NEXTCHEM

UNFOLD
STAMICARBON
15TH SYMPOSIUM 2026

AI-POWERED DIGITAL TWINS AND CARBON FOOTPRINT MONITORING

Ali El Sibai

Martino Trabuio

AGENDA

01 DIGITAL TWIN

02 SOFT NC METER

03 AI-POWERED EVENT DETECTION

04 CARBON FOOTPRINT MONITORING

01

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DIGITAL TWIN

DIGITAL TWINS AND AI IN THE CHEMICAL INDUSTRY

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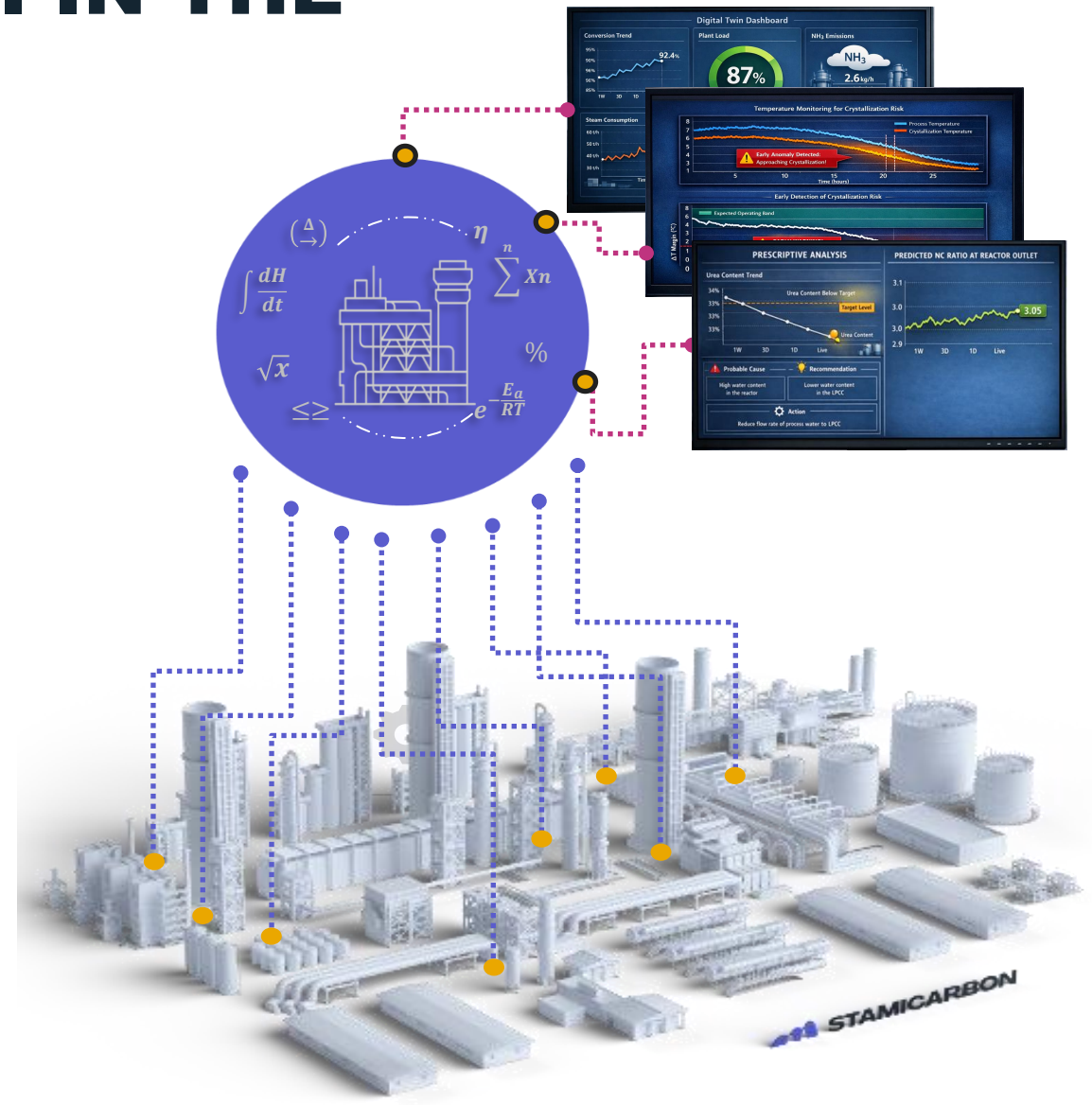
INTRODUCTION



Digital Twin Elements

- Real-time integration of plant data
- High fidelity models
- Intuitive tailored dashboards

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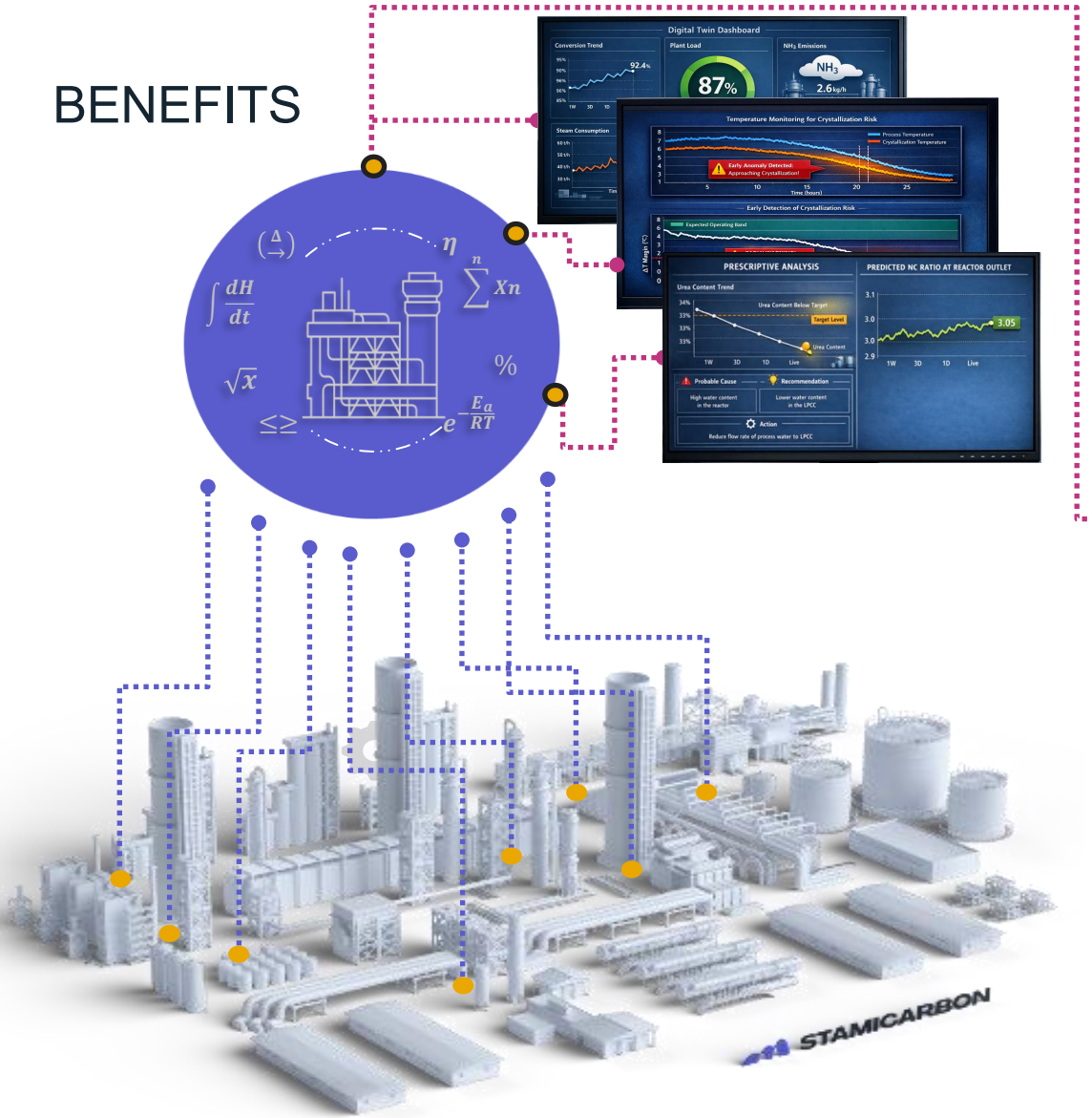
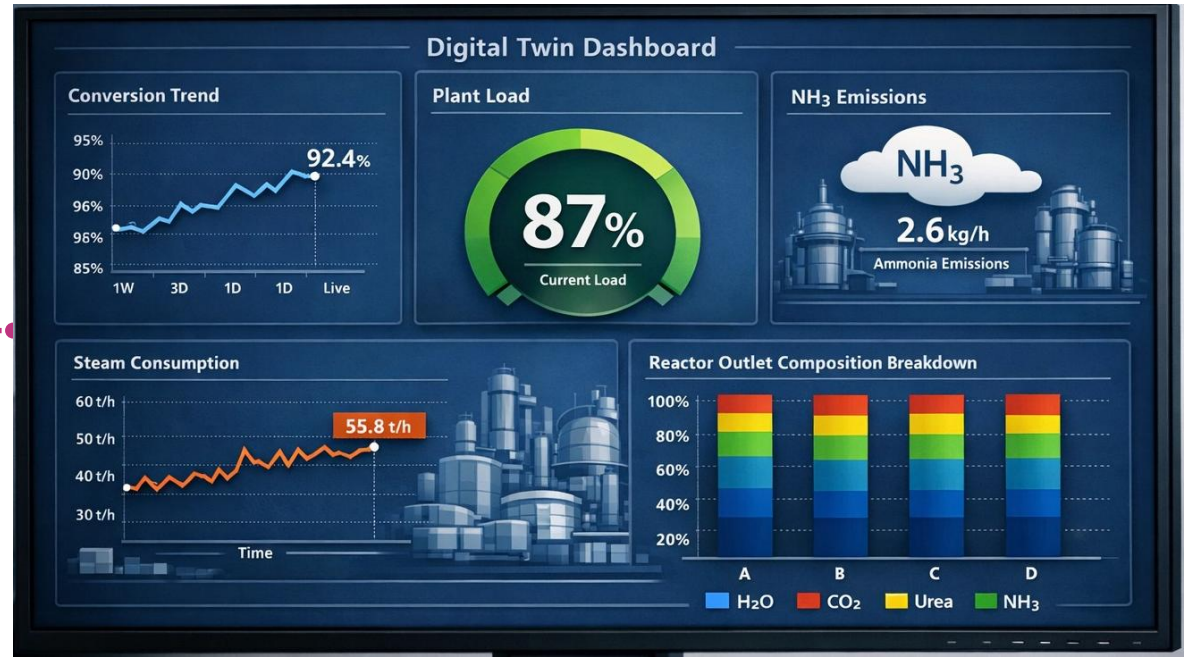
BENEFITS





Enhanced Operational Performance

- Estimation of unmeasured key process variables & kpis
- Real-time insight into process and equipment behavior
- Immediate feedback of operator actions on KPI's and KPV's
- Feedback-driven set-point tuning

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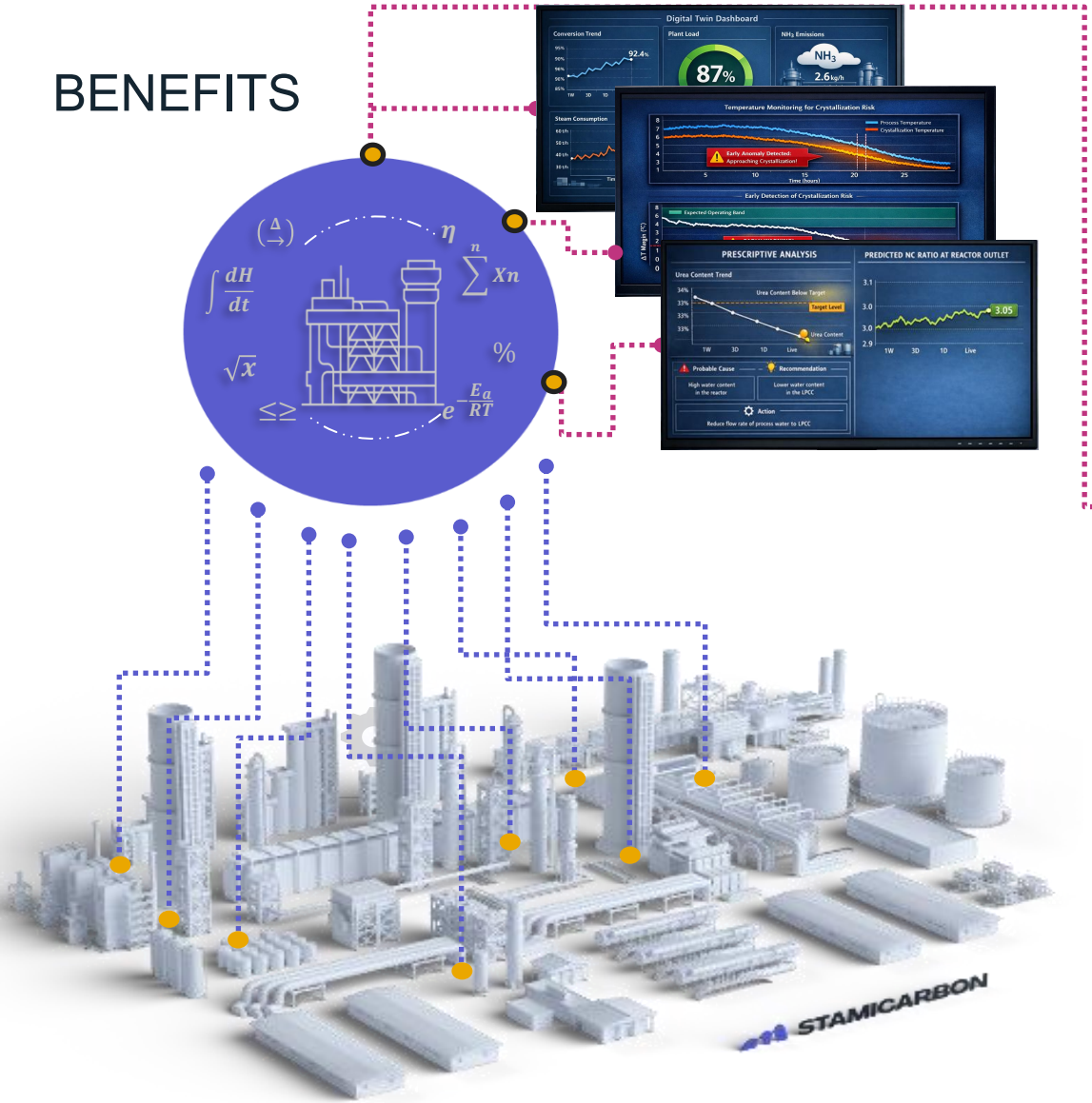
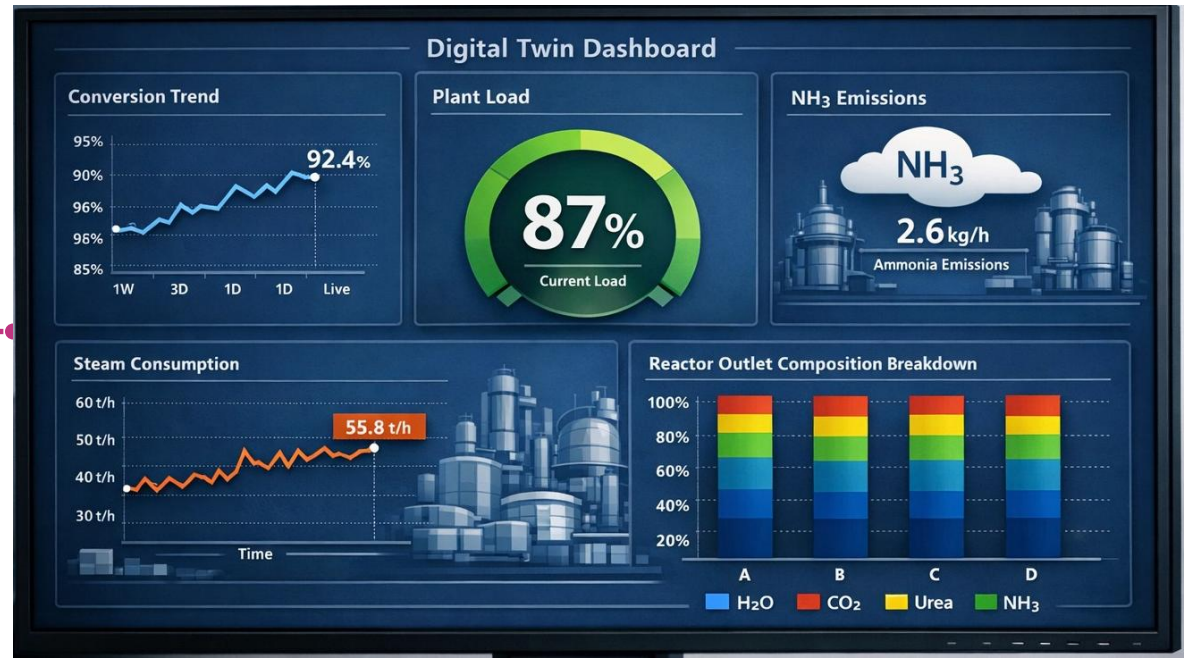
BENEFITS





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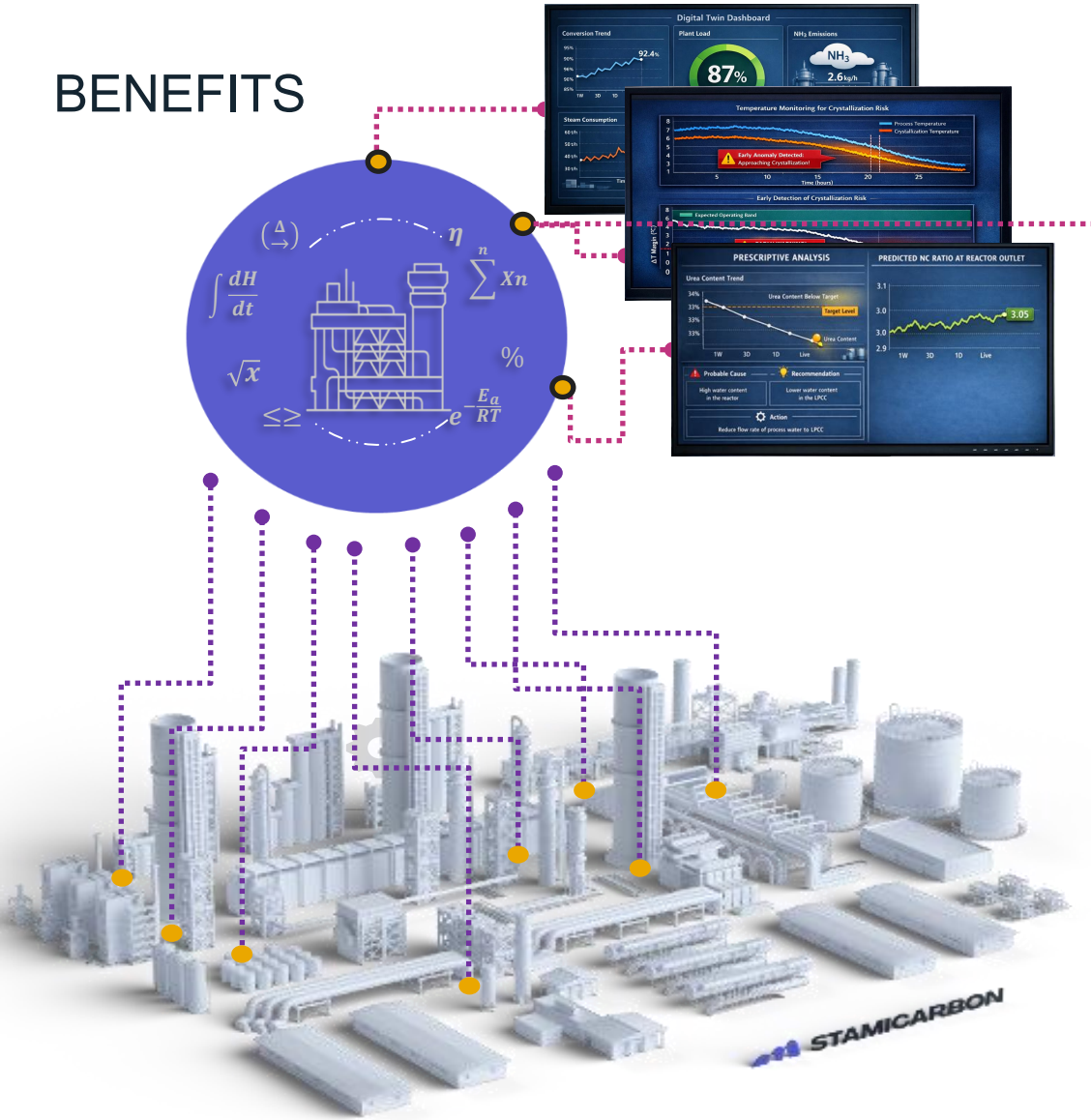

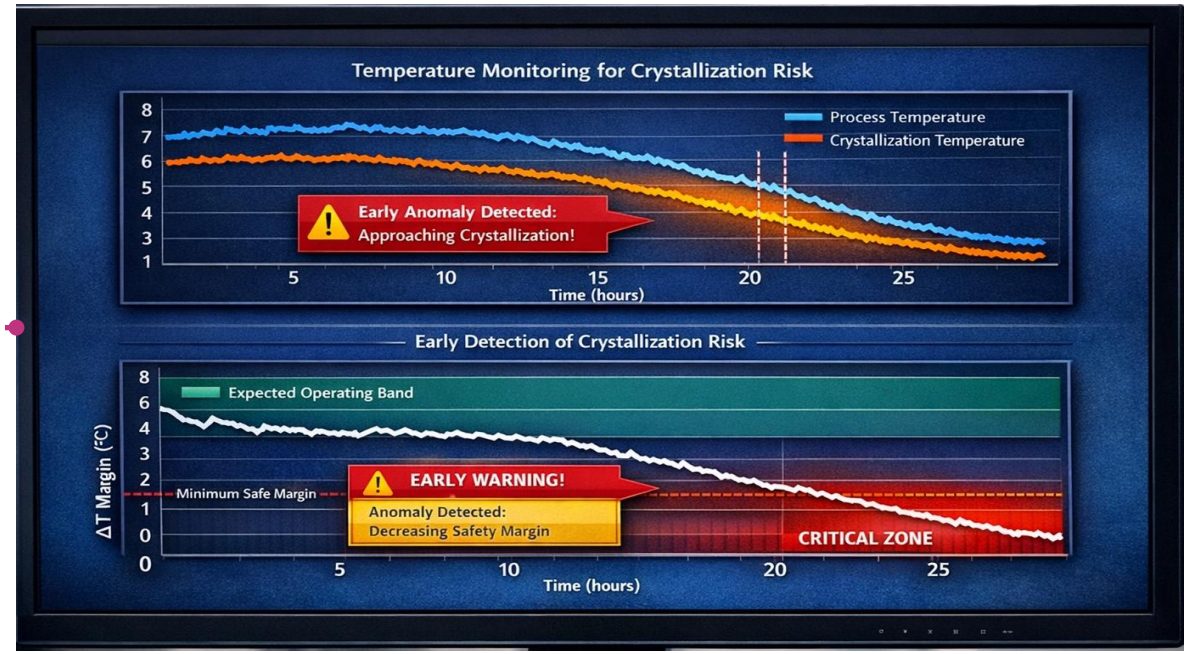

Safety & Reliability Assurance

- Estimation of unmeasured safety-critical variables
- Awareness of proximity to safety constraints

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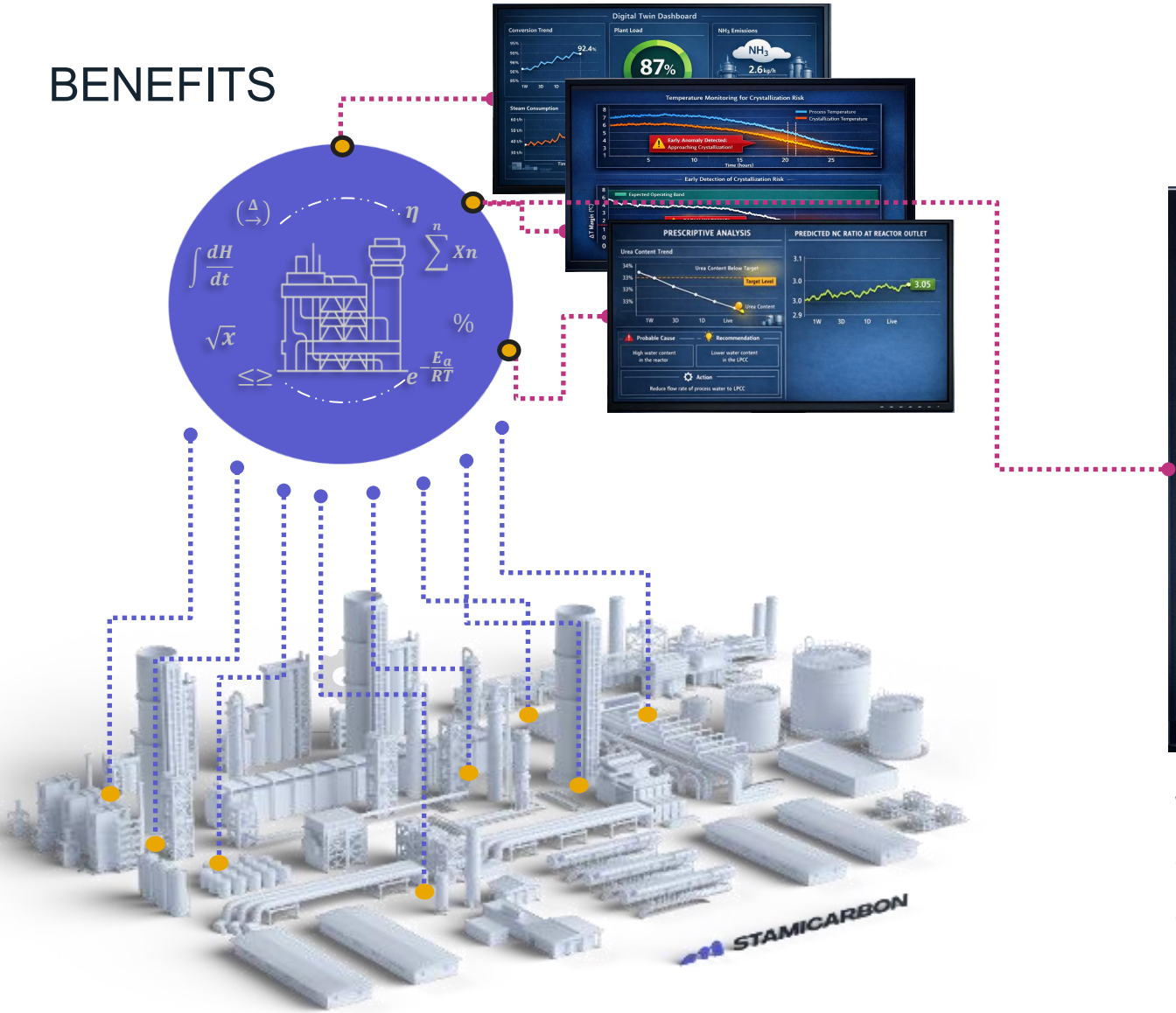

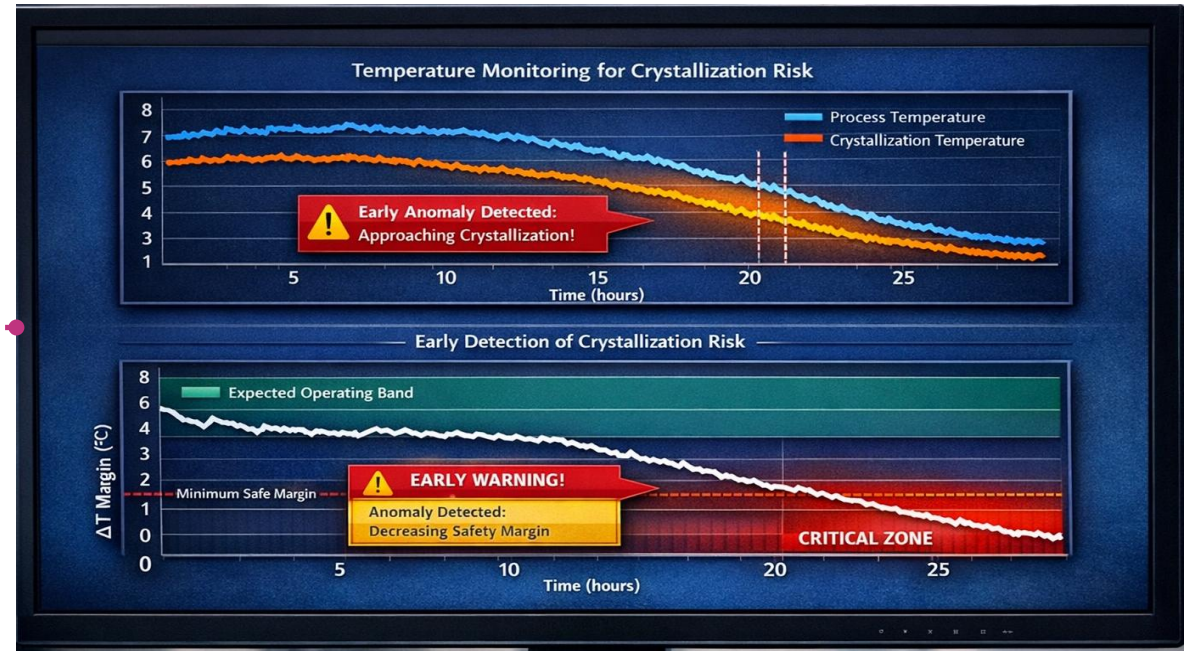

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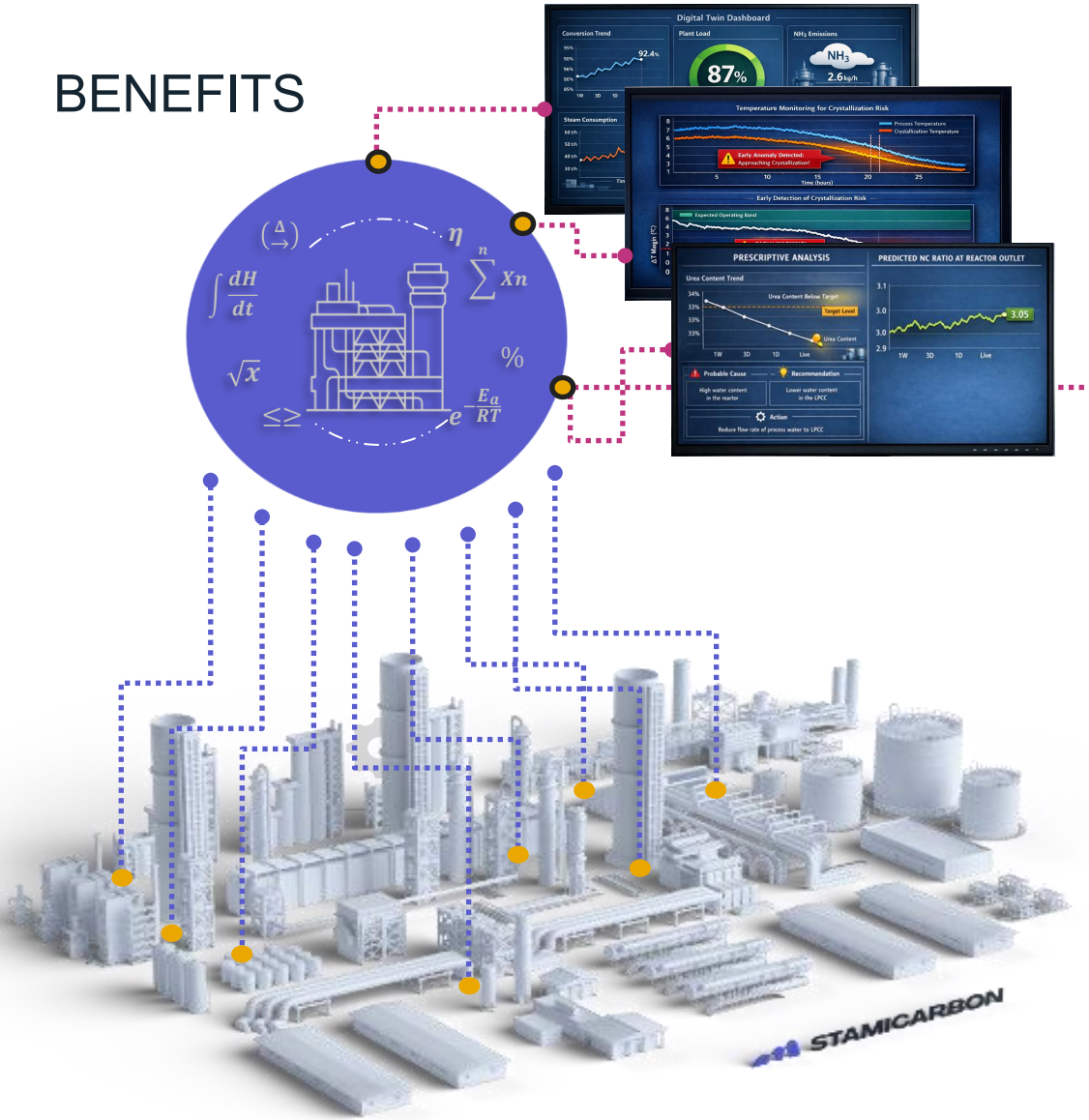

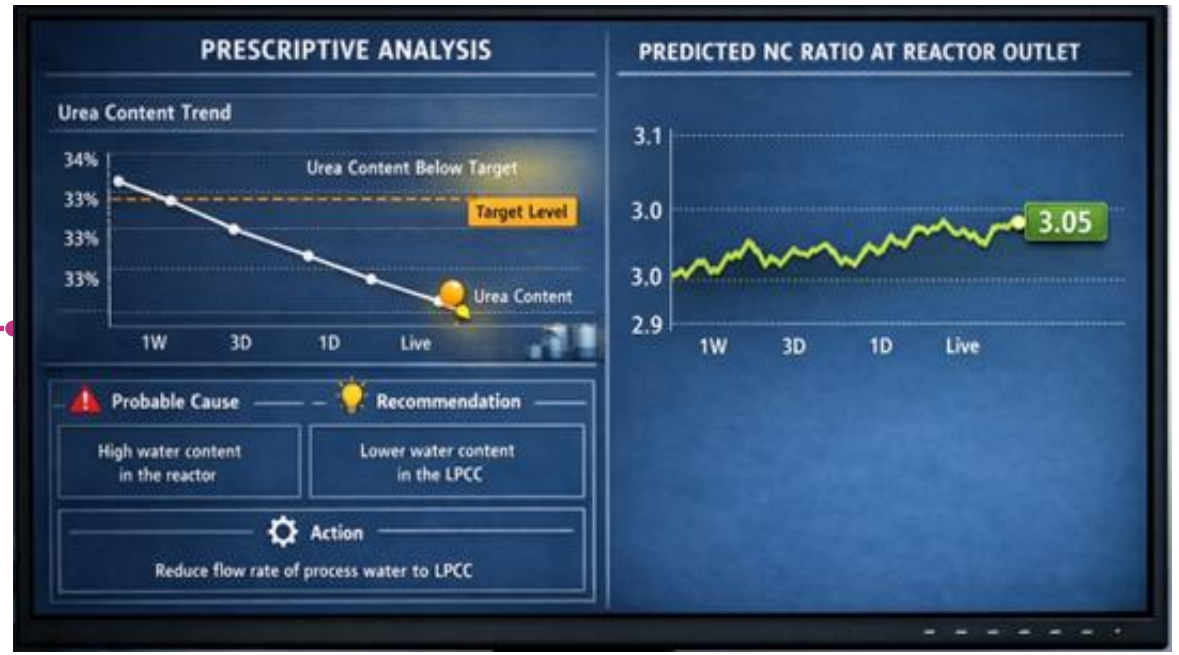

Platform for Advanced AI Tools and Soft Sensors

- Actionable recommendations for optimal & safe operation
- ML-based Estimates of unmeasured or difficult-to-measure variables

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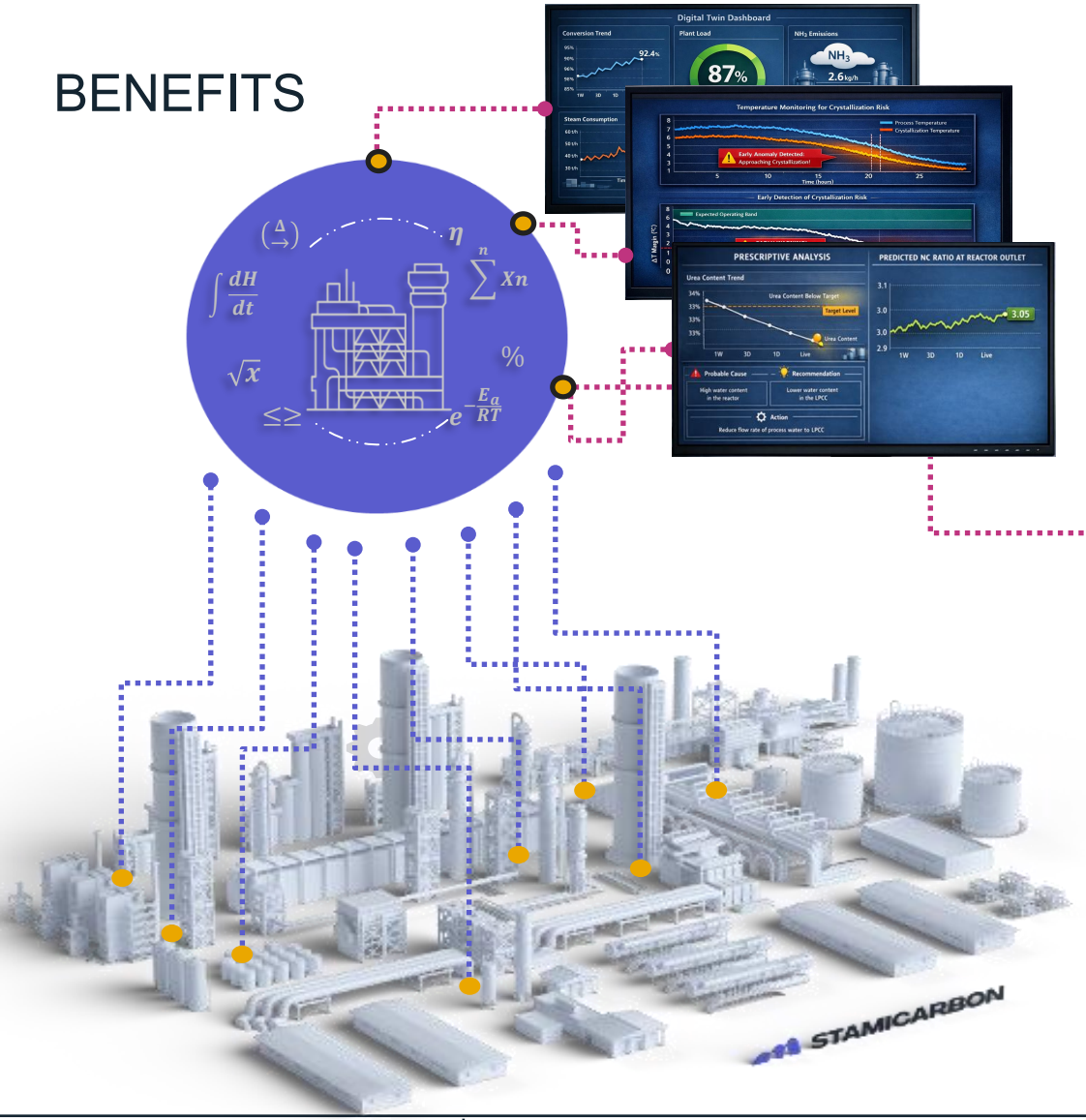

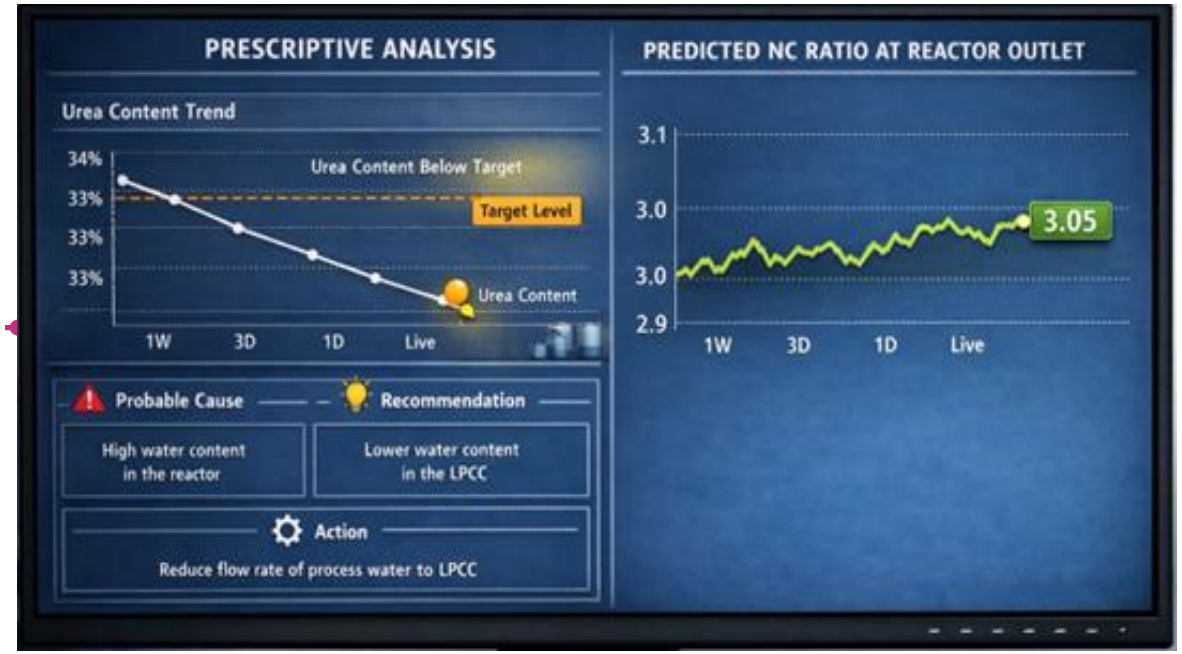

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DIGITAL TWINS AND AI IN THE CHEMICAL INDUSTRY

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DEPLOYMENT IN THE UREA INDUSTRY

- Stamicarbon's **Process Monitor**, part of its NX Stami™ Digital suite, is a prime example

- In one case, Process Monitor enabled a 3-4% increase in capacity & 3-4% reduction in steam consumption

SOFT NC METER: AI-BASED SOFT SENSOR

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DEPLOYMENT IN THE UREA INDUSTRY

- Initially, the Process Monitor leveraged **first-principles models** as core modeling approach.
- Integration of advanced **data-driven models** → value creation.

A successful example of such integration is the Soft NC Meter

02

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SOFT NC METER

SOFT NC METER: AI-BASED SOFT SENSOR

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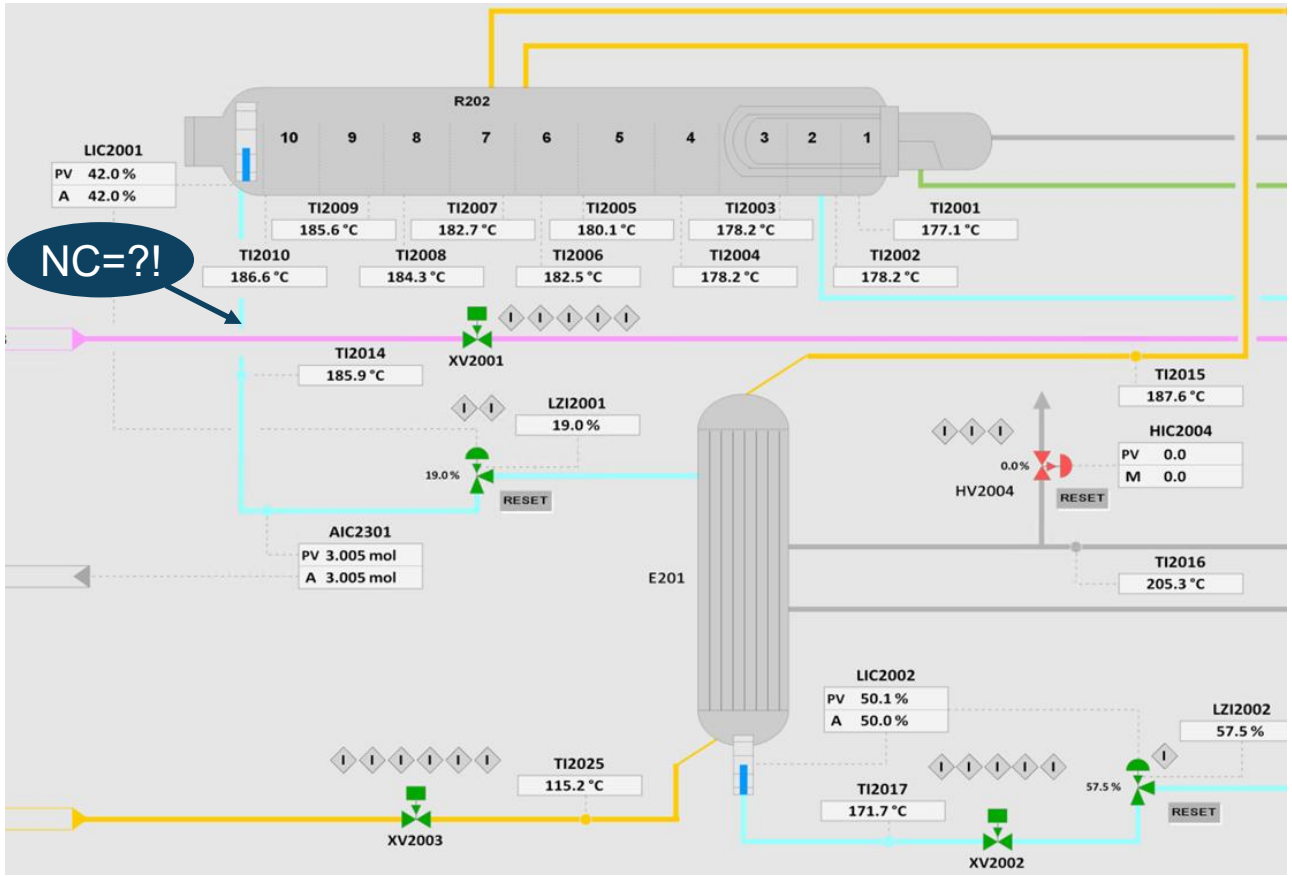
BACKGROUND



- **N/C (NH_3/CO_2) Ratio:** key synthesis parameter directly affecting urea conversion
- Optimal N/C ratio → Maximum conversion & Minimum specific energy consumption
- **N/C Meter:** Dedicated instrument for online measurement of the N/C ratio

SOFT NC METER: AI-BASED SOFT SENSOR

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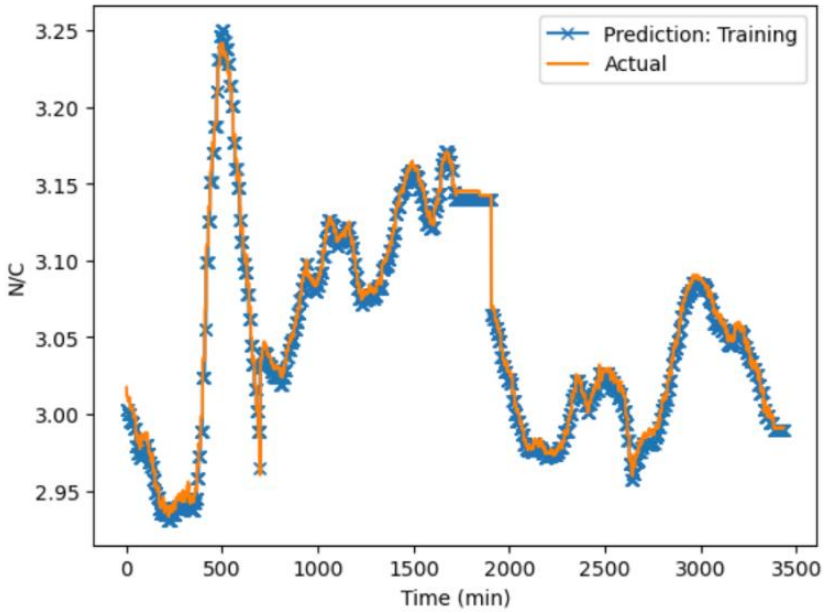
A CASE STUDY

- Client physical NC meter reached the end of its service life.
- ML-based soft NC meter integrated with plant's Process Monitor
- Artificial Neural Network model was developed

Preprocessing of Data (historical) → **Model Training** (Dataset 1) → **Model Validation** (Dataset 2) → **Model Deployment**



- **Model Training Results:**
  - Model uses **17 inputs** (T, P, flowrates) and **one output (N/C)**
  - Close alignment between predicted & measured N/C (MSE=0.00005, R^2=0.996) → Model is <u>well calibrated</u>

SOFT NC METER: AI-BASED SOFT SENSOR

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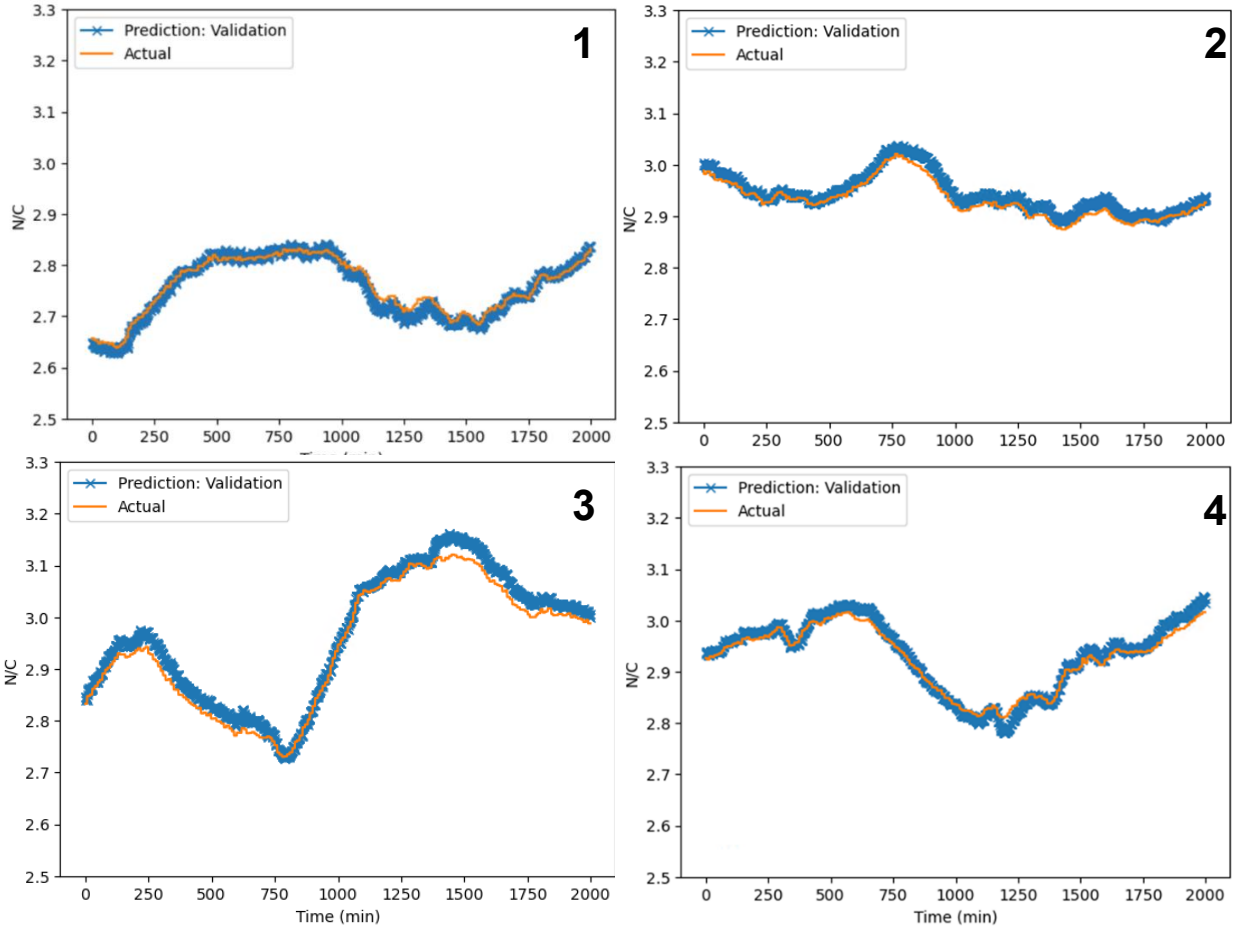
A CASE STUDY

Model Validation Results:



PHASE	R^2	MAE	MSE
Validation 1	0.96	0.013	0.0028
Validation 2	0.97	0.031	0.0012
Validation 3	0.84	0.021	0.00053
Validation 4	0.95	0.018	0.00046

Model Deployment:

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AI- POWERED EVENT DETECTION

AI-POWERED EVENT DETECTION

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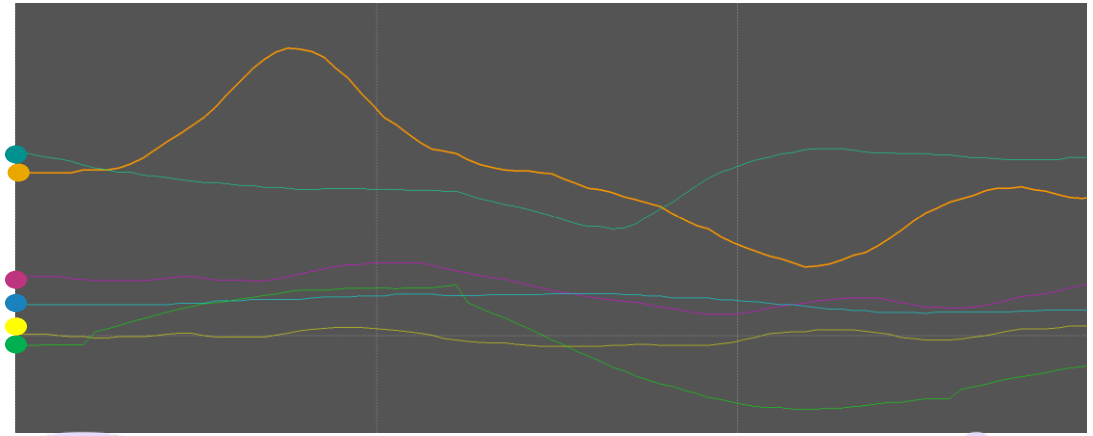
INTRODUCTION AND BACKGROUND

Process anomalies are multivariate problems

- Industrial processes involve dozens of tightly coupled variables
- The DCS relies on univariate alarms where variables are monitored in isolation



AI-POWERED EVENT DETECTION

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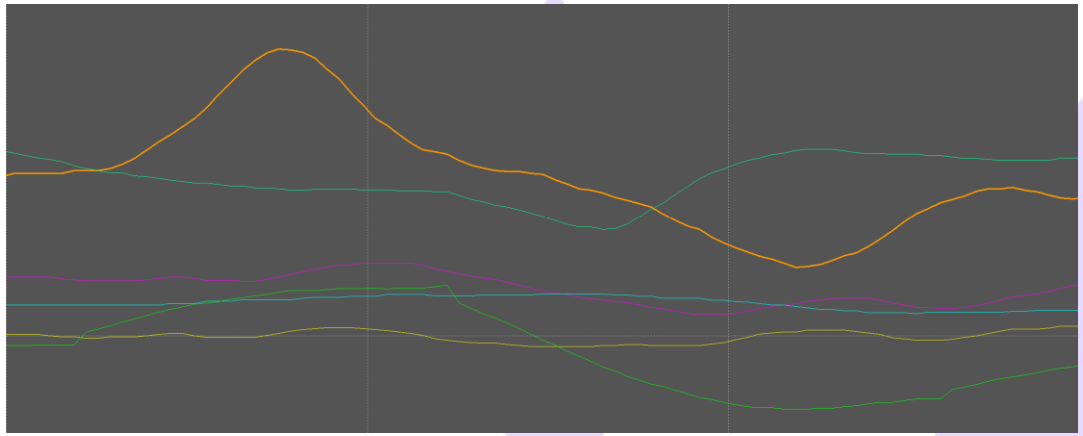

AI-POWERED EVENT DETECTION

Combining plant data, ML models and the process knowledge of a licensor

Detection of abnormal patterns missed by single-variable alarms. Early warning of:

- Process upsets
- Sensor drift
- Equipment degradation

AI-POWERED EVENT DETECTION

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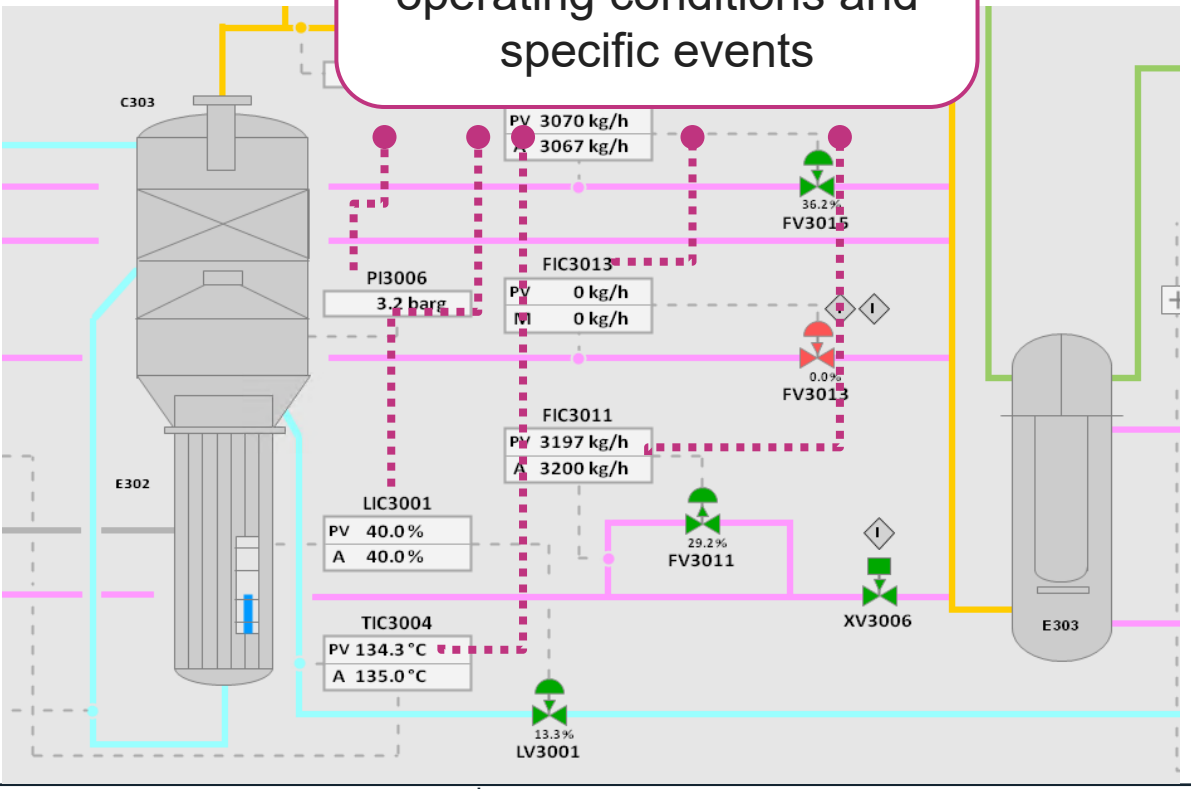
MODEL DEVELOPMENT AND DEPLOYMENT

Data gathering from TTS for optimal and desired operating conditions and specific events



Development of machine learning models for event detection

AI-POWERED EVENT DETECTION

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MODEL DEVELOPMENT AND DEPLOYMENT

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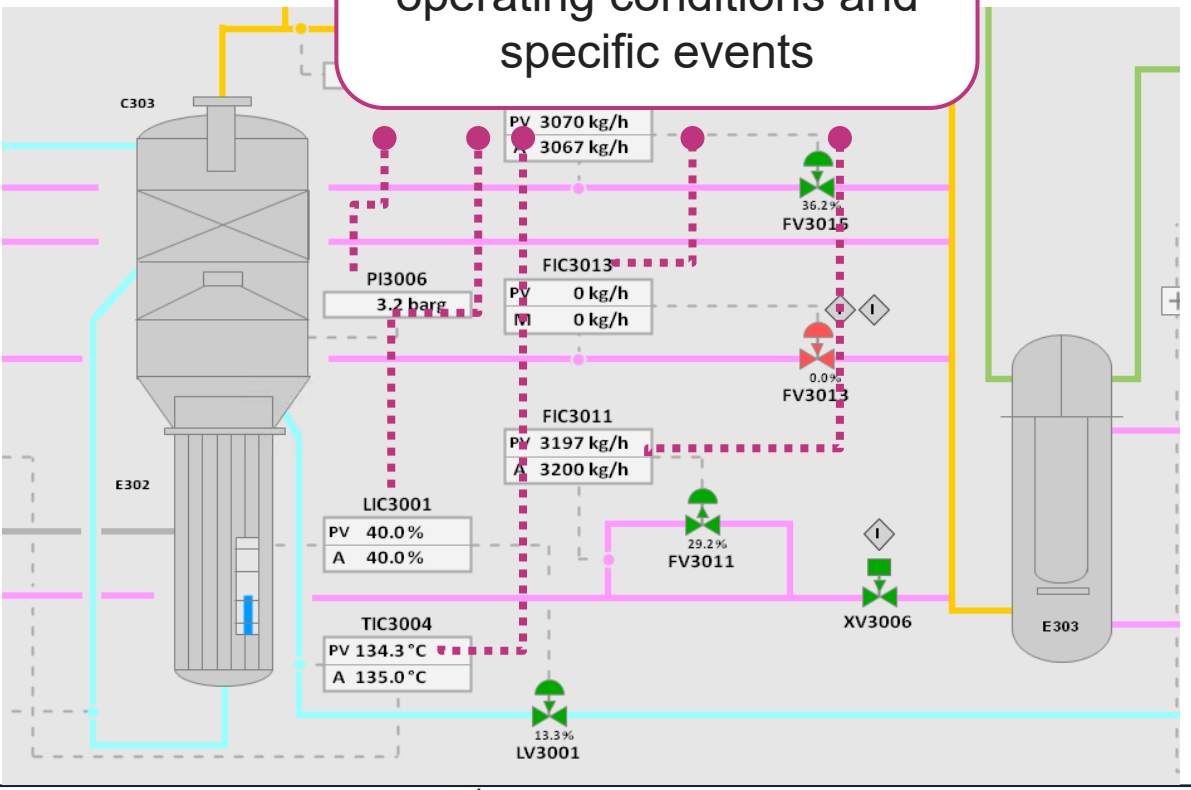

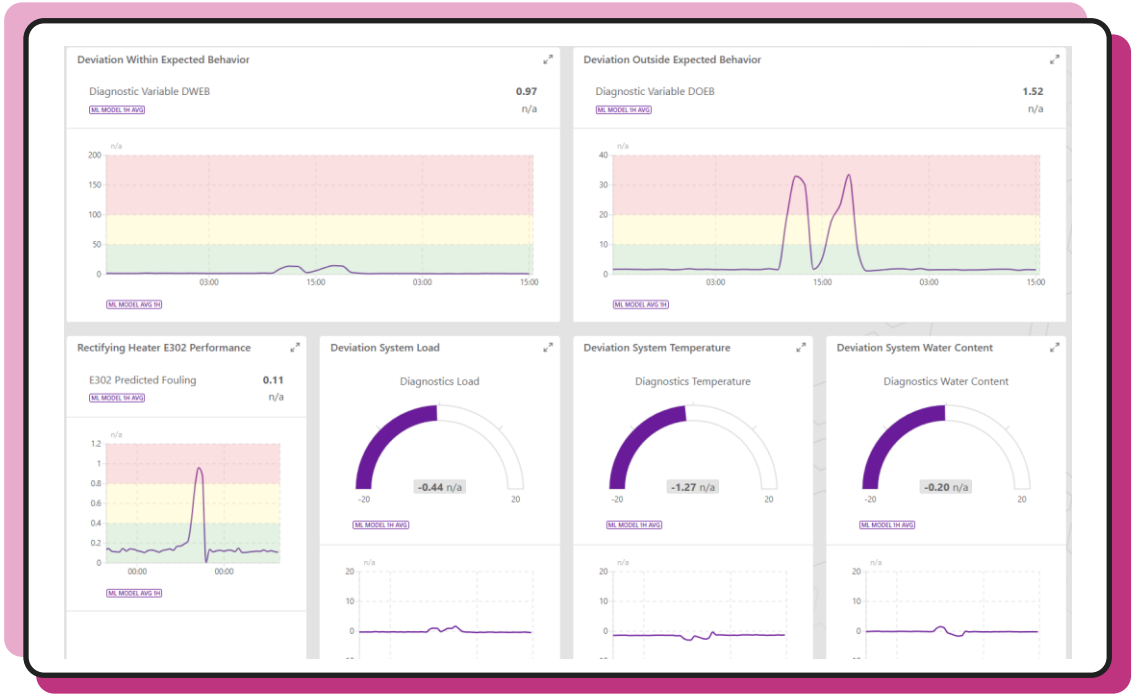

Deployment of the models and dashboard on Process Monitor

AI-POWERED EVENT DETECTION

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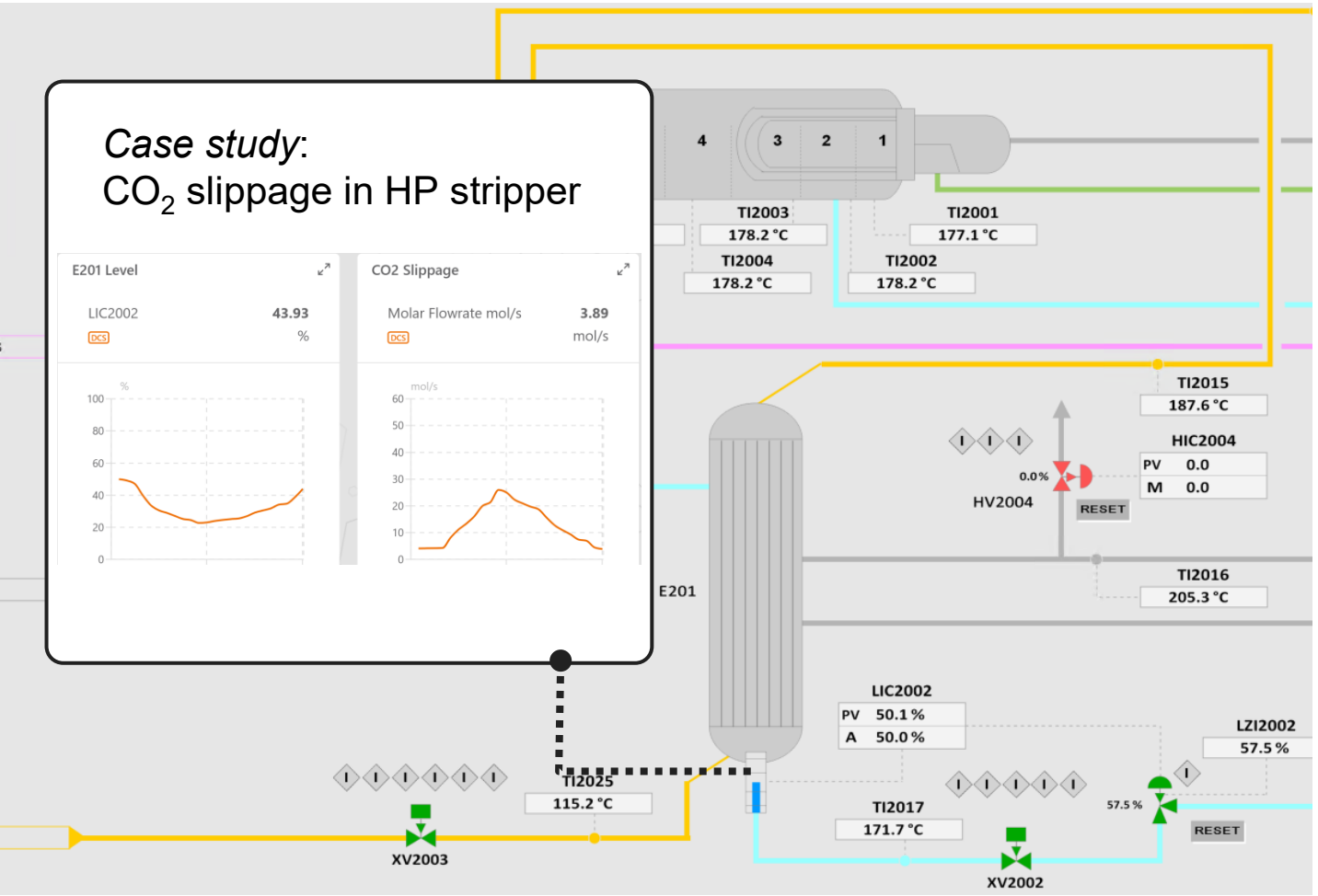
EVENT DETECTION WITH UNSUPERVISED MACHINE LEARNING MODELS



AI-POWERED EVENT DETECTION

EVENT DETECTION WITH UNSUPERVISED MACHINE LEARNING MODELS

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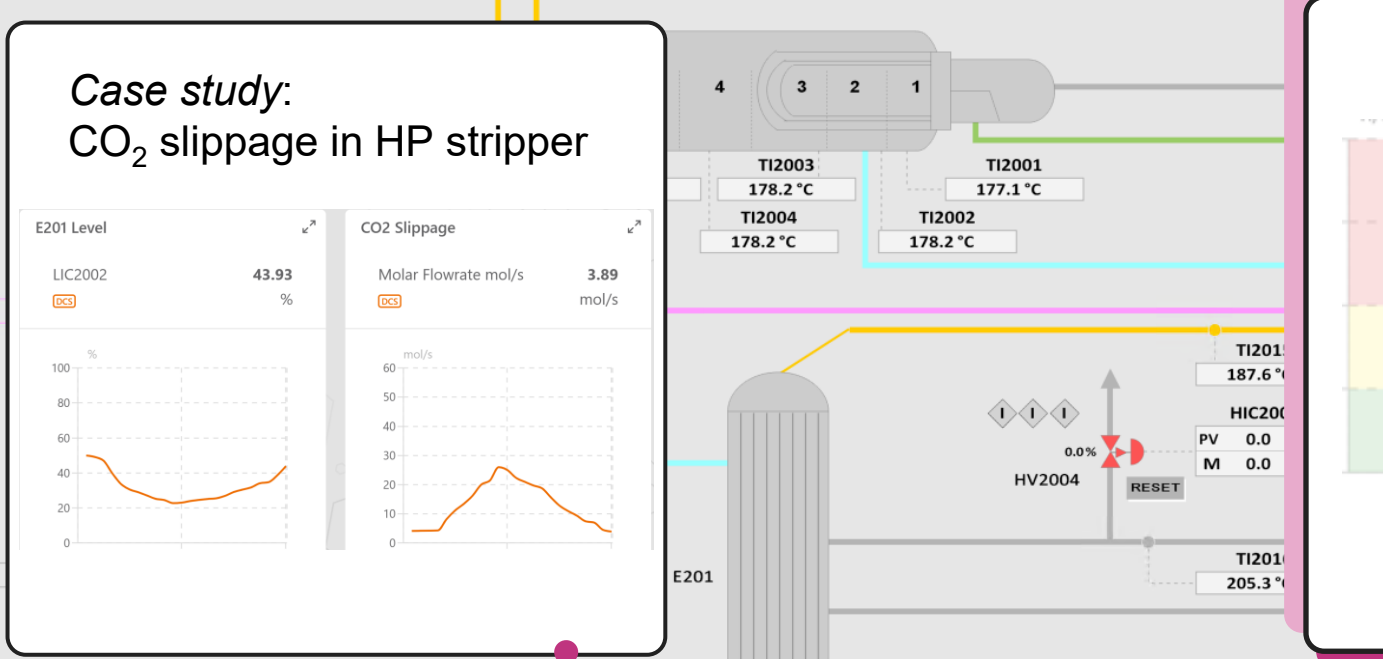
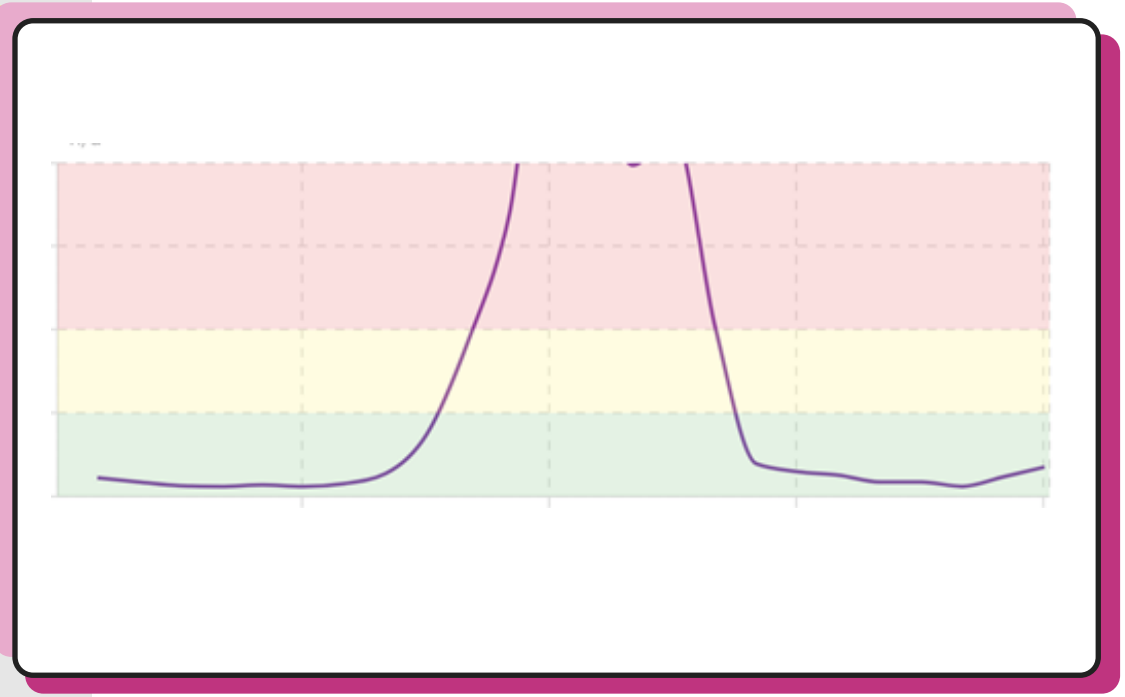
Case study:
CO_2 slippage in HP stripper





- Detection of CO_2 slippage. The ML model detected the deviation, scaling based on the amount of slippage intensity

AI-POWERED EVENT DETECTION

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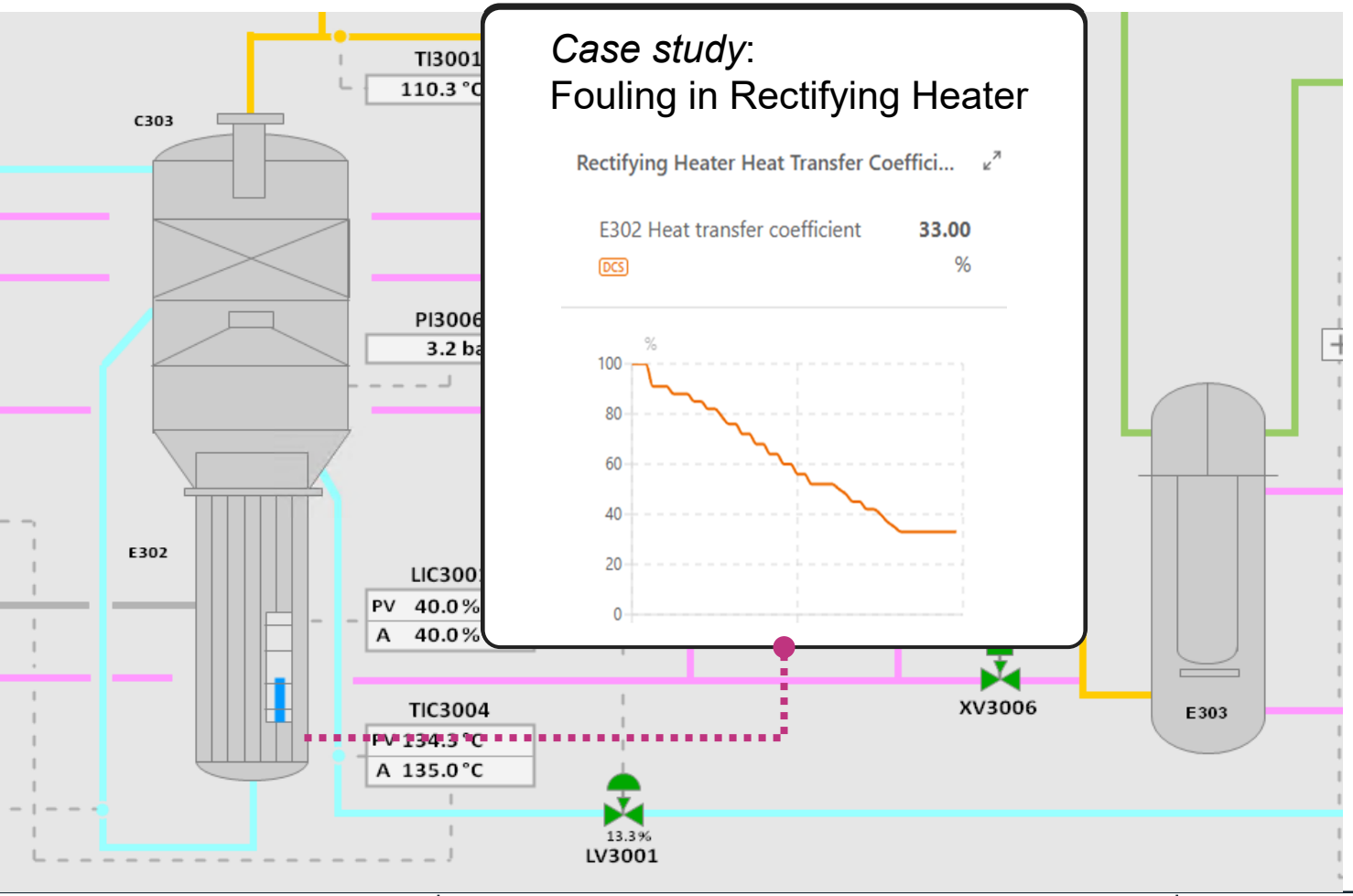
EVENT DETECTION WITH UNSUPERVISED MACHINE LEARNING MODELS



AI-POWERED EVENT DETECTION

EVENT DETECTION WITH UNSUPERVISED MACHINE LEARNING MODELS

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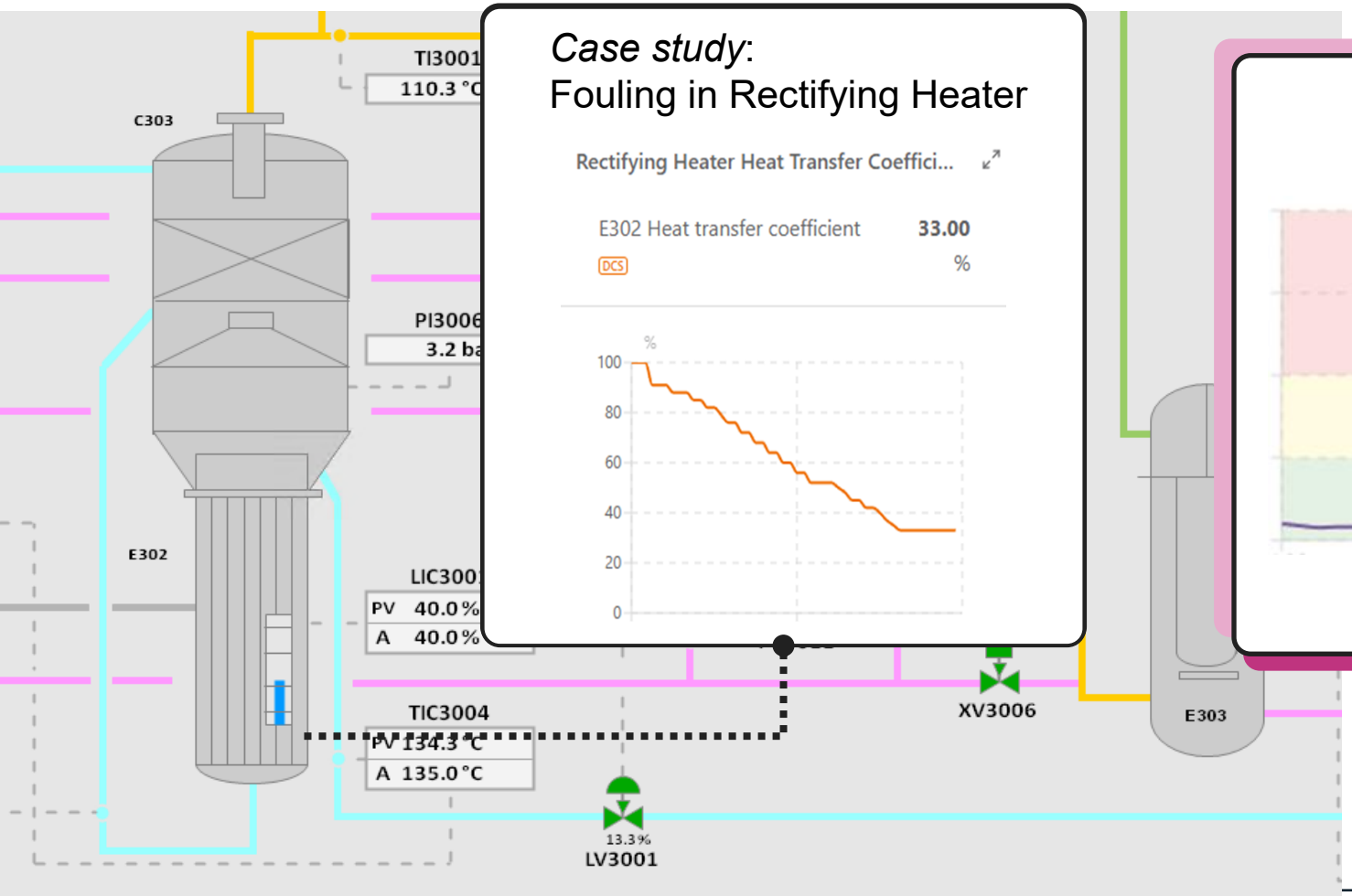
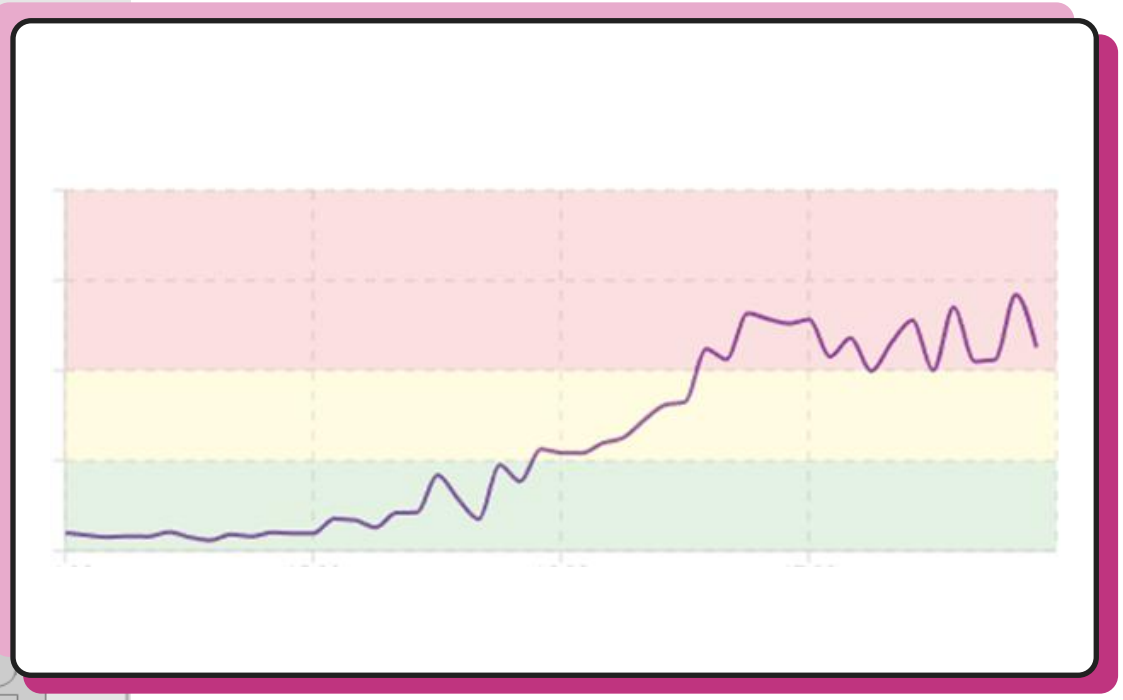


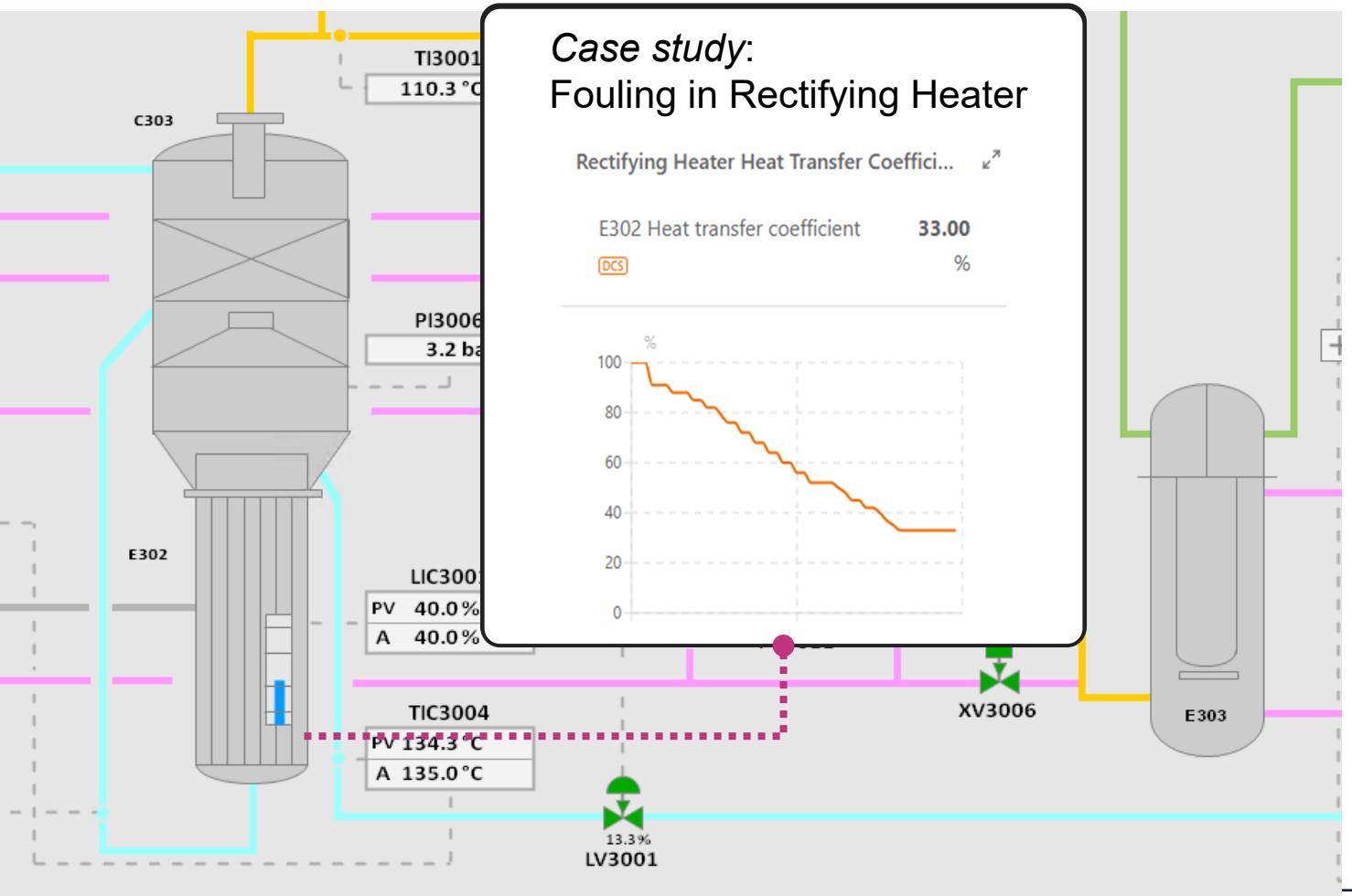
Case study:
Fouling in Rectifying Heater



- Detection of fouling in rectifying heater E302, following the intensity of the reduction on heat transfer coefficient

AI-POWERED EVENT DETECTION

EVENT DETECTION WITH SUPERVISED MACHINE LEARNING MODELS



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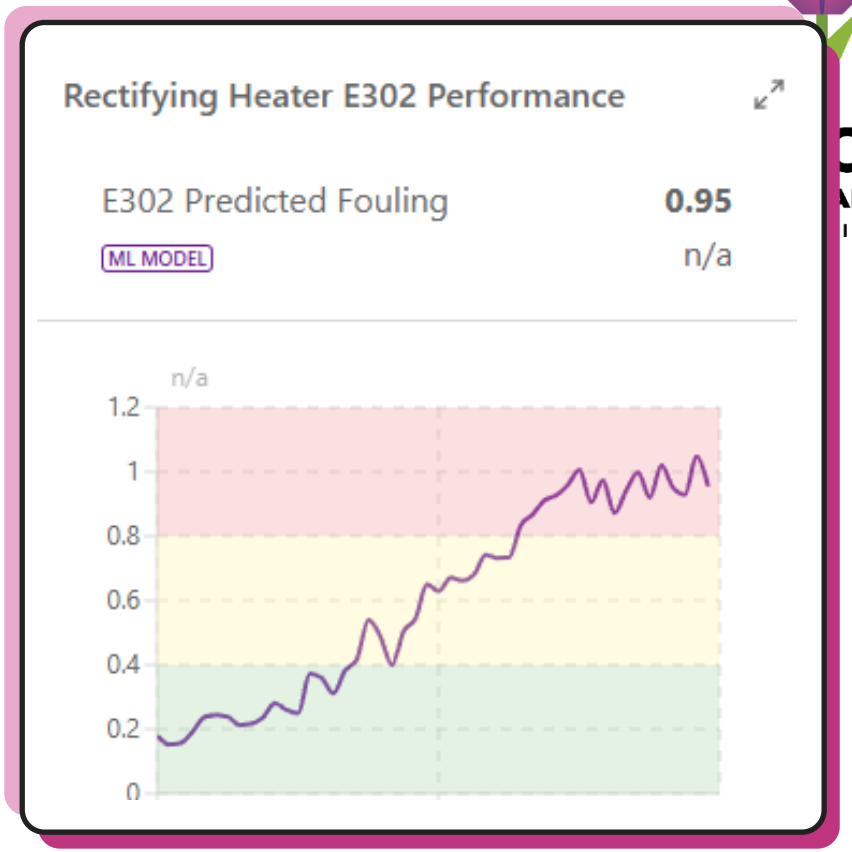
Fouling in Rectifying Heater



- Supervised ML model trained to estimate the fouling of E302.
- The model effectively predicted fouling values

AI-POWERED EVENT DETECTION

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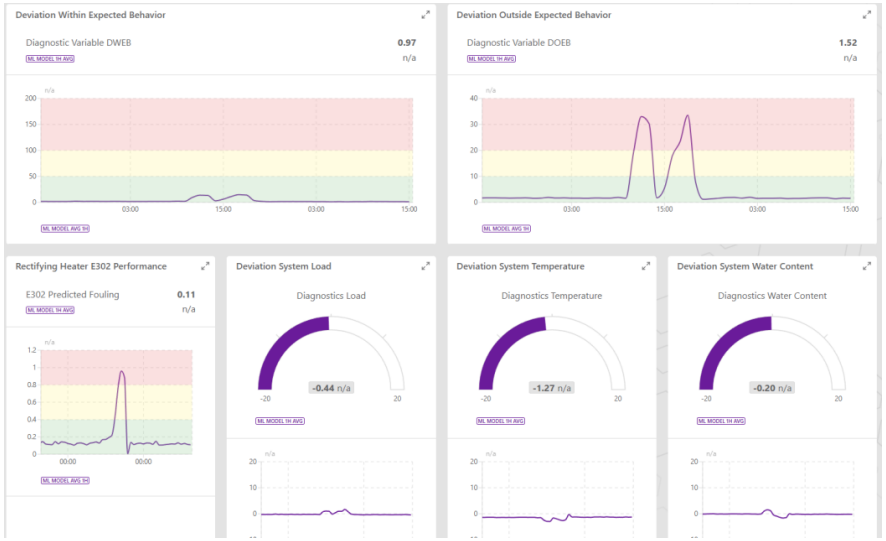
CONCLUSIONS AND FUTURE DEVELOPMENTS

AI-Powered Event Detection

- Combining unsupervised and supervised learning models can create a robust framework for anomaly detection in chemical processes



- **The early detection of process events or equipment degradation directly translates into quicker response and into an economic benefit for the plant**

04

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CARBON FOOTPRINT MONITORING

CARBON FOOTPRINT MONITORING

UNFOLD STAMICARBON 15TH SYMPOSIUM 2026

INTRODUCTION

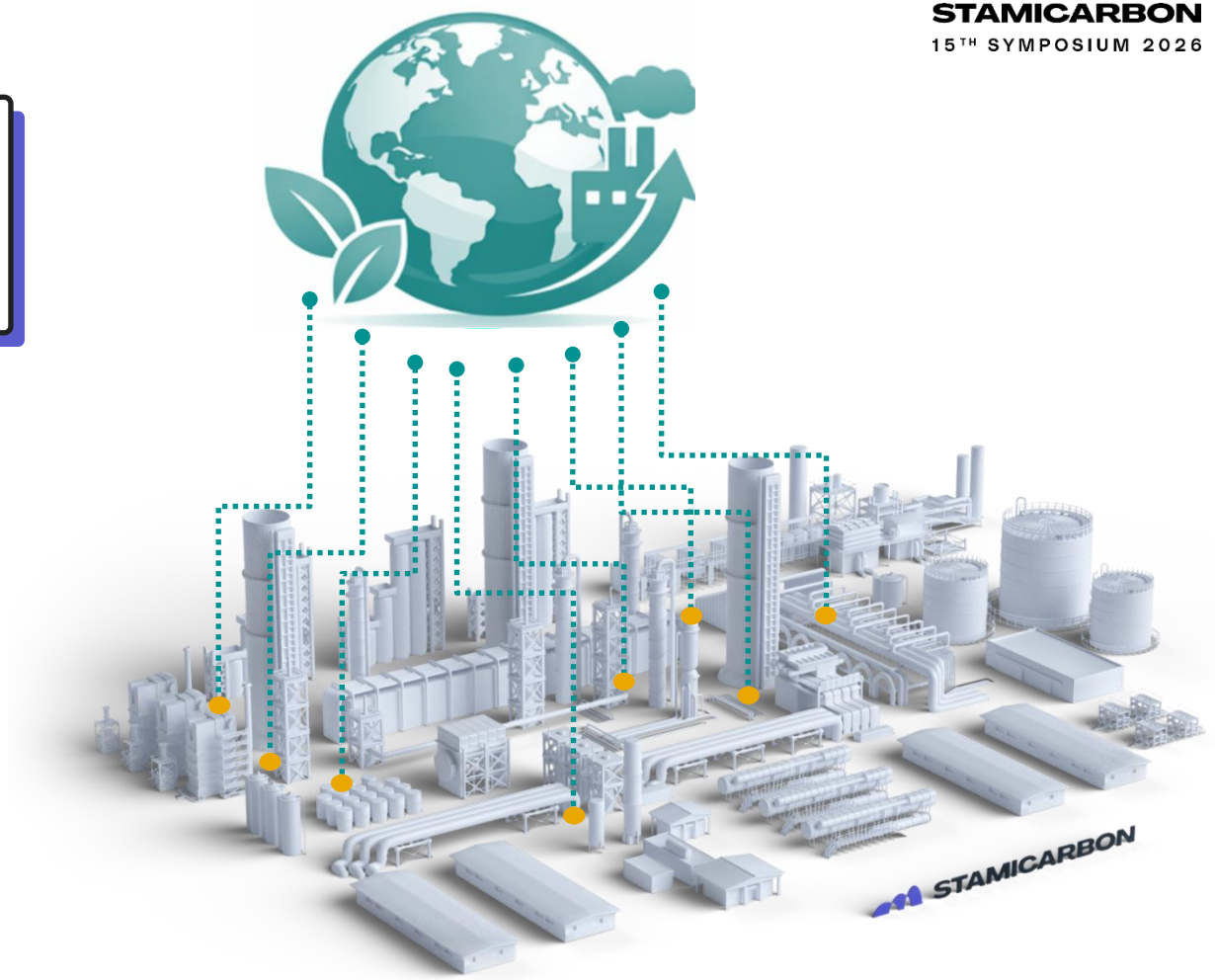
Carbon footprint metrics are evolving from compliance tools to operational KPIs

- Challenges in Carbon Reporting

  Traditional assessments are periodic, manual and discontinuous

- Need for Real-time Monitoring

  Continuous and real-time insights on emissions turns reporting into a tool for efficiency and sustainability



CARBON FOOTPRINT MONITORING

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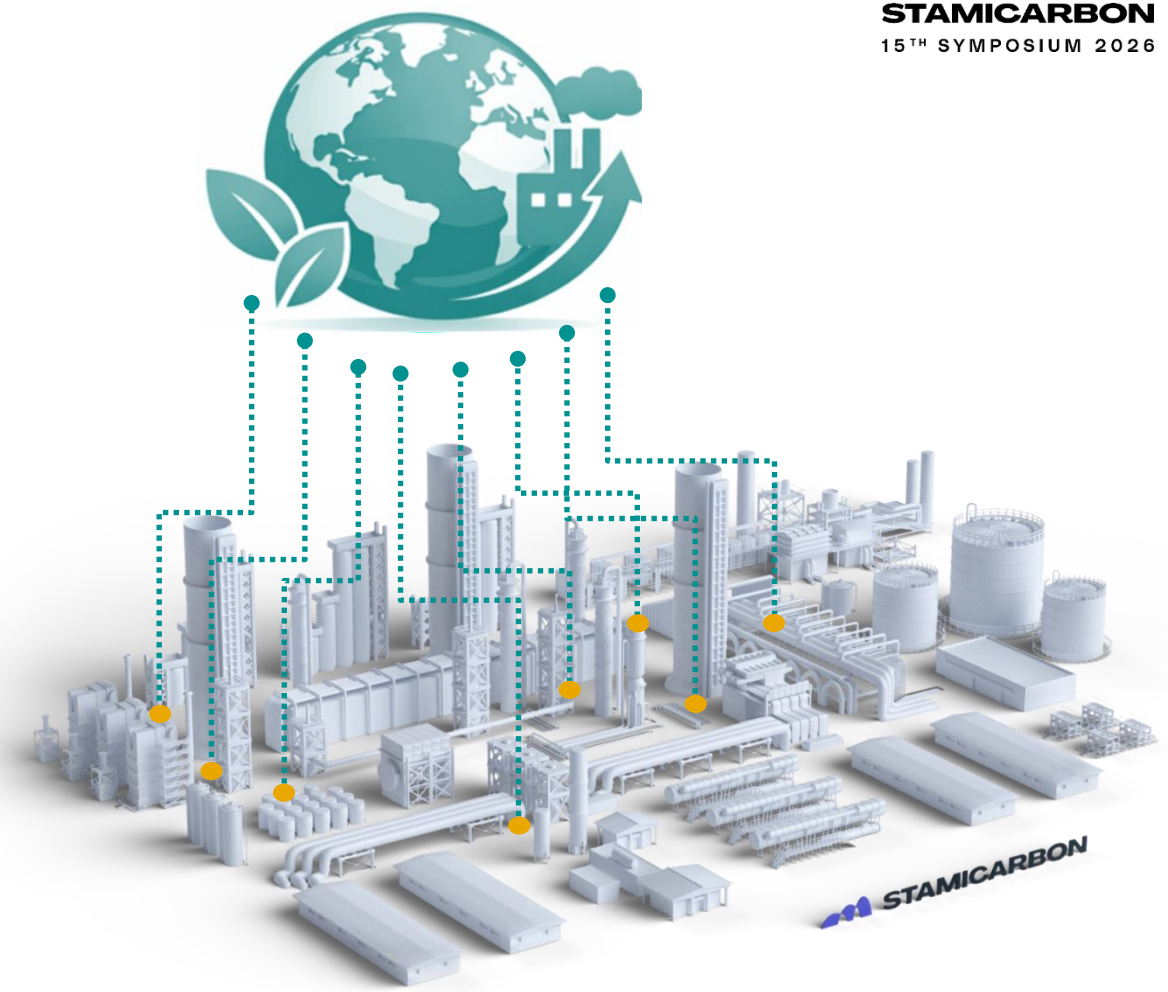
EQUIVALENT CO_2 EMISSIONS CALCULATION

$$\text{Carbon Footprint} = \frac{kg\ CO_2eq.}{ton\ Product}$$

Equivalent CO_2 emissions calculations from the LCA methodology are developed by sustainability experts and embedded into Process Monitor



CARBON FOOTPRINT MONITORING

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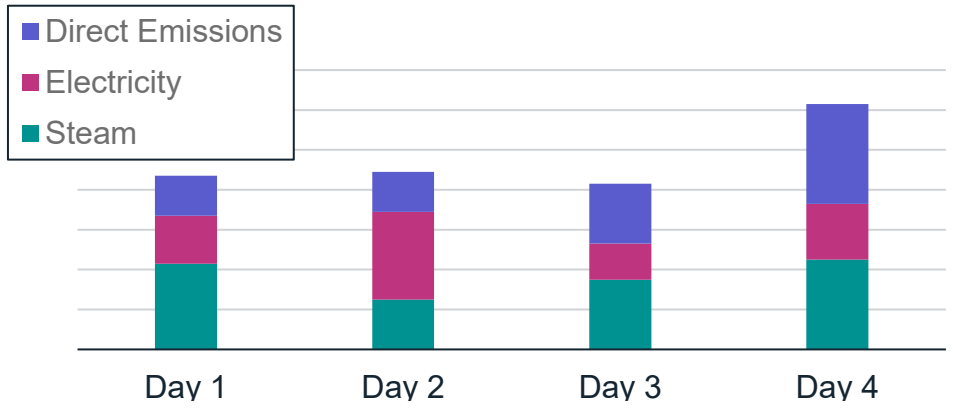
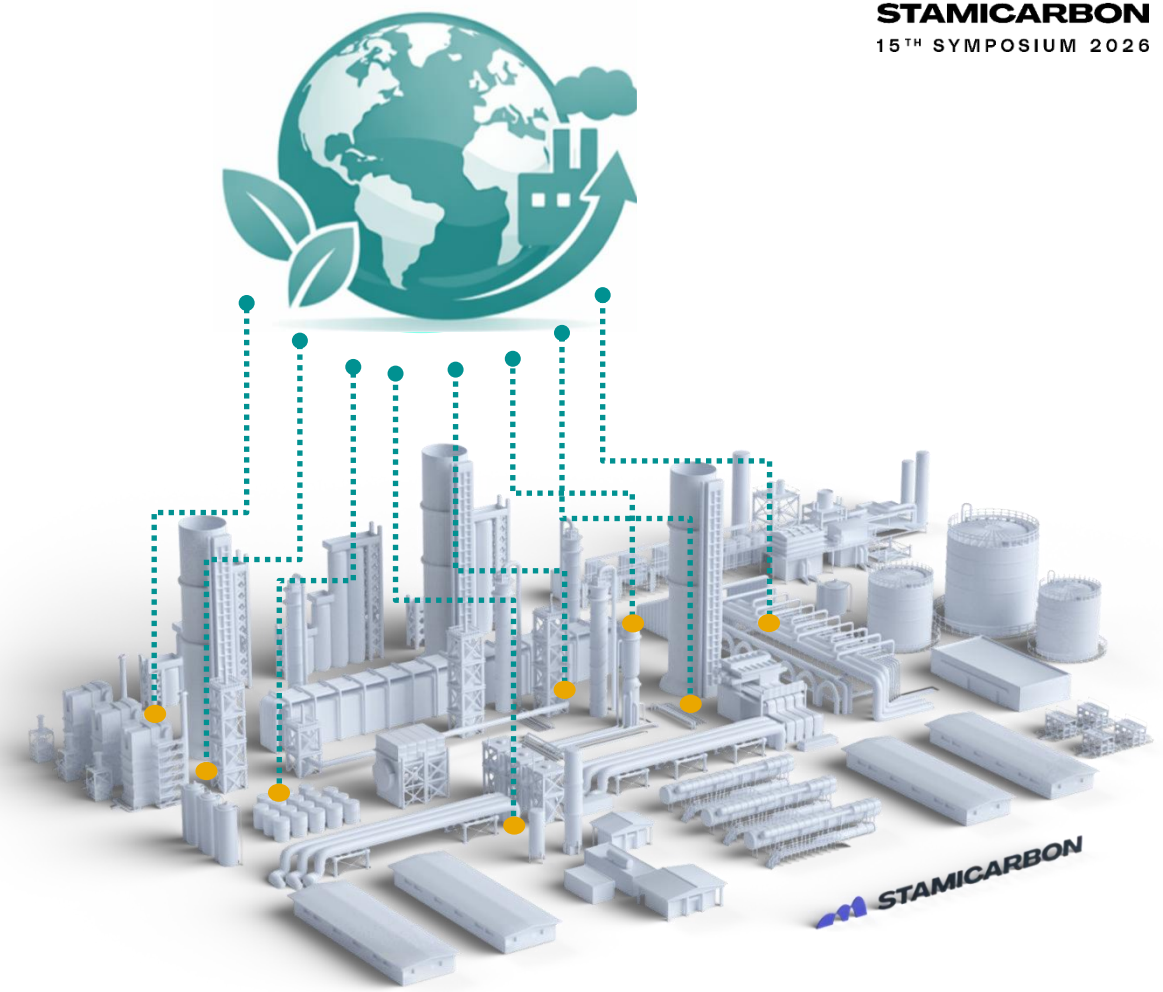
EQUIVALENT CO_2 EMISSIONS CALCULATION

$$\text{Carbon Footprint} = \frac{kg\ CO_2eq.}{ton\ Product}$$

Each contribution to the carbon footprint of the product is calculated and monitored





CARBON FOOTPRINT MONITORING

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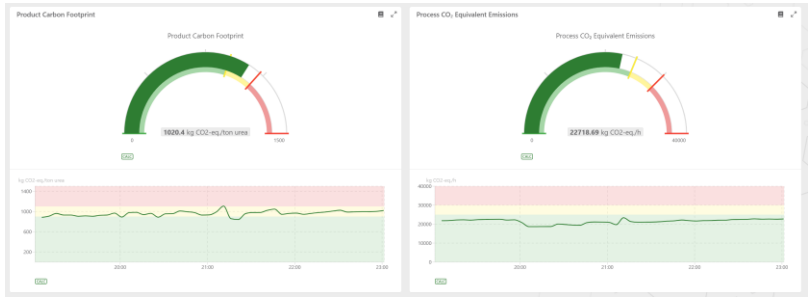
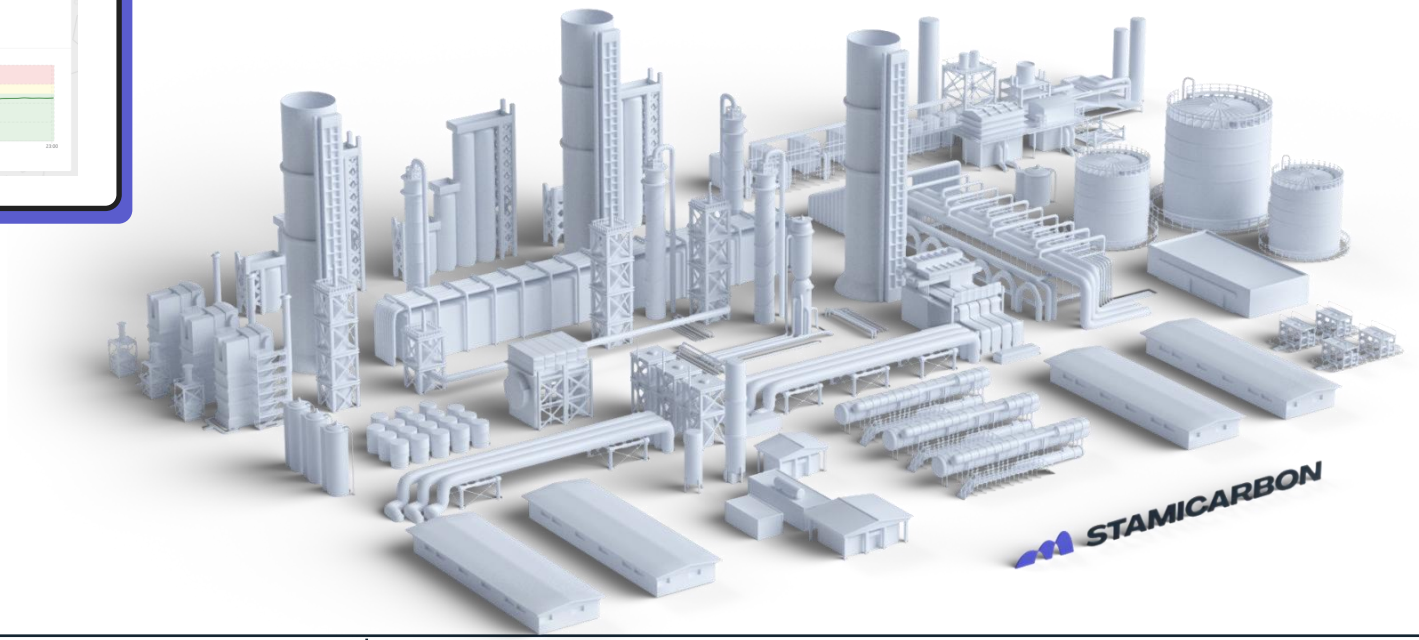
EQUIVALENT EMISSIONS FOR A PLANT

The carbon footprint monitoring can focus only on one process





CARBON FOOTPRINT MONITORING

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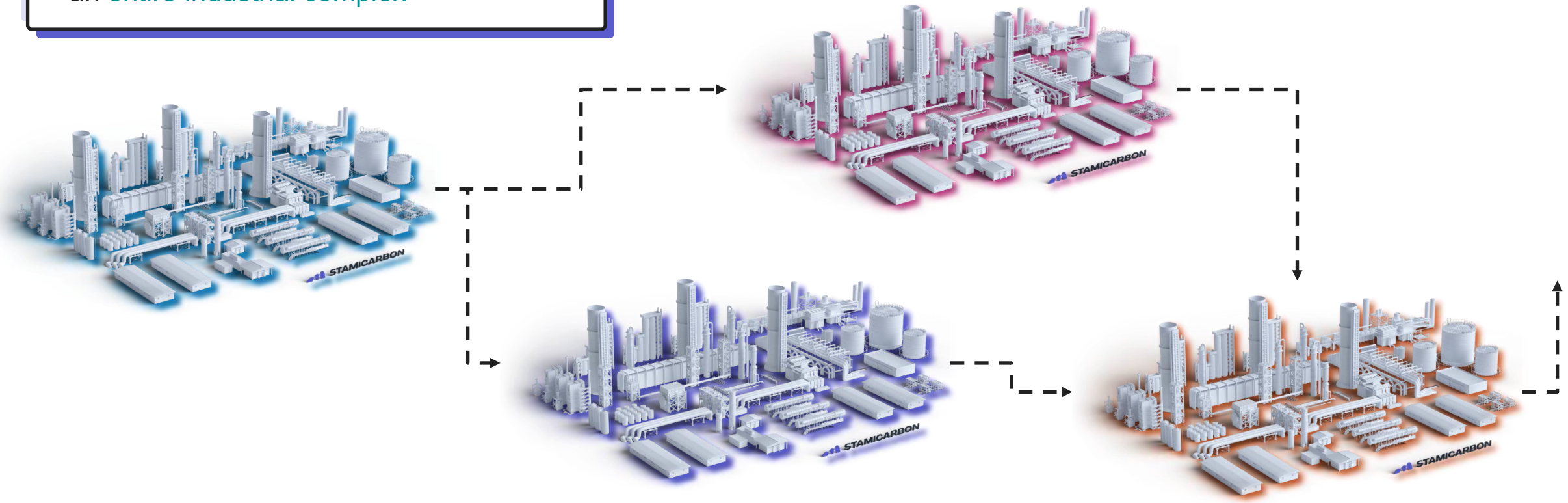
EQUIVALENT EMISSIONS FOR A COMPLEX

The carbon footprint monitoring can manage the CO_2 equivalent emissions of an entire industrial complex



CARBON FOOTPRINT MONITORING

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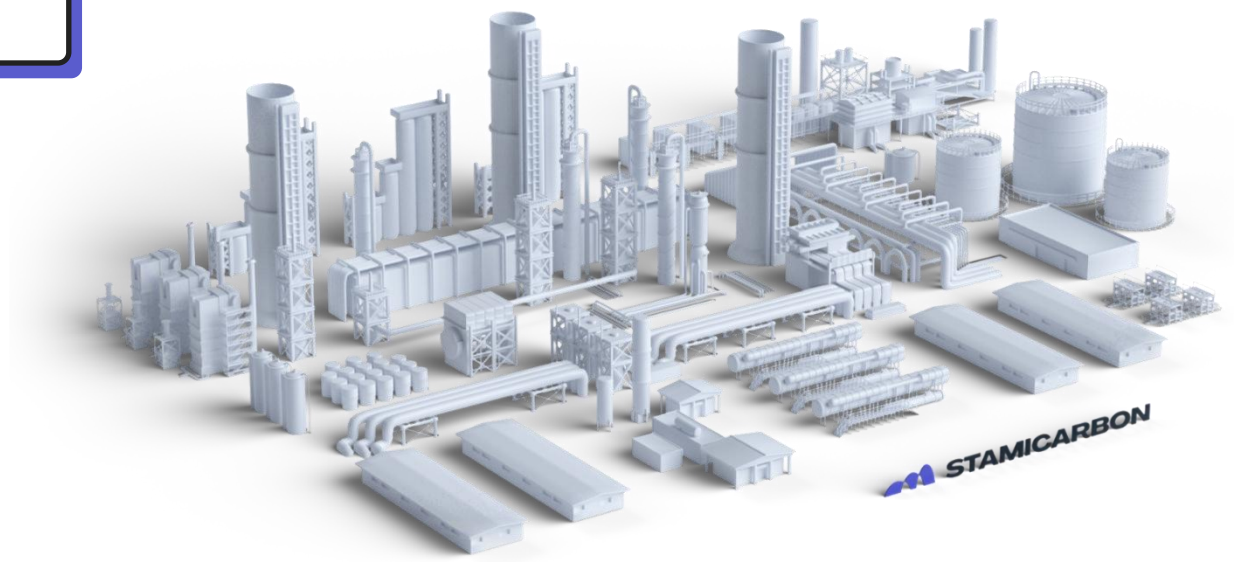
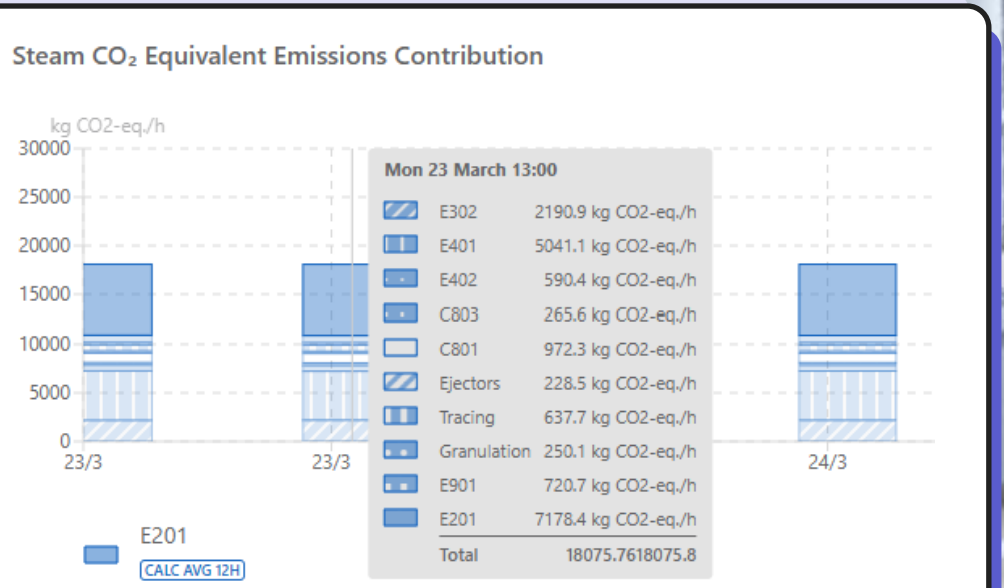
EQUIVALENT EMISSIONS FOR SPECIFIC EQUIPMENT

Process knowledge from the licensor can provide solutions to specific equipment to reduce the process environmental performance

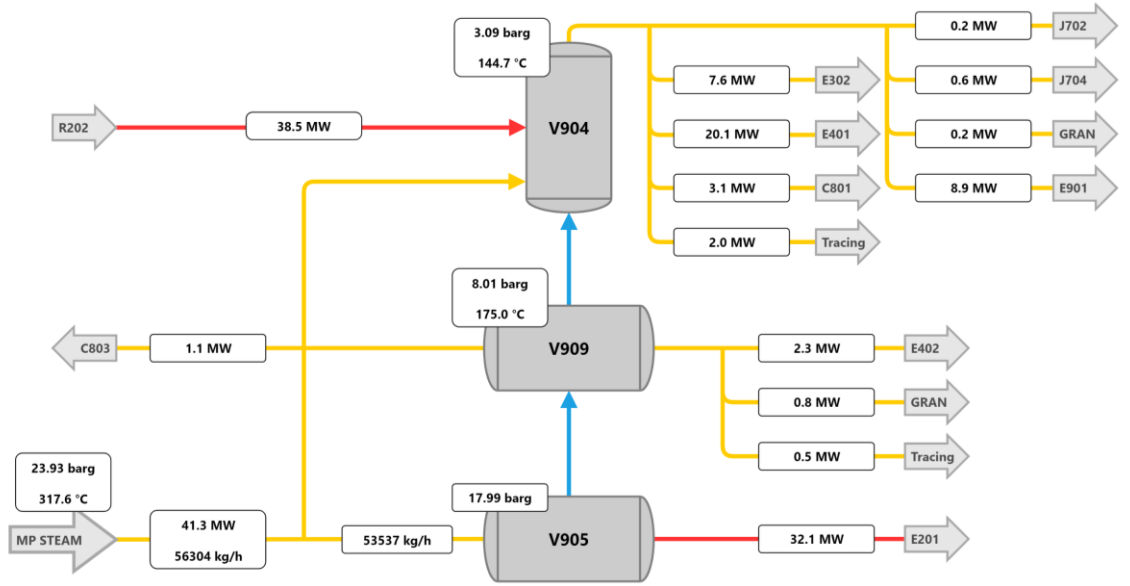


CARBON FOOTPRINT MONITORING

EQUIVALENT EMISSIONS FOR SPECIFIC EQUIPMENT



Insights on the contribution to the CO_2 equivalent emissions of each process equipment



Detailed analysis of the energy usage in the process to develop detailed and specific solution

CARBON FOOTPRINT MONITORING

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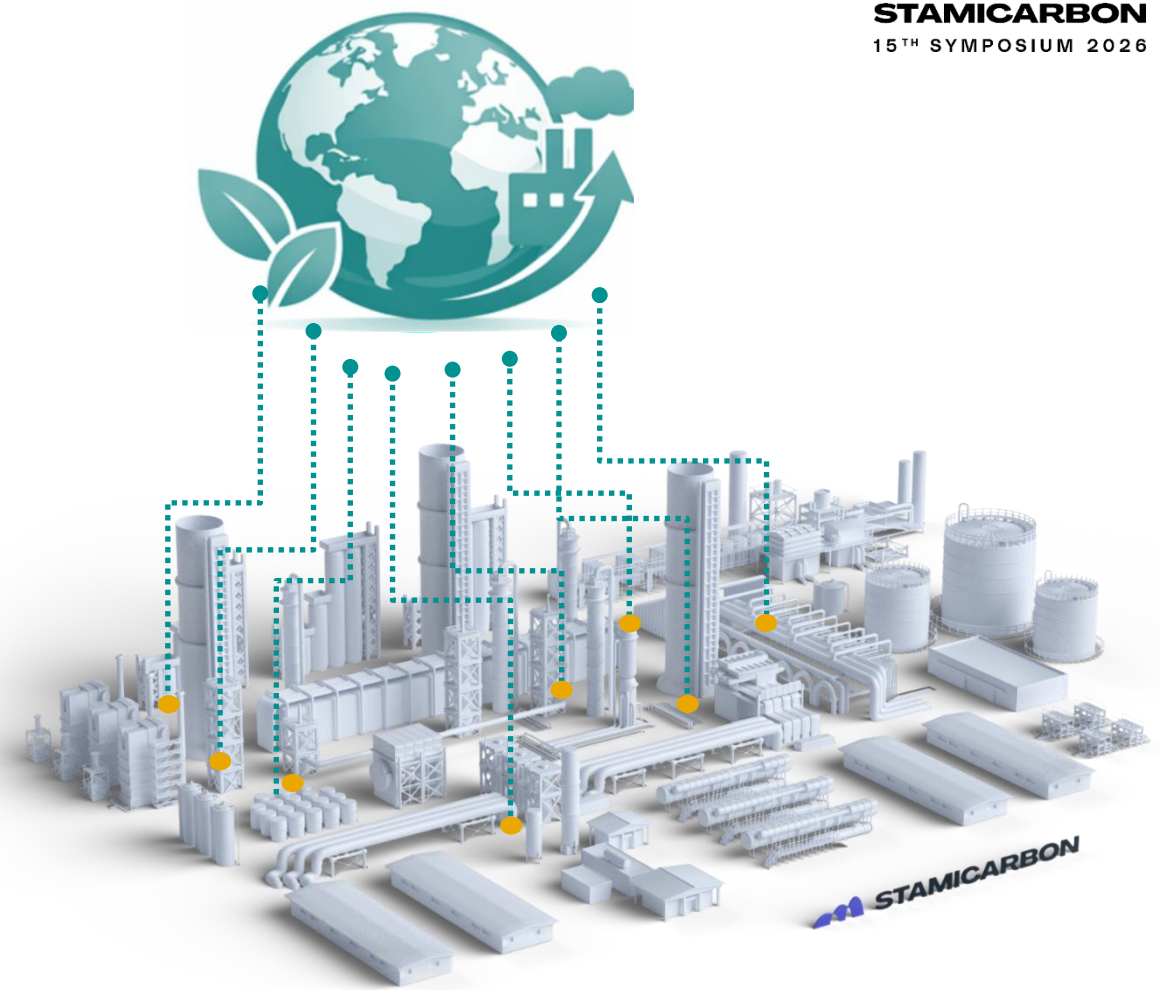
CONCLUSIONS

Benefits of the Carbon Footprint Monitor

- Proactive Emission Management at Every Level
  - The monitor enables real-time carbon management, allowing proactive rather than reactive emission control
- Carbon and Cost Reduction thanks to Tailored Solutions
  - Integrating licensor knowledge to emissions monitoring can offer an unmatched level of information and offer strategies for process improvement



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