, fans and blowers for early failure signs
- Predicts equipment breakdowns 7-10 days in advance
- Cuts downtime and spare inventory costs by 10-30 %

Module 3

Quality and Yield Advisor

- Analyzes furnace profiles to maintain temperature uniformity
- Prevents overheating and scale loss during reheating
- Improves product yield and surface quality by 1-1.5 %

Module 4

Carbon and Compliance Reporting

- Auto-captures Scope 1 & 2 emission data across operations
- Generates SBTi / CBAM-aligned carbon reports instantly
- Builds auditable product-level CO₂ ledger for green steel sales

Module 5

Investment and Abatement Planner

- Quantifies each project's CO₂ reduction and financial return
- Ranks initiatives using AI-driven MACC and ROI analysis
- Guides leaders to fund the highest-impact, fastest-payback projects

BI Dashboards/Reports

Power BI &
Metabase Services

Streamlit
Application with
Modules

Users/RBAC
Management

Security/Infra
Registry

System Audits &
Backups

AI Workbench

Model Registry

KNIME Workflows

Python Models &
Services

KNIME Analytics

Data Sources

PostgreSQL (FS) Schema | Feature Views (FS) | ETLs/APIs

PLC / DCS
& PLC
Historians

SCADA /
HMI
Alarms &
Events

MES &
Production
Records

Utility &
Energy
Meters

Quality,
Lab &
Material
Data

External &
Business
Data
(Markets /
Carbon /
Weather)

PLC / DCS & PLC Historians

(OPC-UA / Modbus / Profibus → Historian)

On-site process signals (zone temps, O₂, fuel/flame, fan flow, motor amps).

SCADA / HMI Alarms & Events

(Event stream → Aggregated Alerts table)

Discrete events, alarms, operator interventions, setpoint changes (critical for anomaly correlation and RCA.)

MES & Production Records

(Batch / Heat metadata, schedule, product IDs)

Heat IDs, charge info, product grade, shift, operator, timestamps (required to normalize SEC and produce product-level KPIs).

Utility & Energy Meters

(Substation meters, gas meters, steam counters, power analyzers)

Electrical, gas, steam, and fuel meters; aggregated to compute SEC, fuel_per_t and plant energy balance.

Quality, Lab & Material Data

(LIMS / QC import)

Material chemistry, slab/billet dimensions, moisture/slag data, scale-loss measurements (links process to yield & quality KPIs).

External & Business Data (Markets / Carbon / Weather)

(CO₂ factors, spot fuel price, ambient conditions)

Emission factors, carbon prices, local ambient temperature/wind, and market inputs used for CarbonSense™ MRV and cost modelling.

SteelSense™ Roadmap



These are the **operator and management-facing advisors** that deliver value.

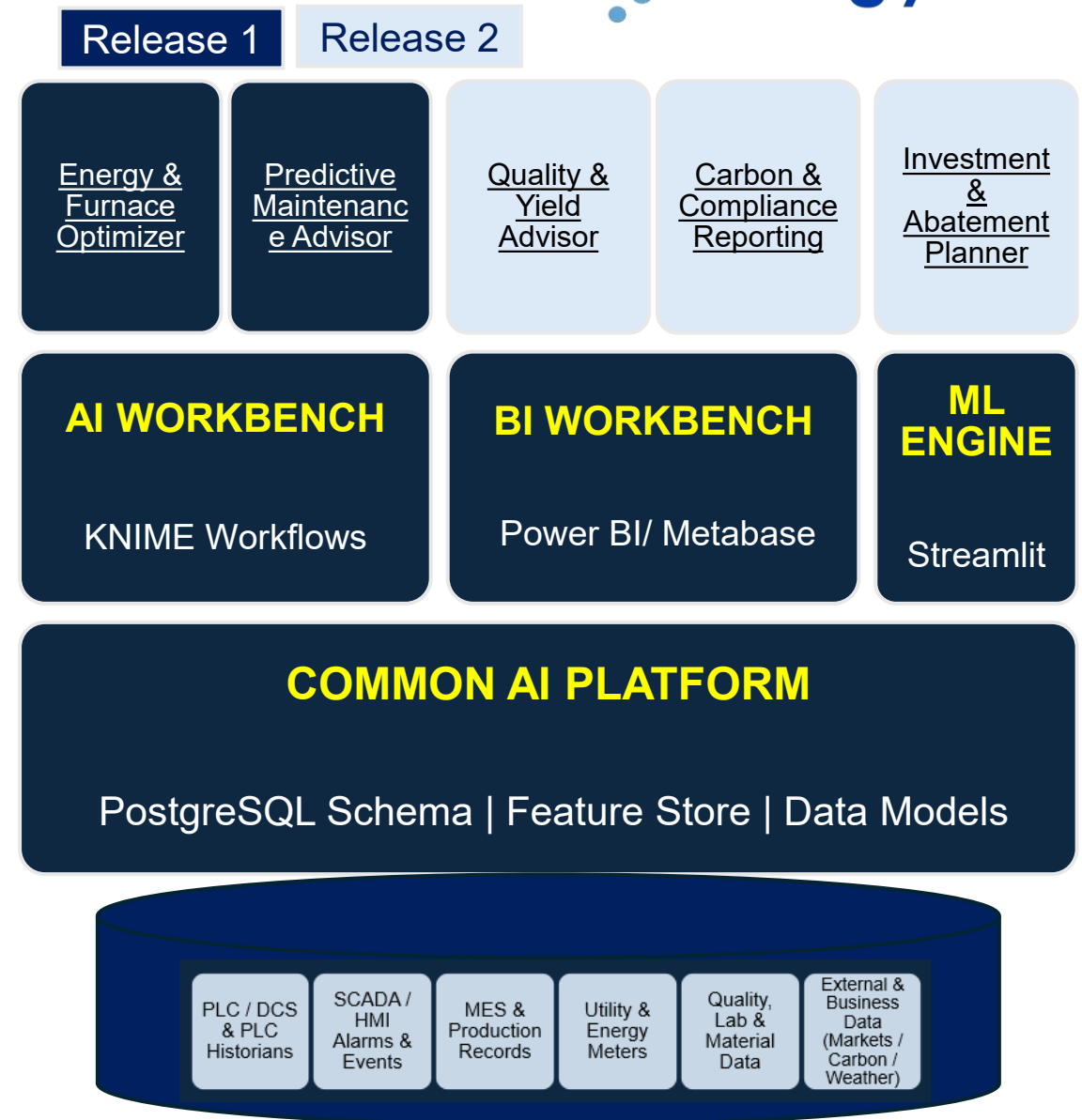
SteelSense™ is getting rolled out in two waves:

Release 1: (Already part of the baseline version)

- **Energy & Furnace Optimizer** (real-time SEC, efficiency and fuel savings)
- **Predictive Maintenance Advisor** (fan/blower RUL, burner/furnace health)

Release 2:

- **Quality & Yield Advisor** (temperature stability, scale reduction, yield gain)
- **Carbon & Compliance Reporting** (heat-wise CO₂, CBAM/ESG audit readiness)
- **Investment & Abatement Planner** (ROI modelling, decarb project planning)

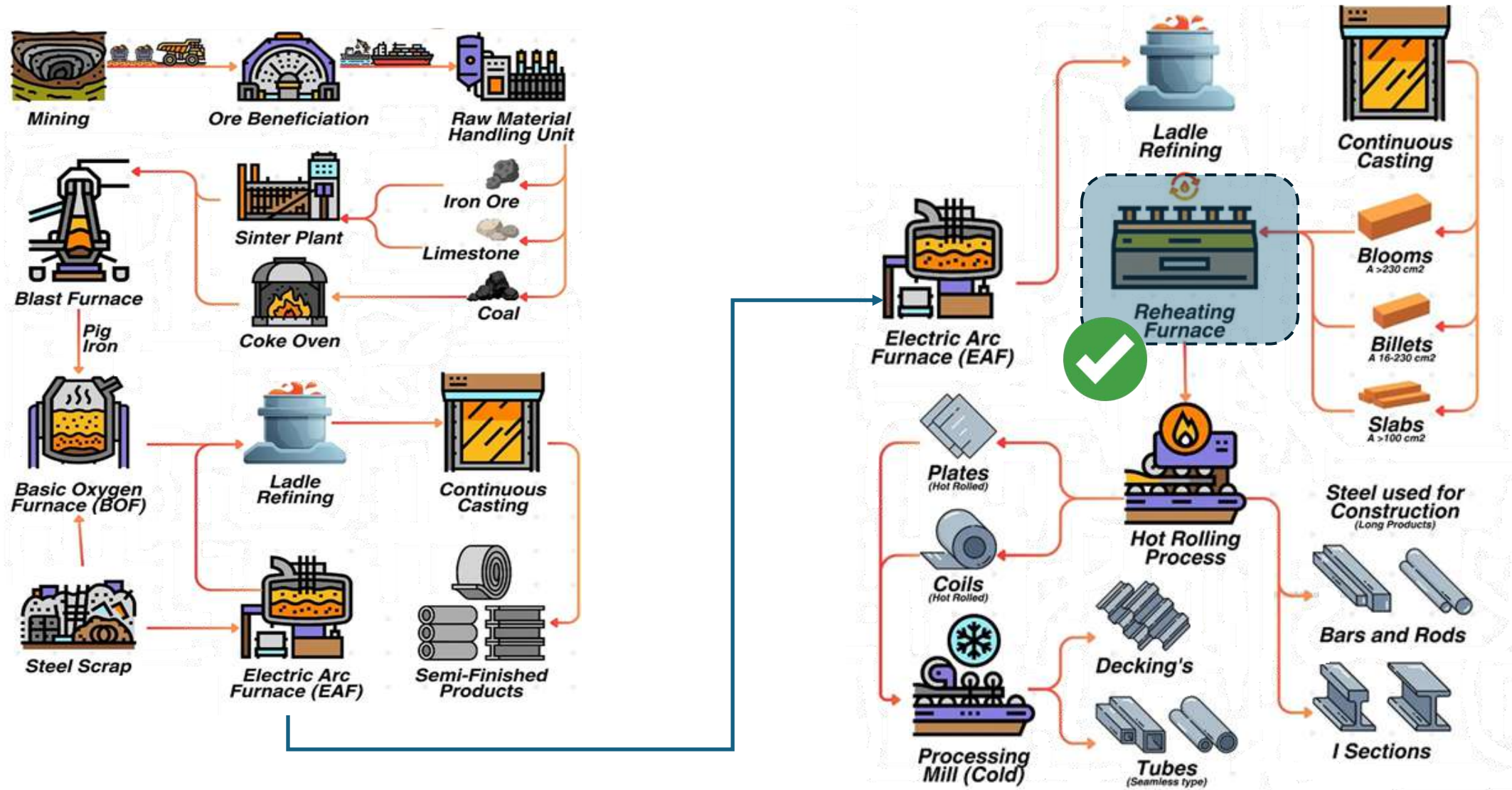


SteelSense™ Scope Matrix



Stage	Asset/Equipment	Sustainability Opportunities	SteelSense™ Scope
Raw Material Handling	Conveyors, stackers, reclaimers, crushers, weigh feeders, dust collectors, shuttle conveyors	Energy-efficient drives	N/A
Sinter/Pellet Plant	Burners, fans, ESPs, scrubbers, strand machines, mixing drums, grate-kiln equipment, cooler fans	Fuel savings, WHR	N/A
Blast Furnace	Stoves, blowers, tuyeres, gas cleaning plant, burden distribution system, skip hoist, cast house equipment	PCI, airflow tuning	N/A
BOF/Converter	Oxygen lances, converters, sub-lances, fume extraction systems, slag detection systems, tilting drives	Energy reuse, slag optimization	N/A
EAF	Electrodes, burners, transformers, water-cooled panels, fume extraction, slag foaming systems, power regulation units	Energy optimization	Partial (future)
Secondary Metallurgy	Ladle furnace electrodes, ladle heaters, vacuum pumps, alloy addition systems, argon stirring systems, ladle turrets	Tap-to-tap energy	N/A
Continuous Casting	Mold oscillators, spray cooling zones, EMS (electromagnetic stirrers), withdrawal rolls, tundish heaters, mold level sensors	EMS & cracking optimization	N/A
Reheating Furnace	Burners, combustion fans, recuperators, zone thermocouples, skid pipes, flue gas analyzers, pressure gauges, walking beams/rollers	SEC, fuel, O ₂ tuning, decarb	YES (Full)
Rolling Mill	Drive motors, gearboxes, stands, roll cooling systems, descalers, loopers, coiling equipment	Temperature drift optimization	Partial (future)
Finishing Line	Coilers, shears, straighteners, tension reels, flying shears, annealing furnaces (in some lines)	Motor optimization	N/A
Utilities	Fans, pumps, compressors, chillers, cooling towers, blowers, substation meters, air handling units	Predictive maintenance	Partial (future)

SteelSense™ Impact Scope (Release 1)



Release 1 Foundation & Fast ROI (6+ Months)

Focus: Reheating Furnace (largest energy consumer)

What it delivers:

- AI-driven furnace optimization (SEC, efficiency, O₂ tuning)
- Predictive maintenance for fans/blowers
- Core KPIs, heat-wise analytics & benchmarking
- Operator What-If Simulations

Business Impact:

- Immediate energy savings
- Stabilized operations across shifts
- Establishes the digital foundation for the plant

Release 2 Plant-Wide Optimization (12+ Months)

Focus: Rolling + Utilities + Carbon Intelligence

What it delivers:

- Rolling mill temperature drift & quality advisor
- Utilities optimization (compressors, pumps, cooling towers)
- Carbon & Compliance reporting (CBAM/SBTi-ready)
- Investment & Abatement Planner (ROI-based decarb planning)

Business Impact:

- 70–80% of plant energy footprint now optimized
- Verified product-level CO₂ footprint
- Better CapEx decisions for decarbonization

Release 3 Smart Steel Plant (18+ Months)

Focus: End-to-End AI & Digital Twin

What it delivers:

- EAF energy optimization
- Secondary metallurgy (LF/RH/VD) analytics
- Continuous casting quality + thermal models
- Full plant digital twin (heat → roll → cool path)
- Plant-wide predictive maintenance

Business Impact:

- Enterprise-wide energy + quality intelligence
- 20–30% emission reduction potential
- Ready for green-steel certification and premiums

Stage	Asset/Equipment	Sustainability Opportunities
Raw Material Handling	Conveyors, stackers, reclaimers, crushers, feeders	<ul style="list-style-type: none"> - Energy-efficient drives & motors - Idle-load reduction - Dust emission control - Optimized material flow to reduce rehandling
Sinter/Pellet Plant	Burners, fans, ESPs, strand machines, kilns, coolers	<ul style="list-style-type: none"> - Fuel savings (coke breeze optimization) - Waste heat recovery (WHR) - Fan power optimization - Improved combustion efficiency - Emissions capture enhancement
Blast Furnace	Stoves, blowers, gas cleaning, burden system	<ul style="list-style-type: none"> - PCI optimization to reduce coke - Hot-blast energy optimization - Stove combustion efficiency - Reduced gas flaring - Top-gas recycling benefits
BOF/Converter	Lances, converters, fume extractors	<ul style="list-style-type: none"> - Oxygen efficiency improvement - Off-gas energy recovery - Lower lime consumption
EAF	Electrodes, burners, transformers, slag foaming	<ul style="list-style-type: none"> - Electrode consumption reduction - Optimal power-on time - Burner energy reduction - Water/panel cooling efficiency - Foamy slag optimization reduces electricity

Stage	Asset/Equipment	Sustainability Opportunities
Continuous Casting	Oscillators, EMS, spray zones, rolls	<ul style="list-style-type: none"> - Spray-water optimization (10–20% reduction) - EMS power efficiency - Defect/cracking reduction (minimizes rework) - Slab surface temperature stabilization
Reheating Furnace	Burners, fans, recuperators, TCs, analyzers	<ul style="list-style-type: none"> - SEC reduction (8–15%) - Fuel optimization (NG/LDO) - O₂ tuning & excess-air reduction - Zone balancing → lower heat loss - Improved thermal efficiency - CO₂ intensity reduction - Waste heat utilization
Rolling Mill	Motors, stands, gearboxes, cooling, loopers	<ul style="list-style-type: none"> - Temperature-drift minimization - Scale-loss reduction (1–3%) - Motor/drive power optimization - Better cooling-water use - Fewer re-rolls / rejects
Finishing Line	Coilers, straighteners, shears, tension reels	<ul style="list-style-type: none"> - Motor efficiency improvement - Reduced rejects and trimming waste - Optimized tension/wrapping reduces energy
Utilities	Fans, pumps, compressors, chillers, cooling towers	<ul style="list-style-type: none"> - Predictive maintenance → lower downtime - Fan/pump power-to-flow optimization - Compressor leakage elimination - Chiller/Cooling tower energy efficiency - Water conservation opportunities

Live Furnace Views

[Zone 1: Preheat]	[Zone 2: Heating]	[Zone 3: Soaking]
Temp: 842°C	Temp: 1145°C	Temp: 1210°C
Target: 850°C	Target: 1130°C	Target: 1200°C
Δ: -8°C (OK)	Δ: +15°C (ALERT)	Δ: +10°C (OK)
Burners: ON	Burners: HIGH	Burners: MID

Billet Tracking

Billet # : 2025-11-27-07:35:12

| Entry Temp: 50°C → Current: 980°C → Expected Discharge: 1185°C

| Uniformity Score: 92/100 (Good)

Combustion & Energy KPIs

O₂ in Flue | Stack Temp | Fuel Flow | SEC (kWh/t)
3.4% (High) | 298°C (High) | 1529 Nm³/hr | 128.9 (↑)

What-If Simulator

Inputs: Zone1 +5°C | Zone2 -10°C | O₂ -0.4% | Speed +10%

Outputs: SEC: 123.8 (-5.1%) | Fuel: -6.3% | CO₂: -4.7% | D/T: +5°C

AI Recommendations (Live)

Reduce O₂ from 3.4% → 3.0% (Fuel saving: 4.1%, CO₂ ↓ 3.2%) |
| Lower Zone 2 temp by 10°C to prevent overheating
| Increase soak time by 15 sec for better discharge stability

SteelSense™ - Typical Operator View



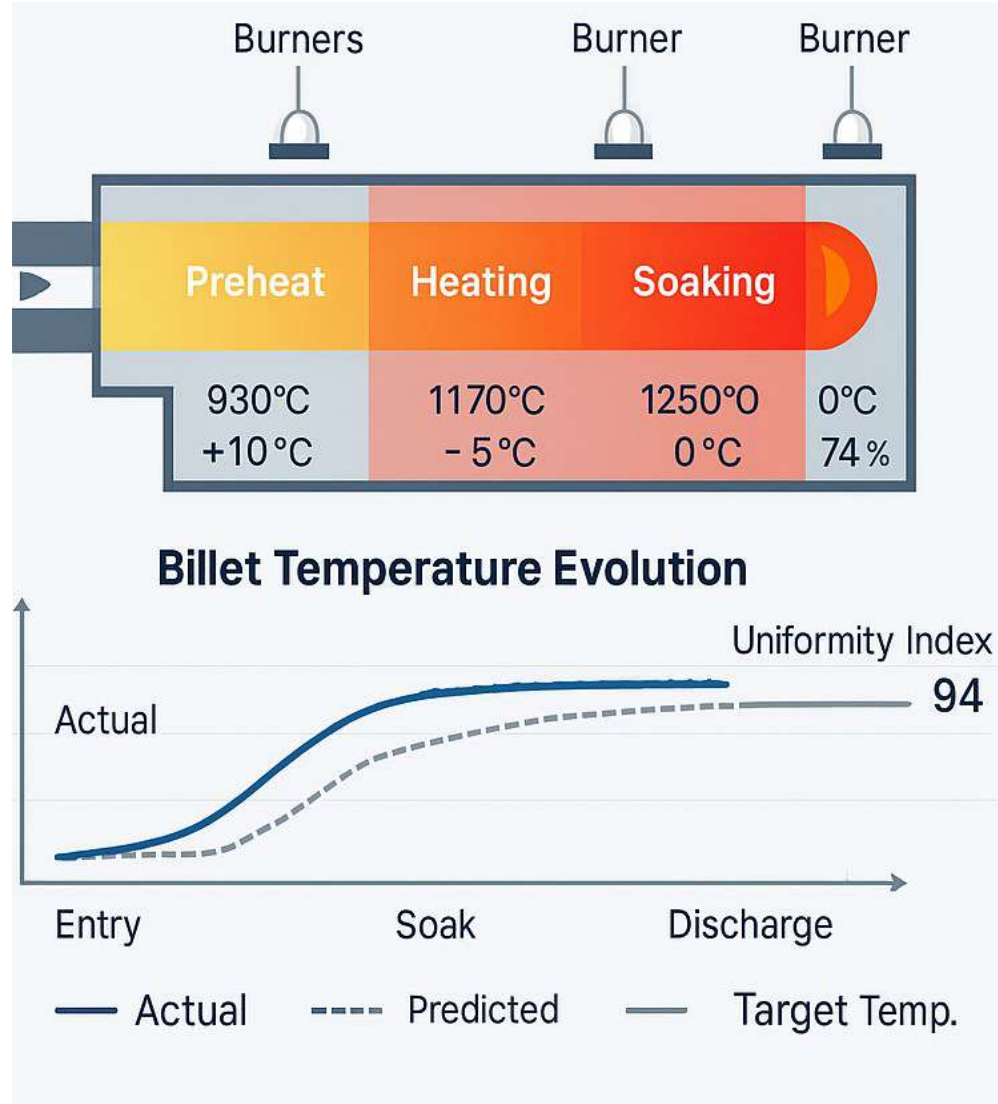
Furnace Views

Billet Tracking

Efficiency KPIs

Recommended Actions

What-If Simulations



Combustion & Efficiency KPIs

O ₂	2,8 %	SEC	1,03 MWh	61,%
Stack	280°C	Efficiency		61,5 %
Fuel	153 Nm ³ /h	CO ₂		0,18 t O/t

Recommended Actions

- Reduce Zone 2 12 °C
- Decrease O₂ fr → 3.2 % for efficiency gain
- Increase soak time 20 sec
- Expected fuel saving: 4,2 %

1245°C SEC

SEC

1,06 MW/t

Fuel

What-If Simulation

Zone Temperatures

Production Speed

Fuel

CO₂ 9 %

CO₂ 0,79 tCO₂/t

Component	Operator Views	What It Means Operationally	Value to End User
Furnace Zones (Preheat, Heating, Soaking)	Color-coded zones with live temperatures and deviation values	Real-time thermal behavior of each furnace zone shown visually	Quick understanding of zone imbalance, overheating, underheating → direct impact on energy and quality
Burner Indicators	Small burner icons above each zone	Which burner groups are active, firing sensitivity, and load trends	Helps detect uneven firing, burner faults, excess fuel usage
Zone Temperatures	°C values under each zone with +/- deviations	Difference between actual vs target temperatures	Instant detection of inefficiencies → corrective tuning by operators
Billet Temperature Evolution Curve	Actual (blue), Predicted (gray), Target (light)	AI-predicted billet temperature rise from entry → soak → discharge	Helps stabilize discharge temperature, improve yield, prevent scale
Uniformity Index (Score)	Numeric score (e.g., 94) displayed next to curve	Measures how evenly billet heats across its cross-section	Higher uniformity = lower fuel, better mechanical properties, higher yield
O₂ (Flue Gas Oxygen)	Shown as % (e.g., 2.8%)	Indicates excess air level; key driver of furnace efficiency	Lowering excess air reduces fuel + CO ₂ emissions
Stack Temperature	Temperature of exhaust gases (e.g., 280°C)	Measures heat losses through the stack	Detects insulation issues and burner inefficiency
Fuel Flow	Nm ³ /hr or kg/hr	Real-time energy consumption	Tracks inefficiency instantly; allows quick fuel tuning
SEC (Specific Energy Consumption)	MWh/t or kcal/kg	Amount of energy required per ton of steel heated	Gold KPI for cost savings & decarbonization; used for CBAM calculation
Furnace Efficiency	% efficiency (e.g., 61.5%)	Ratio of useful heat absorbed vs heat input	Reflects actual performance against design capability
CO₂ Emissions	tCO ₂ /t	AI-based CO ₂ per ton produced	Mandatory for CBAM, SBTi, customers needing low-carbon steel
Recommended Actions (AI Guidance)	Adjust Zone °C, reduce O ₂ , increase soak time	Digital twin's real-time optimization suggestions	Brings operator performance to "expert level" across all shifts
Expected Impact (Fuel/SEC)	ΔSEC, ΔFuel, ΔCO ₂ shown as percentages	AI estimates benefits if recommended actions are applied	Quantifies savings → supports decision-making instantly
What-If Simulation Panel	Sliders for zone temps, speed, fuel, O ₂	Allows operators to simulate future scenarios safely	Eliminates guesswork; prevents inefficiency before it happens
Simulated Outputs	Updated SEC, Fuel, CO ₂ predictions	Digital twin calculations after input adjustments	Enables predictive planning rather than reactive operations

Layer of Intelligence	What SteelSense™ Does	How It Works (Technical)	Business Value
Physics Engine (Domain Physics)	Models real furnace behavior using scientific principles	<ul style="list-style-type: none"> Heat-transfer equations (radiation, convection, conduction) Burner & combustion models O₂ balance & flue gas dynamics Material heating curves & soak behavior 	<ul style="list-style-type: none"> ✓ High accuracy from day one ✓ Stable predictions ✓ Operators trust results (physics-based)
Machine Learning Engine (Adaptive ML)	Learns from real operation patterns across heats, shifts, seasons	<ul style="list-style-type: none"> Multivariate time-series learning Pattern detection in burner firing Anomaly detection in zones Continuous retraining from new data 	<ul style="list-style-type: none"> ✓ Improves every day ✓ Captures plant-specific anomalies ✓ Adjusts instantly to changing operations
Furnace Calibration Layer (Plant-Specific DNA)	Customizes the model for each furnace's unique thermal personality	<ul style="list-style-type: none"> Calibration for flame distribution Zone leakage compensation Burner age & wear modeling Operator tuning behavior mapping 	<ul style="list-style-type: none"> ✓ Precision tuned to your plant ✓ No "generic" model errors ✓ Outperforms traditional simulators
Real-Time Sensor Fusion	Blends SCADA/PLC data into the twin in milliseconds	<ul style="list-style-type: none"> OPC/Modbus connectors Noise filtering Missing-signal handling Real-time cooling/fuel adjustments 	<ul style="list-style-type: none"> ✓ Live visibility ✓ No manual input required ✓ Response faster than human operators
Optimization Engine	Recommends best zone temperatures, O ₂ %, fuel load	<ul style="list-style-type: none"> Gradient-based optimization Reinforcement-like logic Constraint-aware tuning 	<ul style="list-style-type: none"> ✓ X% fuel savings ✓ Better discharge uniformity ✓ Consistency across shifts
Digital Twin Learning Loop	Twin updates prediction accuracy every heat	<ul style="list-style-type: none"> Error correction models Historical performance comparison Feedback learning 	<ul style="list-style-type: none"> ✓ Twin becomes smarter with time ✓ Less dependency on "star operators"
Explainability Layer	Translates complex AI decisions into simple operator actions	<ul style="list-style-type: none"> Feature importance Transparent diagnostics Human-readable guidance 	<ul style="list-style-type: none"> ✓ High adoption ✓ Zero guesswork ✓ Faster training of new operators

Optimize Every Calorie of Energy - From Combustion to Emissions

Module 1

Predictive Maintenance Advisor

Problem:

- Fuel flow, O₂, and zone temperature are manually tuned, causing 2-5 % energy loss and CO₂ spikes.

AI Approach:

- Multivariate regression + Gradient Boosting models learn ideal O₂/excess-air balance.
- Reinforcement Learning fine-tunes set-points dynamically.
- Digital twin simulates “what-if” impact on efficiency and SEC.

Outcomes:

- 2-5 % fuel reduction (≈ \$10-15 M/yr per 5 Mtpa plant)
- 0.1-0.15 t CO₂e/t emission reduction
- Furnace efficiency stabilized > 72 %

Predict Failures Before They Happen - Protect Productivity & People

Module 2

Energy & Furnace Optimizer

Problem:

- Critical fans, pumps, and blowers fail unexpectedly; maintenance is reactive.

AI Approach:

- Isolation Forest + Autoencoder anomaly detection on vibration, temperature, and load.
- RUL (remaining useful life) prediction from trend analysis.
- Alert dashboard linked to CMMS / SAP PM workflows.

Outcomes:

- 10-30 % downtime reduction
- 20 % inventory optimization
- Fewer emergency repairs → safety ↑

Predict Uniformity - Deliver Quality Every Heat Cycle

Module 3

Quality & Yield Advisor

Problem:

- Over- or under-heating causes scale loss, yield drop, and rework.

AI Approach:

- Random Forest + Neural Network model predicts Δ (soak-exit temp) uniformity index.
- Correlates furnace zones, rolling speed, chemistry, and load pattern.
- Feedback loop recommends optimal soak temp & dwell time.

Outcomes:

- 1-1.5 % yield gain
- Reduced scaling loss and rework
- Real-time uniformity heat maps

Turn Emissions Data into Monetizable Carbon Intelligence

Module 4

Carbon & Compliance Reporting

Problem:

- Scope 1 & 2 data scattered across spreadsheets → CBAM/SBTi reporting painful.

AI Approach:

- Automated data collection from EMS, ERP & energy meters.
- AI reconciles activity data with emission factors.
- Generates product-level CO₂e ledger & audit trail aligned with SBTi & EU CBAM.

Outcomes:

- 90 % faster GHG reporting
- 95 % data accuracy validated for audits
- “Green Steel” readiness for buyers and financiers

Module 4 + Extended scope (CarbonSense™)



Capability Layer	AI System Advisor	After Integration with CarbonSense™	Impact
Data Collection	Energy & fuel data from furnaces, utilities	Auto-synced to CarbonSense™ MRV engine	Single-source truth for verified emissions
Computation	Calculates SEC → CO ₂ e internally	CarbonSense™ applies certified factors & methodologies (GHG Protocol, ISO 14064)	95 %+ audit-grade accuracy
Ledgering	Stores reports in plant DB	CarbonSense™ writes immutable blockchain ledger per batch/product	Tamper-proof record for CBAM / ESG audits
Monetization	None	CarbonSense™ tokenizes verified reductions → Carbon Credits / Green-Steel Certificates	Converts savings into tradable assets
Compliance Reporting	Manual CBAM PDFs	Automated submission / registry integration (Gold Standard, Verra, UNDP)	Zero-touch audit readiness

Integration Blueprint

Emission Data Ingestion (SteelSense™)

Energy, fuel, material throughput, O₂, temperature.

Emission Computation (CarbonSense™)

Applies verified emission factors, boundaries, scopes.

Ledger & Tokenization (CarbonSense™)

Each verified reduction → carbon credit / digital certificate.

Sync-back to Reporting (SteelSense™)

Dashboard shows verified tCO₂e saved + potential credit value (\$).

Compliance / Audit Output

CBAM, SBTi, GHG reports auto-generated with ledger link.

Rank Every Green Investment by ROI and CO₂ Impact

Module 5

Investment & Abatement Planner

Problem:

- Hundreds of potential projects - no clarity on which delivers best value.

AI Approach:

- Regression + scenario optimization engine quantifies Δ fuel, Δ CO₂, Δ cost.
- Generates dynamic MACC curve with real process data.
- Integrates CapEx/OpEx & financial KPIs for each action.

Outcomes:

- Board-ready portfolio with ranked projects
- Visibility of payback vs carbon savings
- Enables CAPEX prioritization & green bond eligibility

Quantified Business Impact



Module	Key KPI Impact	Quantified Benefit
Energy & Furnace Optimizer	<ul style="list-style-type: none"> Fuel efficiency (Gcal/t or kWh/t) CO₂ intensity per ton of steel 	<ul style="list-style-type: none"> 3-5 % fuel reduction 2-3 % lower CO₂e 12-15 month payback
Predictive Maintenance Advisor	<ul style="list-style-type: none"> Equipment uptime Maintenance cost per hour of operation 	<ul style="list-style-type: none"> 10-30 % downtime reduction 5-8 % maintenance cost savings 7-10 day advance failure prediction
Quality & Yield Advisor	<ul style="list-style-type: none"> Temperature uniformity Rework and scrap ratio 	<ul style="list-style-type: none"> 1-1.5 % yield improvement 3-5 % scrap reduction 2-3 % product quality gain
Carbon & Compliance Reporting	<ul style="list-style-type: none"> Scope 1 & 2 reporting accuracy Carbon cost avoidance (CBAM, SBTi) 	<ul style="list-style-type: none"> 8-15 % cut in plant CO₂ intensity Verified carbon ledger per coil/billet Readiness for CBAM audits
Investment & Abatement Planner	<ul style="list-style-type: none"> ROI prioritization of decarbonization projects Cost of carbon abatement (MACC curve) 	<ul style="list-style-type: none"> 10-25 % better Capex allocation 2-4 year faster payback on green upgrades Full financial × carbon ROI visibility

Stakeholders	SteelSense™ Delivers
Plant Operators	Real-time furnace and process optimization
Sustainability Heads	Verified Scope 1 & 2 CO ₂ e data with audit trails
Finance Teams	CapEx prioritization and ROI-linked abatement dashboard
CXOs / Boards	Unified visibility of operational + environmental KPIs
Investors / Regulators	Certified low-carbon production readiness for CBAM & ESG financing

Data Acquisition → AI-Driven Analytics → Advisory Intelligence → Action & Verification

Layer	Key Function	Value Delivered
Data Source Layer	Collects real-time data from PLC/DCS, sensors, MES, ERP, energy meters, lab data	Unified operational visibility
Integration & Data Lake Layer	Cleanses, contextualizes, and aggregates multi-system data	Single version of truth for all assets
AI/ML Analytics Layer	Predictive, prescriptive & anomaly models (efficiency, RUL, yield, CO ₂)	Continuous optimization & foresight
Advisory Application Layer	Modules: Energy Optimizer, Maintenance, Quality, Carbon, Investment	Converts analytics to actionable insights
Visualization & Action Layer	Dashboards for operators, engineers, and CXOs	Instant decision-making & verification
Governance & Compliance Layer	Audit trail, model registry, user control, MRV reporting	Regulatory assurance & trust

Stack Layer	Technology Components	Highlights
Edge & Control Layer	PLC/DCS (Siemens, ABB, Allen-Bradley), IoT sensors, OPC-UA connectors	Real-time data capture & buffering
Data Ingestion Layer	MQTT, Kafka, Node-RED, REST APIs	High-frequency, event-based ingestion
Data Storage & Lakehouse Layer	PostgreSQL / TimescaleDB, Hadoop / Delta Lake	Structured + time-series storage
Processing & AI Layer	Python, Scikit-learn, PyTorch, TensorFlow, KNIME	Model training, forecasting, anomaly detection
Application & Integration Layer	Streamlit / React UI, FastAPI microservices, Docker, Kubernetes	Modular deployment & scalability
Security & Governance Layer	Role-based access (OAuth2), API keys, audit logs, encryption (AES-256)	Data security, traceability, compliance
Deployment & Ops Layer	Hybrid: On-prem VM + Cloud (Azure / GCP / AWS) + Edge gateway	24x7 uptime, redundancy, fail-safe sync



ProcureSense™

Sustainable Procurement Hub

- Green supplier scoring
- EPD/LCAs verification
- ESG-compliant sourcing



SteelSense™

AI Advisor for Sustainable Ops

- Energy & Furnace Optimizer
- Predictive Maintenance
- Quality & Yield AI
- Carbon Reporting (CarbonSense™)
- Investment Planner



CarbonSense™

Carbon MRV & Monetization

- Scope 1-3 CO₂e tracking
- MRV & Ledger (Blockchain)
- Credit issuance / registry
- ESG & CBAM compliance

From Sustainable Procurement → Intelligent Production → Verified Carbon Impact

Business Function	Platform	Purpose	Outcome
Procurement	ProcureSense™	Sources sustainable raw materials and vendors, manages supplier ESG and LCA data	Greener supply chain inputs
Operations	SteelSense™	Optimizes manufacturing — energy, quality, carbon, investment	Lower operational emissions
Sustainability	CarbonSense™	Verifies CO ₂ reductions, issues credits, and ensures compliance	Converts efficiency into certified carbon assets

Together, ProcureSense™, SteelSense™, and CarbonSense™ form a closed-loop sustainability stack:

- *ProcureSense™ ensures responsible sourcing.*
- *SteelSense™ drives intelligent, low-carbon production.*
- *CarbonSense™ certifies and monetizes every verified emission reduction.*

Why SteelSense™ ?

AI-Native

- Predicts, optimizes, and self-learns (not rule-based dashboards).

Carbon-Verified

- Can be integrated with CarbonSense™ MRV ledger for audit-grade CO₂ tracking.

Modular + Scalable

- Deployable by plant area or full digital twin.

Financially Quantified

- Converts every optimization into ROI, yield, and carbon credit metrics.

Built for Industry 4.0+

- Works with existing PLC/DCS, ERP, and sustainability systems.

SteelSense™ = Industrial AI × Carbon Intelligence × Financial Impact

SteelSense™ transforms steel plants into *AI-driven, carbon-verified ecosystems*. It doesn't just optimize energy and quality - it creates a measurable bridge between **operational excellence** and **carbon monetization**.

Together with **CarbonSense™**, it forms the world's first **end-to-end AI + MRV platform** for *Green Steel Intelligence*.





Exit App

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- Feature Engineering
- AI Models**
- KPI Dashboard
- WhatIf Simulator
- Efficiency Predictor
- Anomaly Dashboard
- Quality Predictor
- Combustion Optimizer

AI System Advisor for Sustainable Steel

AI Models — Regression & Anomaly Detection

Supervised Regression Models

Target metric

specific_energy_consumption

Choose features

stack_temp × preheat_actual_... × heat1_actual_te... × heat2_actual_te... × soak_actual_temp × charge_temp_in × o2_in_flue × combustion_air... ×

Train Model

Unsupervised Anomaly Detection

Signals to monitor for anomalies

stack_temp × o2_in_flue × excess_air_percent × material_mass_f... × aux_power_total × fd_fan_flow × id_fan_flow ×

Detect Anomalies

timestamp	stack_temp	o2_in_flue	excess_air_percent	material_mass_flow	aux_power_total	fd_fan_flow	id_fan_flow	anomaly
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KPI Dashboard

Overall Summary

Avg SEC (kWh/t)

124.6

Avg Thermal Efficiency (%)

72.3

Avg Throughput (t/h)

55.4

Avg Fuel per Ton

4.014

Rows: 72 | Days: 3 | Total anomalies: 0

Daily Trends

Hourly Profile

Daily Table

Daily KPI Trends

	date	avg_throughput_tph	avg_fuel_flow	avg_fuel_per_t	avg_efficiency_pct	avg_sec_kwh_per_t	avg_stack_temp	avg_o2_pct	avg_excess_air_pct	avg_charge_in_temp	avg_charge_out_temp	avg
0	2025-10-01	56.1075	227.8854	4.0882	72.4004	123.6808	894.5042	3.4508	11.7375	149.6792	1150.9667	
1	2025-10-02	54.9925	217.7796	3.9681	72.0658	126.5483	899.6042	3.5504	12.3542	152.9125	1153.4583	
2	2025-10-03	55.1117	218.9538	3.9864	72.4288	123.6417	902.8333	3.4404	11.1167	152.0708	1149.5625	



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What-If Simulator

Adjust operating knobs and estimate effect on efficiency & SEC using simple elasticities.

Efficiency change per 1% absolute O₂ in flue (points)

-0.40

Efficiency change per 1% excess air (points)

-0.08

SEC change per 1% absolute O₂ (kWh/t)

2.00

SEC change per 1% excess air (kWh/t)

0.60

Baselines — O₂: 3.48 %, Excess Air: 11.74 %, Efficiency: 72.30 %, SEC: 124.62 kWh/t

Target O₂ in flue (%)

3.48



Target Excess Air (%)

11.74





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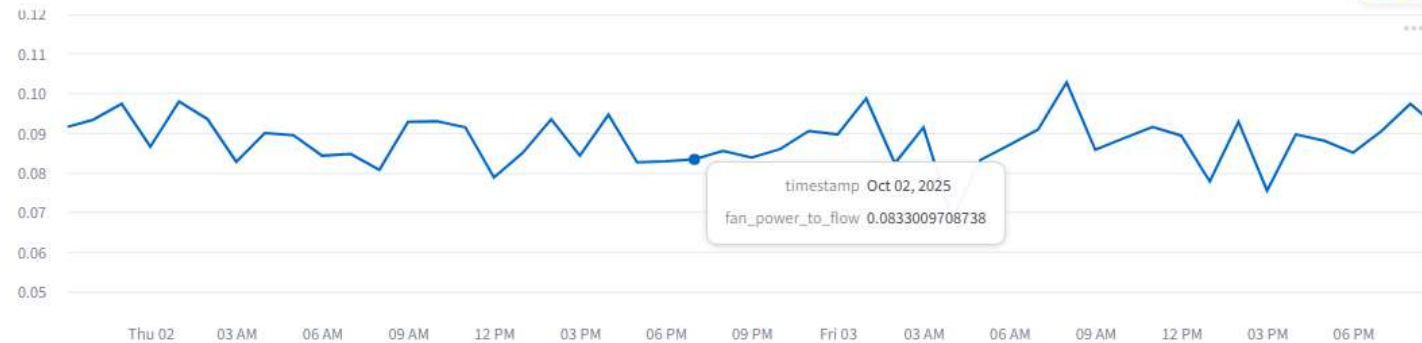
Quality Predictor

Combustion
Optimizer

AI System Advisor for Sustainable Steel

Predictive Maintenance (Trend-based)

Health Indicator — Fan Power to Flow Ratio



Interpretation

- Higher ratio \Rightarrow more power per unit flow
- Can indicate:
 - Fan fouling
 - Duct blockages
 - Bearing wear / mechanical losses

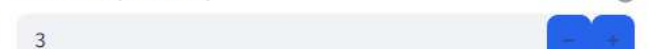
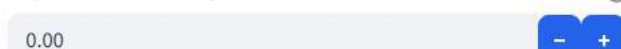
We'll now estimate a simple RUL signal based on the recent slope of this ratio.

RUL Heuristic — Trend in Health Indicator

Window for slope (days)

Slope threshold (ratio/day)

Minimum days of history



3-day slope (ratio/day)

0.000216

Thank You

Driven by Data. Designed for Industry.

