



Plant Performance

Increasing Efficiency in Daily Operation

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Vita

1989 -1995 Electrical Engineering at the University of Technology Aachen, RWTH Aachen

1995 -2000 Ph.D. student at the Institute of Process Control Engineering, RWTH Aachen

since 2000 Managing Director of LeiKon GmbH, Herzogenrath

since 1997 Member of the German normative DIN DKE committee
K931 ‘System aspects in automation and process control’

since 2011 Chairman of the NAMUR Working Group 2.4 ‘MES’
(Manufacturing Execution Systems)

Since 2013 Authorized Expert for Automation Technology
– officially appointed and sworn expert of CCI Aachen (chamber of commerce and industry)

Competences

LeiKon

Technical Consulting Planning System Integration

Process Control Engineering

Alarm-Management

MES & MOM

Energy- & Ressource-management

Vertical Data Integration

IT Security in Automation

Production Data Management

Functional-Safety

Challenges in Process Industry

Global Competition

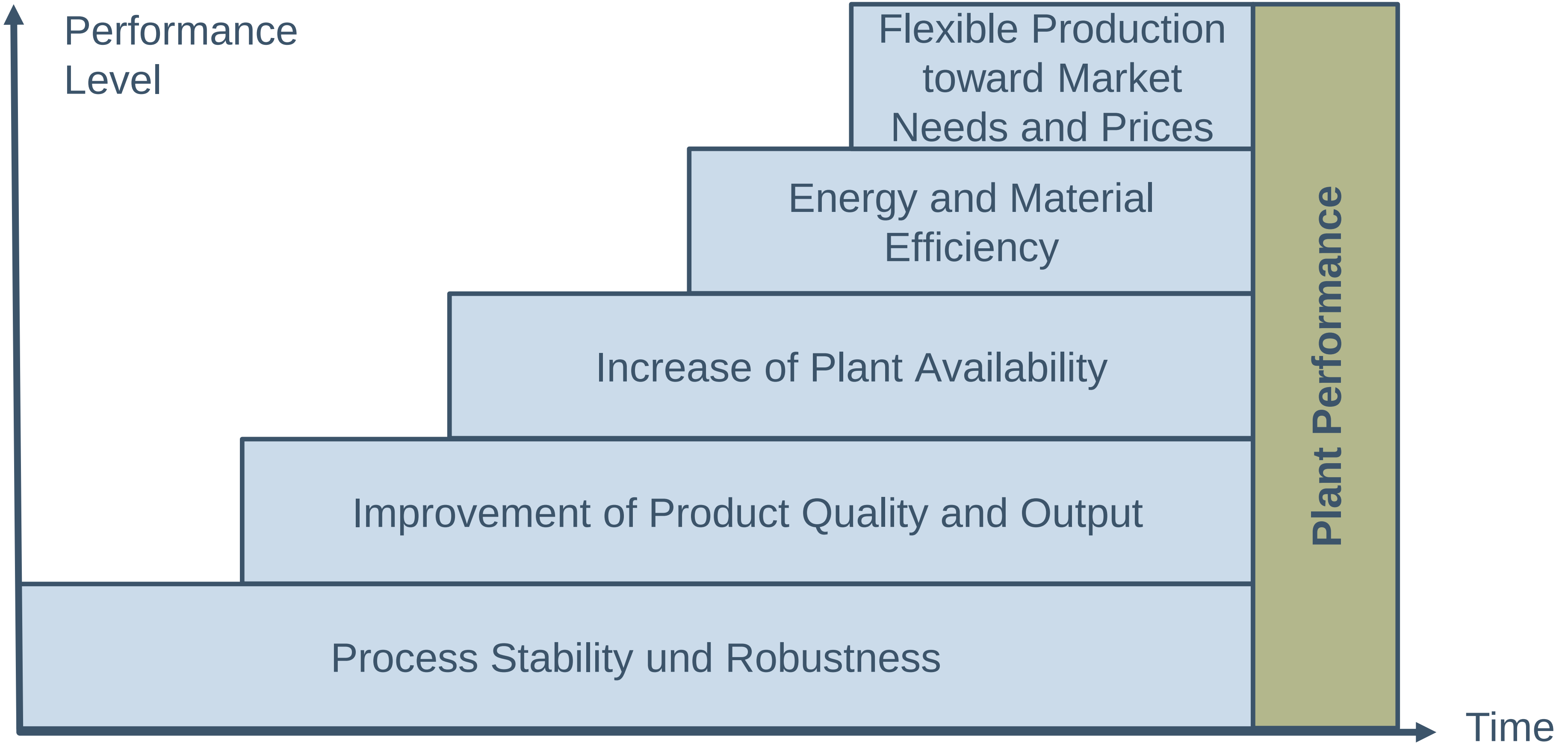
Environmental, Safety & Security Regulations

Dynamic of Market Needs

Requirement:

Operate Plants „best possible“

Definition „Plant Performance“



Definition „Plant Performance“

Plant Performance

PI (Performance Index)

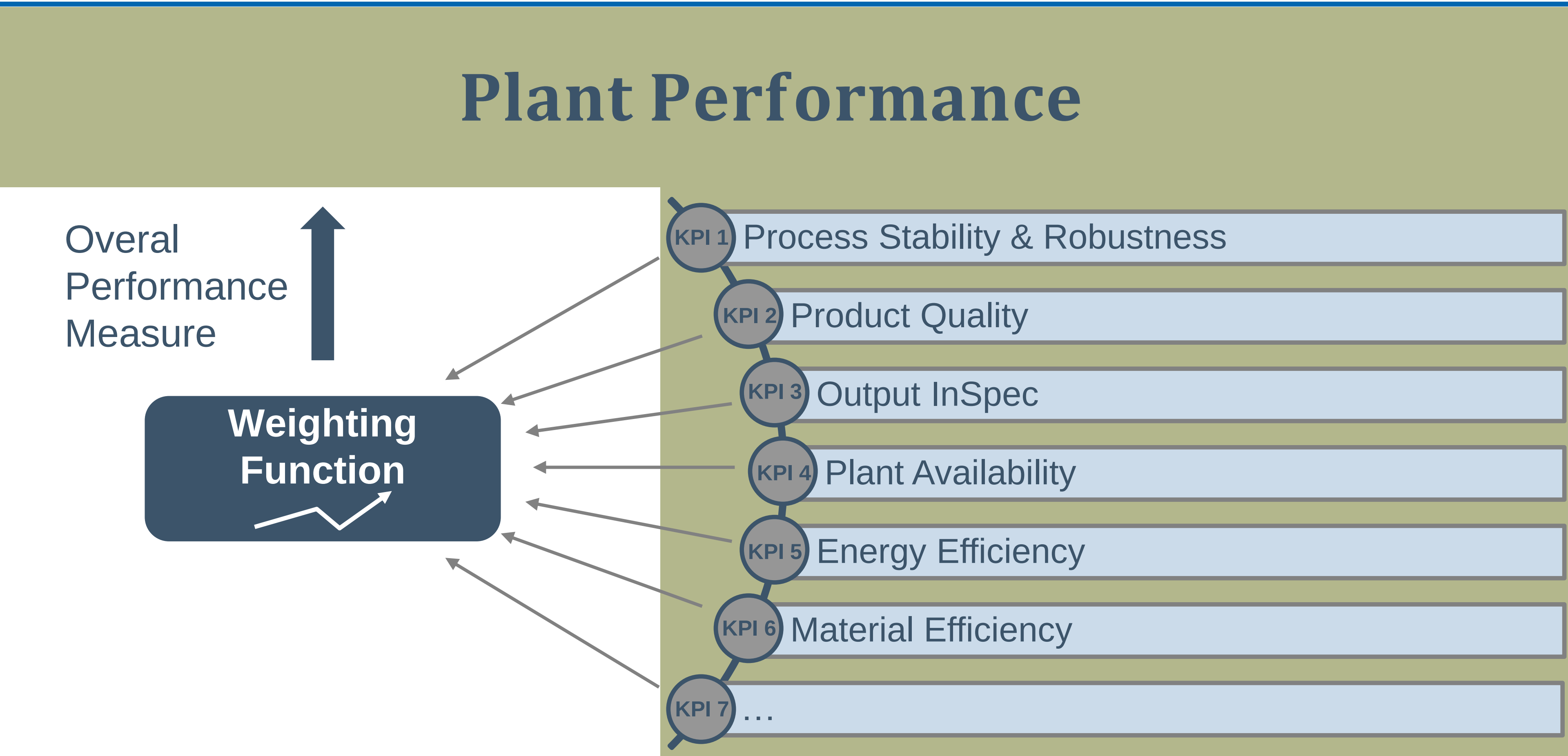
= quantitative measure for one specific aspect of Plant Performance

KPI (Key Performance Index)

= very important PI

- KPI 1 Process Stability & Robustness
- KPI 2 Product Quality
- KPI 3 Output InSpec
- KPI 4 Plant Availability
- KPI 5 Energy Efficiency
- KPI 6 Material Efficiency
- KPI 7 …

Definition „Plant Performance“



Plant Performance

Using KPI to improve Plant Performance

- **short-term**
  - Process Control
- **medium-term**
  - Maintenance
  - Change of Devices
- **long-term**
  - Plant & Process Design

KPI Measures

Plant Performance

short-term
- Process Control

medium-term
- Maintenance
- Change of Devices

long-term
- Plant & Process Design

Use of KPIs

Example - Bad Actor Analysis

LeiKon

Retrospective Use

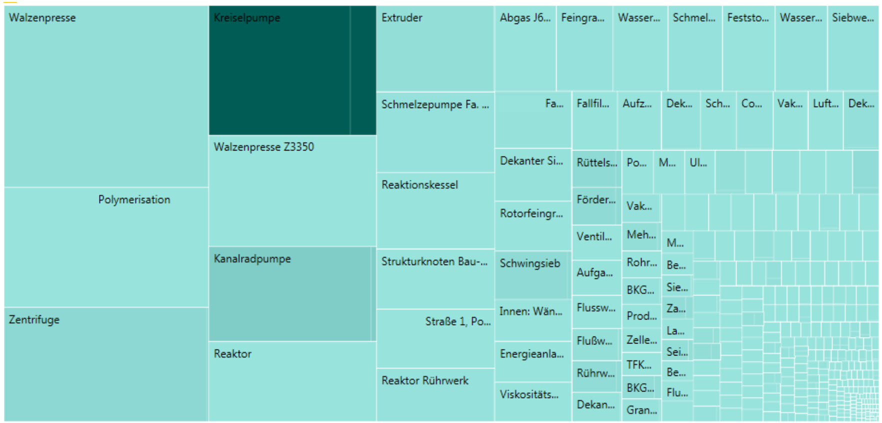
History

Prediction

now

Find Potentials to Improve

Monitor Performance Tendencies



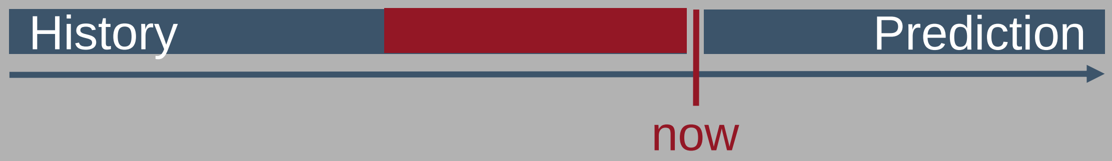
1. Size of rectangles: Cost of Repair
2. Colour: Maintenances Activities

1. Size of words:
   Frequency of mention a specific word
2. Colour: Maintenance Cost

KPI – Fields of Application

Operative Use

Steer production



Examples of Usage

- Target-oriented Set Points (Optimized Targets)
- Decision Support for Process Control
- Order Management (Detail Planning)
- …

System Functions

- Online Monitoring (Dashboards)
- KPI based open and closed loop control
- Real time Optimization
- …

KPI – Fields of Application

Operative Use

Steer production

RESOURCE EFFICIENCY FOR EUROPE

NAMUR **NE 162**

Resource Efficiency Indicators for Process Industry

The MORE Project is supported by the European Commission under the FP7 programme (contract 604068)

Resource efficiency Indicators - Examples

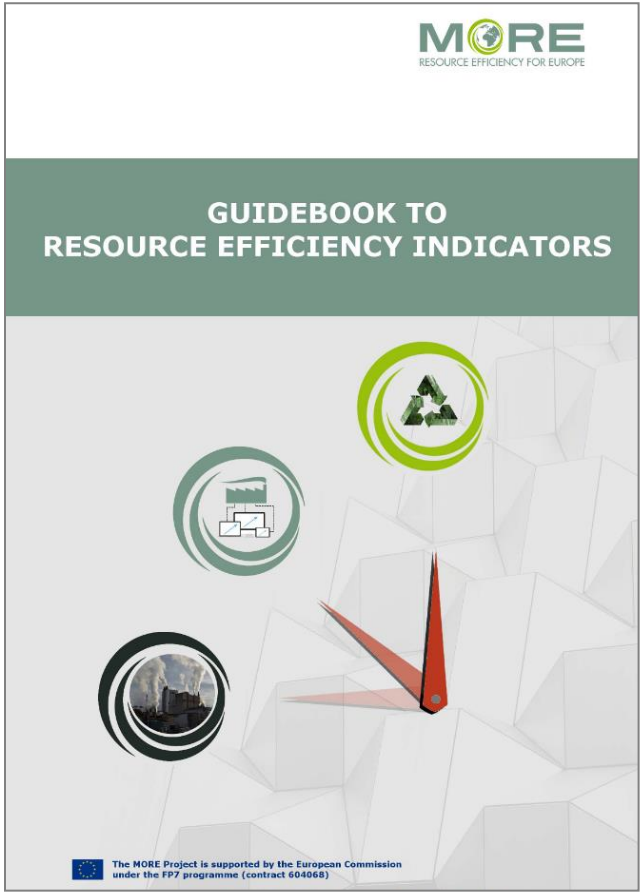
Table 2. Overview of REIs defined for continuous processes.

Indicator Name	Catch Phrase	Formula	Measurements needed	Comment
Energy required (ER)	Specific Energy Consumption	$REI_{ER,A,k} = \frac{\sum_{i=1}^{nE} E_{i,k}}{\sum_{j=1}^{nP} m_{P,j,k}}$	All energy inputs and outputs and all product streams	Can be separated into different energy types
Raw Material required	Specific Raw Material Consumption	$REI_{R,i,k} = \frac{R_{i,k}}{\sum_{j=1}^{nP} m_{P,j,k}}$	The relevant raw material inputs and all product streams	
Utilities required	Utilities/Raw Material required per unit of product (air, water, DI-water)	$REI_{U,i,k} = \frac{U_{i,k}}{\sum_{j=1}^{nP} m_{P,j,k}}$	The relevant utility and all product streams	
Material Yield	Overall process yield based on mass flow	$REI_{Y,k} = \frac{\sum_{j=1}^{nP} m_{P,j,k}}{\sum_{j=1}^{nP} R_{j,k}}$	All raw material inputs and all product streams	Possibly streams such as air must also be considered, if the molecules end up in the product
Overall resource yield	Overall process yield based on weighted flows	$REI_{RY,k} = \frac{\sum_{j=1}^{nP} C_{P,j} m_{P,j,k} + \sum_{i=1}^{nE} C_{E,i} E_{i,out,k}}{\sum_{j=1}^{nR} C_{R,j} R_{j,k} + \sum_{i=1}^{nE} C_{E,i} E_{i,in,k}}$	All energy inputs and outputs, all raw material inputs and all product streams	Depends on the chosen weighting which must be consistent
Overall Efficiency based on Energy Currency	Energy streams of different nature are weighted by an energy currency which accounts for the different value or exergy of the energy streams, e.g. electrical power has a higher value compared to steam	$REI_{ORE,k} = \frac{\sum_{j=1}^{nU} C_{U,j} U_{j,in,k} - \sum_{j=1}^{nU} C_{U,j} U_{j,out,k}}{\sum_{j=1}^{nP} m_{P,j,k}} + \frac{\sum_{j=1}^{nR} C_{R,j} R_{j,k} - \sum_{j \in N_{p,out}}^{np} C_{P,j} m_{P,j,k}}{\sum_{j=1}^{nP} m_{P,j,k}} + \frac{\sum_{i=1}^{nE} C_{E,i} E_{i,in,k} - \sum_{i=1}^{nE} C_{E,i} E_{i,out,k}}{\sum_{j=1}^{nP} m_{P,j,k}}$	All energy inputs and outputs, all raw material inputs and all product streams, all utility streams	
Waste	Mass of waste type per unit of product	$REI_{W,i,k} = \frac{W_{i,k}}{\sum_{j=1}^{nP} m_{P,j,k}}$	The relevant waste stream and all product streams	
Overall weighted waste	Sum of waste weighted with "waste "currency" per unit of product	$REI_{OWE,k} = \frac{\sum_{i=1}^{nW} W_{i,k} C_{W,i,k}}{\sum_{j=1}^{nP} m_{P,j,k}}$	All waste streams and all product streams	

Table 3. Overview of REIs defined for batch processes.

Indicator	Abbreviation	Formula	Hierarchy level	Efficiency factor
Overall resource efficiency	ORE_i	Case-specific	Plant level	Case-specific
Total material efficiency	TME	$\frac{m_{product}}{\sum_k m_{in,k}}$	Batch level	Material
Specific material input	MI_k	$\frac{m_{in,k}}{m_{product}}$	Batch level	Material
Material efficiency with recycle	$ME_{recycle,k}$	$\frac{\sum_p m_{k,stoic,p}}{m_{in,k} + (m_{in,recycle,k} - m_{out,recycle,k})}$	Batch level	Material
Heat product	HP	$\frac{\sum_i Q_{generated,i}}{m_{product}}$	Batch level	Energy
Electrical energy efficiency	EEE	$\frac{m_{product}}{\sum_i W_{el,i} - \sum_j W_{generated,j}}$	Batch level	Energy
Cooling energy efficiency	CEE	$\frac{m_{product}}{\sum_m W_{cool,m}}$	Batch level	Energy
Heating Energy efficiency	HEE	$\frac{m_{product}}{\sum_i Q_{H,i} - \sum_j Q_{generated,j}}$	Batch level	Energy
Total waste production	TWP	$\frac{\sum_j m_{waste,j}}{m_{product}}$	Batch level	Environmental
Water usage	WU	$\frac{m_{water,in}}{m_{product}}$	Batch level	Environmental

Resource efficiency Indicators - Examples



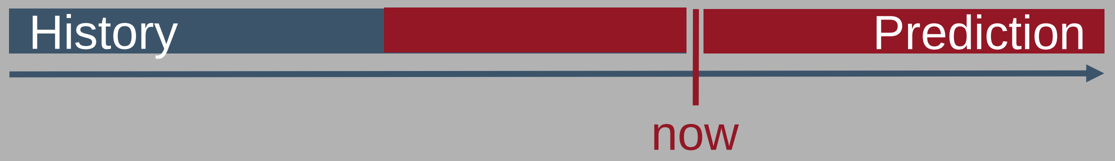
http://www.more-nmp.eu/wp-content/uploads/2017/03/MORE_Guidebook_web_final.pdf

Resource efficiency Indicators – Online Monitoring

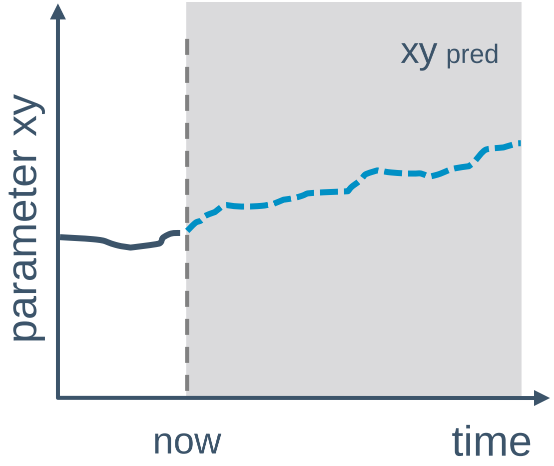
Resource efficiency Indicators – Online Monitoring

Operative Use

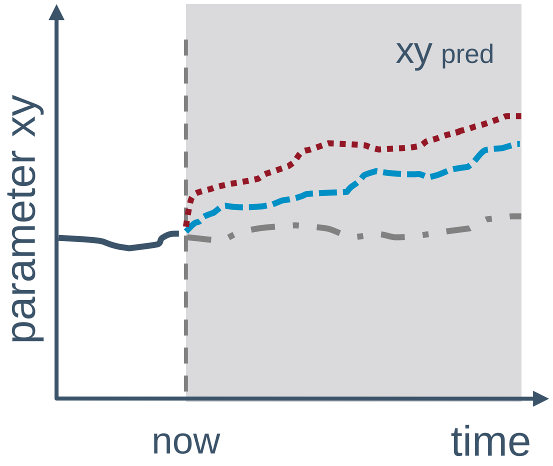
Decision Support



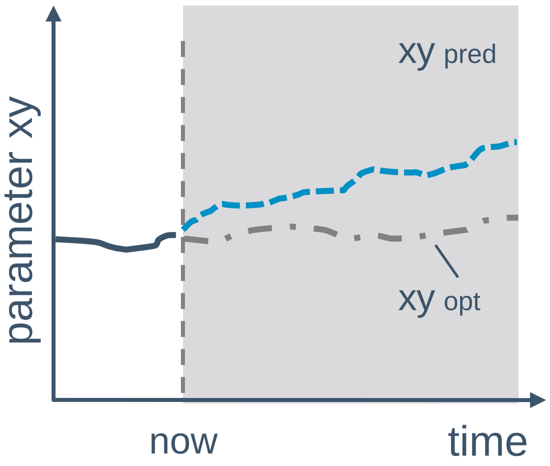
Prediction Mode



Maneuver Mode



Recommendation Mode

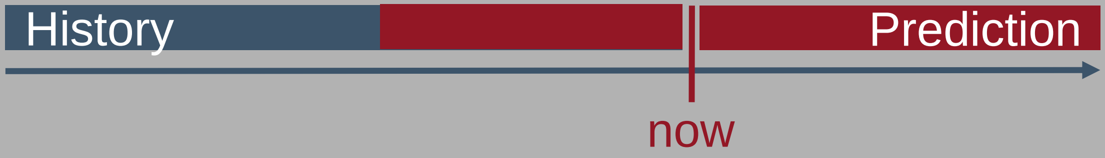


Example: Power Plant – KPI using math. model of Water- and Steam Circulation

Resource efficiency – Plant Scheduling

Operative Use

Decision Support



COORDINATED PRODUCTION
FOR BETTER RESOURCE EFFICIENCY

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the European Union's Horizon 2020 research and innovation programme under grant agreement No 723575.

Plant Performance

- Missing Data
- Data Outlier and Data Gaps
- Selection of suitable KPIs and suitable Weighting Functions
- Benchmarks to assess the Plant Performance
- Interpretation and Freedom to initiate Measures depends on:
  - Operating Point and Load
  - Control Strategy
  - Quality of Raw Material
  - Ambient Conditions (Weather, …)

→ Comparison to **„best possible“ at similar conditions**

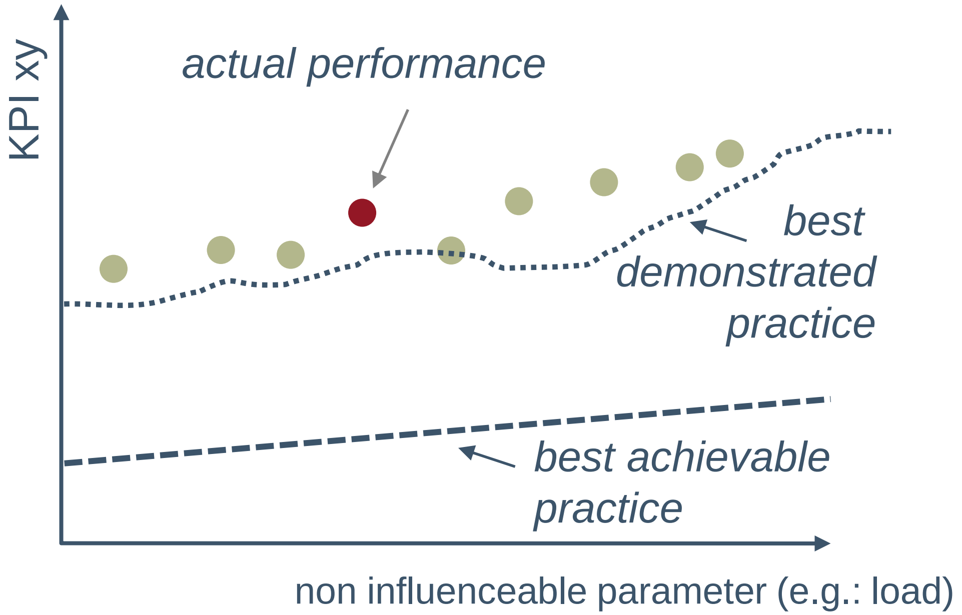
$KPI_{normalized}$

Use of normalized KPI – Situative Context

$$KPI_{norm} = \frac{\text{KPI}}{\text{KPI}_{\text{reference}}}$$

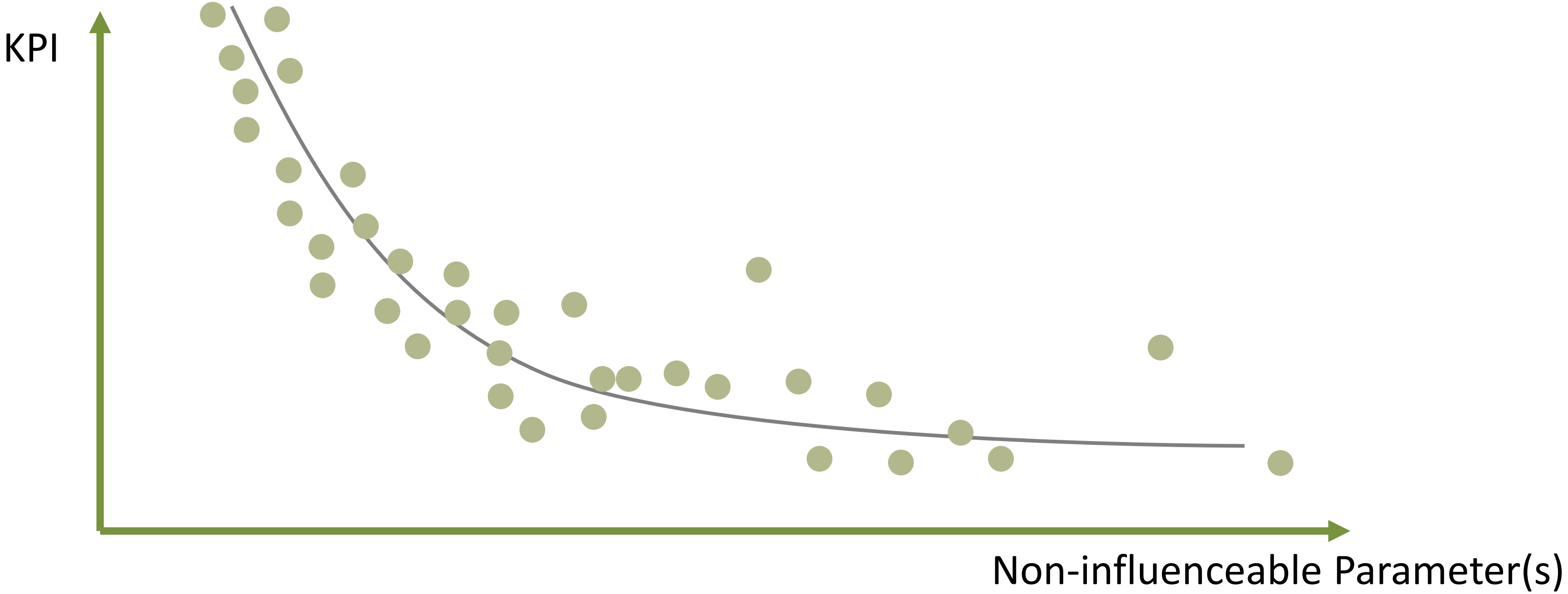
„best possible“

- in relation to the past
  => **„Best demonstrated Practice“**
- in relation to a theoretical optimum
  => **„Best achievable Practice“**



Use of normalized KPI – Situative Context

$$KPI_{norm} = \frac{\text{KPI}}{\text{KPI}_{\text{reference}}}$$



Use of normalized KPI – Situative Context

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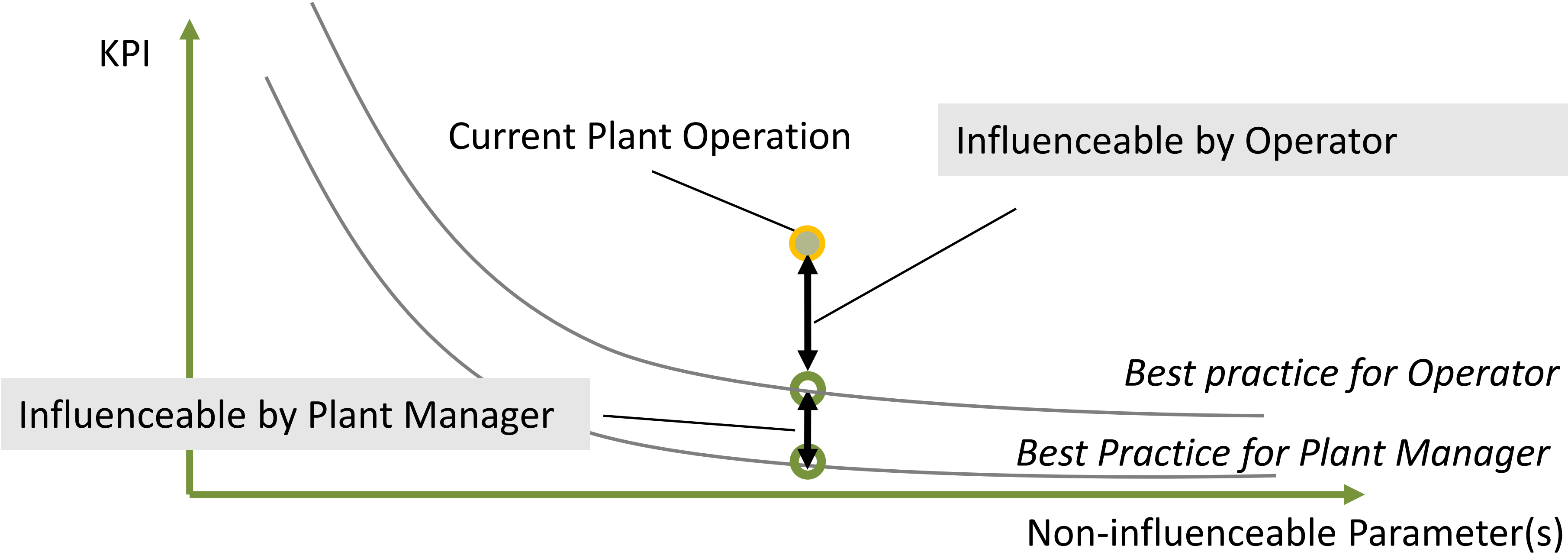
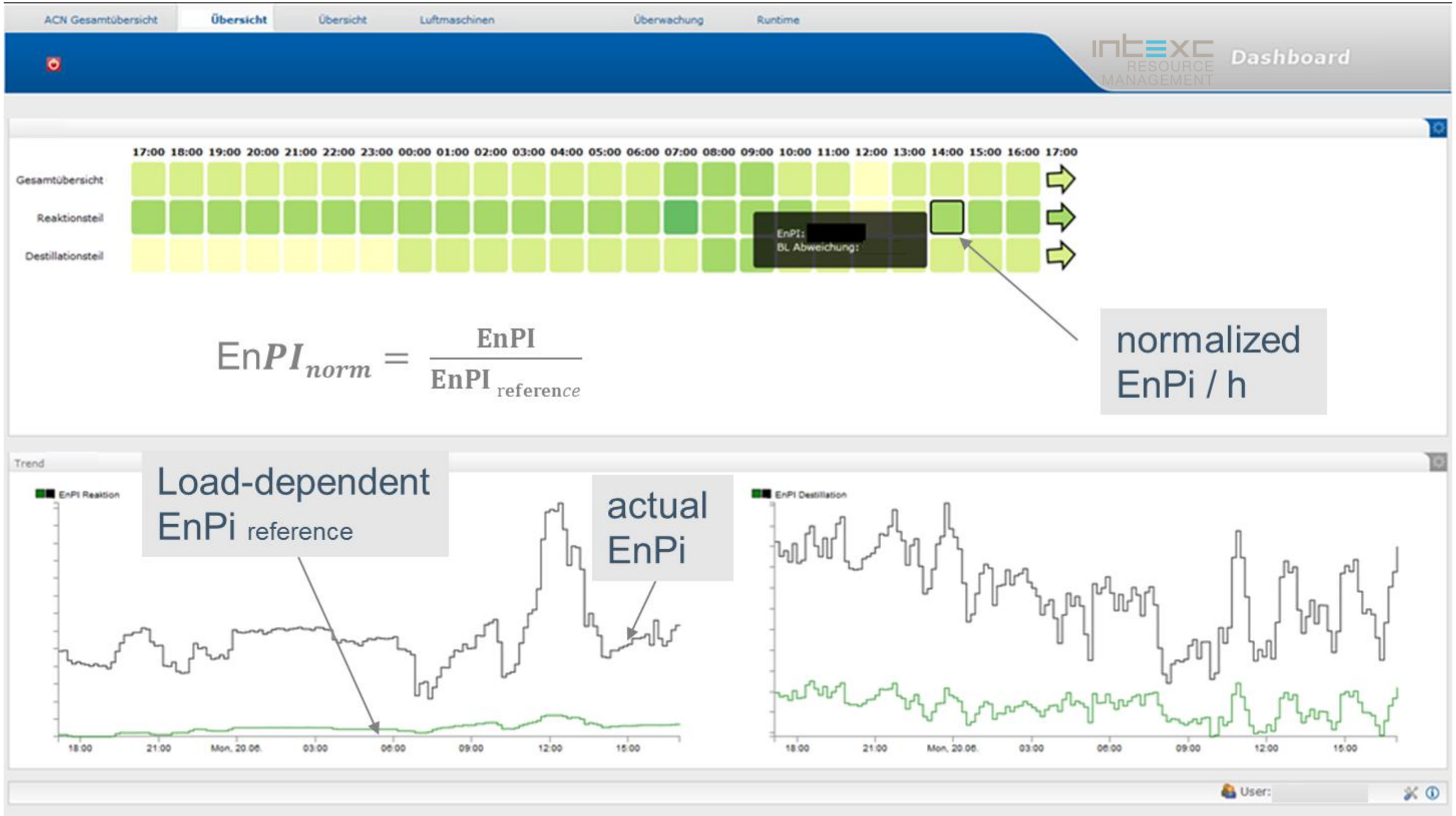
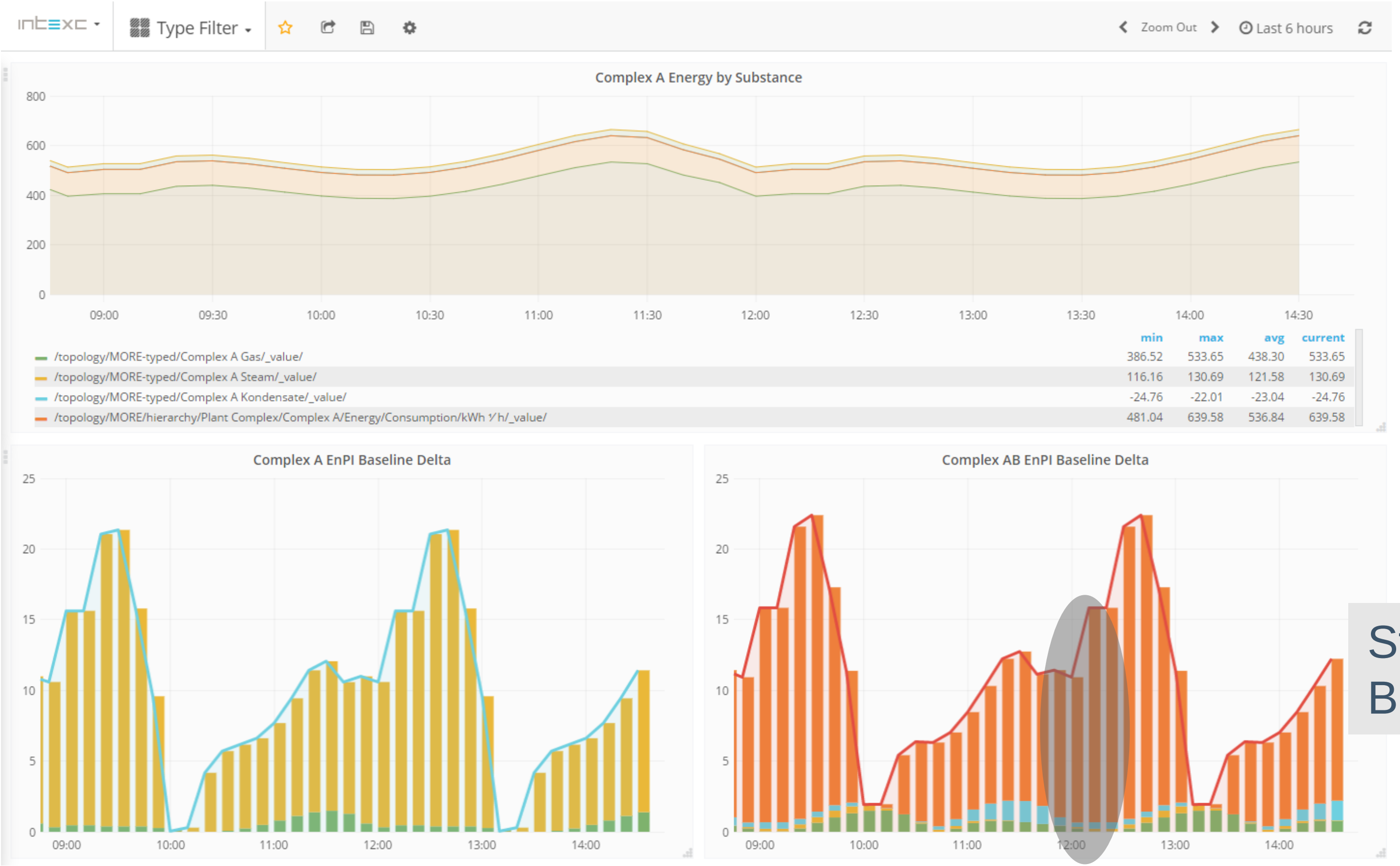


Use of normalized KPI – Dashboard Monitoring



Use of normalized KPI – Dashboard Monitoring



Stacked Bar Charts

New IT Approach in Process Industry

Computation of REIs itself is not very complicated if the necessary measurements are available and are sufficiently accurate

Computations can be implemented in state-of-the art DCS, SCADA, MES or PIMS systems

But what about site wide KPI applications with hundreds/thousands of measurements, different requirements of KPI analyses and complex resource flow structures?

Give Data a Context

Information Models

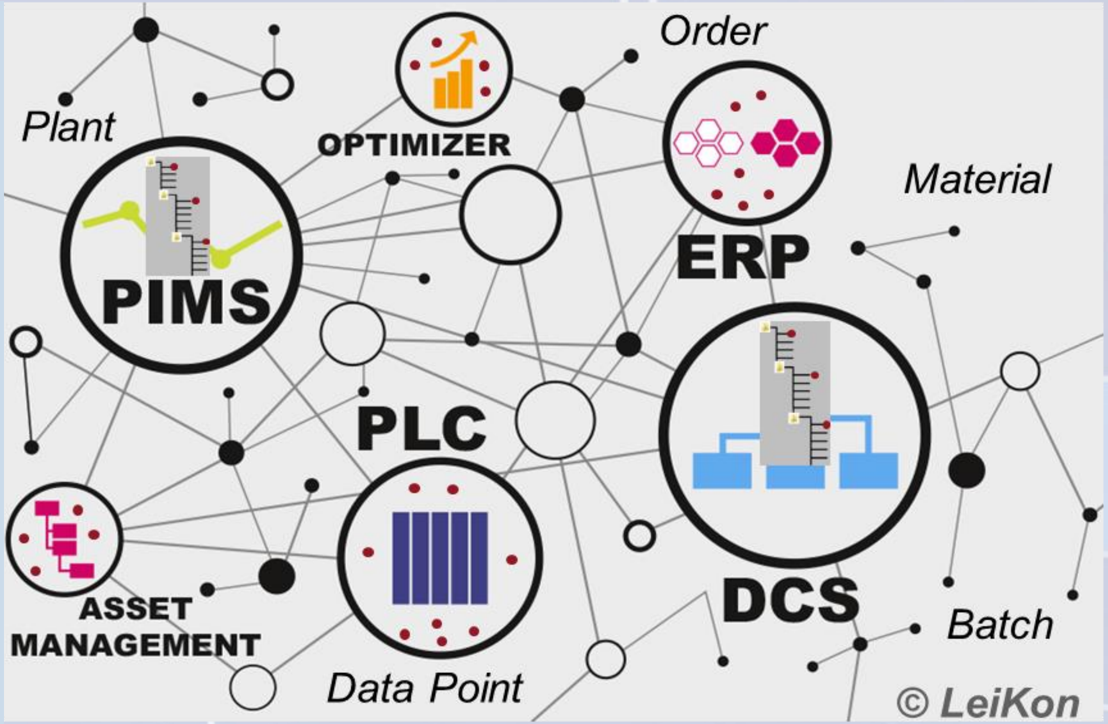
Give Data a Context

Information Models

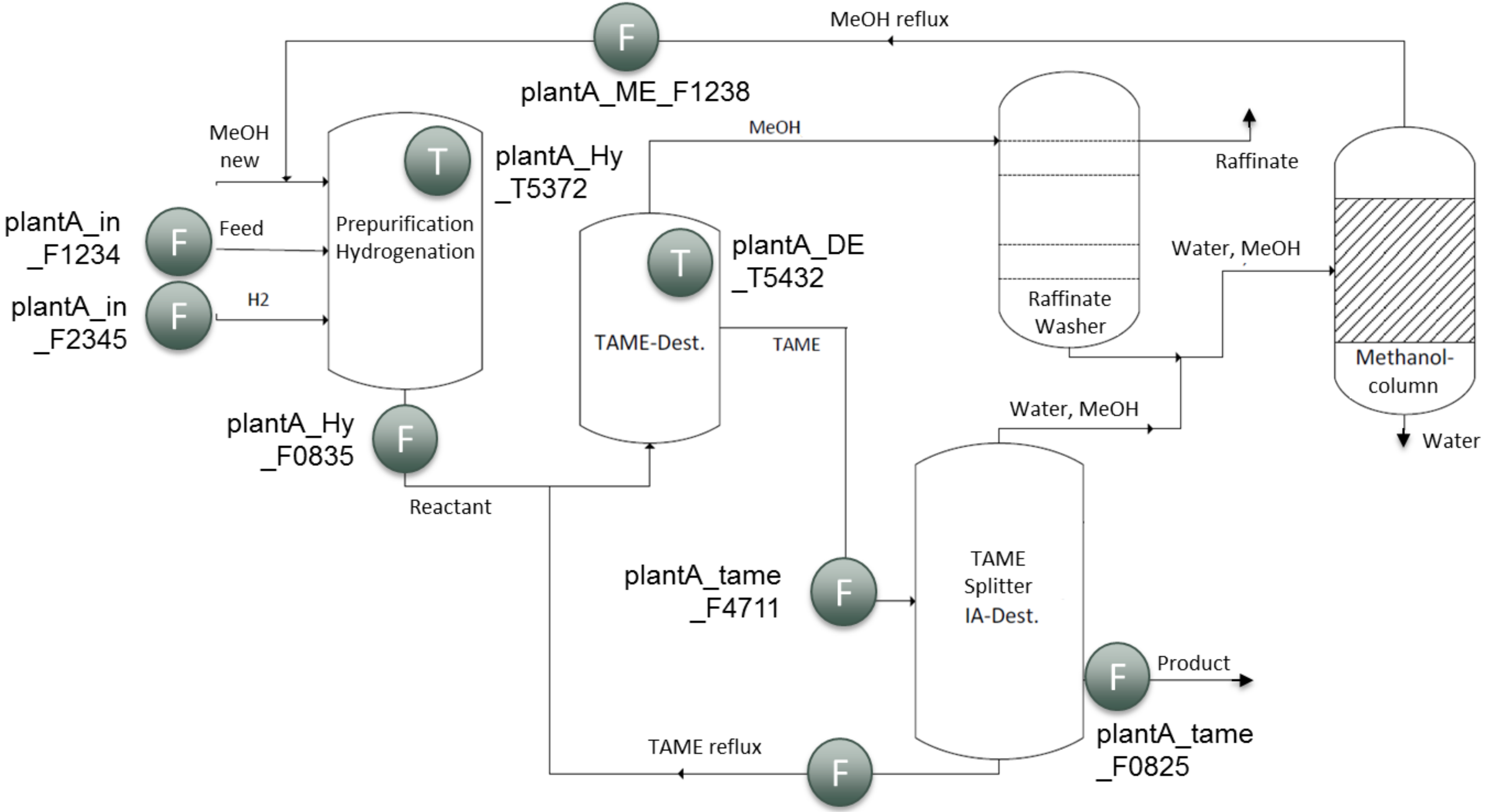
Today Information are stored „Data Point oriented“

Information missing:

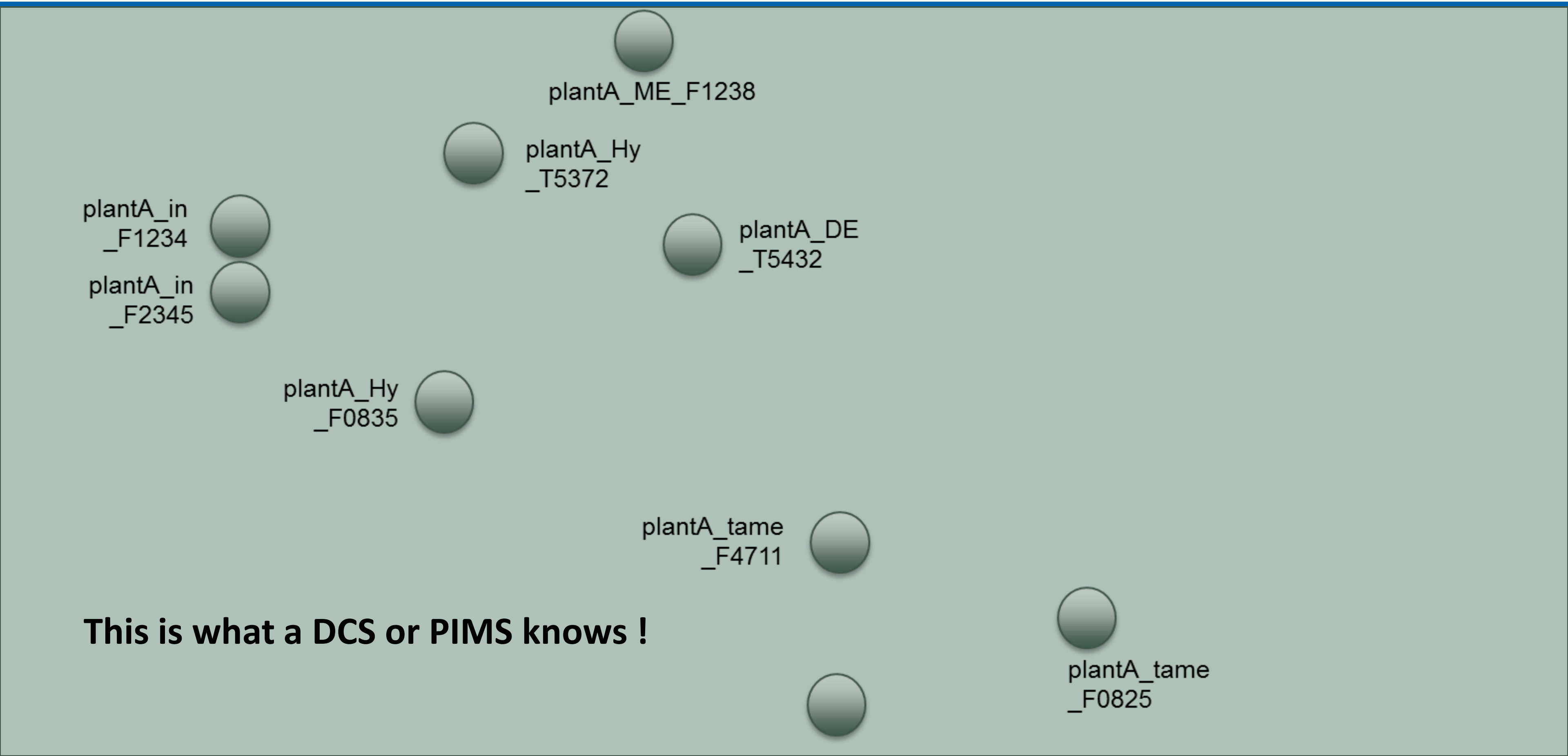
- Semantic of Data Points
- Interdependencies
- Links to process steps, plant units or balance envelopes



New IT Approach in Process Industry

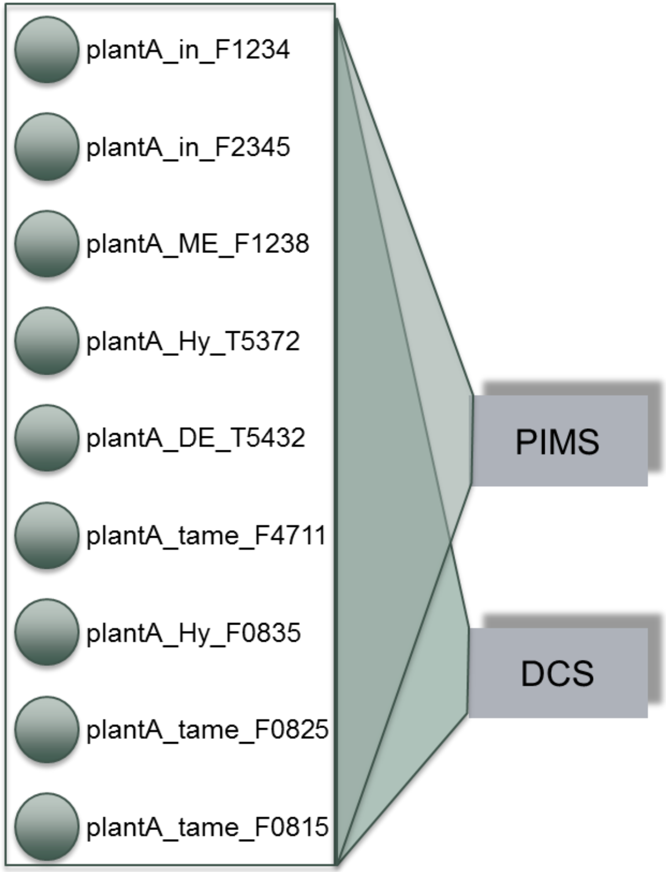


New IT Approach in Process Industry



This is what a DCS or PIMS knows !

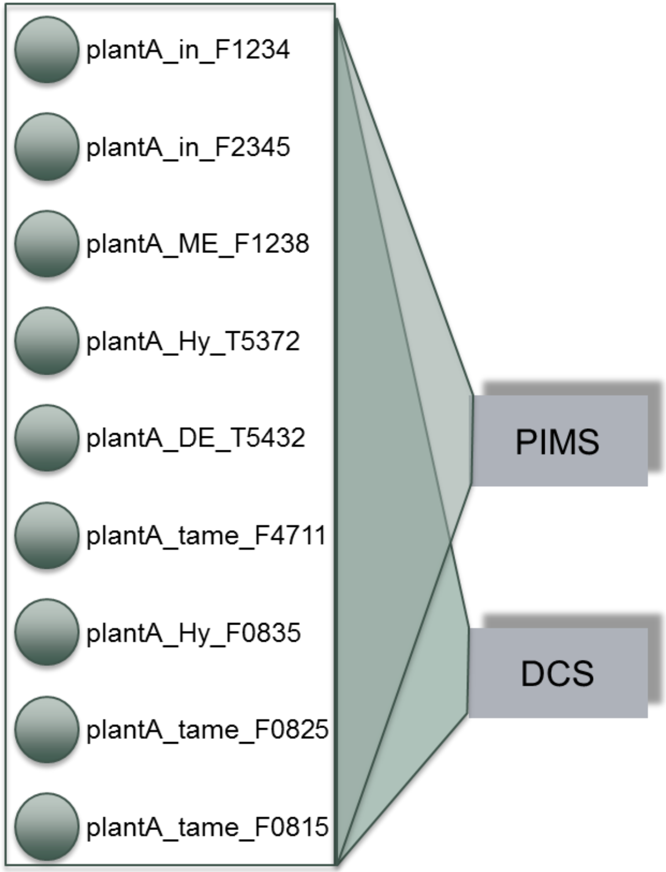
New IT Approach in Process Industry



Information missing

- What is the source and target of a flow represented by a flow measurement?
- What measurement represents a raw material, utility , product or by-product?
- What substance will be represented by each flow measurement?
- What is the energy content of a mass flow measured by a flow measurement?
- For which balance boundaries is a measurement relevant?

New IT Approach in Process Industry



Specific Raw Material Consumption	$= \frac{R_{i,k}}{\sum_{j=1}^{n_P} m_{P,j,k}}$	The relevant raw material inputs and all product streams

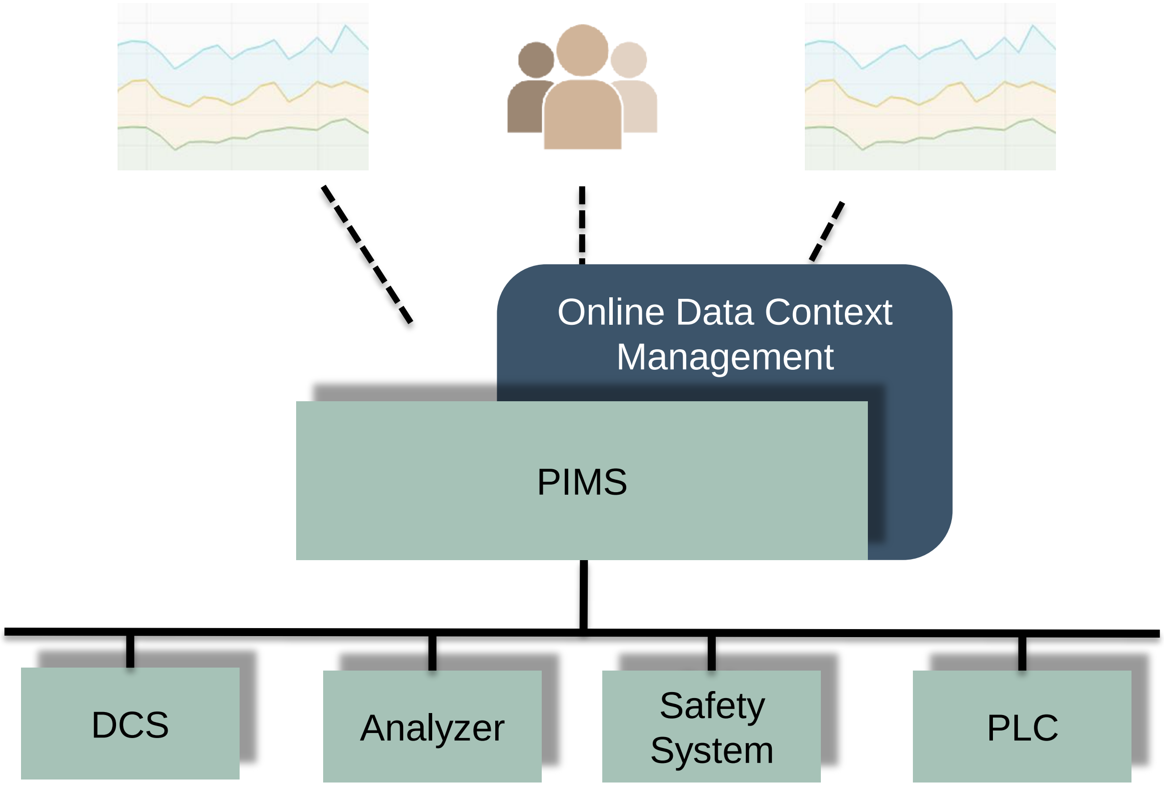
$$\mathbf{RawPi}_{\mathbf{Hy}} = \frac{\text{plantA\_in\_F1234} + \text{plantA\_in\_F2345}}{\text{plantA\_Hy\_F0835}}$$

Plant-Specific one-by-one Calculations

- high effort for site/company wide approach
- high effort for change management
- non-transparent calculation method

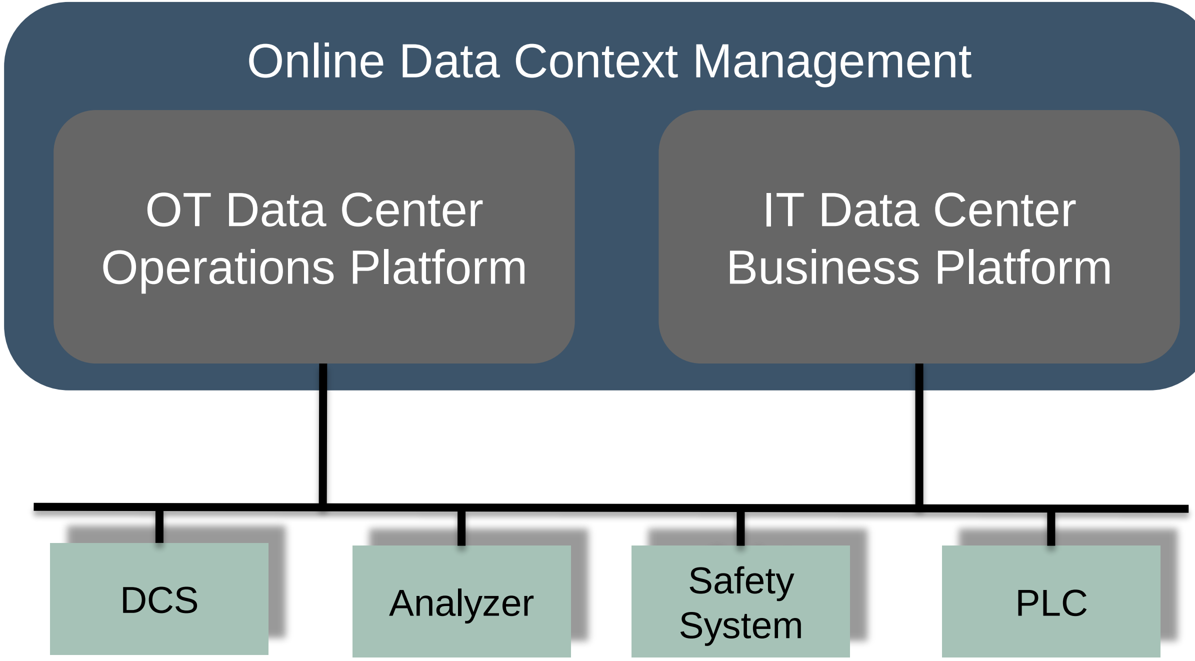
Context Based Online Data Management

Todays Centralized PIMS Architecture



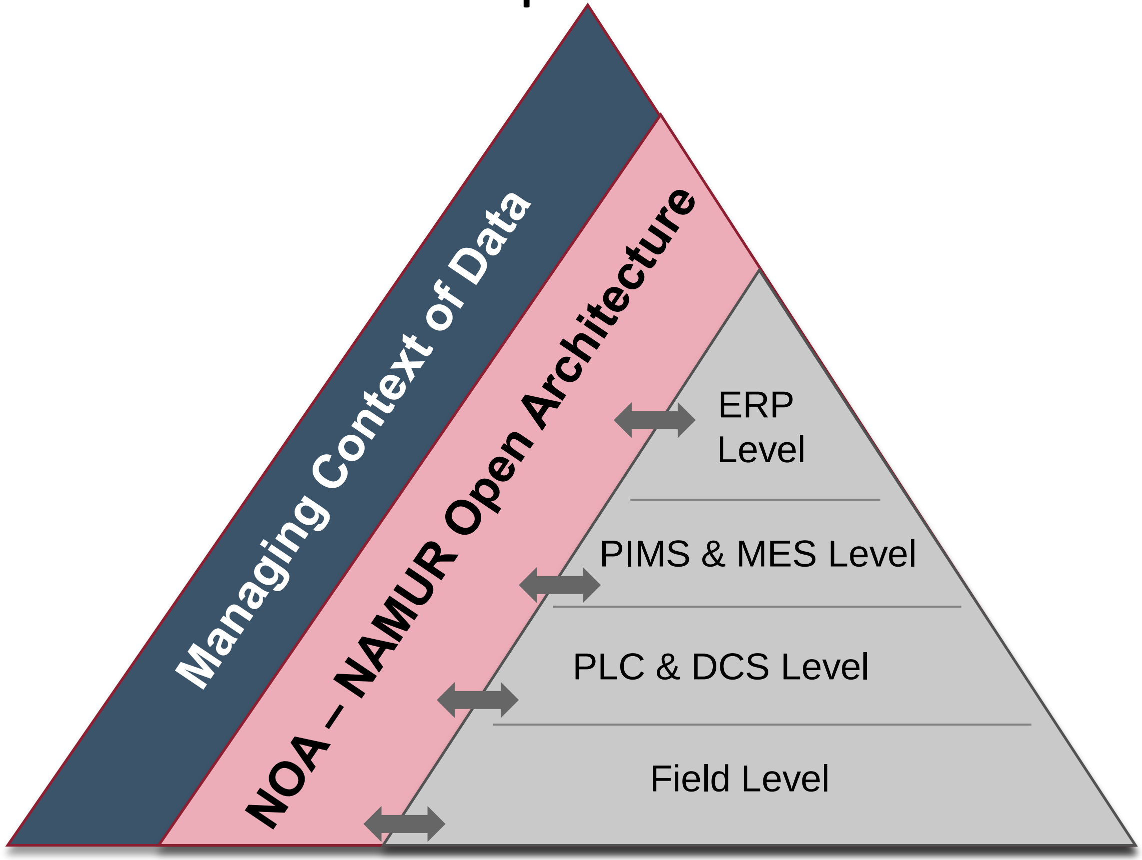
Context Based Online Data Management

Modern Data Center Architectures



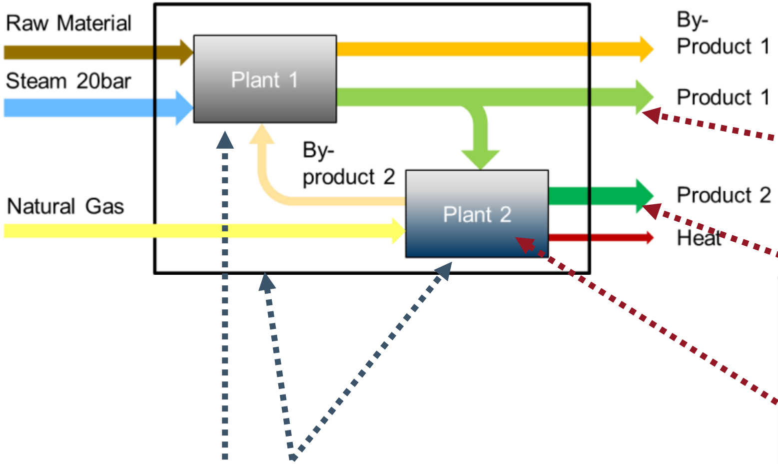
Context Based Online Data Management

NAMUR Open Architecture

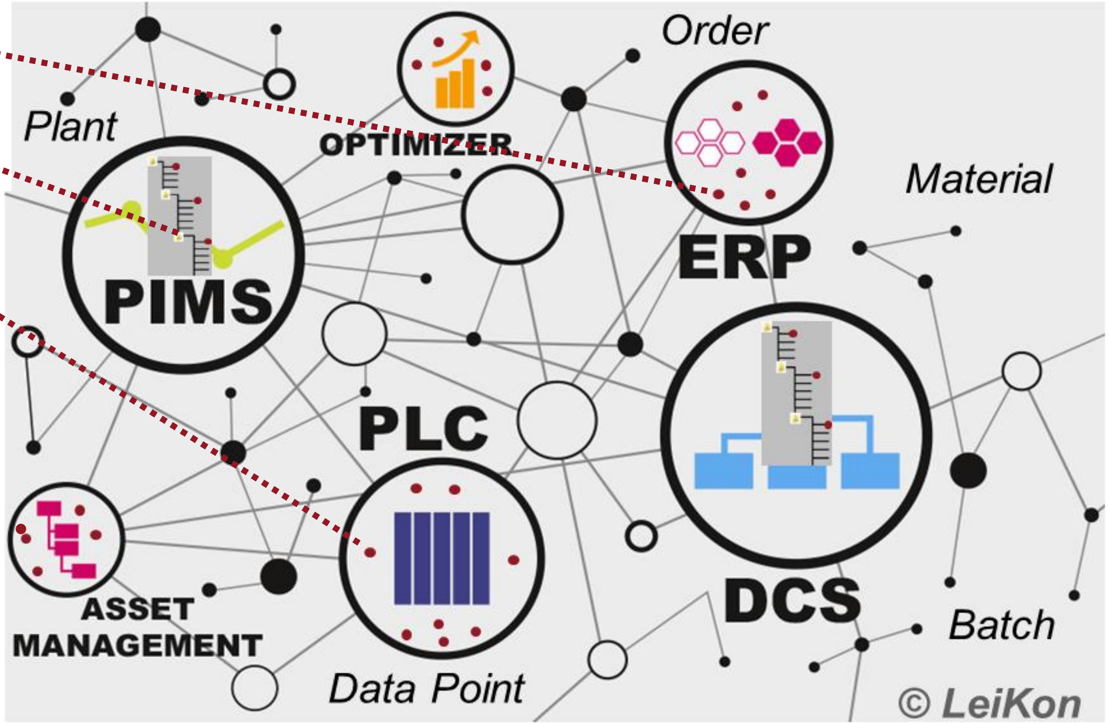


Context Based Online Data Management

Give Data a Context



Energy Balance = 0
Mass Balance = 0



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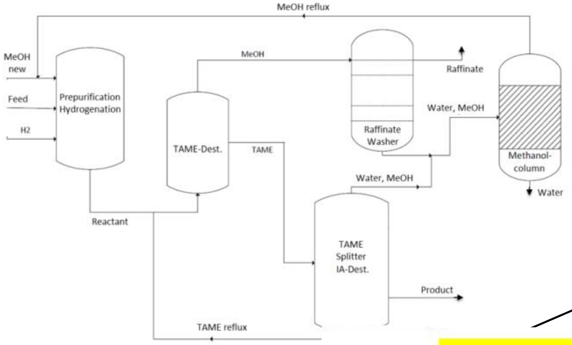
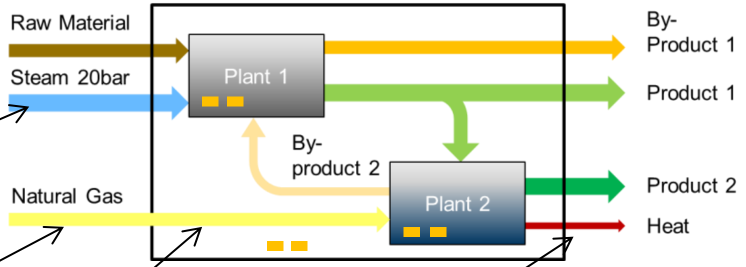
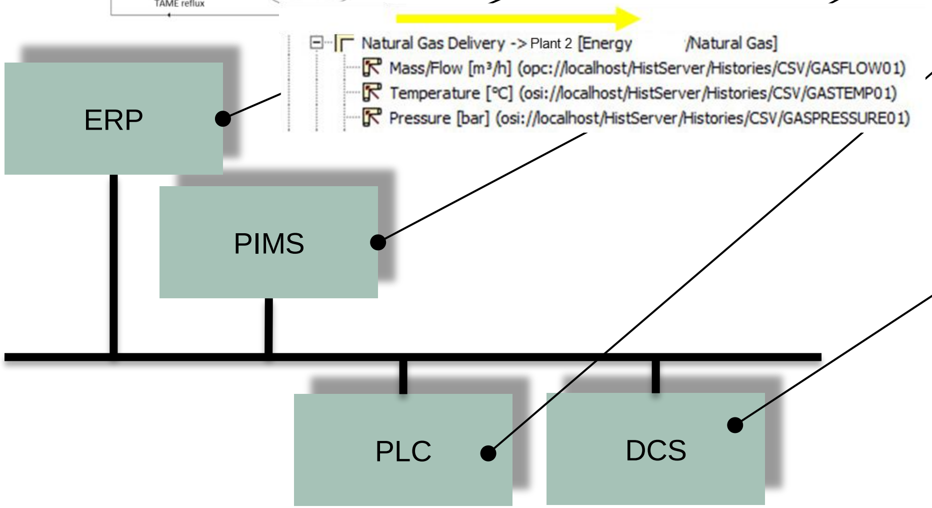






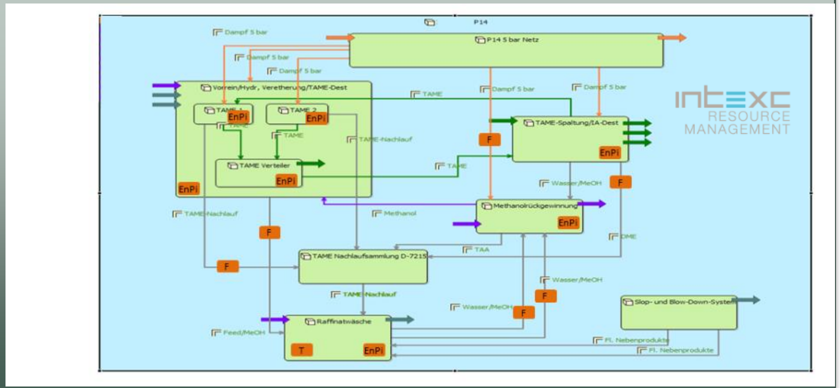
KPI Calculations:

- $EnPi = \frac{Sum\ of\ in-/outcoming\ Energy\ Streams}{Sum\ of\ outgoing\ Product\ Streams}$
- $RawPi = \frac{Sum\ of\ incoming\ Raw\ materials}{Sum\ of\ outgoing\ Product\ Streams}$
- …

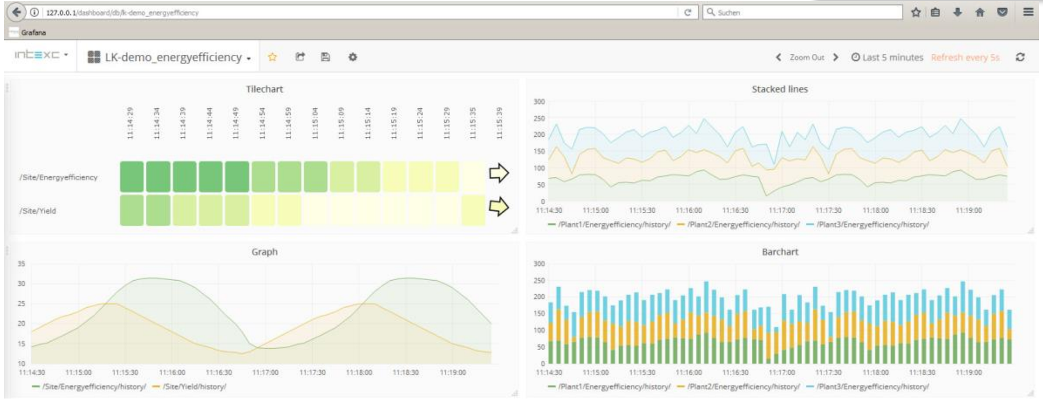
Context Based Online Data Management

Give Data a Context

Runtime Environment

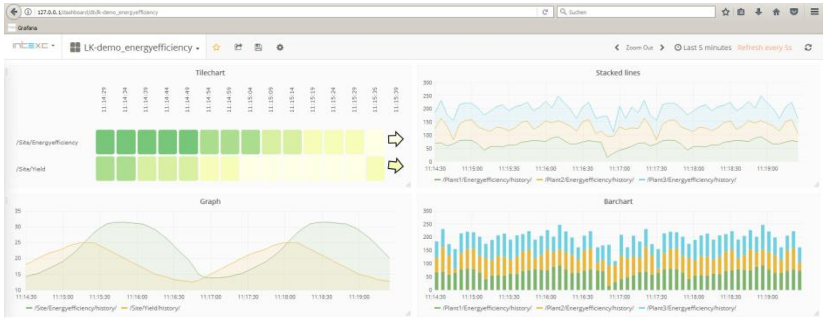


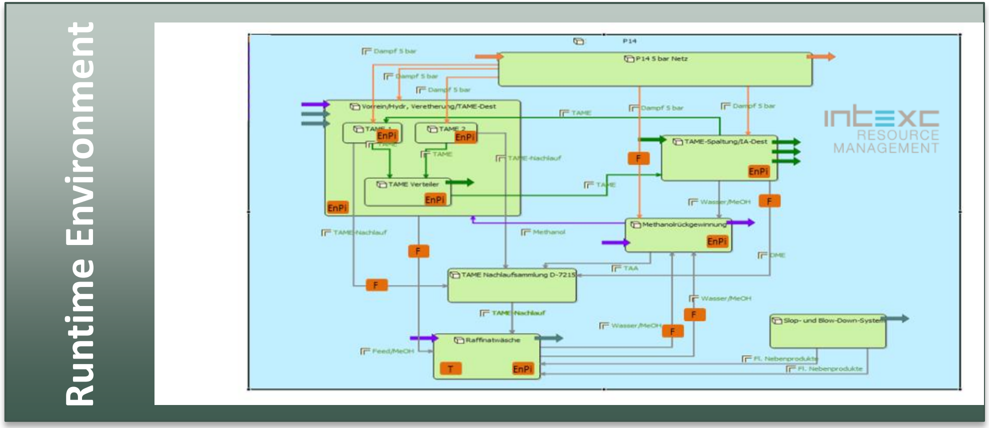
Open Remote API
Web Interface



Context Based Online Data Management

Give Data a Context



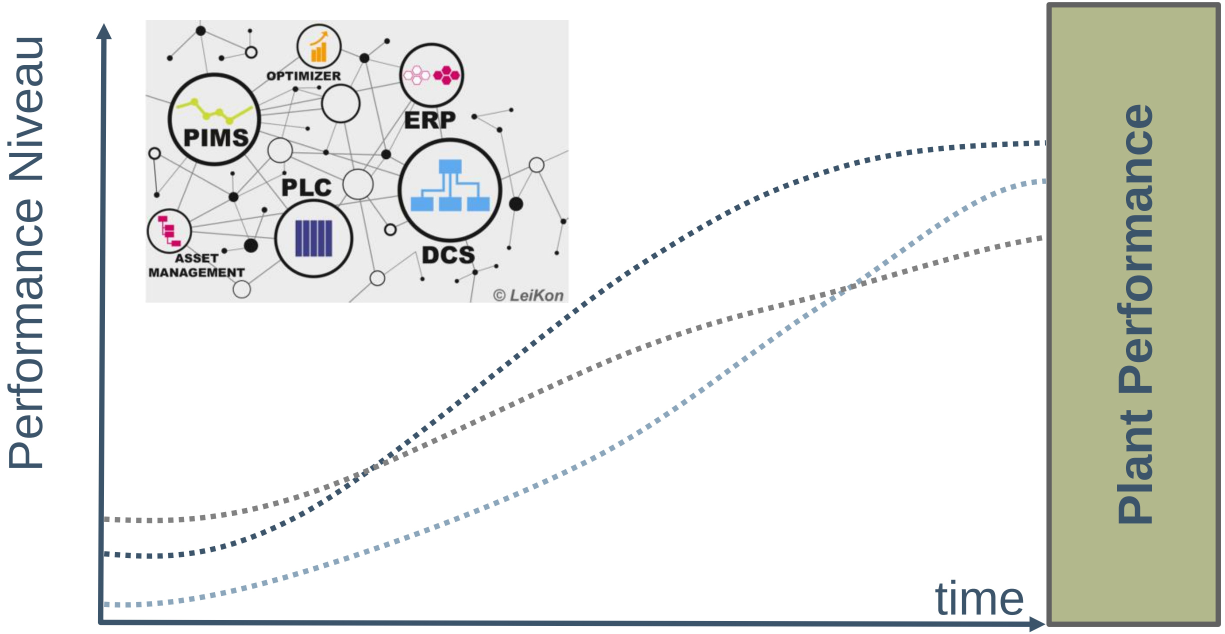


- **Transparency of all Energy and Material Flows**
- **Knowledge and Calculation Hot Spot** (Context Management)
- **Detection of Cause and Effect Correlations**

- **Use of Structure and Context Information**
- Calculation of unmeasured Data Points
- online Plausibility Checks of Process Data
- online Adjustment Calculus of over-determinated Data Points
- online Calculation and aggregation of KPIs

Plant Performance

„Plant Performance" is and will remain an important strategic goal in process industry



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