

VirtMet

Simulation-Enhanced Soft Sensors for Industrial- Grade Virtual Sensing: From Concept to Compliance

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Industry & Process Analytical Technology

Measurement from users' perspective

Objective

- **provide reliable process parameters (insights)**
 - Quantitative measurement, quality or safety monitoring,
 - obligatory measurements, *e.g. emission monitoring*
 - ...



Industry & Process Analytical Technology

Measurement from users' perspective

Challenges

- Cope with complexity
 - From sensor to analyzer shelter
 - Safety, plant conditions, sample, sampling systems, reference materials, measuring systems, standards, hundreds of parameters, unique expertise, logistics, ..
- Demand for long-term expertise
- Vulnerability
 - Technical problems aren't localized within measuring device
 - Small deviation within the system may cause significant impact on measurement result
- ...



Industry & Process Analytical Technology

Measurement from users' perspective

Challenges

- High investment costs (CAPEX)
- High operational expenditures (OPEX)
- Sustainability

Demand for significant improvement



Industry & Process Analytical Technology

Measurement from users' perspective

Ongoing Innovation

- Evolution of PAT technology
 - novel sensing principles, smarter devices, architectures, in-situ ...
- Use of device data (NOA)
 - increase availability of HW and reliability of process parameters
 - optimize maintenance operations



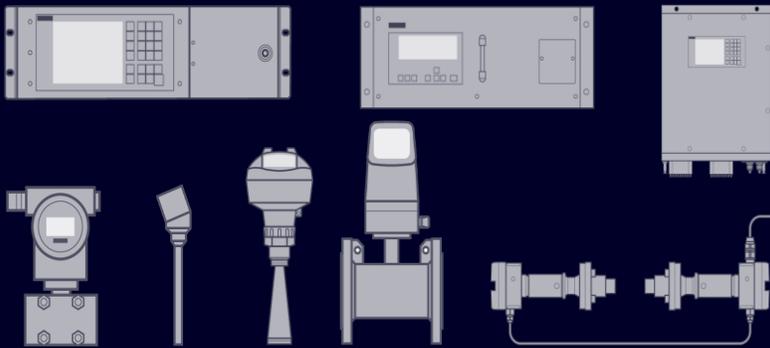
Any bigger steps than evolution?

Innovation beyond conventional evolution

Objective - provide reliable process parameter [e.g. Emission]

New way of thinking how to get it

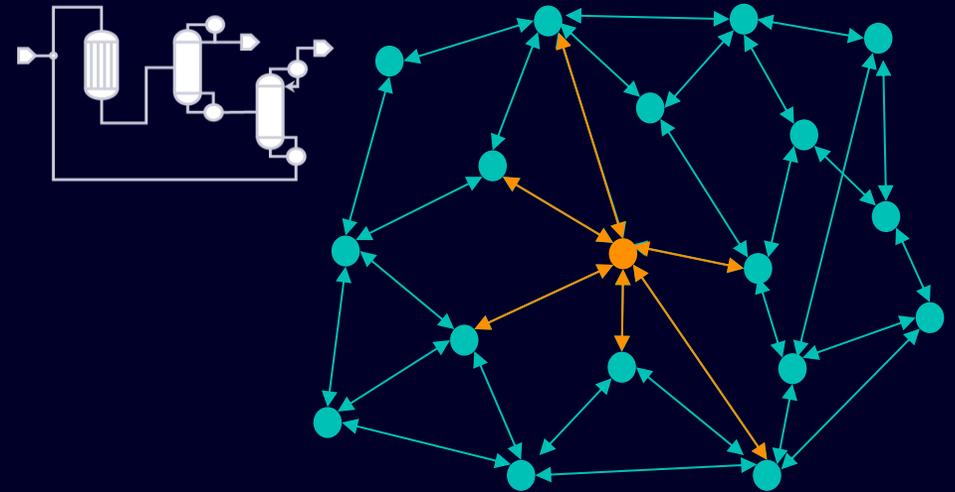
Process Analytics (Physical and Chemical Sensing)



Installing a complex measurement system to directly measure target gas or liquid components at a specific point, requiring high investments.

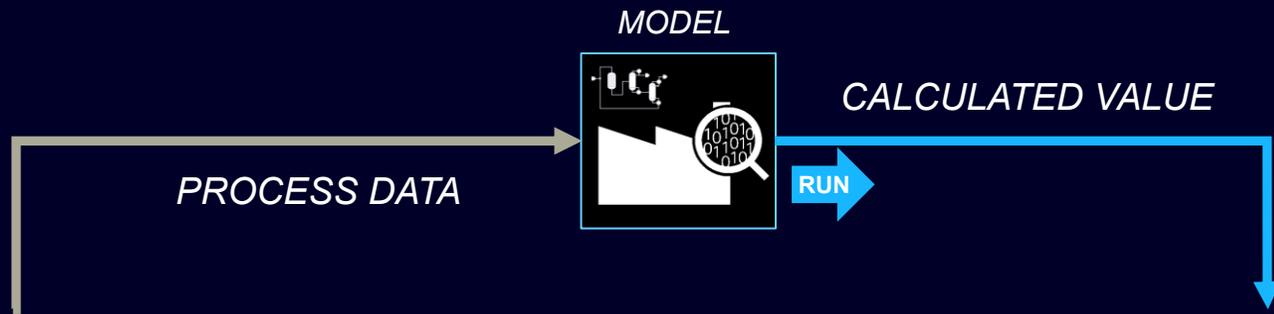


Process Analytics (Virtual Sensing)

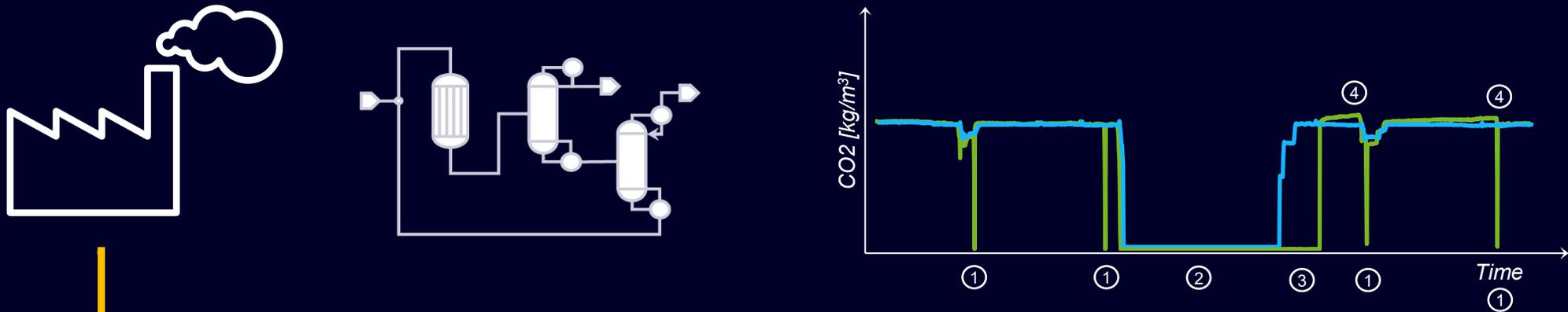


Use plant data and sensor network information to indirectly derive target components based on a deterministic process model. Temporary physical sensing is used to set up or adapt the model.

Example Emission monitoring by “white box” modelling



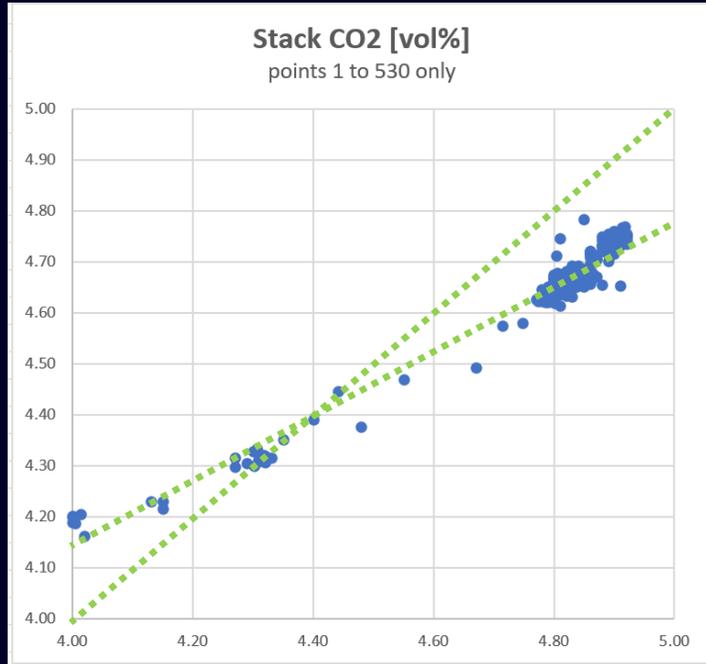
Model development relies on detailed plant/process descriptions. It offers good interpretability and individual solutions. Can operate beyond known data space. Complexity and computing performance are crucial, requiring simulation tools. Key skills: mechanical engineering, physics, chemistry. High engineering effort.



- 1. Analyzer not available / calibration
- 2. Plant shutdown
- 3. Analyzer off
- 4. Analyzer system unstable during calibration

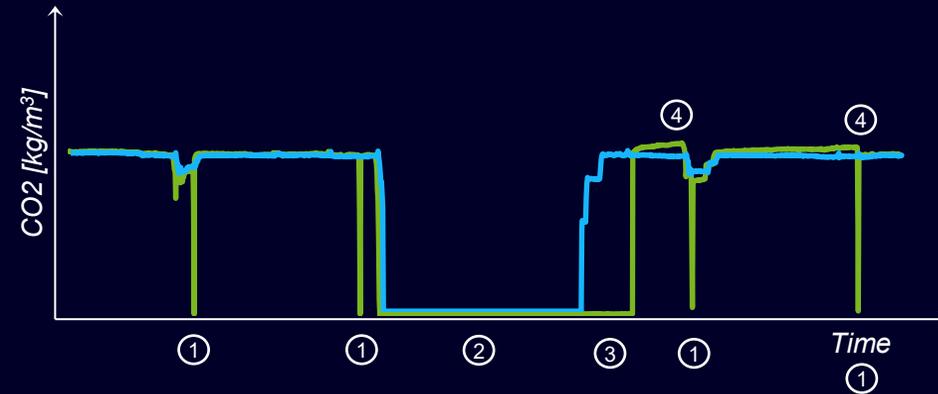
Learning about uncertainty

Reference measurement of the target value crucial for the entire evaluation



Industrial Measuring Systems: Key Considerations

- Measuring systems in industrial applications are **highly complex**.
- Beyond instruments, **sampling systems, procedures, and reference materials** play a critical role.
- **Validation** of data from reference measuring systems is essential to ensure accuracy and reliability.



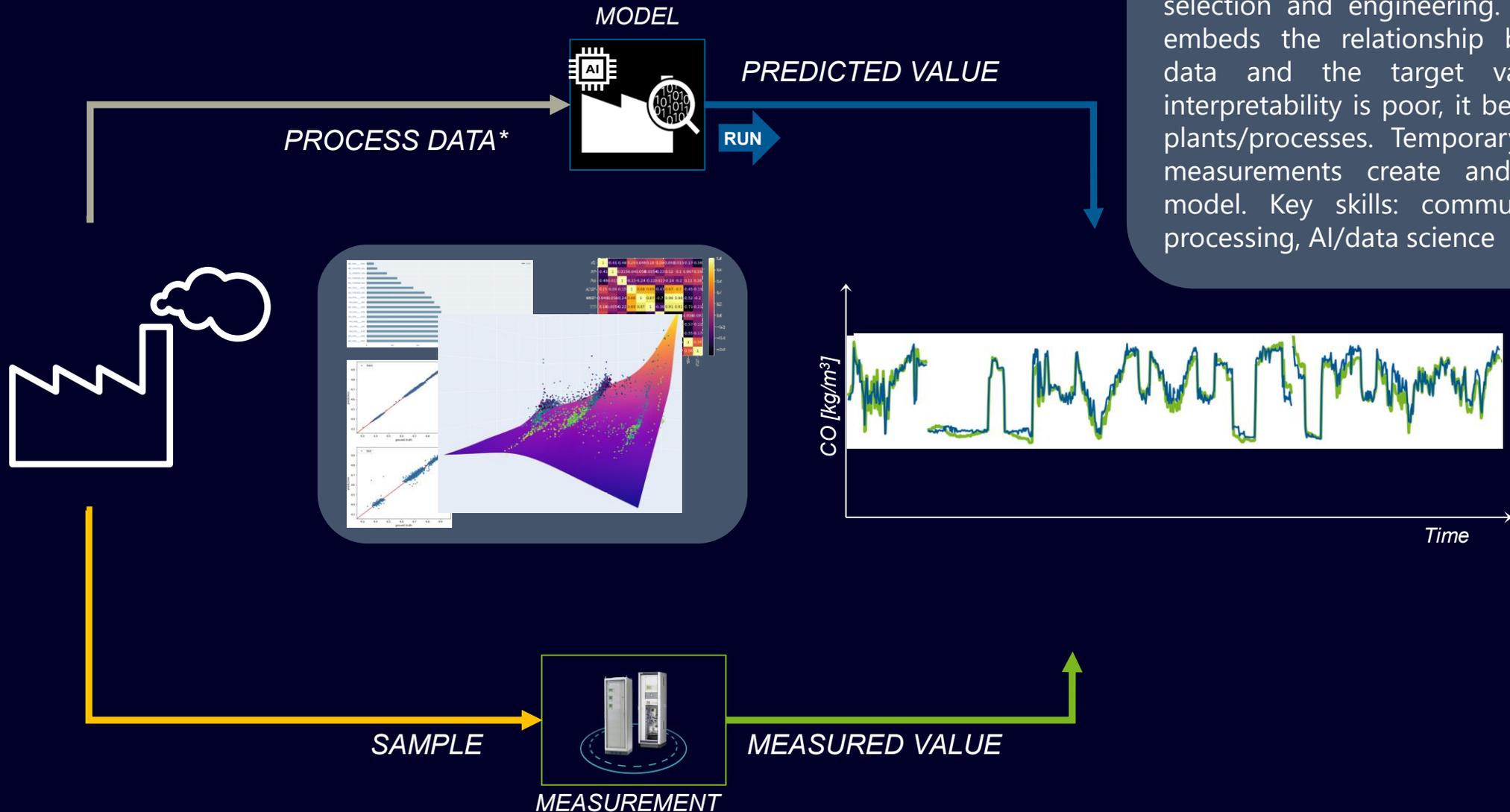
1. Analyzer not available / calibration
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3. Analyzer off
4. Analyzer system unstable during calibration



MEASURED VALUE

MEASUREMENT

Example Emission monitoring by “black box” modelling



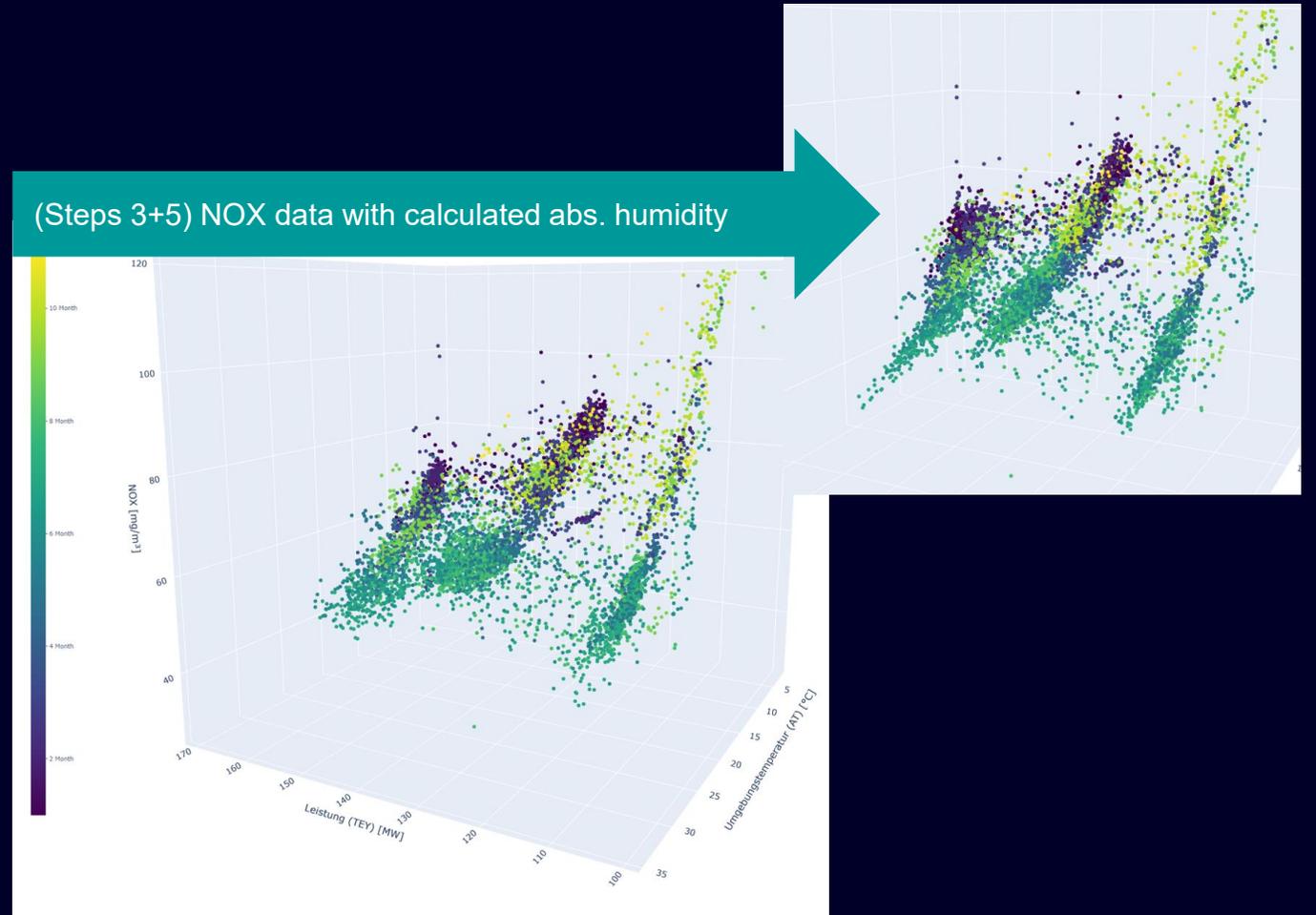
Data processing is crucial for model development and operation, including selection and engineering. The AI model embeds the relationship between input data and the target variable. While interpretability is poor, it benefits complex plants/processes. Temporary target value measurements create and validate the model. Key skills: communication, data processing, AI/data science

“Black box”

Feature engineering phase uses “sub-elements” of simulation

Feature Engineering – Key Steps

1. Data Cleaning (missing values, outliers)
2. Transformation & Scaling (normalization, log transform)
3. New Feature Creation (interactions, time-based features)
4. Feature Selection & Dimensionality Reduction
5. Use Domain Knowledge



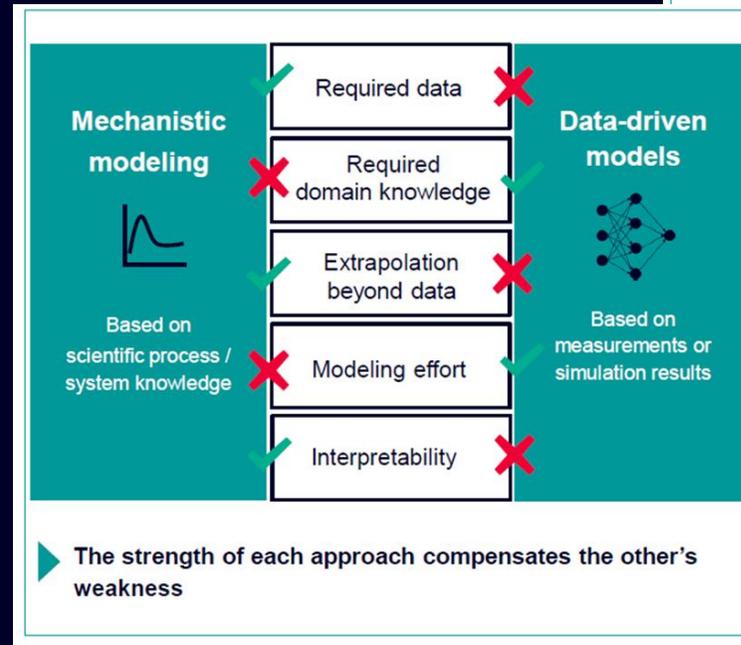
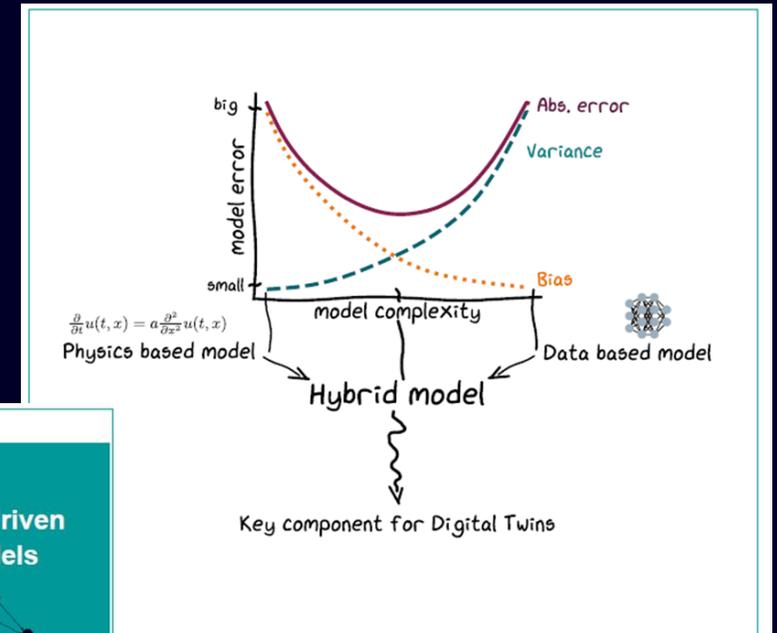
Combination of modelling approaches hybrid and multi-model

Hybrid modelling

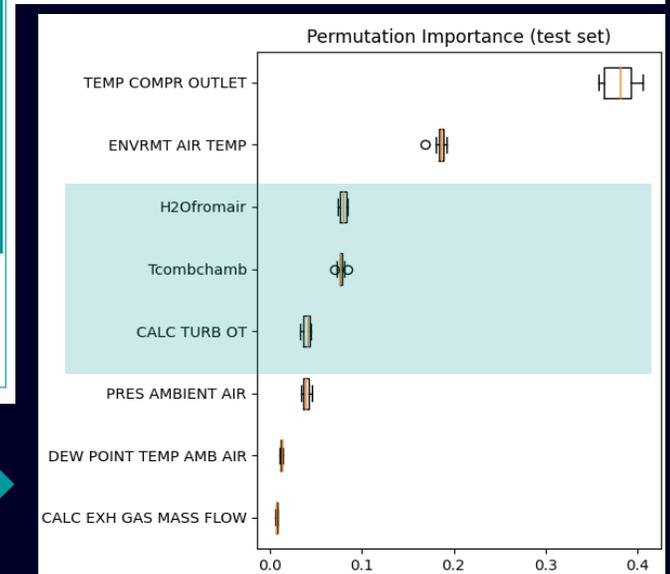
- Combining strengths

Final Solution Characteristics (multi-model)

- Delivers multiple target values, not just one (e.g., CO₂, CO, NO_x, O₂, ...)
- Uses varied modeling approaches:
 - Machine Learning (black box)
 - Simulation (white box)
 - Hybrid models (grey box)



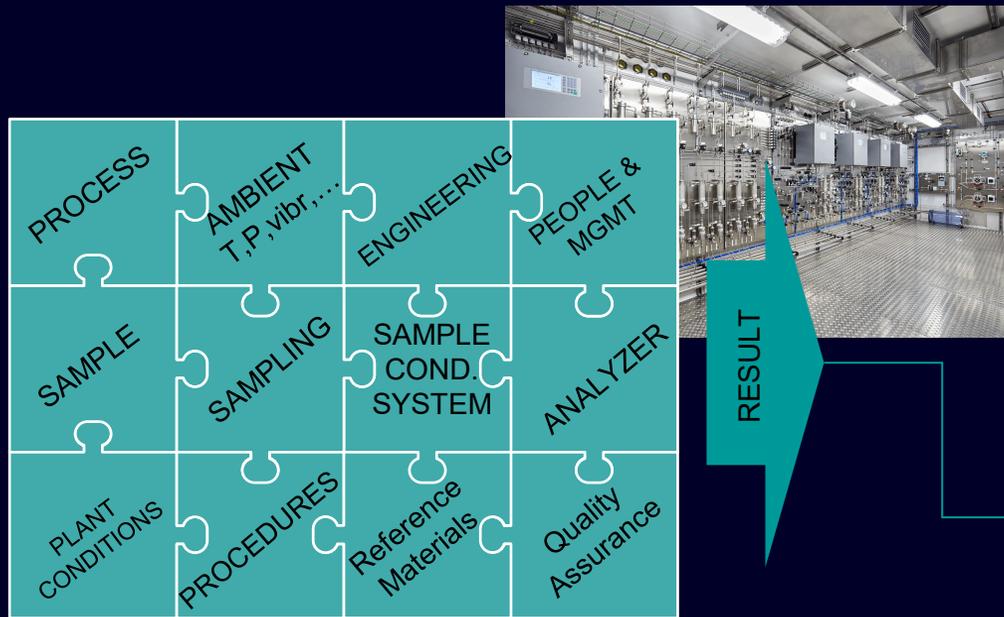
Simulated values contribute to the set of model features



Analytical solution isn't just a sensor – Virtual Sensor isn't just a model

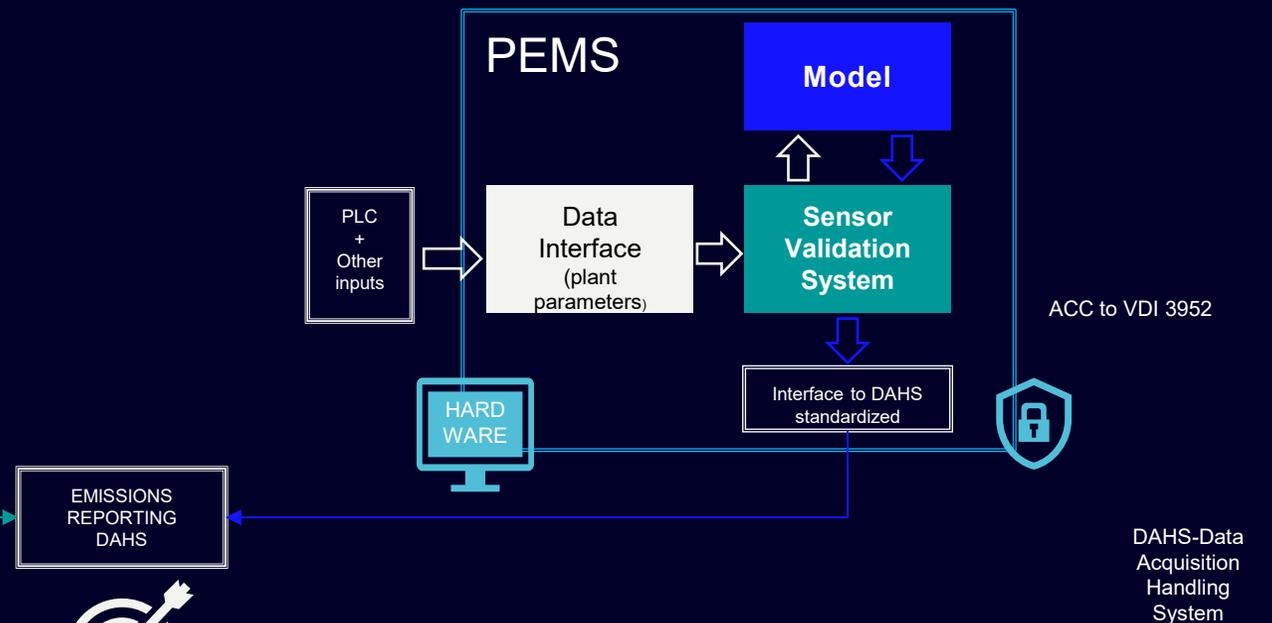
Architecture behind the solution

Process Analytics (Physical and Chemical Sensing)



Mature and universal technology, complex, reliable but costly, demanding unique expertise, challenging for (global) process industry.

Process Analytics (Virtual Sensing)



Expanding technology, growing number of reliable solved applications, known limits (no randomness), enables enhanced process optimization



What defines industrial grade AI ?

Industrial-grade AI



Robust

Reliable, secure, and trustworthy AI for industry

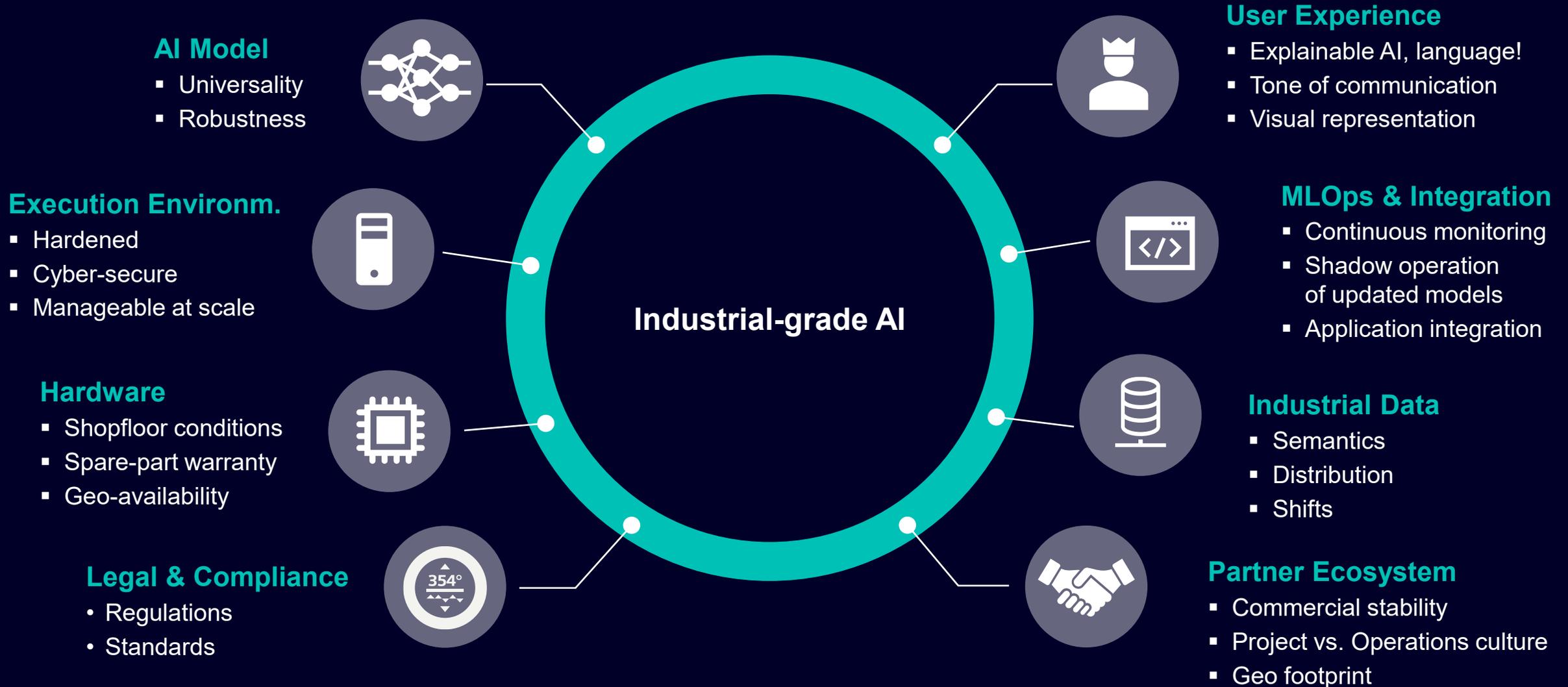
Accessible

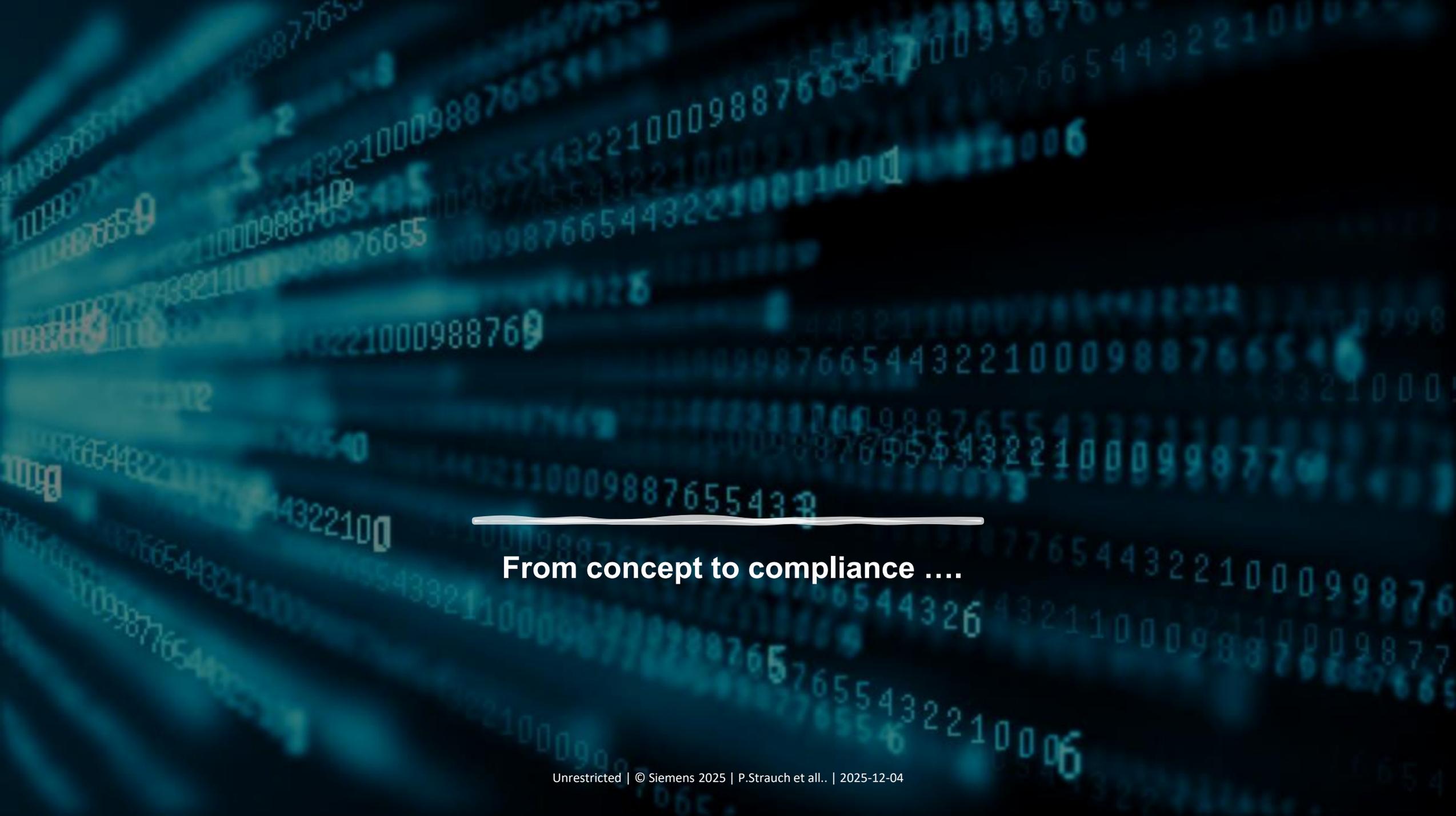
Accessible to everybody, anywhere, and anytime

With Purpose

Supporting partners to achieve their scalability, quality, and sustainability targets

Industrial-grade AI – Design Considerations along the Tech Stack





From concept to compliance

From Concept to Compliance

From technological perspective

- Since more than 10 years growing number of implementations but still very limited experience within the Gas Analysis Community
- Different types of modeling require different countermeasures
- Interpretability isn't equal reliability
 - Use of domain knowhow strongly recommended
- Industrial Grade properties for the entire lifecycle need to be considered

Approvals & standards

- Increasing standardization activities for Predictive Emission Monitoring Systems*
 - US EPA Part 60 PS 16 & Part 75
 - VDI 3952 (recommendation released 2024);
 - Activities towards standard gained
 - CEN TS 17198; EN 12583; (problems)
 - Status: a lot to do and long way to go !
- Rising activities for gas analysis beyond emission monitoring
- Artificial Intelligence
 - EU AI Act - to be considered

SUMMARY

Virtual Sensing technology responds to the demands of PAT users



Less effort for risk reduction

- Provide process parameters during breakdowns of measuring systems
- New art of validation - compare real & virtual result

Efficiency

- Speed up response time (lab or slow measurement)
- Reduce costs of measurement points due to the substitution of hardware-based sensors by soft sensors or hybrid with low-cost sensors
- Use of process insights out of the model for further optimization
- ...

Conventional Measurement



Remains

as reference technology for non-deterministic processes (e.g., waste incineration, safety applications).

New Role:

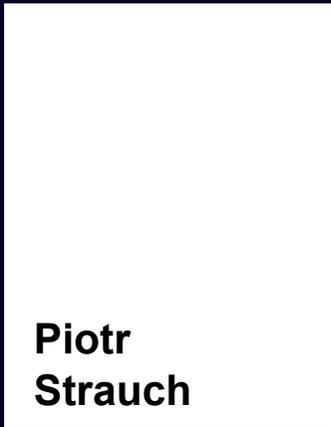
Set up and maintain models

> *NAMUR Technologie Roadmap Process
Sensoren 2027+*

APPROACH IS NOT LIMITED TO EMISSION MONITORING

THANK YOU !

Q & A...



**Piotr
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Siemens AG

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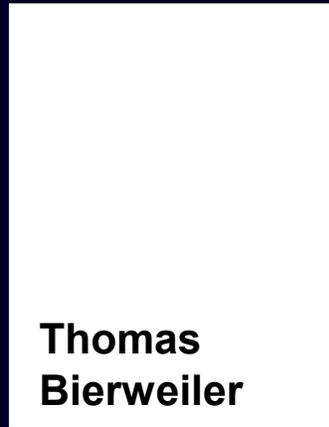
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