Energy Management

ΣΕΒ Round table 12/2022

Αργύρης Τσιγκαλής SIEMENS A.E. Digital Industries Technical Sales Support Manager

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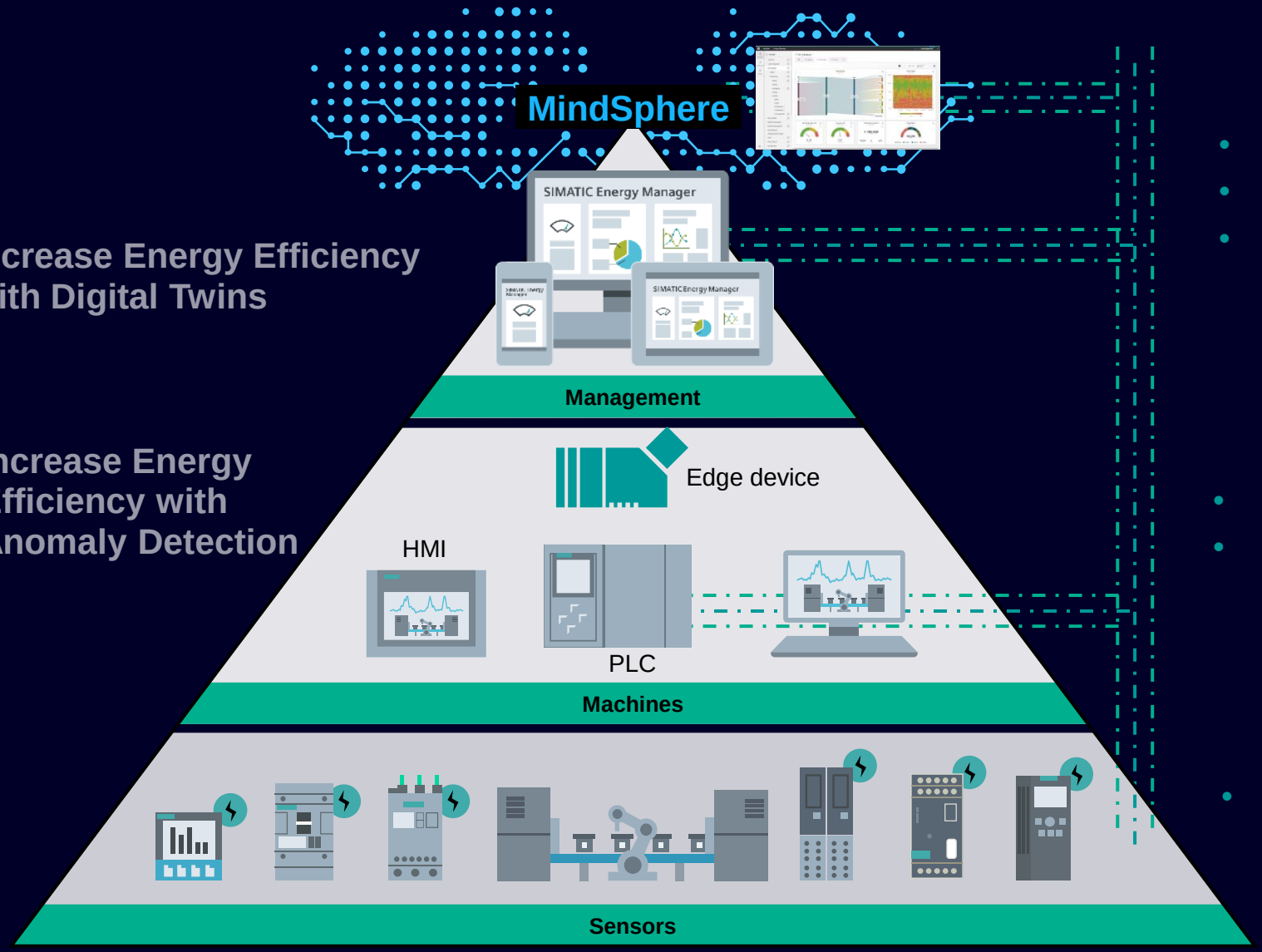
Energy management at different levels



- Increase Energy Efficiency with Digital Twins
- Increase Energy Efficiency with Anomaly Detection

- Analyze energy data
- Forecast energy consumption
- Manage efficiency measures

- Calculate machine efficiency
- Avoid load peaks

- Collect energy data

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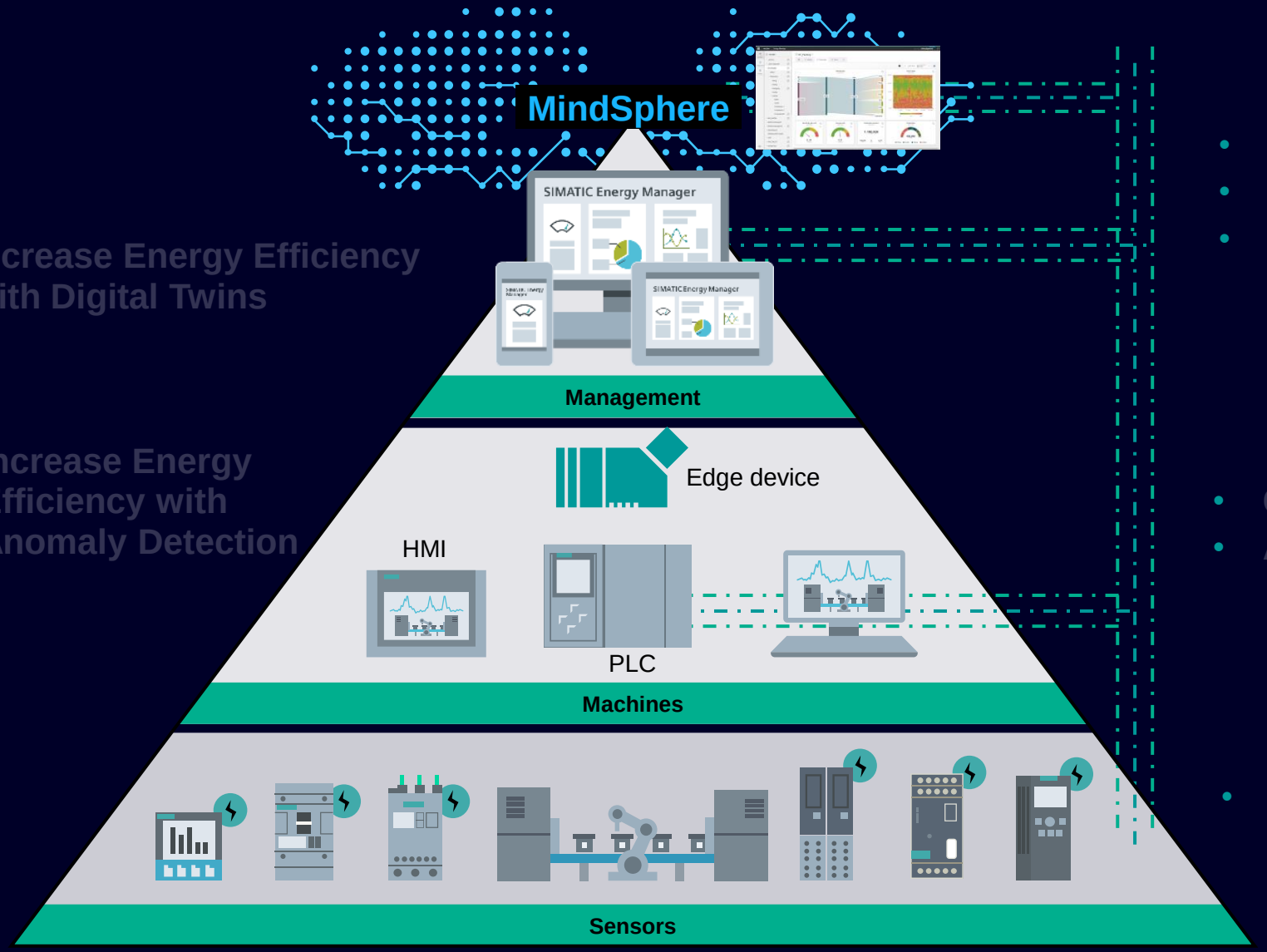

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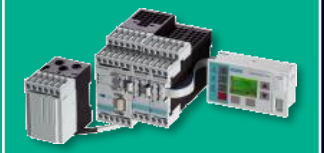
Measurement of all energy types integrated in the automation

	Measuring devices					Integrated measuring function		
	Measuring electrical energy [kWh]			Measuring non-electrical energy types		Measuring electrical energy [kWh]		
Product								
Designation	SIMATIC ET 200SP Energy Meter	SIMATIC S7-1200 SM 1238	7Kx PAC series	SITRANS series	WKx 40	3WA air circuit breaker / 3VA molded case circuit breaker	SINAMICS converter	SIMOCODE pro Motor management

Easy integration of energy data with SIMATIC Energy Suite

** Measuring Instruments Directive - relevant for measurements requiring official calibration*

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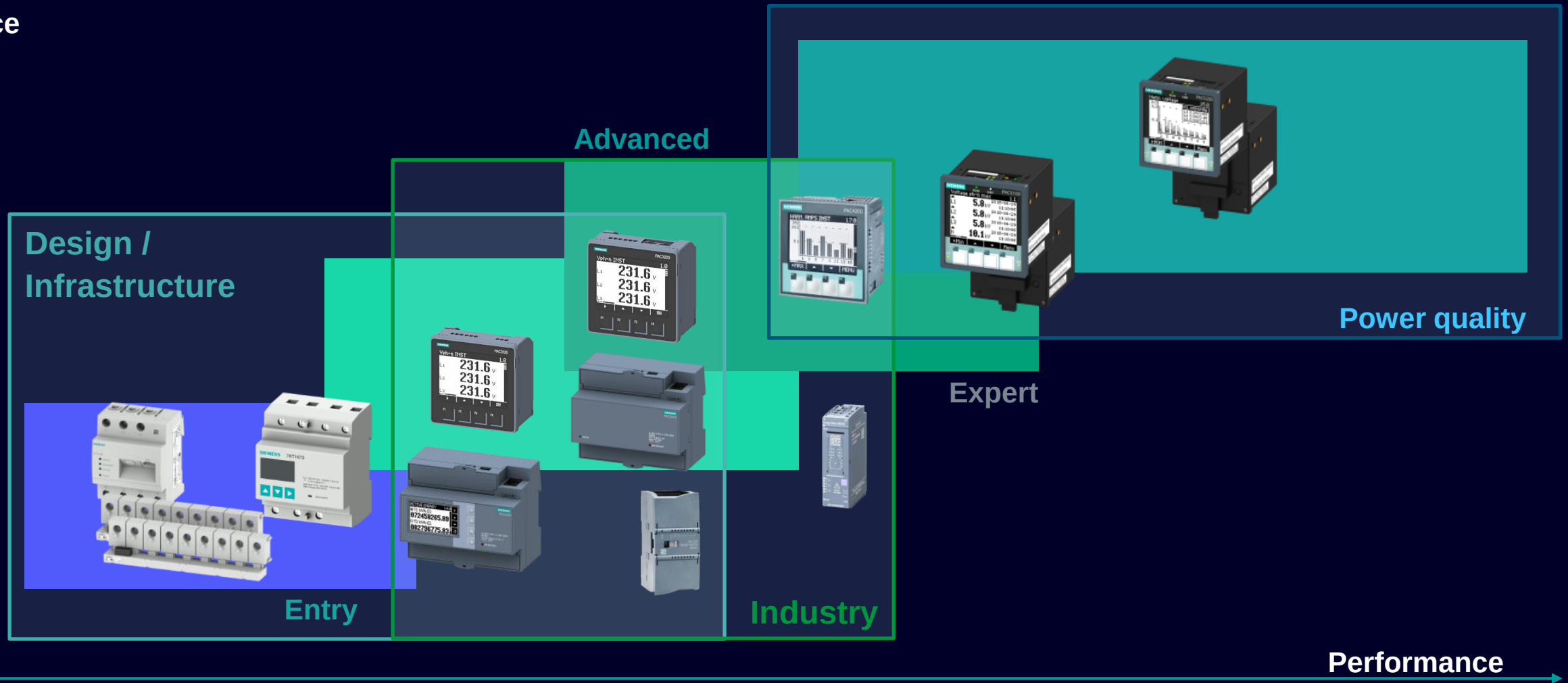
Electrical energy measurement
Price /performance overview of metering devices



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SITRANS FX - Vortex flow measurement
SITRANS FX330

Precise measurement of steam, gases, compressed air and conductive/non-conductive liquids
(no contamination/low viscosity/high flow velocity)

Properties:

- Completely designed to meet the **SIL 2/3 safety standard according to IEC 61508**
- **ATEX II2 G - Ex ia IIC T6 ... T2 Gb**
- Cost-effective energy calculation with **net heat quantity measurement by monitoring flow, pressure and temperature**
- **Integrated pressure and temperature compensation** for lower installation costs and higher accuracy
- Integrated nominal width reduction ensures high rangeability and thus more cost-effective installations and a lower risk of leakage

Pipe diameter: DN 15 to DN 300 mm

Measurement accuracy: 0.5%

Communication options: 4-20 mA HART, Profibus PA, Foundation Fieldbus

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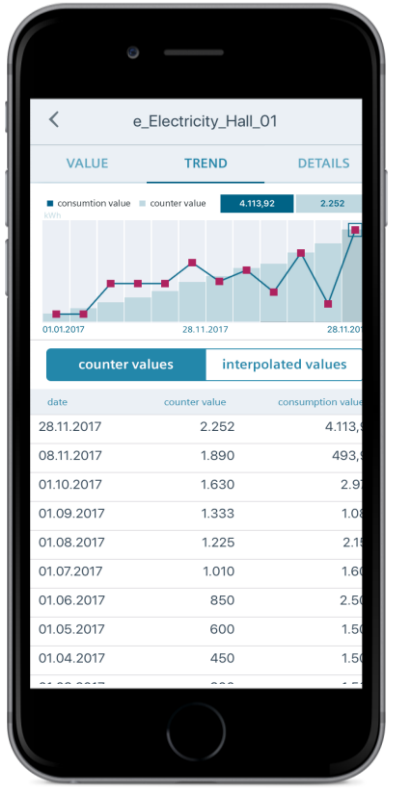
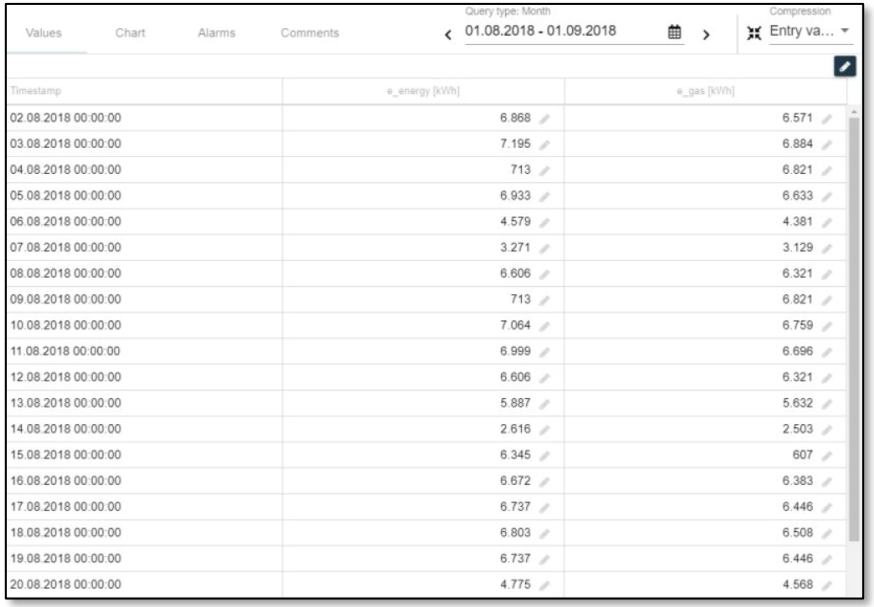
Manual data acquisition





Via mobile app

- Counter identification with scanning of the **QR- or Barcode**
- **Plausibility review** during the data entry
- **Graphical trend representation** of the last 12 acquired as well as interpolated values
- **Offline mode** – data acquisition possibility
- Support of **encrypted communication** (https)

Not all data is available in an automatic way. Production figures or consumption data can also be entered manually

- Mobile Data Recording
- Matrix (Web, Full Client)
- Automatic data reading form MS Excel

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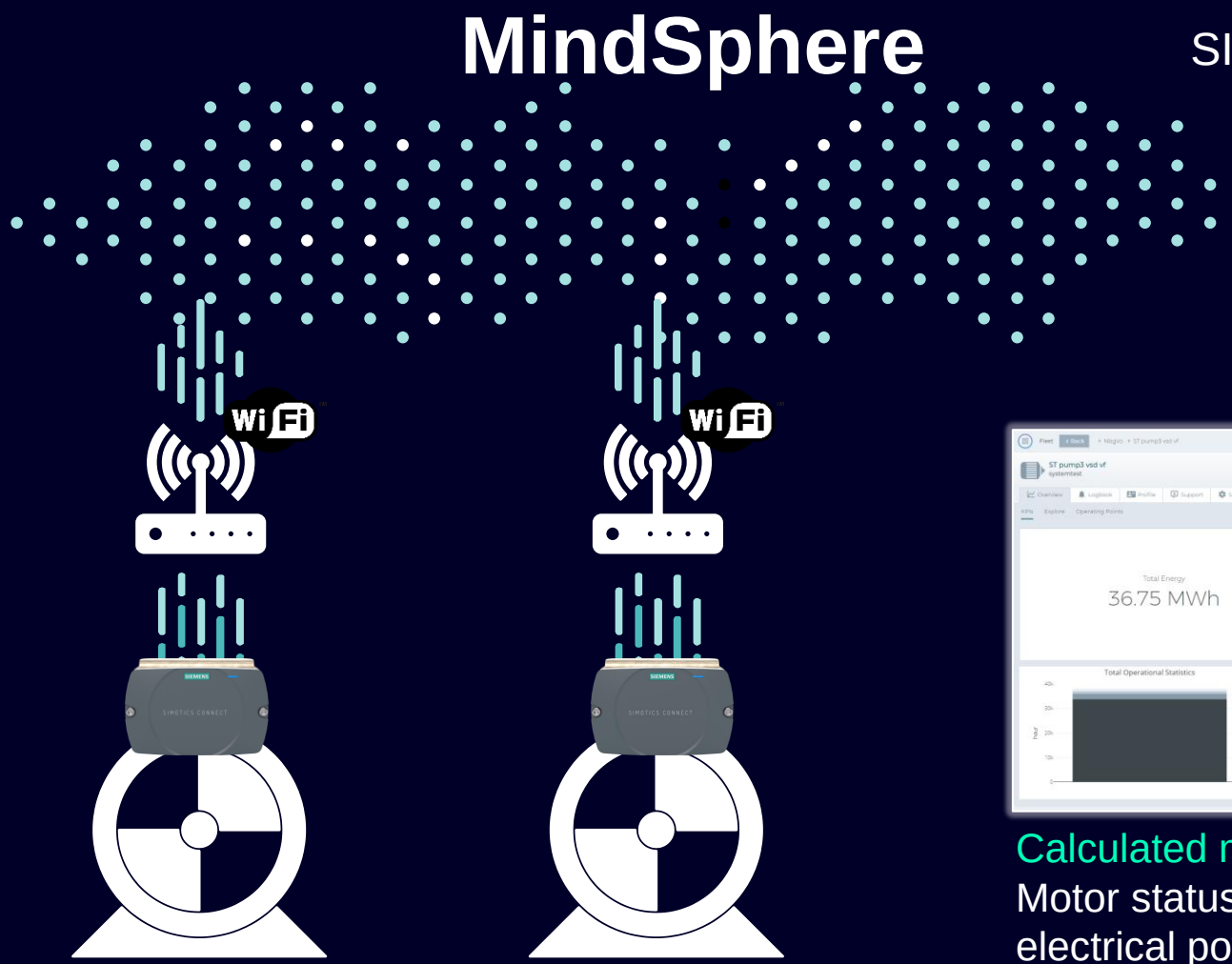
Measuring with IIoT

- Battery-powered, Wi-Fi data transfer
- Built-in sensors :
  - **Temperature**
    - 40°C to + 85°C
  - **Overall vibration**
    V_{RMS} in 3-axis
  - **Magnetic field**
    0.01 Hz to 300 Hz



SIDRIVE IQ
Fleet

Calculated motor parameters:
Motor status (on/off), speed, torque, electrical power, energy consumption, number of motor starts, operating hours

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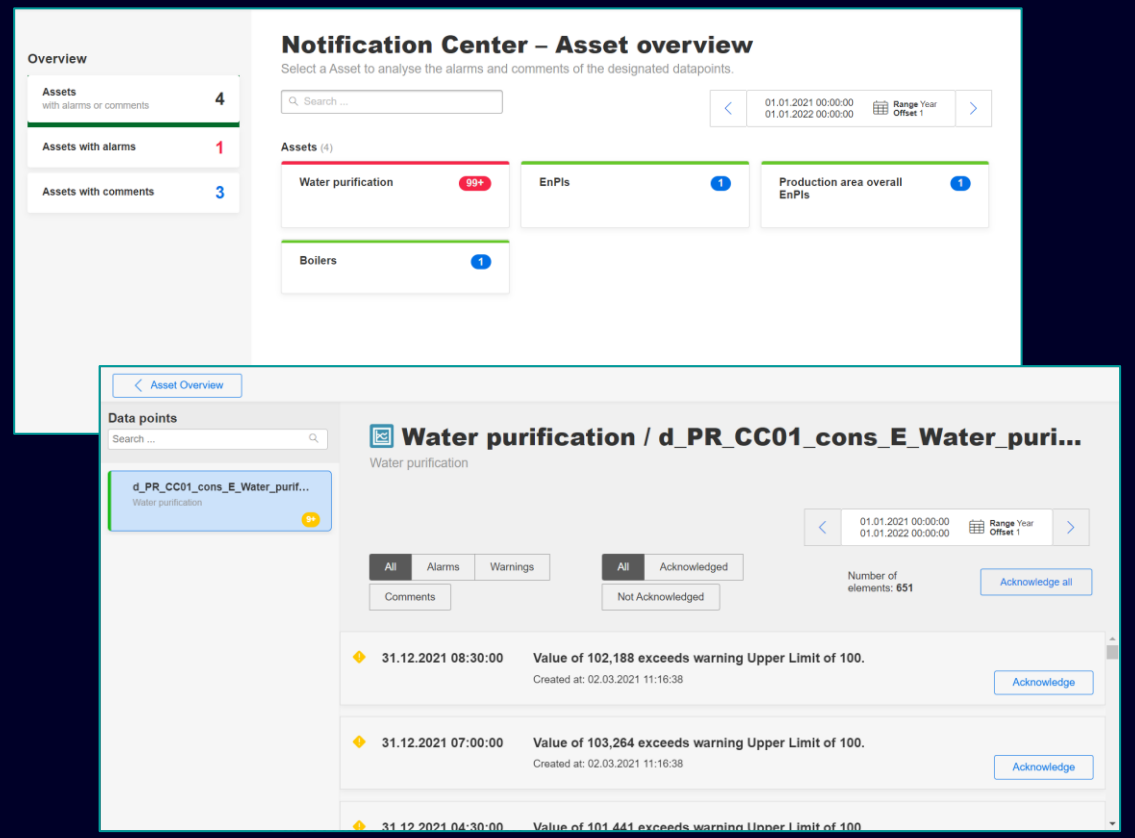
Data monitoring and alarming

- Values that deviate from the plausibility limits can be displayed in a configurable reporting list or sent by e-mail.
- Gap detection of collected data ➔ Missing values can be automatically replaced with substitute values
- Alarming via E-Mail
- Data validation report shows data quality in the system



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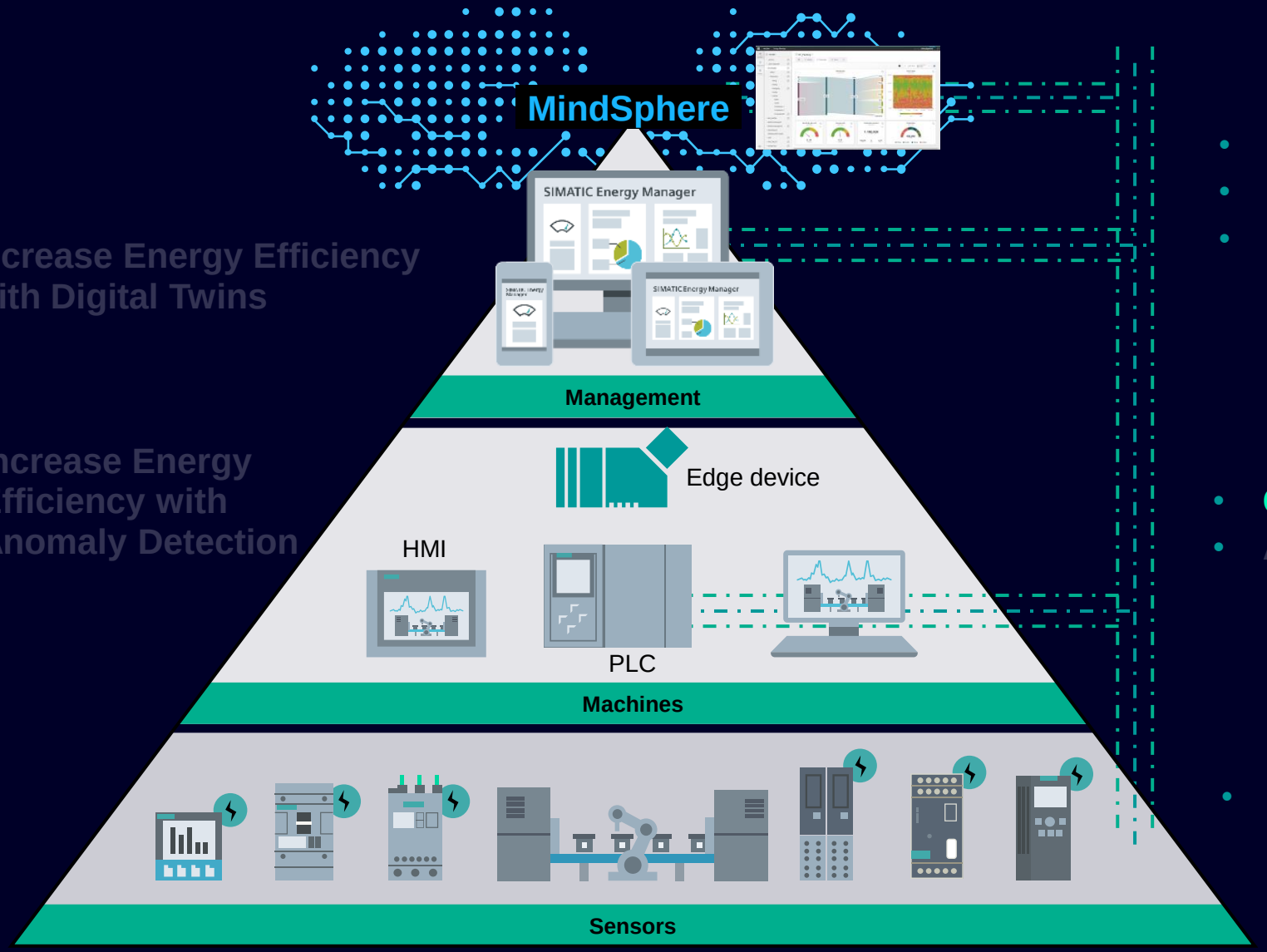
Energy management at different levels



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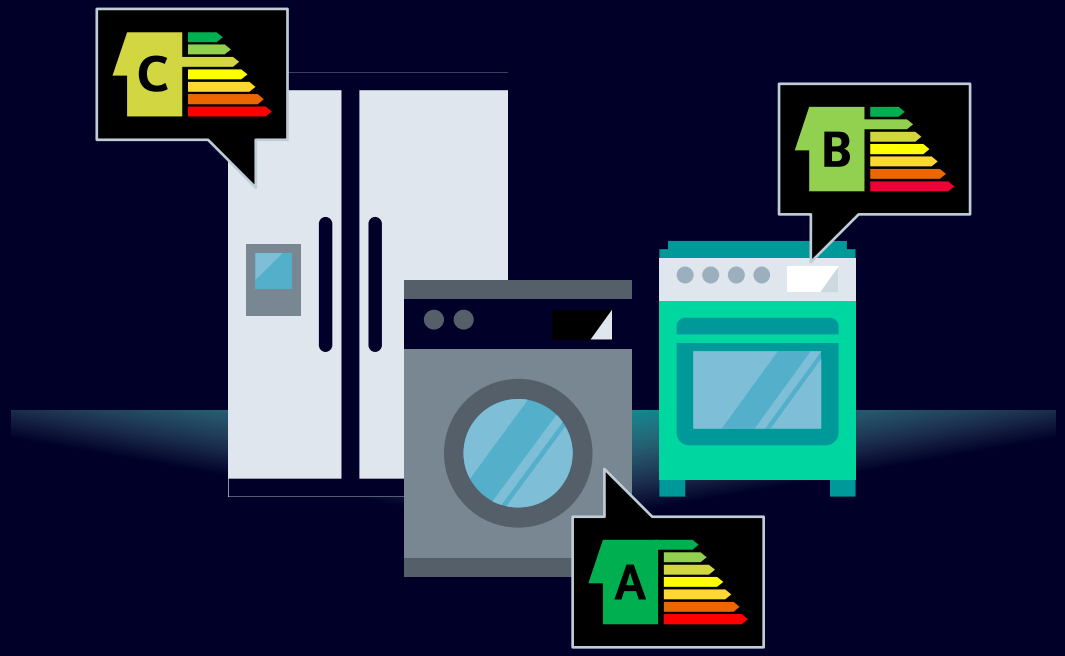
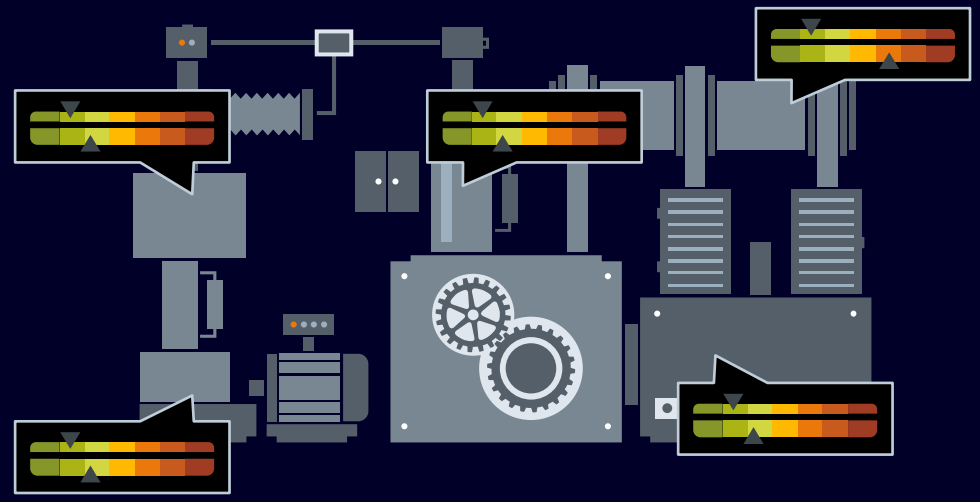
Machine energy efficiency

The simple efficiency evaluation of
household appliances is already standard



Now, the reliable
efficiency evaluation for industrial machinery is also possible



This does, however, require expertise and the right tools

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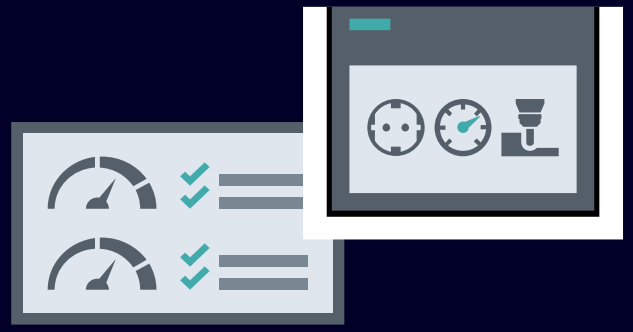
Requirements for a comparative and valid energy efficiency evaluation

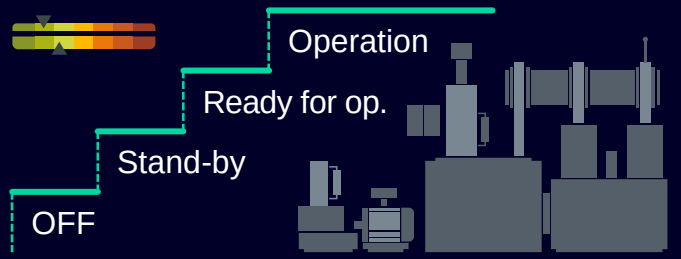
Continuous analysis

Monitoring of energy efficiency of machines and also in particular an efficient mode of operation of this machine



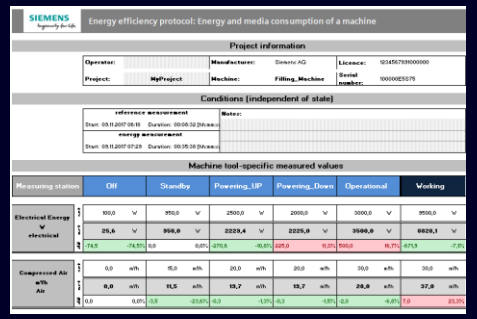
Status-related energy analysis

From shutdown condition to ongoing operation



Energetic profile

And acceptance form based on the VDMA standard 34179 and energy efficiency report for detailed analysis



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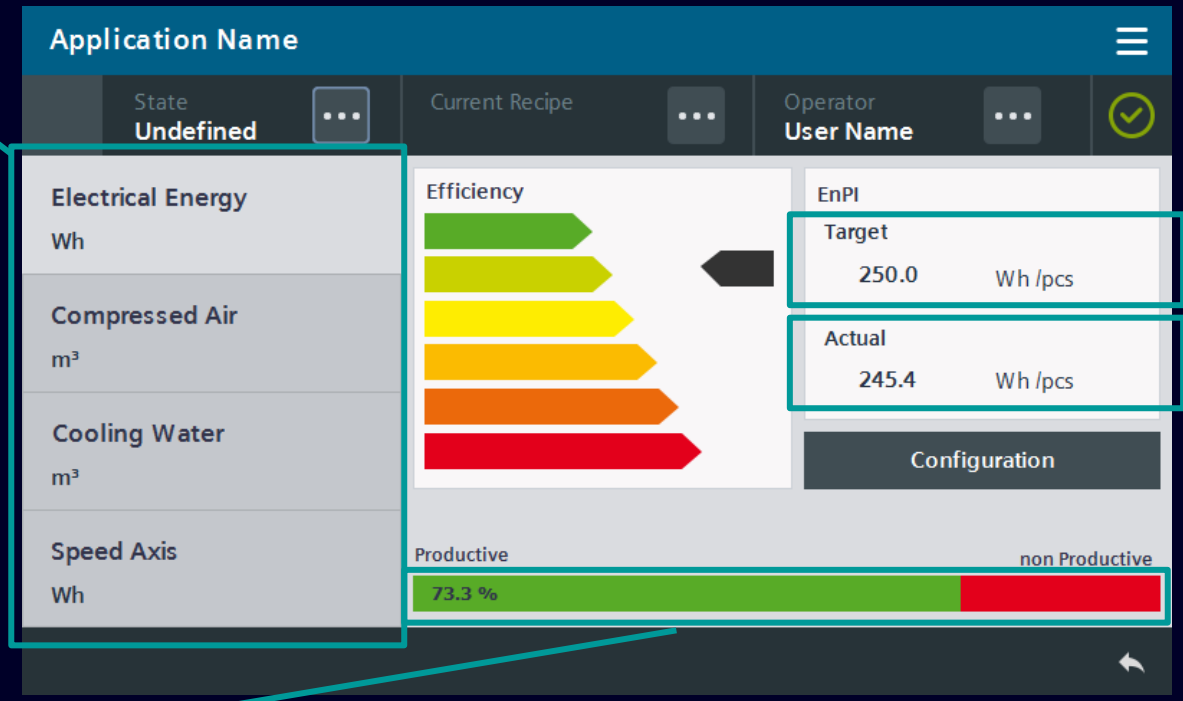
Machine energy efficiency - details per measuring point

Selection measuring point

Current energy per piece



Target energy per piece

Value-added energy

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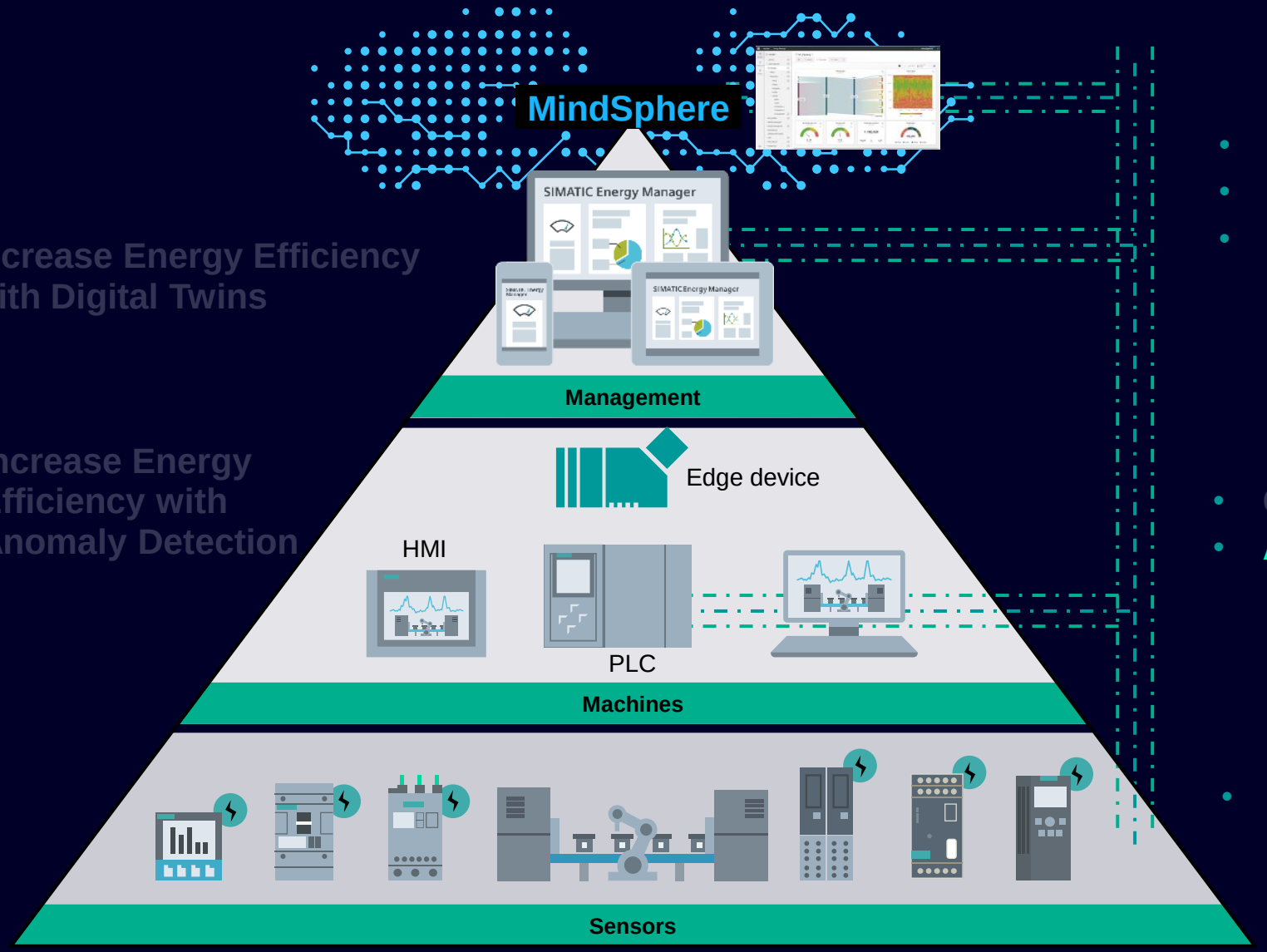
Energy management at different levels



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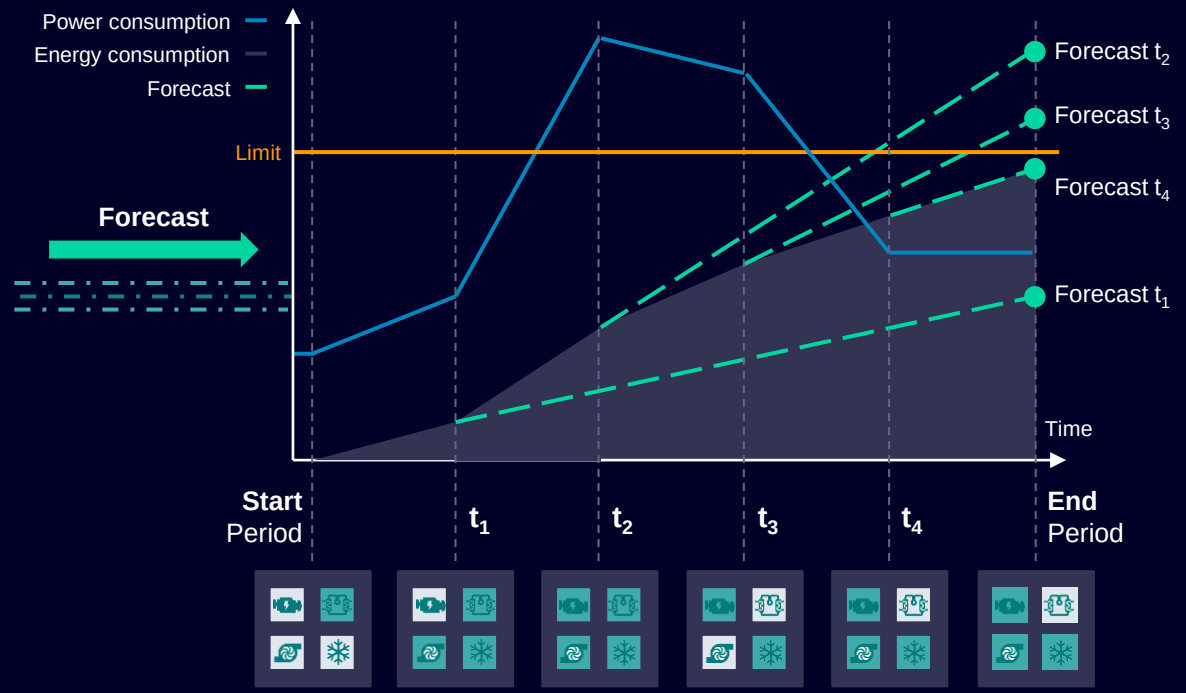
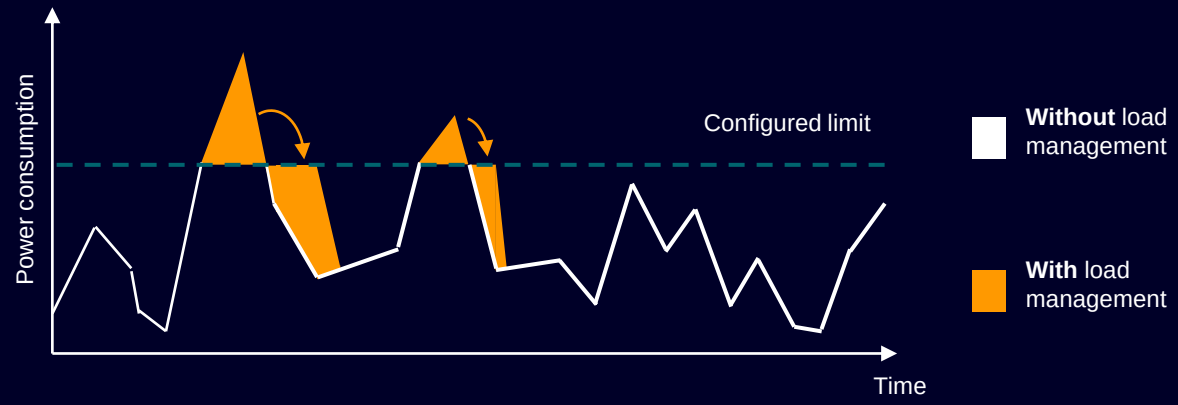
Load management enables automatic peak load reduction

Priority	
1	Generator
2	Heating
3	Compressor
4	Ventilation

Load management software

- Continuously **calculates the forecast** of the energy demand at the end of the period
- **Switches actuators on or off** depending on available potential
- Actuators are switched **according to configured priority**





Forecast	---	< Limit	> Limit	> Limit	< Limit	---
Switching action	Heating **on**	Compressor & ventilation **on**	Generator **on**	Heating & compressor **off**	Compressor **on**	---
Energy demand	↗	↑	↘	↓	↗	---

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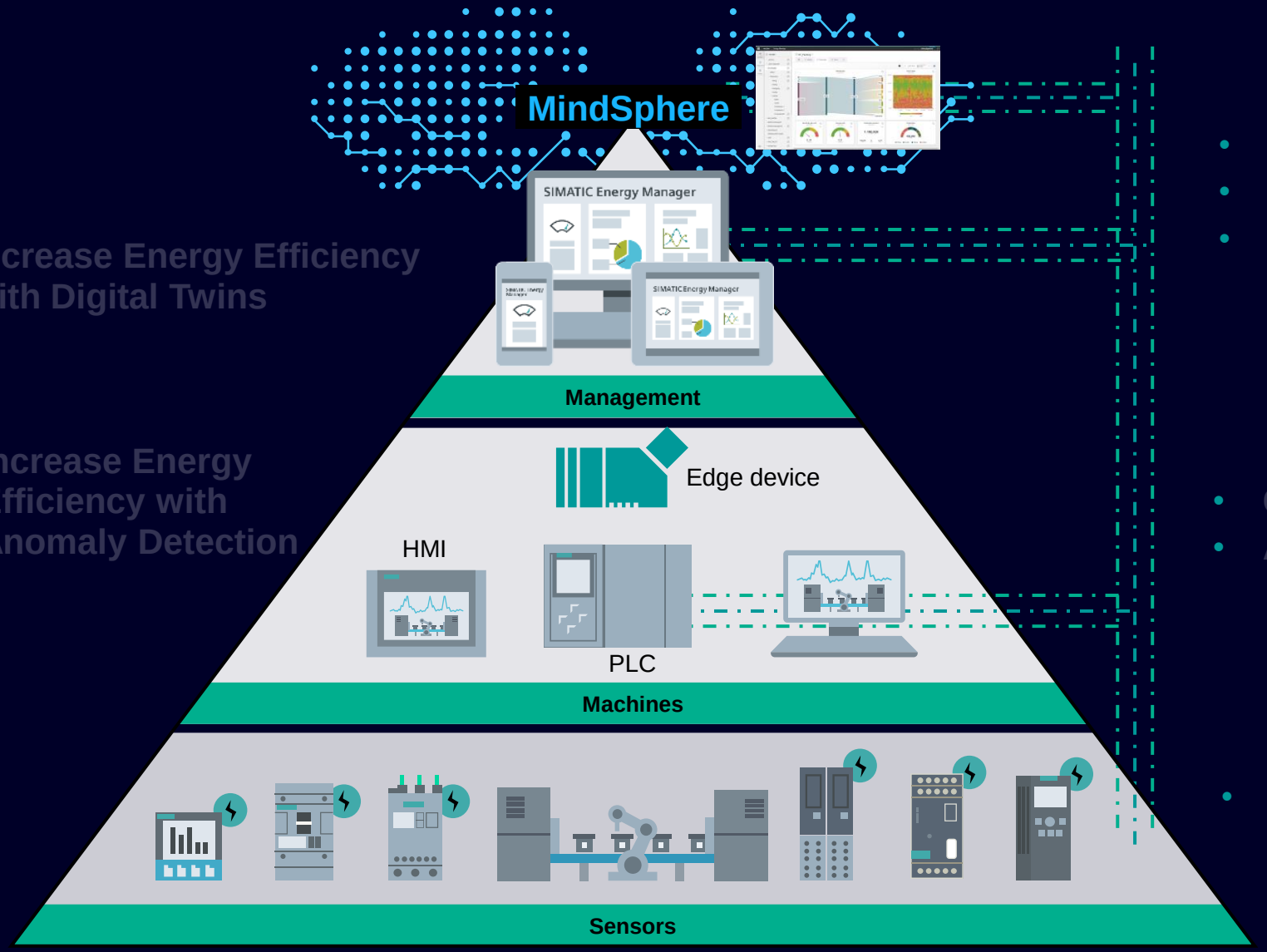
Energy management at different levels



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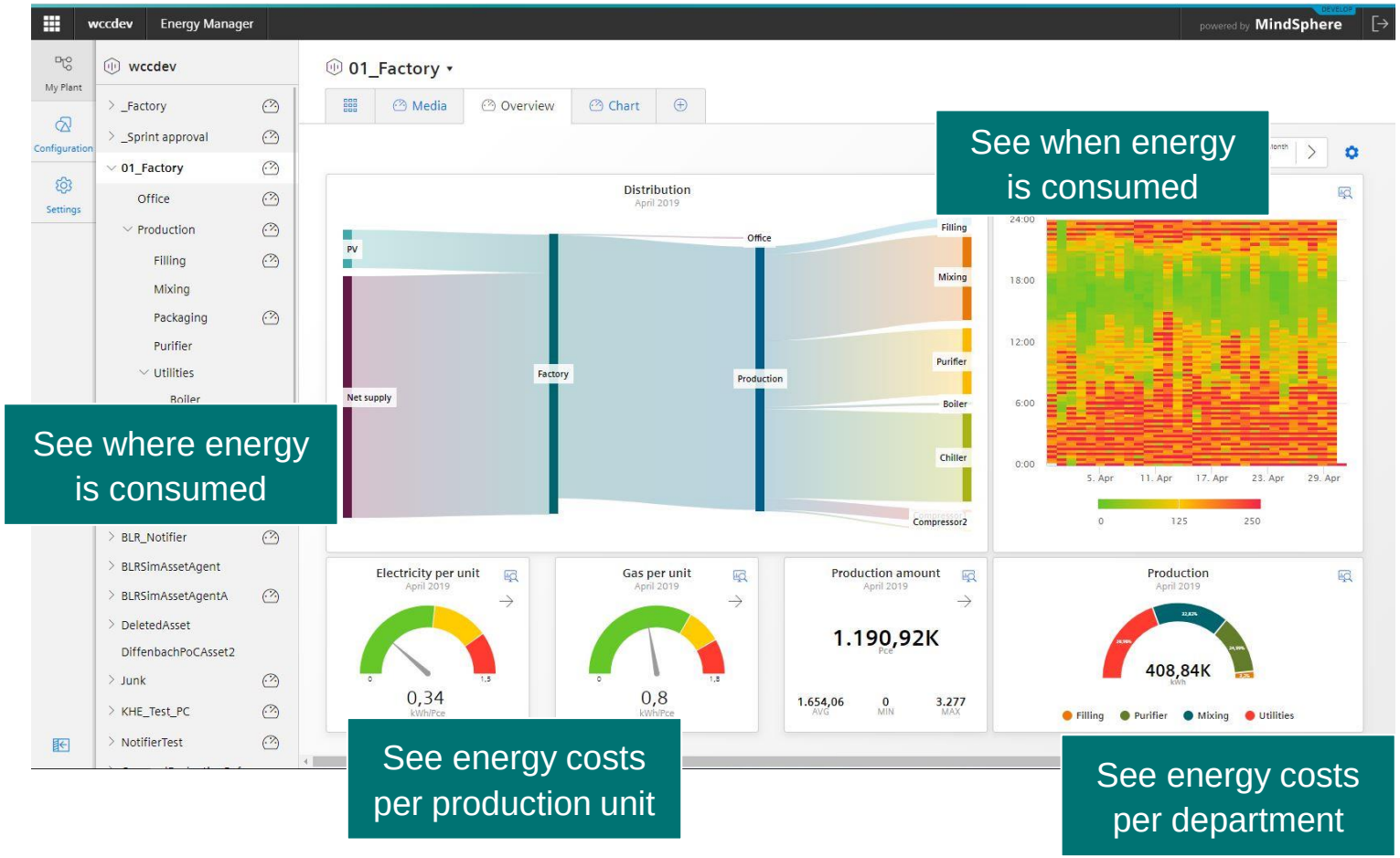
Dashboards - Transfer data to information



Using custom dashboard with energy related widgets to transfer data to information

- Sankey Diagram provides an overview about the energy flow → see where energy is consumed
- In the heat map the value is represented as color. → see when energy is consumed.
- Additional Widget types like Gauge, Pie Chart, Value, Chart are used to display KPIs in a way that measures can derived immediately.

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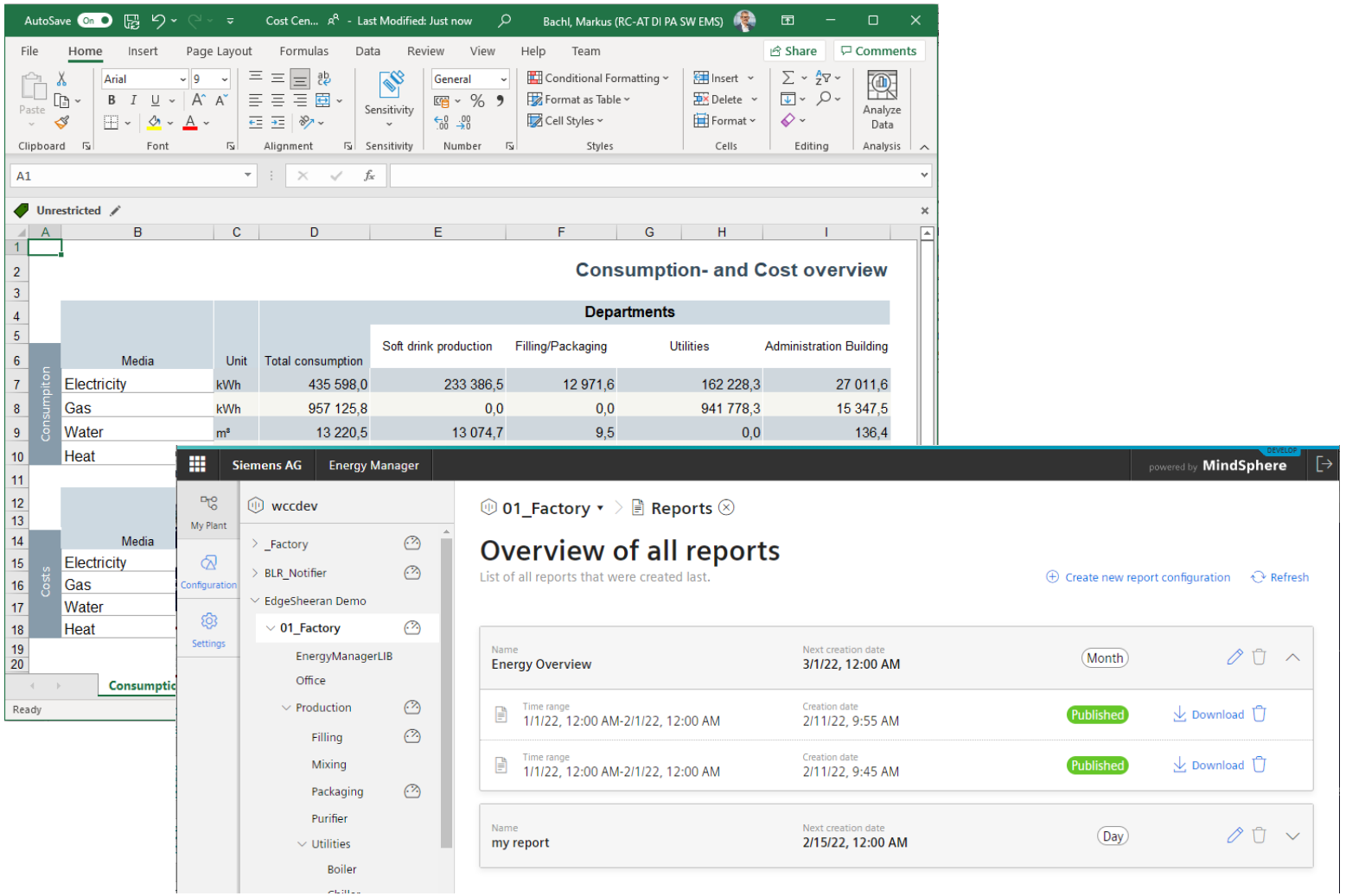
Reporting capabilities



Situation

- For documentation and information sharing purposes it is necessary to provide important KPIs in an Excel spreadsheet
- The effort to prepare an Excel Report is often very high.

Requirements

- Provide Excel reporting capabilities
- User has to be able to define custom reports with full flexibility in terms of layout and content.
- Distribute the report automatically to the appropriate stakeholders

Benefits

- Easy to use reporting capabilities
- Reduce the effort for information sharing
- Complies to ISO 50001

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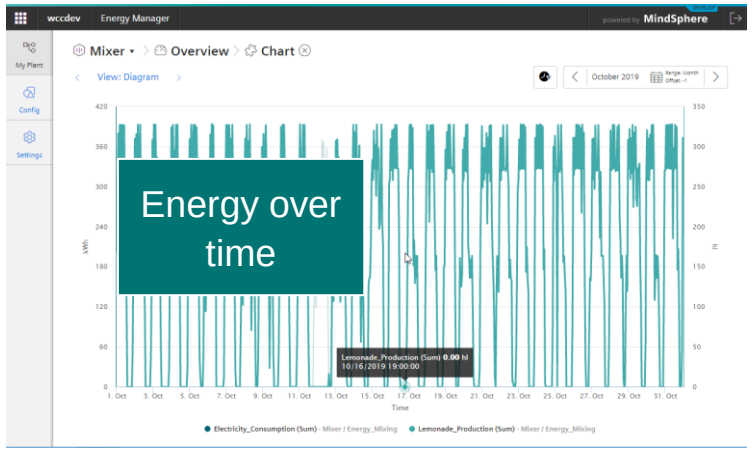
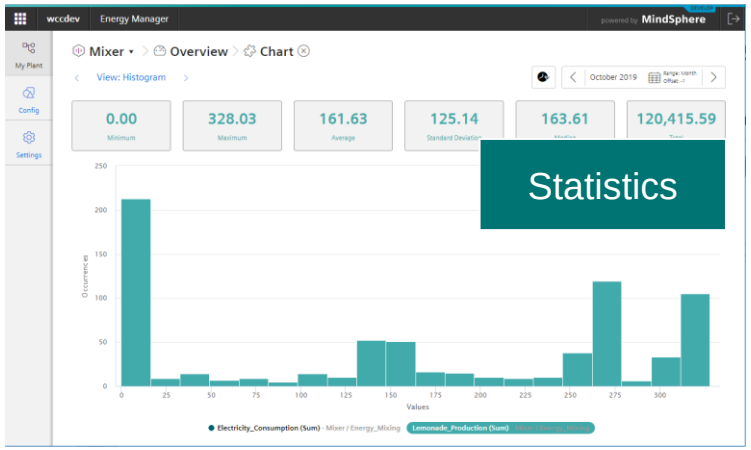
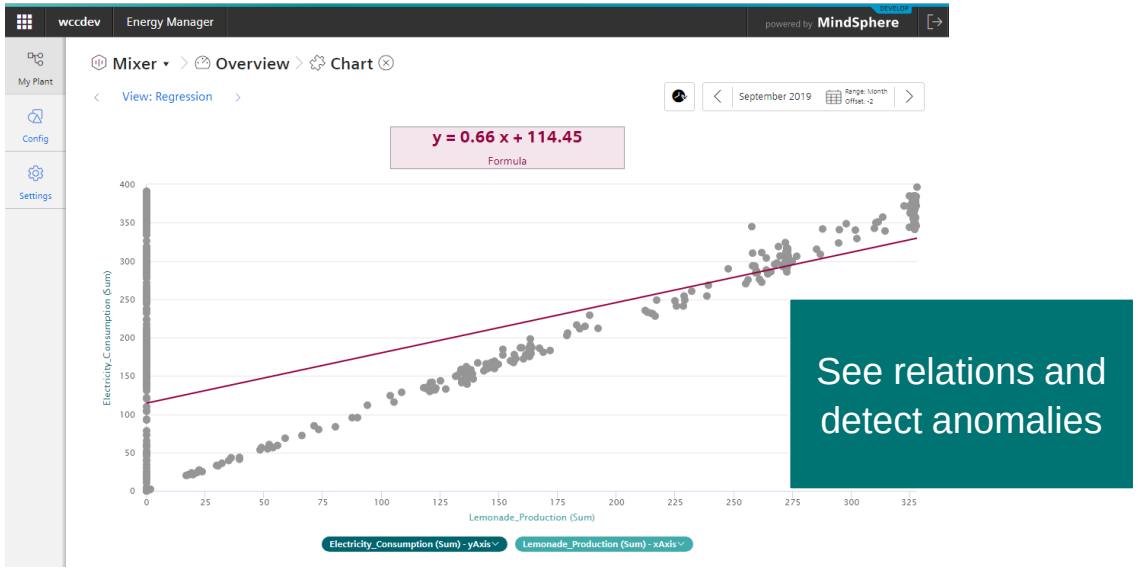
Out of the box analytics







Detailed information for each widget in the dashboard

- The diagram view provides detailed information in a configurable resolution (e.g. 1h) to see any anomalies like peaks,..
- Statistic view provides a histogram for each parameter including the statistic. (min, max, average, median, standard deviation and sum)
- Regression view provides the possibility to display the data in a x-y chart including a trend representing the plant characteristic.

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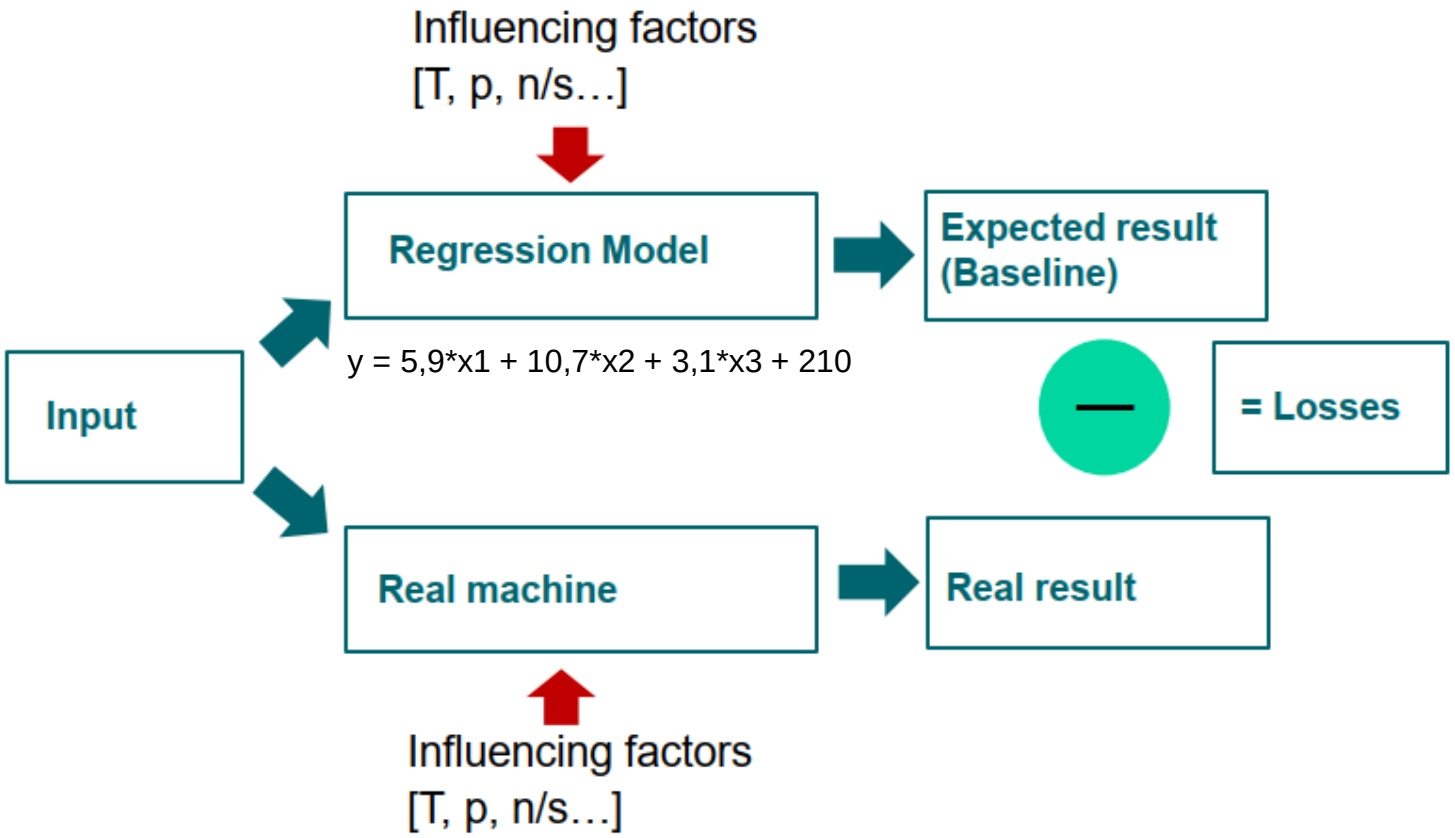
Multi Variable Regression analysis



- Easy to use without being a data scientist
- Provide a baseline considering the influencing parameters
- Inform the user if the deviation between baseline and actual value e.g. consumption exceed a configurable limit
- Detect inefficiencies considering parameter influencing the e.g. consumption
- Approach complies to ISO 50006

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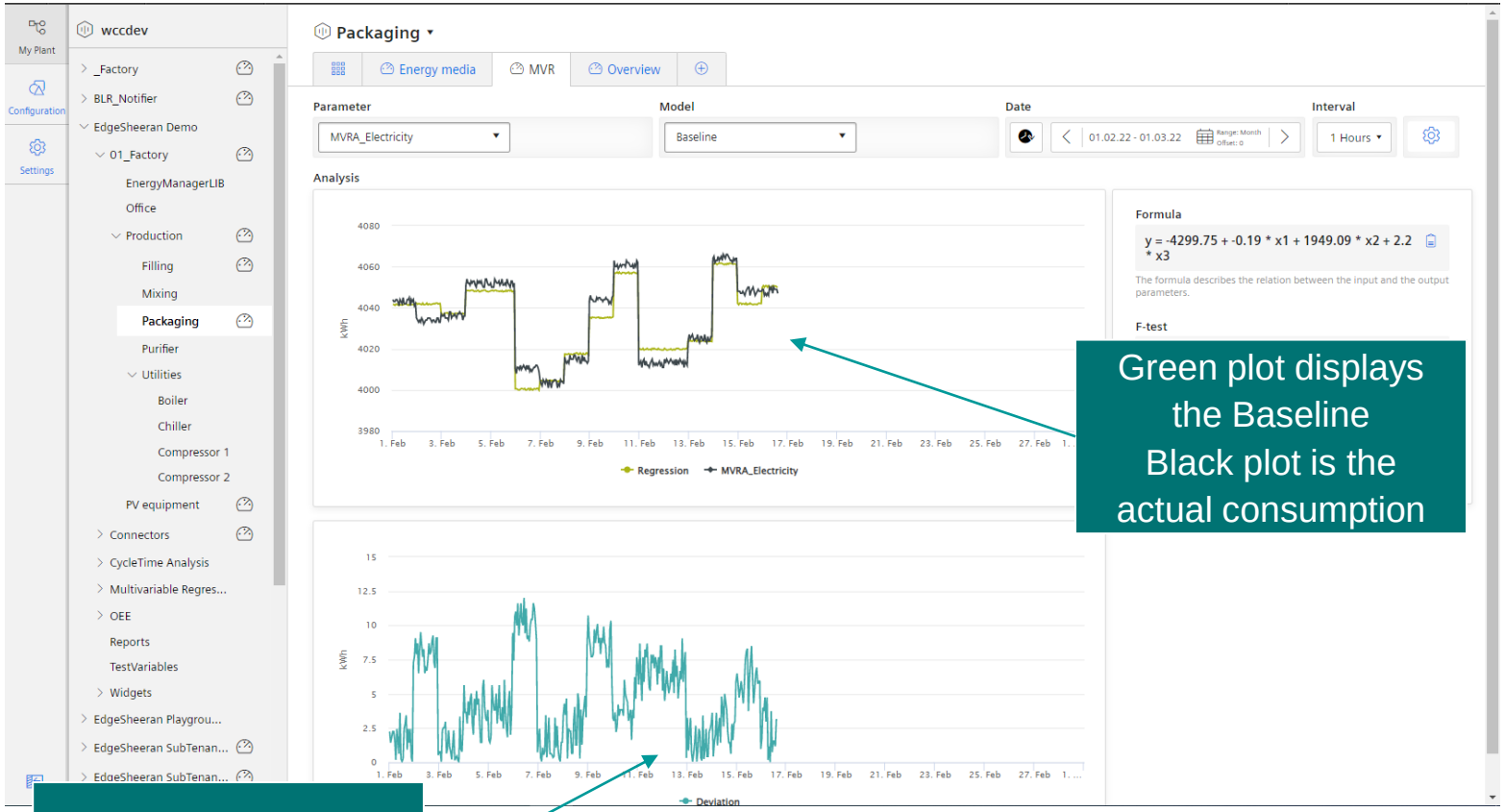
Energy Manager for MindSphere
Multi Variable Regression analysis



Green plot displays the Baseline
Black plot is the actual consumption

Deviation between baseline and actual consumption

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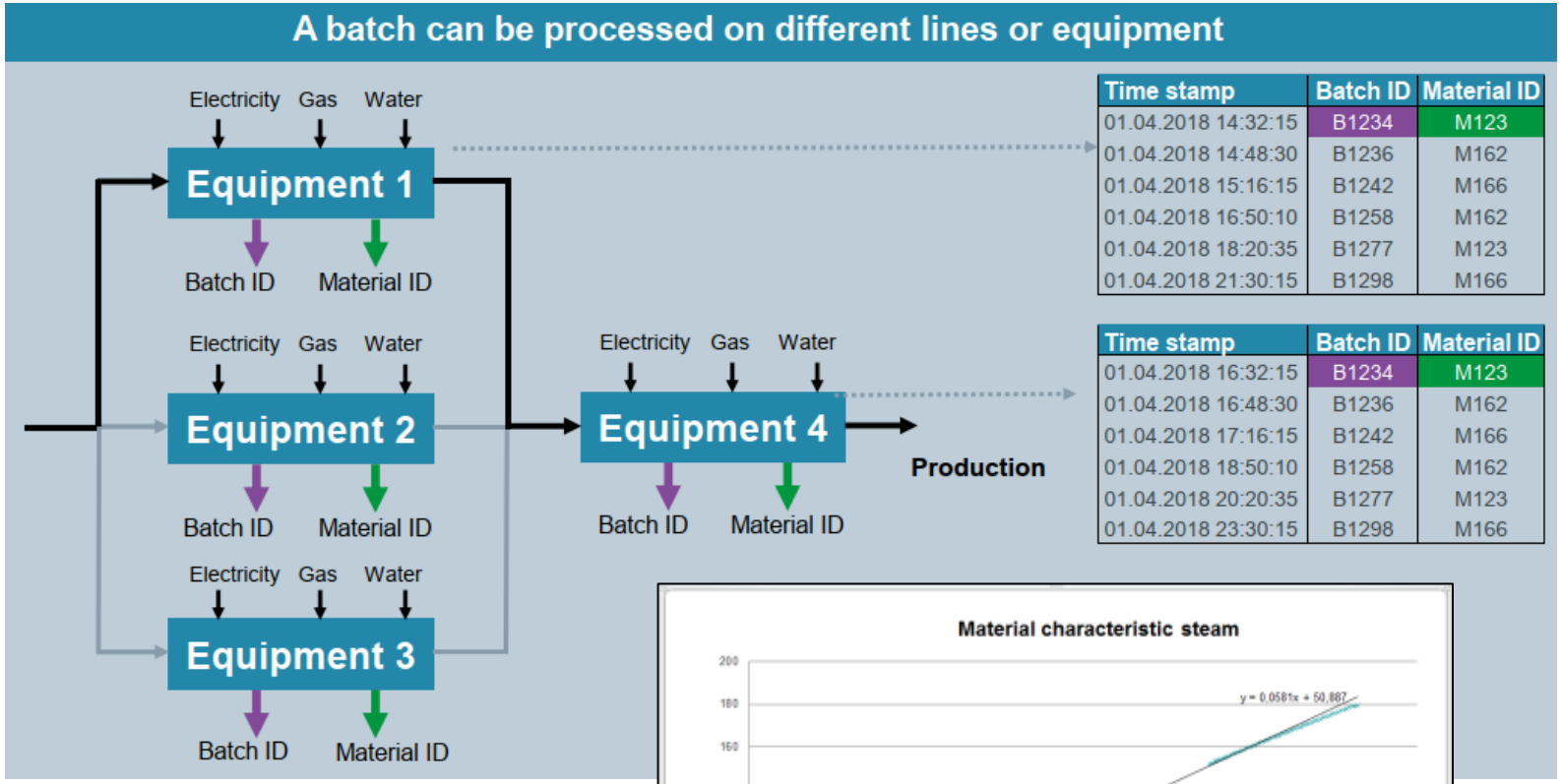
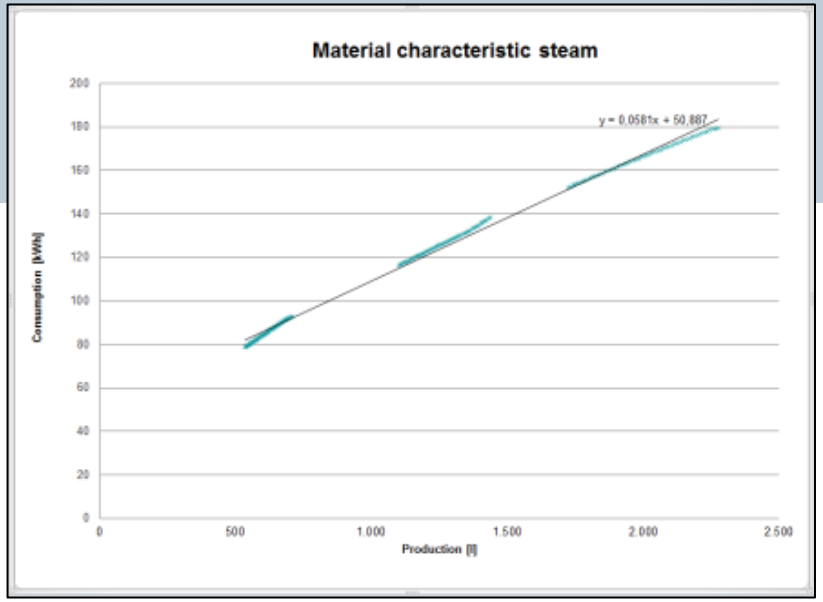
Batch and Material related analyses
Fundamental approach



Time stamp	Batch ID	Material ID
01.04.2018 14:32:15	B1234	M123
01.04.2018 14:48:30	B1236	M162
01.04.2018 15:16:15	B1242	M166
01.04.2018 16:50:10	B1258	M162
01.04.2018 18:20:35	B1277	M123
01.04.2018 21:30:15	B1298	M166

Time stamp	Batch ID	Material ID
01.04.2018 16:32:15	B1234	M123
01.04.2018 16:48:30	B1236	M162
01.04.2018 17:16:15	B1242	M166
01.04.2018 18:50:10	B1258	M162
01.04.2018 20:20:35	B1277	M123
01.04.2018 23:30:15	B1298	M166



- A batch is a certain amount of a produced good of a material (or a sort). This amount is produced on a specific equipment.
- For the production of this amount electricity, gas and water are required
- Based on this data the material characteristic can be determined (y = k*x + d) for each material

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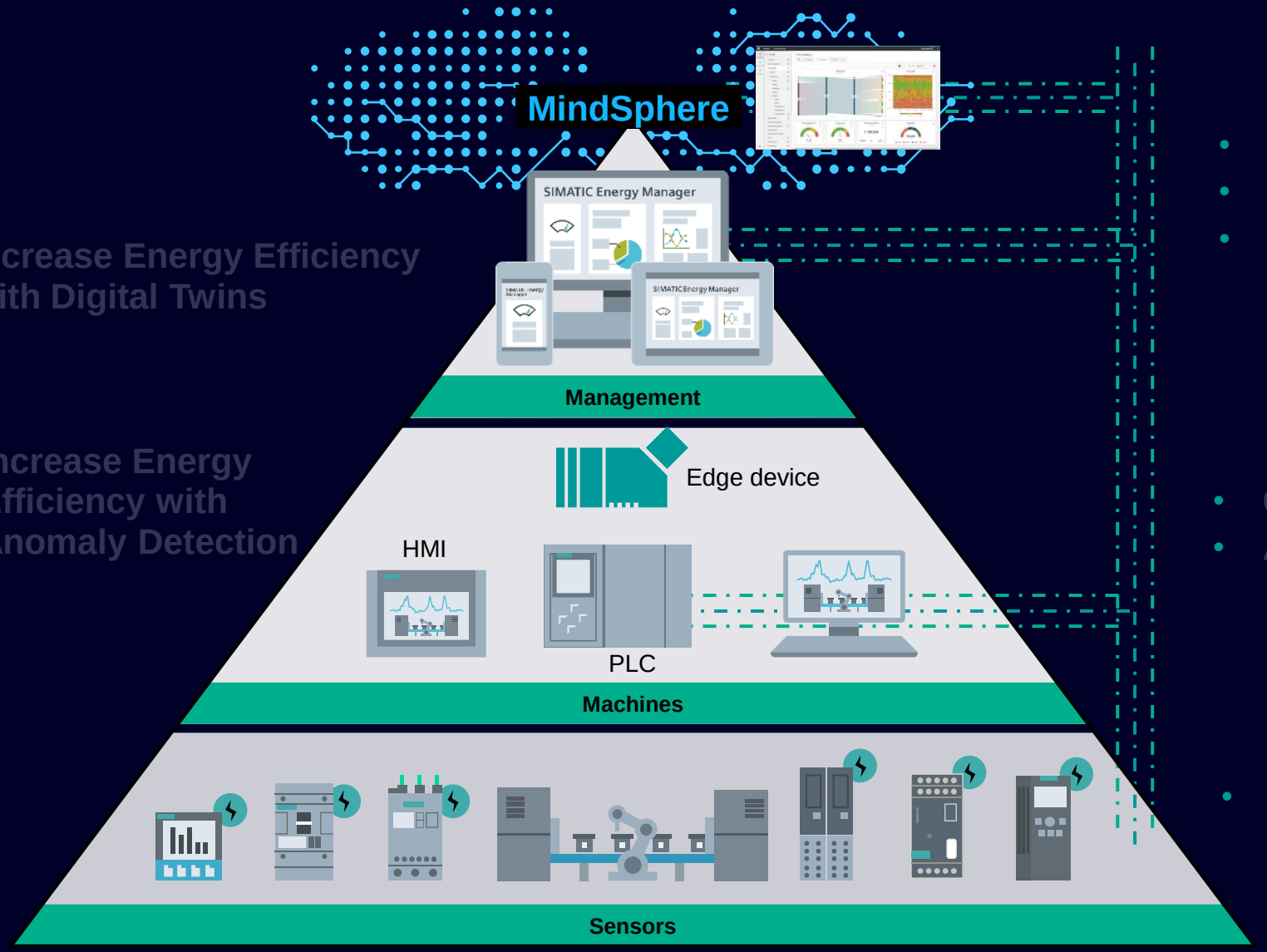
Energy management at different levels



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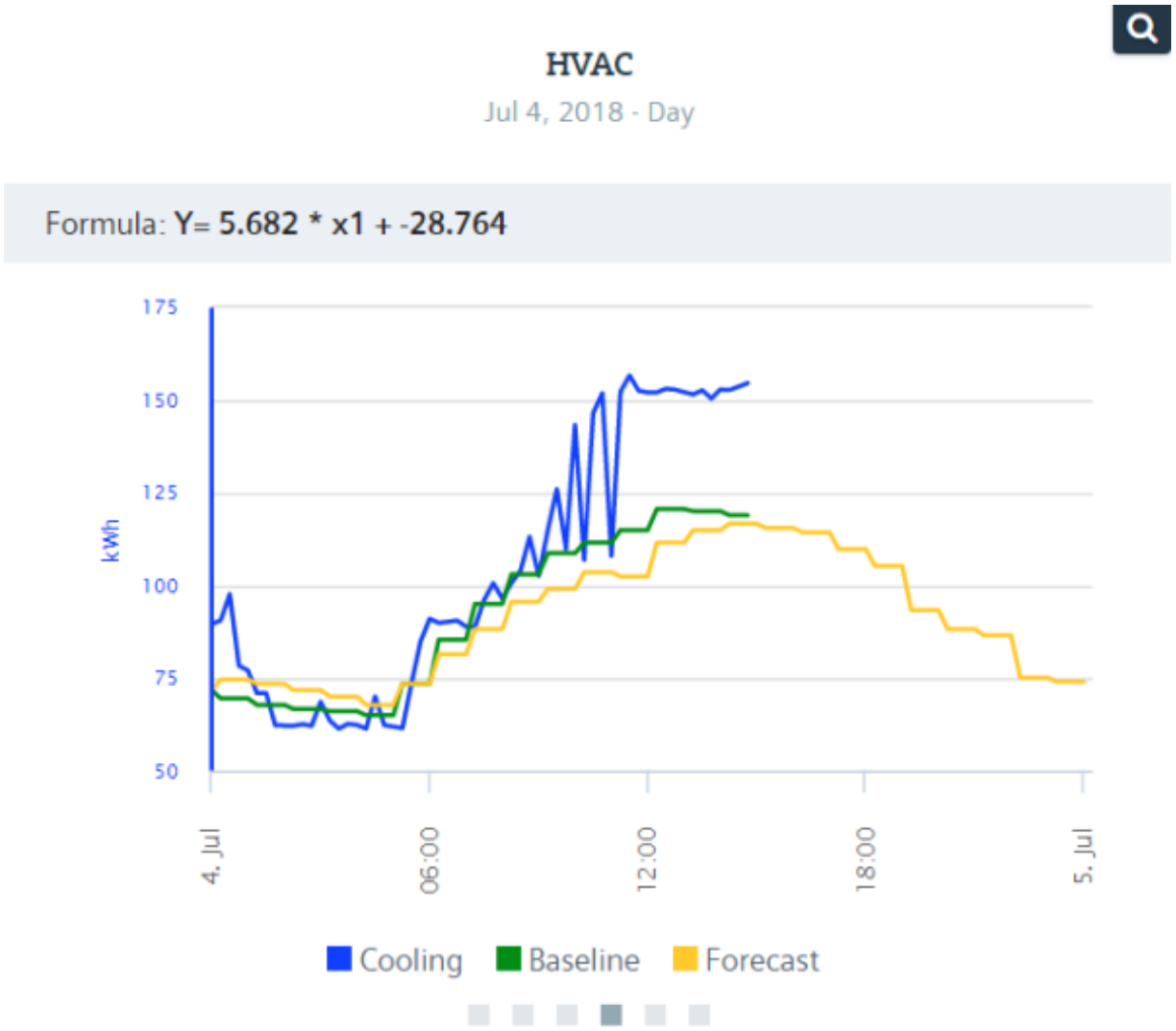
(1) Forecasting with Multi-Variable regression analysis



Multivariable regression analyses ➔ The impact of one or more factors on the energy consumption is determined and considered in the Baseline calculation

If the influencing factors are available in the future, for example as weather forecast, it is possible to make statements about the future energy consumption

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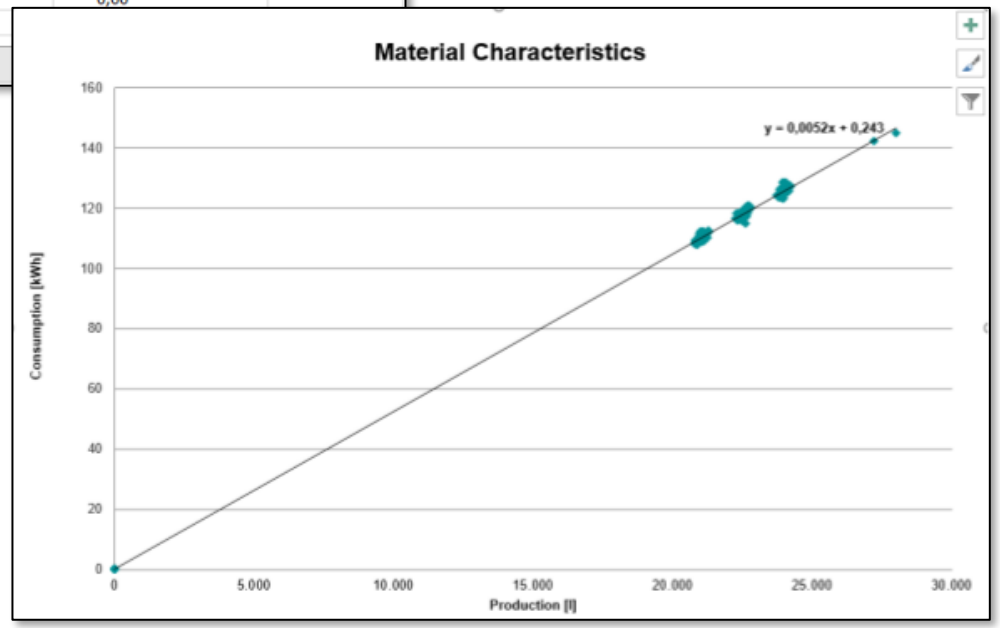
(2) Forecasting based on production plans

	A	B	C	D	E	F	G
1	Production plan M01						
2	1	Processes					
3	1	Correction					
4	Filling Line 01						
5	From	To	Material	Description	Quantity	Correction	comment
6	01.01.2018 00:00	01.01.2018 03:30	Soft drink2		27.872,00		
7	01.01.2018 03:30	01.01.2018 08:00	Soft drink3		26.958,00		
8	01.01.2018 08:00	01.01.2018 10:15	Soft drink1		22.418,00		
9	01.01.2018 10:15	01.01.2018 11:15	No material		0,00		
10	01.01.2018 11:15	01.01.2018 14:15	Soft drink2		24.041,00		
11	01.01.2018 14:15	01.01.2018 15:15	No material		0,00		
12	01.01.2018 15:15	01.01.2018 18:45	Soft drink3		20.911,00		
13	01.01.2018 18:45	01.01.2018 19:45	No material		0,00		
14	01.01.2018 19:45	01.01.2018 22:00	Soft drink1		22.517,00		
15	01.01.2018 22:00	01.01.2018 23:00	No material		0,00		
16	01.01.2018 23:00	02.01.2018 02:00	Soft drink2		23.994,00		
17	02.01.2018 02:00	02.01.2018 03:00	No material		0,00		
18	02.01.2018 03:00	02.01.2018 06:30	Soft drink3		21.121,00		
19	02.01.2018 06:30	02.01.2018 07:30	No material		0,00		
20	02.01.2018 07:30	02.01.2018 09:45	Soft drink1		22.401,00		
21	02.01.2018 09:45	02.01.2018 10:45	No material		0,00		
22	02.01.2018 10:45	02.01.2018 13:45	Soft drink2		24.070,00		
23	02.01.2018 13:45	02.01.2018 14:45	No material		0,00		
24	02.01.2018 14:45	02.01.2018 18:15	Soft drink3				

Filling Line 01



- In the prognosis based on a production plan the characteristics of a produced material (sort) is the fundament of the prognoses
- It is important that this characteristic has a linear behavior. In this case the characteristic is defined by the linear regression curve with the formula $y=kx+d$
- This future produced amount of a product is imported with the production plan

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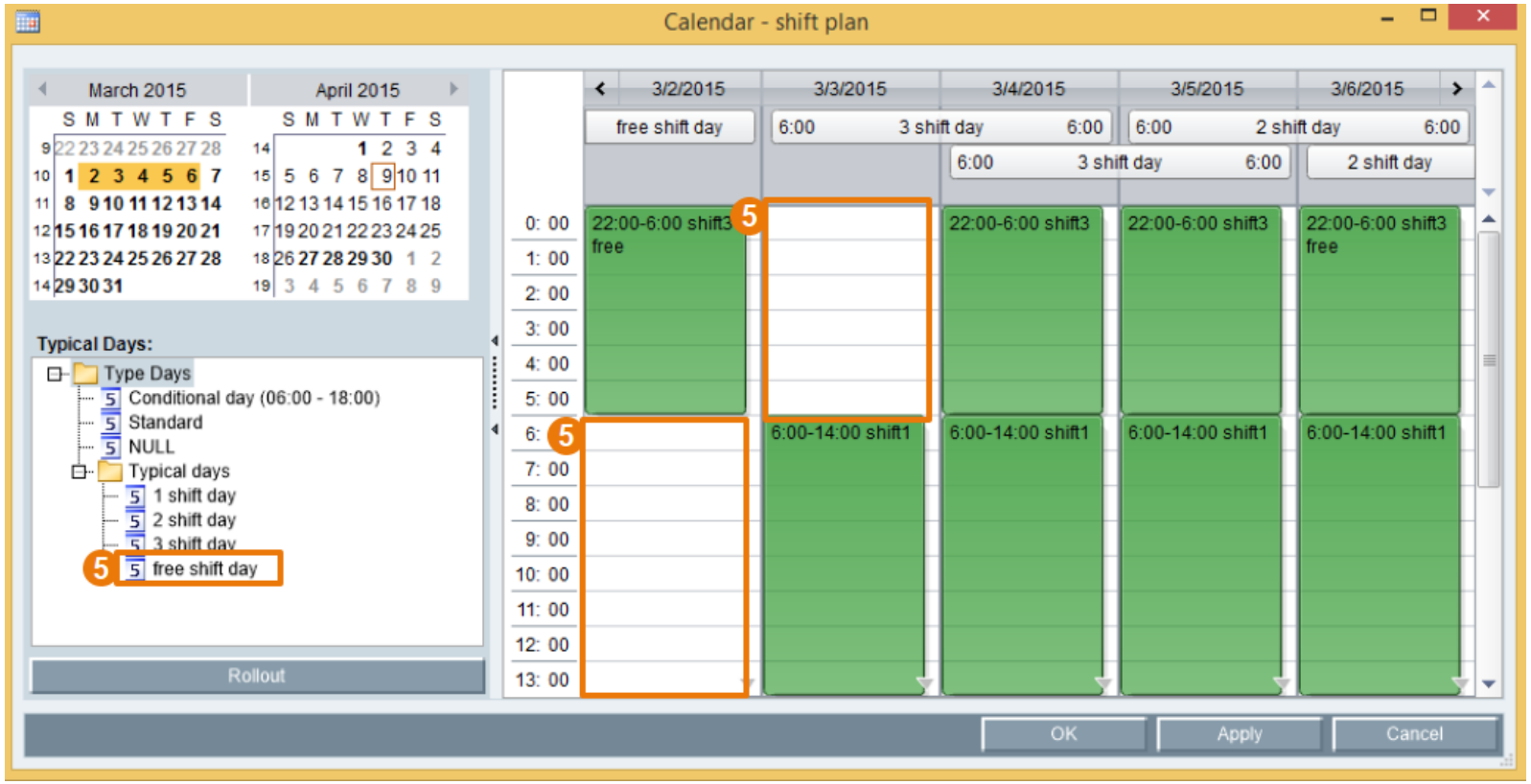
(3) Forecasting based on shifts



Note: In this example, 4 typical days are needed.

- 1 shift day (Saturday)
- 2 shift day (Friday and Thursday)
- 3 shift day (Monday till Wednesday)
- Free shift (Sunday and Holidays)

Prediction based on shifts delivers two main statements of a particular shift :

- Firstly, average energy consumption of intervals over a past time period (e.g. hourly average consumption of a shift over a month in the past)
- based on that, the predicted consumption of intervals over a future time period (e.g. predicted hourly consumption over a month in the future)

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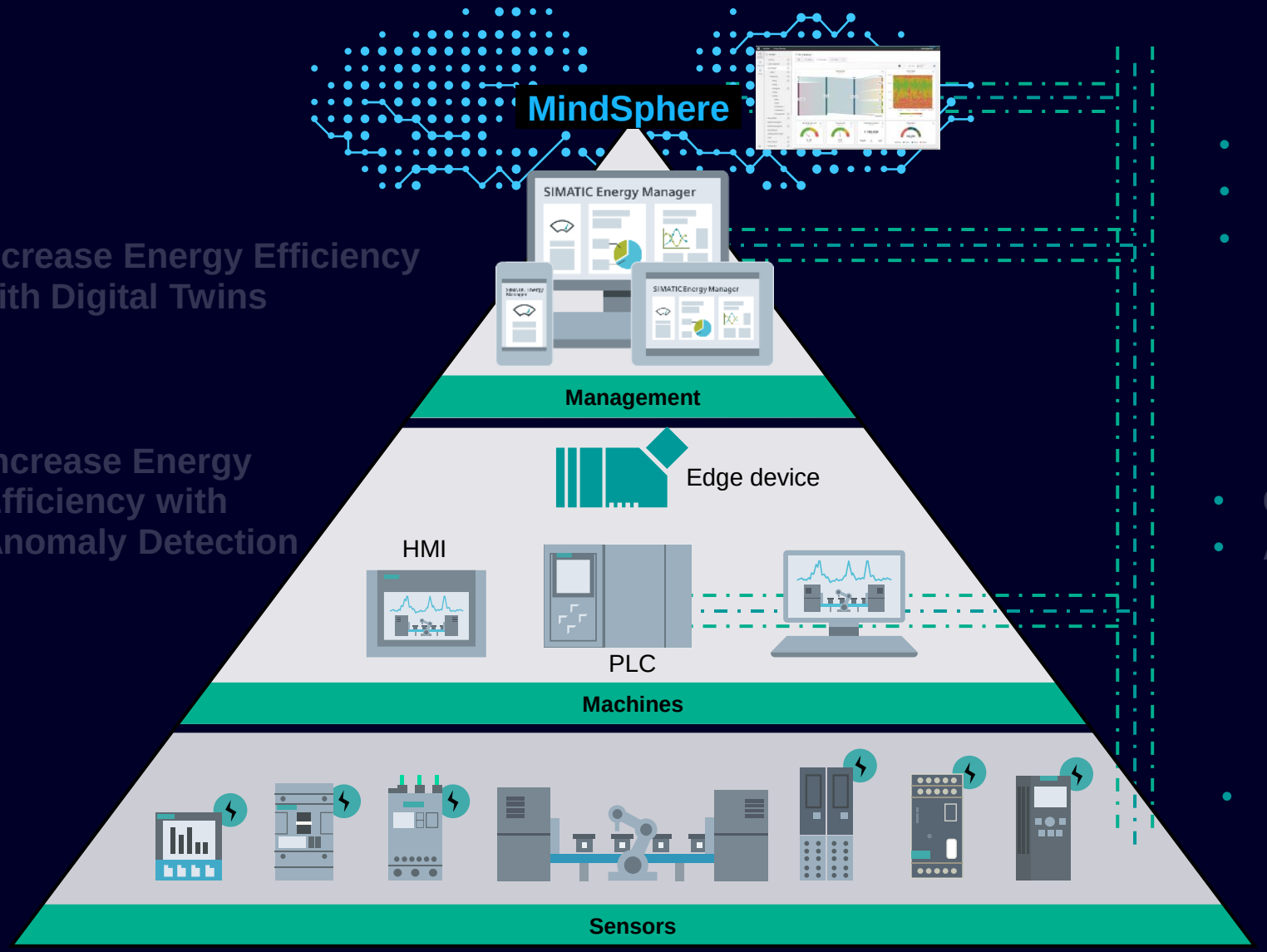

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Comply to ISO 50001 Measure Management

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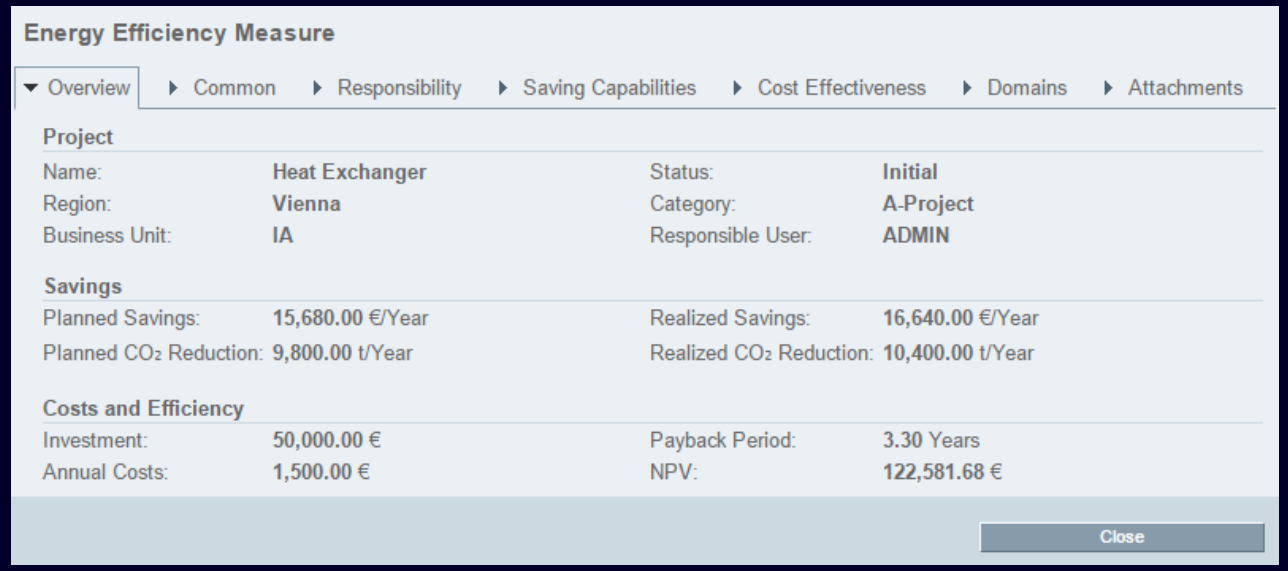
- Overview about all energy efficiency measures
- Log real savings for each measure
- Overview about possible savings considering costs and CO2 emissions



Return of Investment (ROI)

the relation between the planned savings and the investment.

Pay back period

The required duration which is needed in order to generate the invested capital

Net present value (NPV)

The value of future payment in the present

Provides information about how much and where you should spend your money

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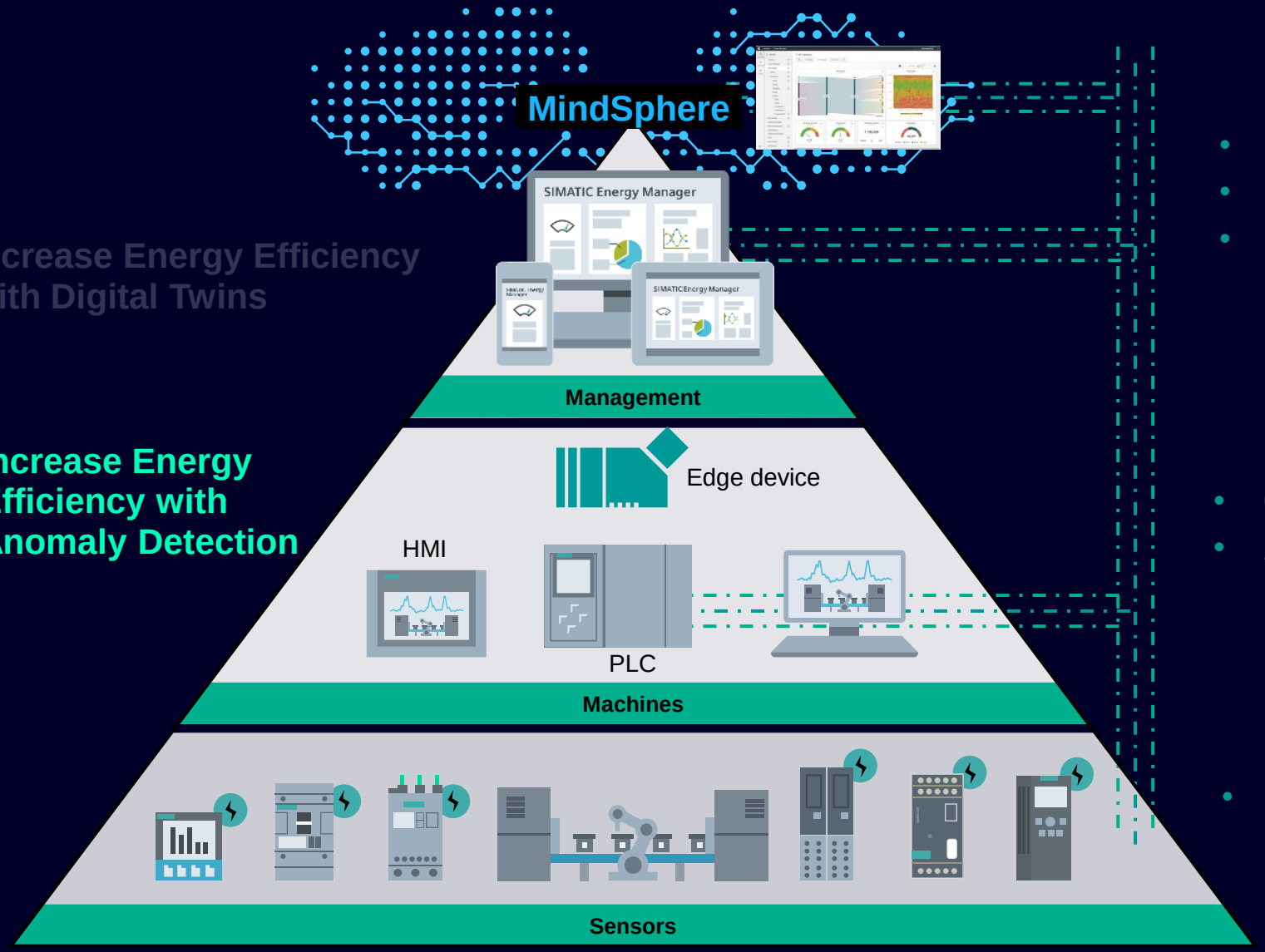
Energy management at different levels



- Increase Energy Efficiency with Digital Twins

- **Increase Energy Efficiency with Anomaly Detection**

- Analyze energy data
- Forecast energy consumption
- Manage efficiency measures

- Calculate machine efficiency
- Avoid load peaks

- Collect energy data

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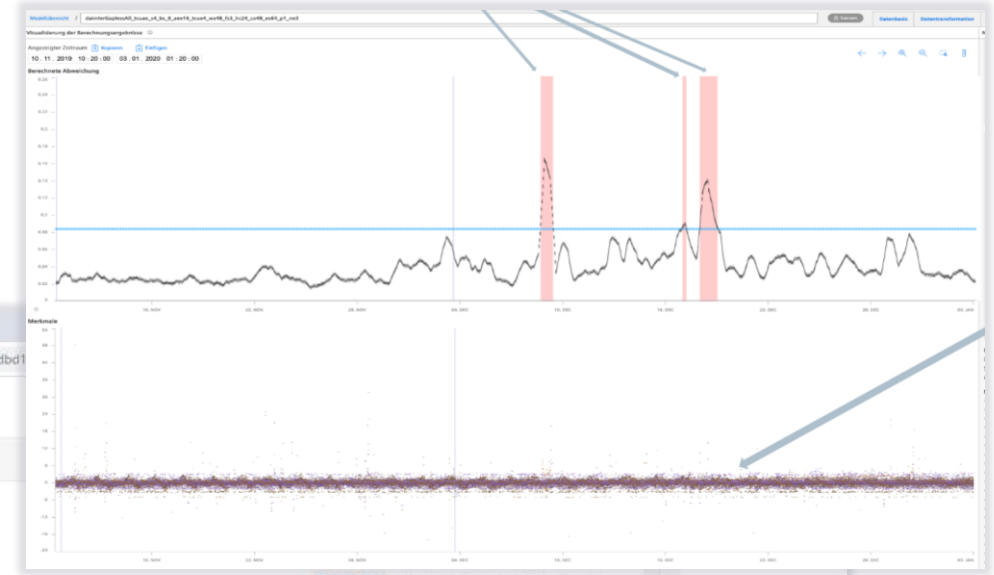
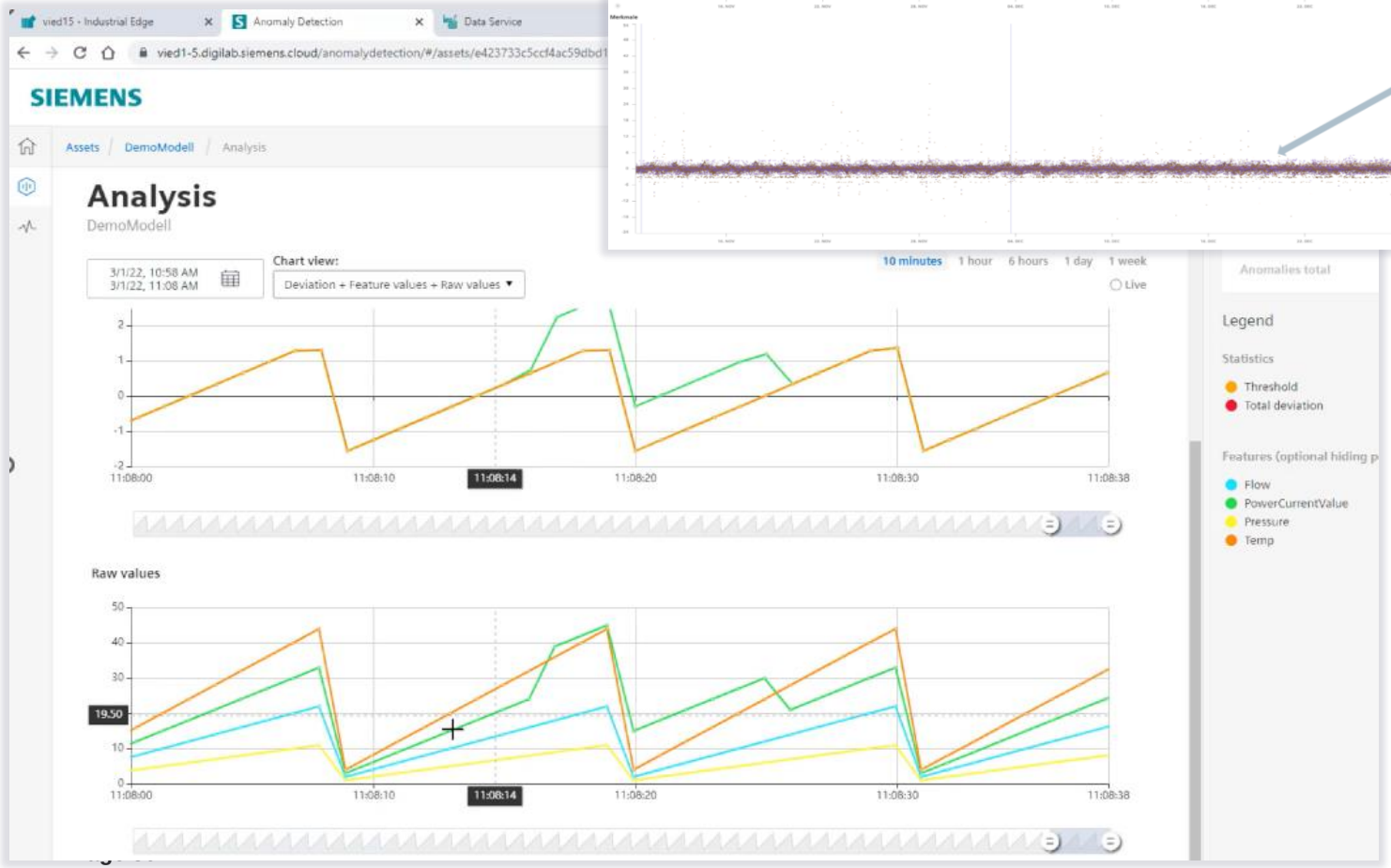
Anomaly Detection





AI/Analytics methods of Anomaly Detection enable you to detect abnormal behavior, signs of damage, or vulnerabilities in production processes very early, long before they affect the entire production.

- **Full Relationship Analysis**, (FRA) which relates each input dimension to all other dimensions at each point in time
- **Deep Time Analysis** (DTA), adds temporal behavior (behavior across time) to the algorithm as a causal structure, including the corresponding context

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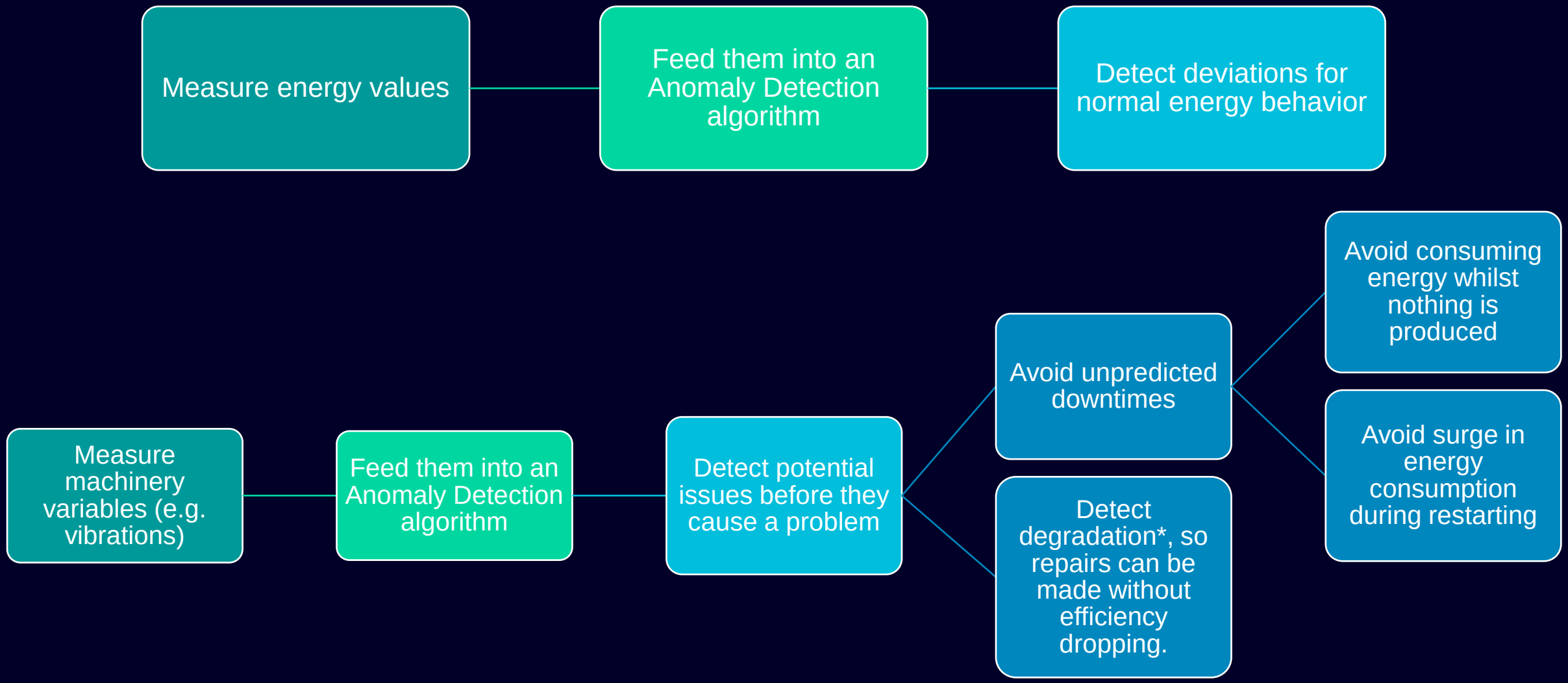
Energy efficiency via Anomaly Detection



(*) Machinery running in a degraded state typically uses more energy and reduces potential output.

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Product Pump
> Mixing Station

ROI < 3 months

⬇0.8% ⬇2.2k€ ⬆3d

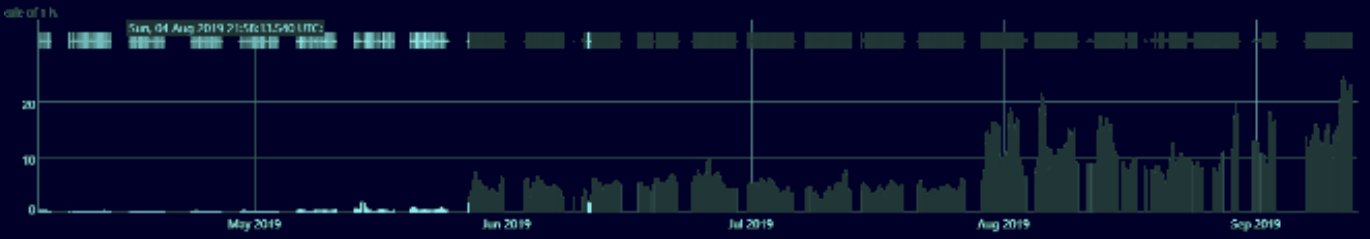
Reduced Losses | Avoided Cost* | Time to failure

* Potential cost savings for one incidence

Saving Potentials with SITRANS SCM IQ

CIP Time	372.-
CIP Medium	16.-
Yield	710.-
Energy	1.133.-
	2.231.- per failure

- Reduction in utilities losses – steam, heating, cooling
- Reduced secondary damage / cost of repair
- Avoid emergency spare part delivery



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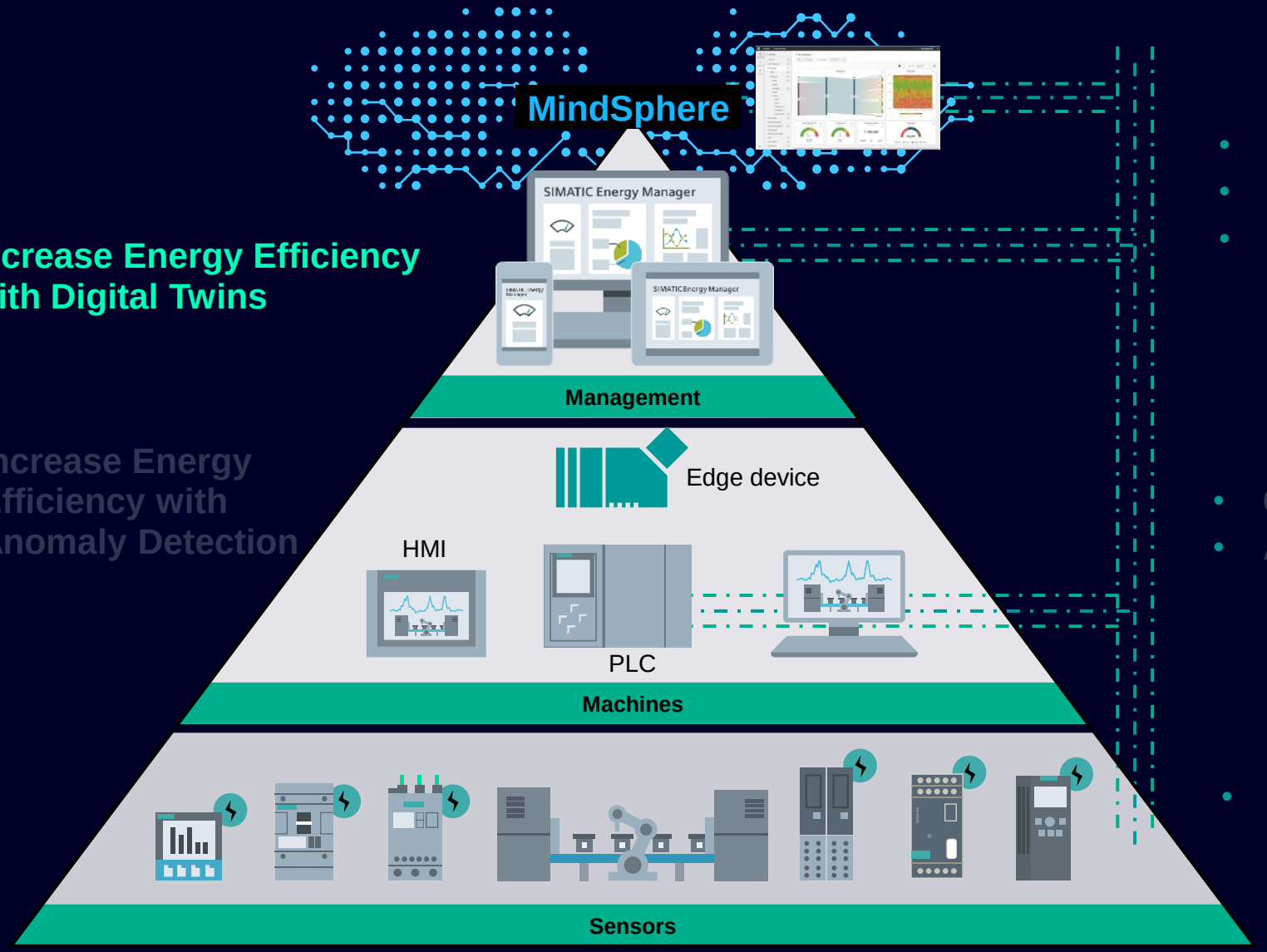
Energy management at different levels

- **Increase Energy Efficiency with Digital Twins**

- Increase Energy Efficiency with Anomaly Detection



- Analyze energy data
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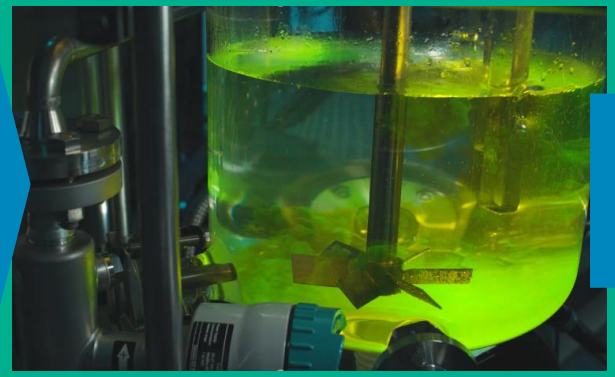
What is a digital twin?

A **digital twin** is a virtual representation that serves as the real-time digital counterpart of a physical object or process.

Physical World

Operational Factors
operational parameters e.g. temperature, speed, acceleration, operation time

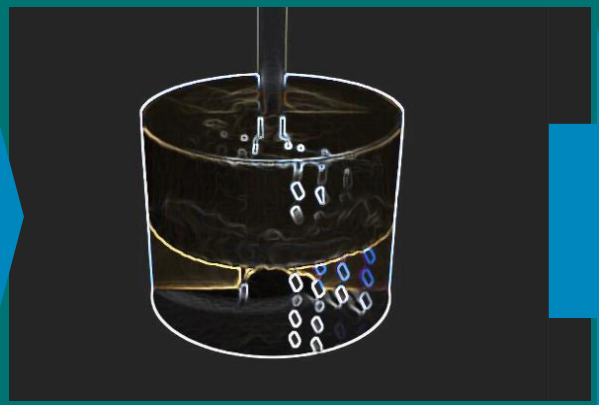


Behavior of a real object
As output e.g. Energy consumption, throughput of a line, deformation of a bottle

Virtual World

Input

Operational Data
operational parameters e.g. temperature, speed, acceleration, operation time



Output

Behavior of digital twin
As output e.g. Energy consumption, throughput of a line, deformation of a bottle

Behavior estimation
Behavior of digital twin reflects a approximate behavior in certain aspects of a real object

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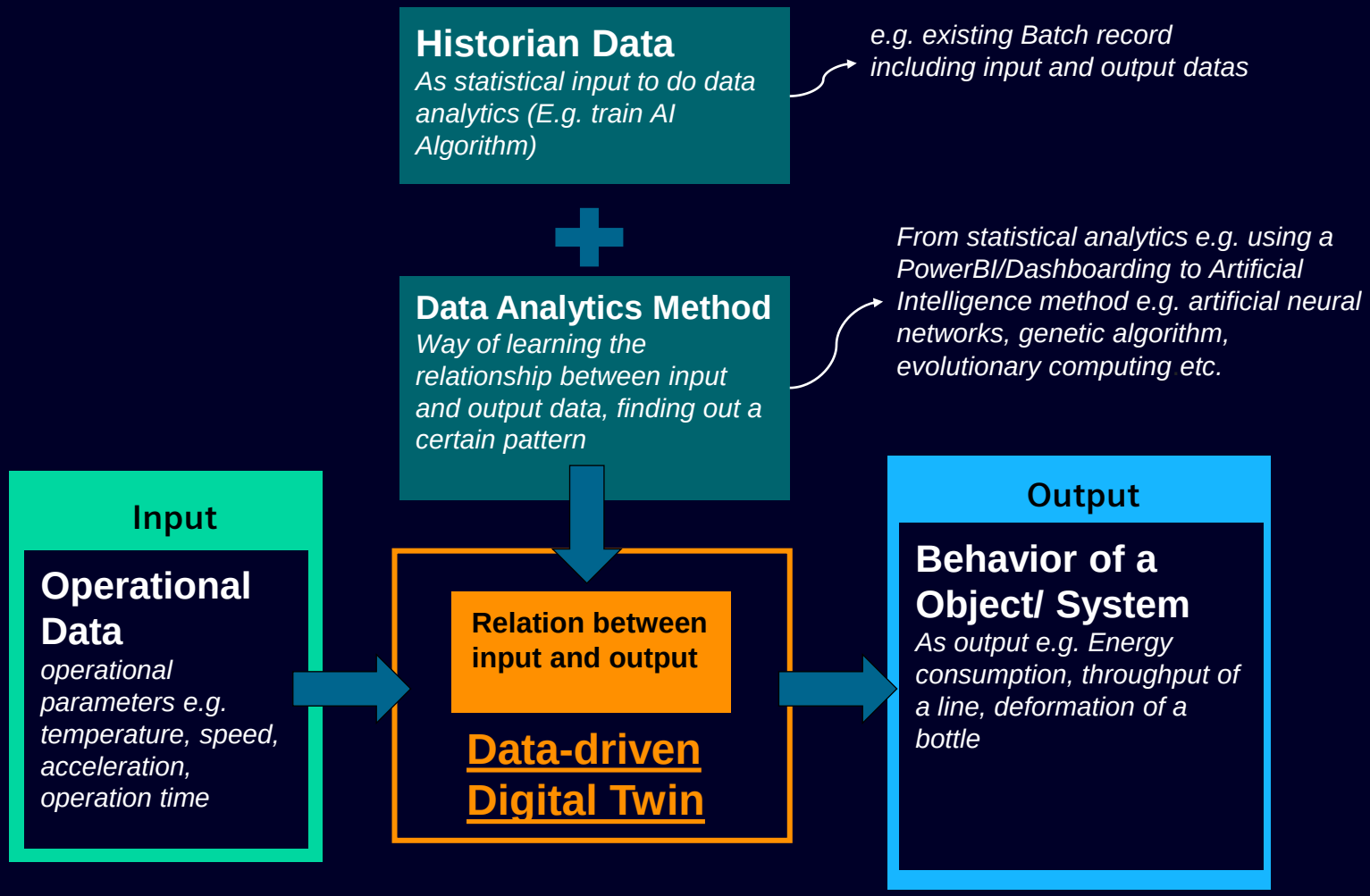
Data-driven Digital Twin

A Data-driven Digital Twin is a sorted data sets that reflects the relation between the input and output. Based on enough amount of historian data, it can be a statistical analytics via dashboarding with certain filter, or it can be trained by AI algorithm.



Use- case

Process optimization

By analyzing the data and define the best operational data

Behavior prediction

e.g. finding certain pattern that happened in the past and deliver the closest result

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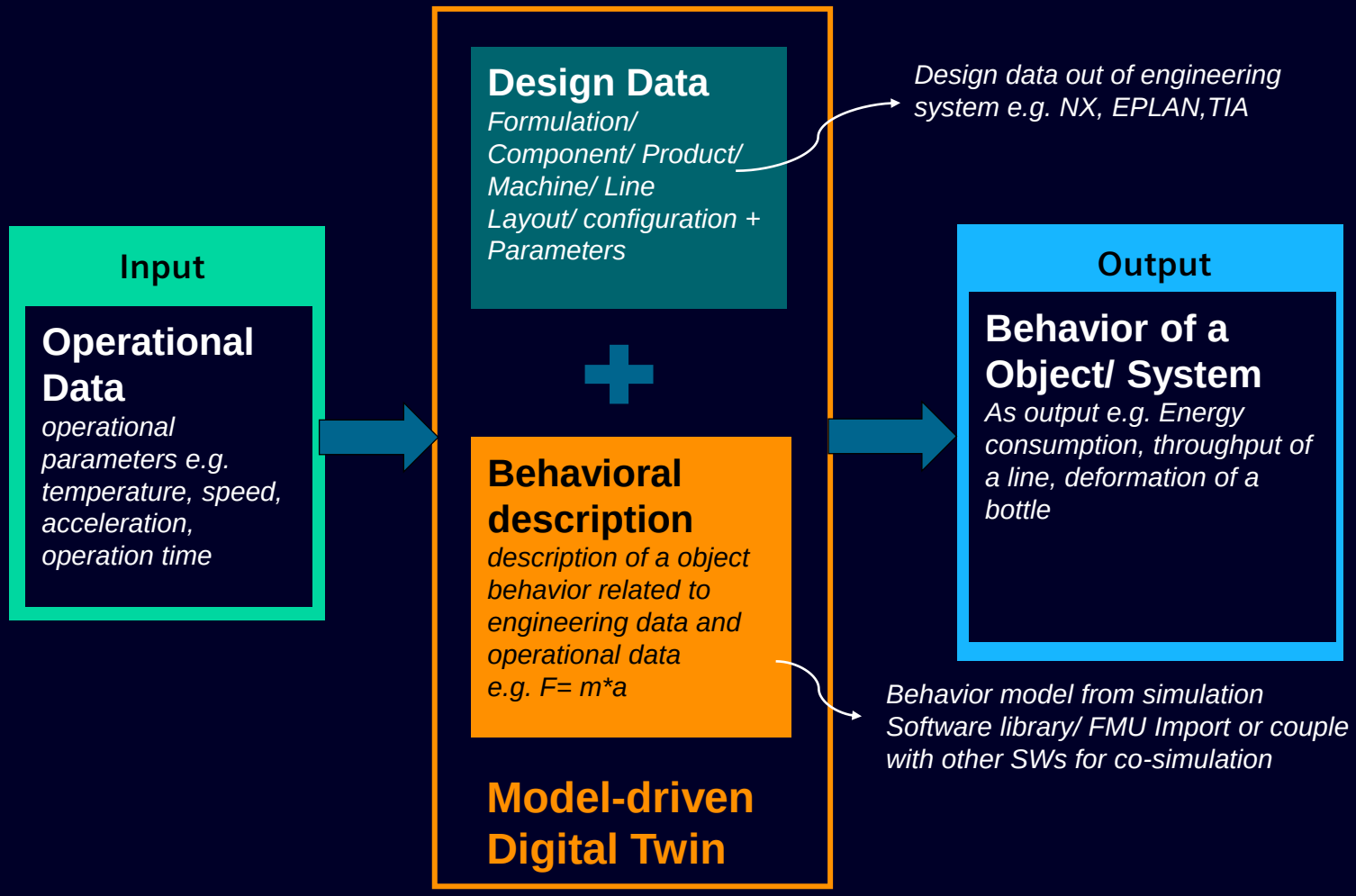
Model-driven Digital Twin

The Model- Digital Twin is the semantically linked collection of the relevant digital artefacts including design data + behavior description. It receives operational data as input, as result, it can show a certain behavior of a certain object or a system.



Use-cases

Process optimization

By adjusting certain operational data to reach the best outcome of the operation

Design optimization

By adapting design/ engineering data to achieve the desired behavior

Behavior prediction

e.g. virtual sensors, predictive maintenance, quality prediction

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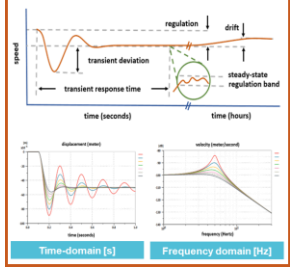
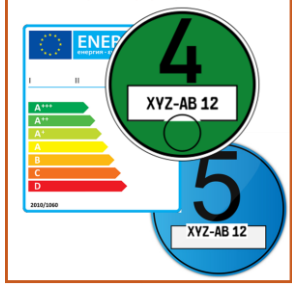
Model-driven Digital Twin

Model based system simulation

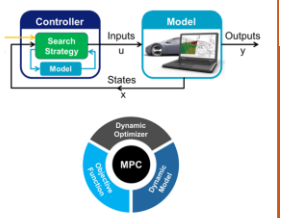
System design and dynamics

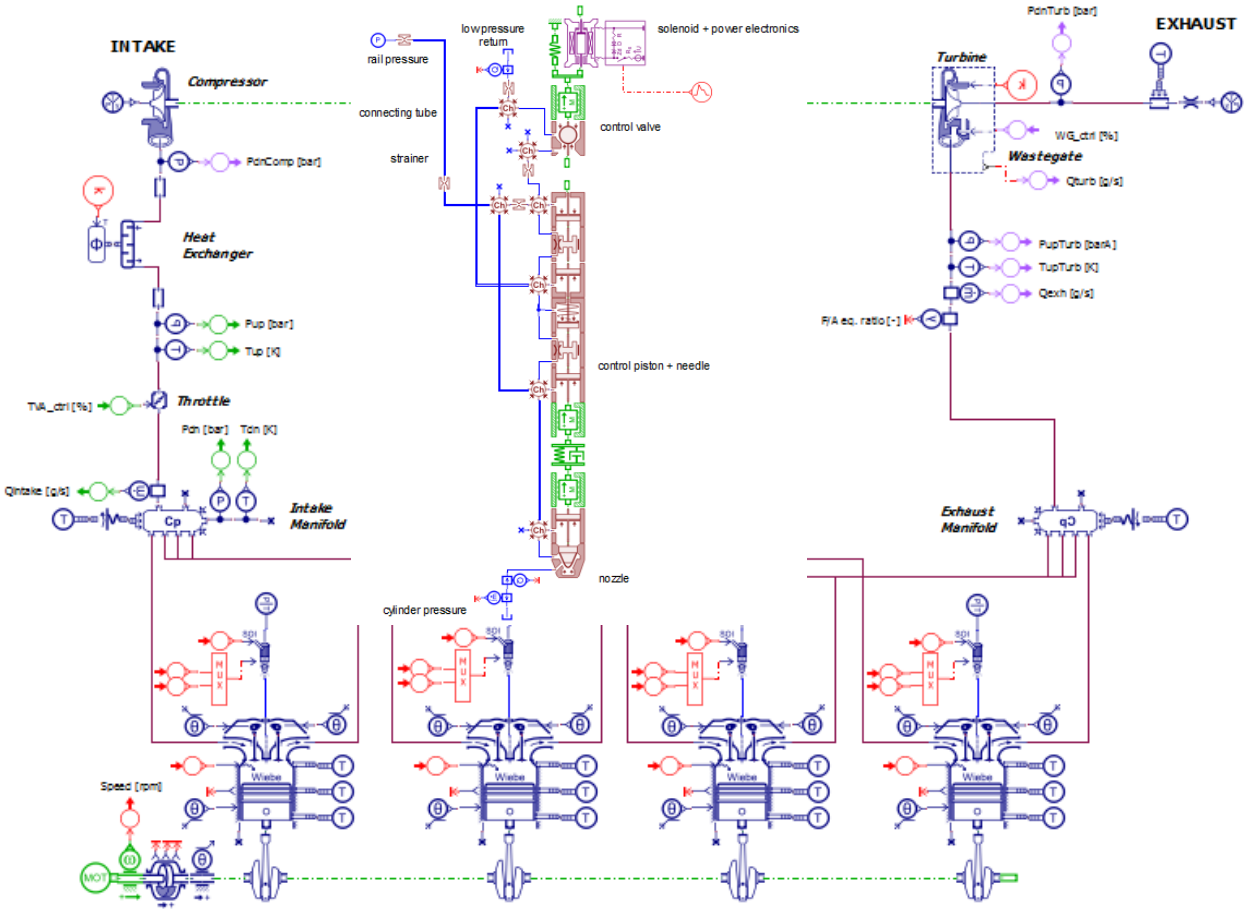


Energy, emissions



Physical controlled systems





Simcenter Amesim addresses 3 pillars for designing smart products:

- **System design.** Predict dynamic behaviors with time responses, transients and drifts with time.
- **Green design.** Simcenter Amesim addresses energy management capabilities to identify losses and to optimize energy saving.
- **Plant models for controls.** The plant model includes the physical system with its actuators and sensors.
- **Libraries** Signal and controls, Mechanics, Hydraulics, Pneumatics, Electrics and Electro-mechanics, Energy storage, Battery, Thermal and Thermodynamics, IC Engine, Exhaust, Aerospace and Defense

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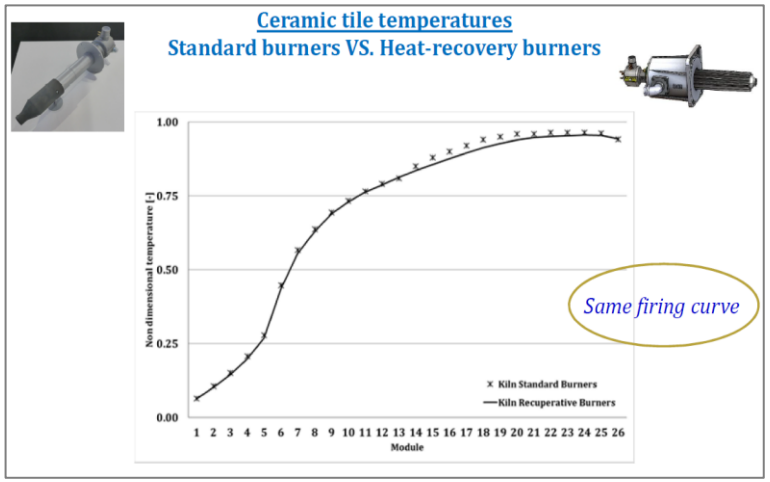
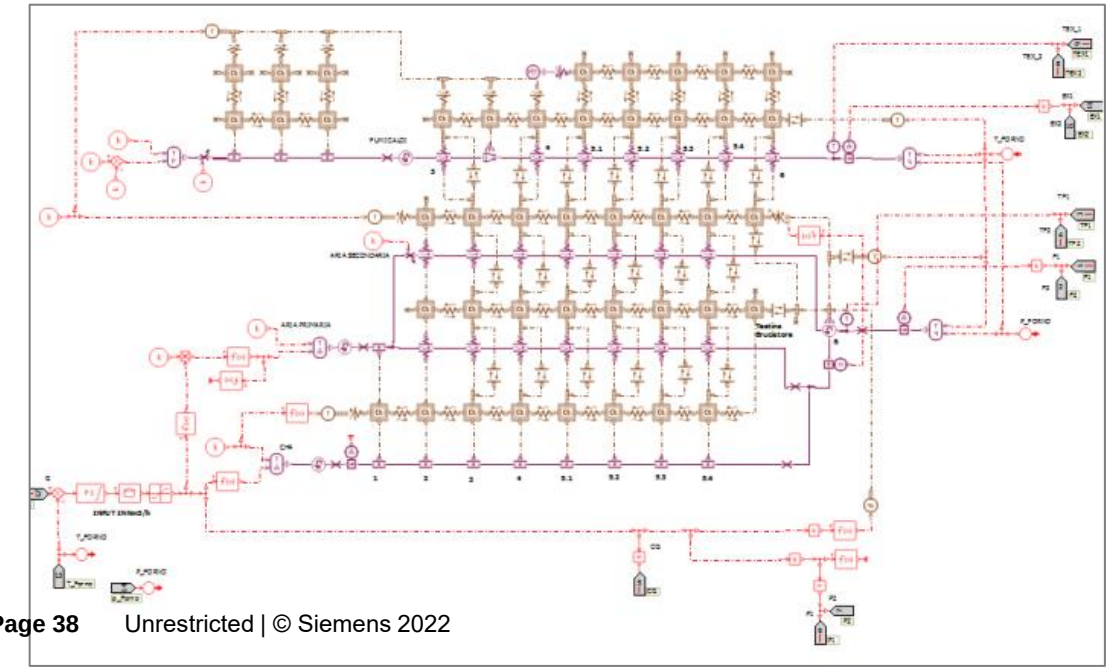
Model-driven Digital Twin

Energy efficiency analysis of a ceramic kiln under operating conditions





- Simulate a kiln under actual operating conditions (Length = 90m, Production rate = 5000 kg/h)
- Simulated phenomena: Gas physical properties, Air Flow, Thermal exchange, Tiles motion, Time dependency, Kiln materials, Insulation, Temperature control strategy
- Compare with simulation standard burners vs heat-recovery burners holding constant the product quality
- Kiln fuel (CH4) consumption reduced by 10%

Source: "Combined numerical approach for the energy efficiency analysis of a ceramic kiln under actual operating conditions", *STAR Global Conference 2017 – BERLIN*

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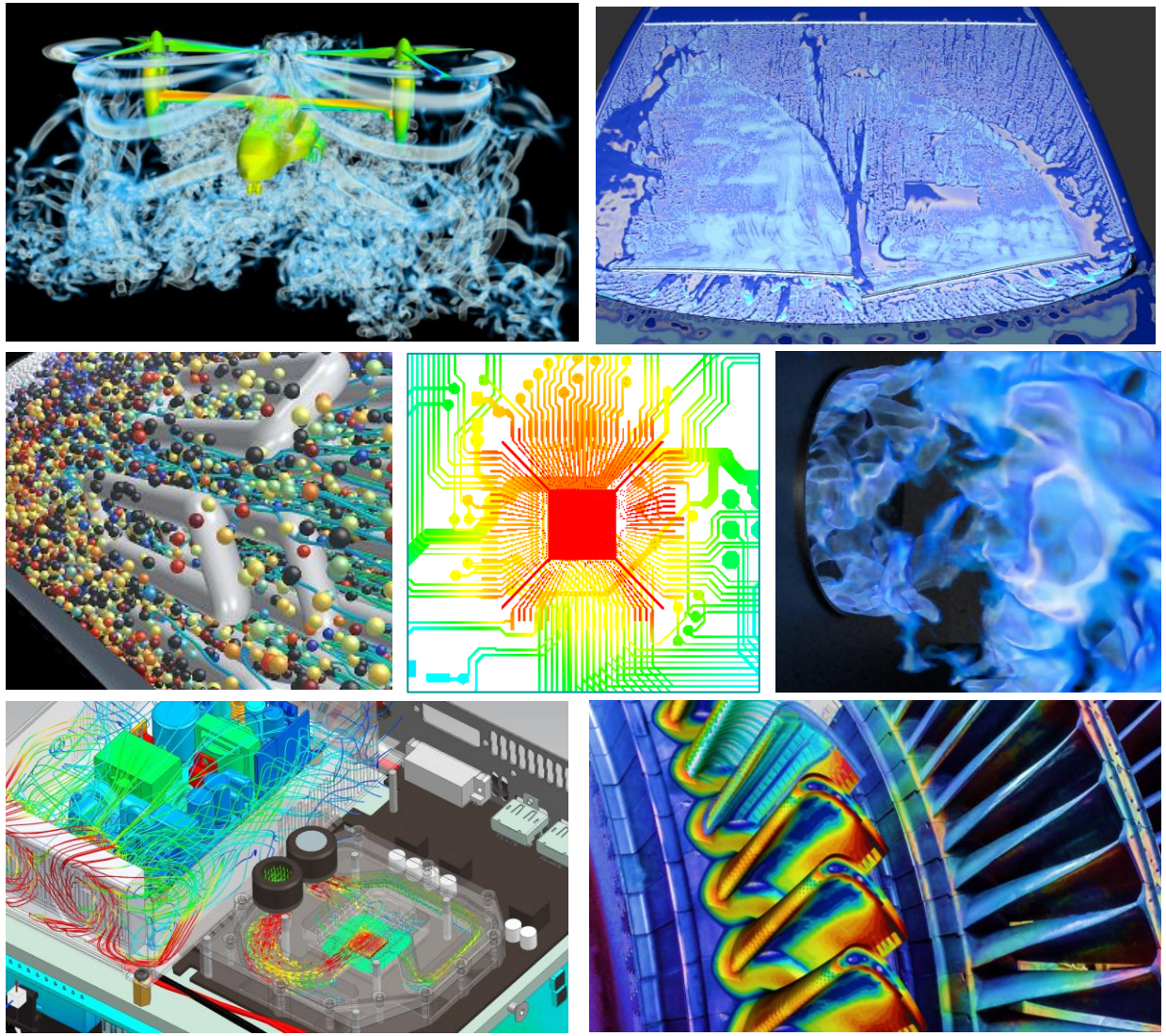
Model-driven Digital Twin
3D Multiphysics simulation



- Multiphysics simulation comes into its own when more than one physics is coupled:
  - Flow and Heat Transfer
  - Particles
  - Solid Mechanics
  - Electro-magnetics
  - Reactions and electro-chemistry
  - Multiphase

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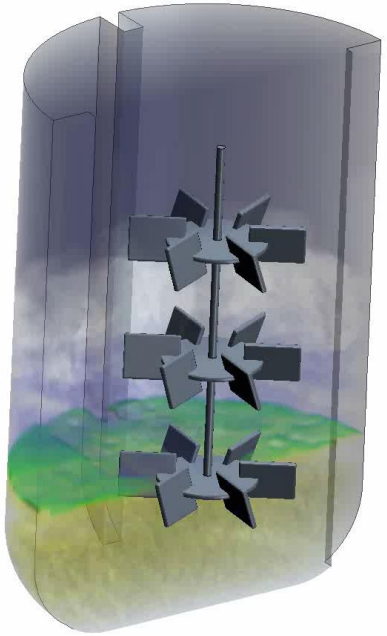
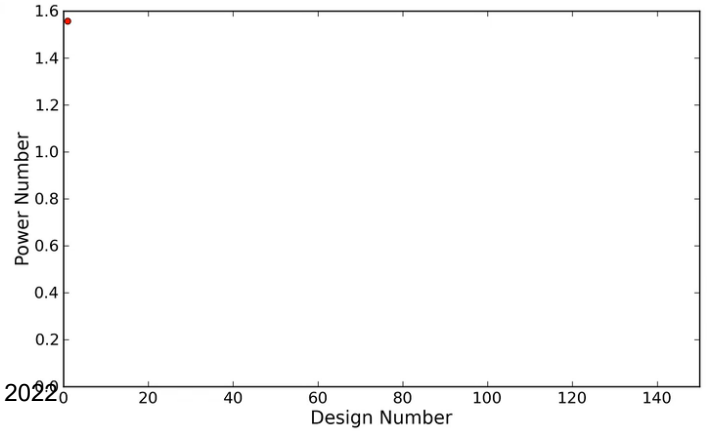
Model-driven Digital Twin
Reduce power consumption for ethanol production



Blend Time: 0.010 (s)
Power Number: 11.605

Simcenter HEEDS
Design Space Exploration
Look for better design alternatives

Blend Time: 0.010 (s)
Power Number: 1.921



Objectives:
- Minimize power consumption
- Maximize velocity at vessel base

Parameters/Constraints:
- Vary impeller speed
- Vary impeller position
- Vary blade pitch
- Vary blade twist angles

Results:
- 42% reduction in power consumption
- 44% increase in velocity at vessel base

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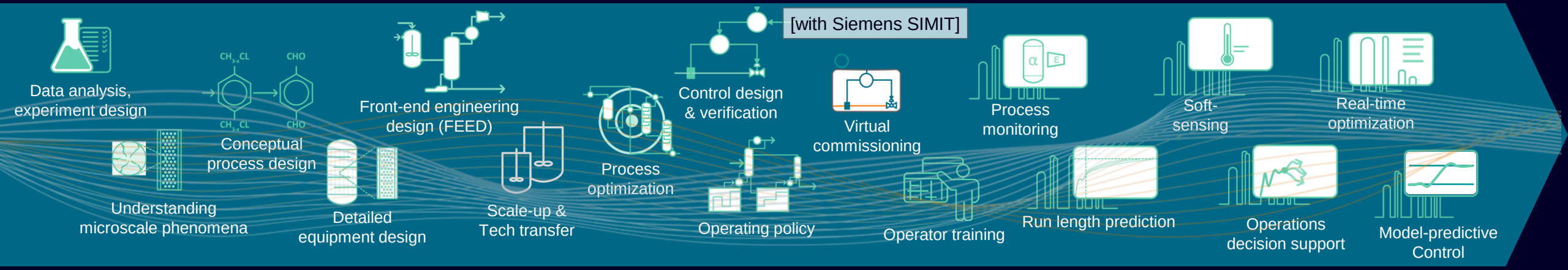
Model-driven Digital Twin
Advanced Process Modelling



Advanced process modelling is a combination of three elements:

1. **Mathematical models** based on chemical engineering first-principles theory
2. **Experimental data** – laboratory, pilot or operating plant – used to fit the empirical parameters in the model (or 'validate' the model)
3. **Advanced solution techniques** – for example, optimization – to exploit the rich information in the model and its predictive capability.

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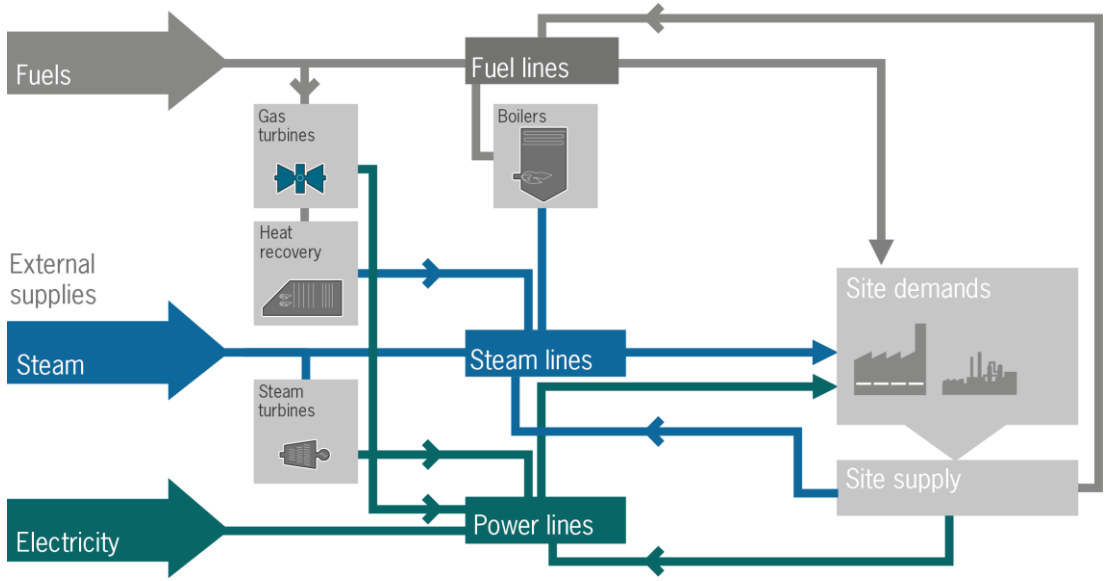
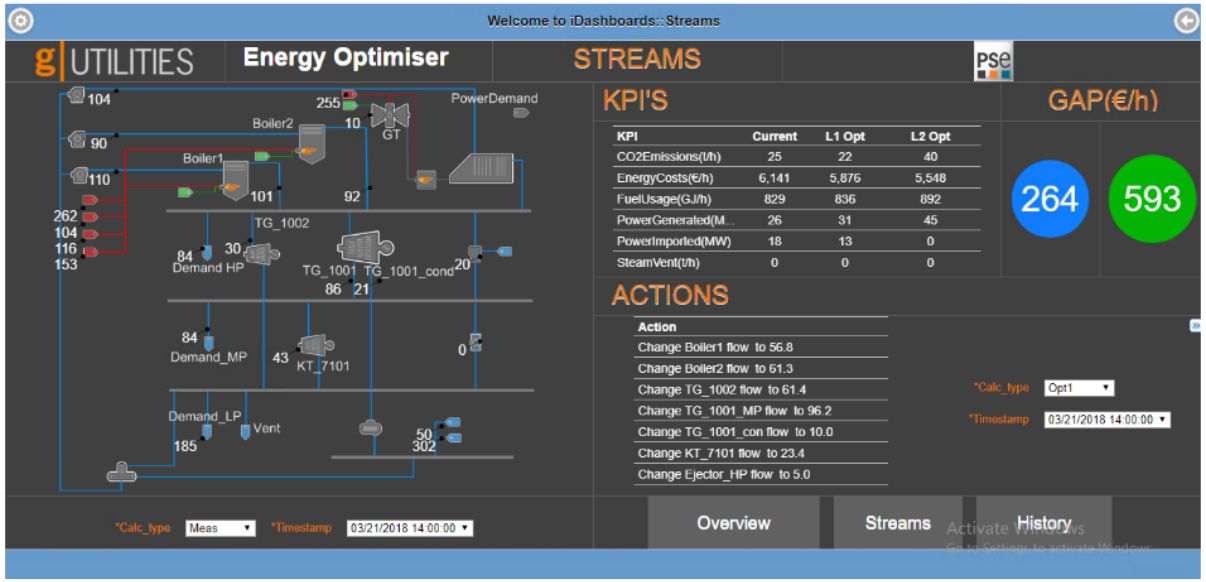
Model-driven Digital Twin
Site utilities emissions and energy cost optimization



Plants consume fuels, electricity and steam in time-varying quantities, and via multiple routes. The process plants themselves can generate steam and fuels, electricity can be sold to the grid and the prices of the various components can change hourly. Added to this complexity are day-to-day changes in major equipment availability.



Petrochemicals & Chemical

- Complexity:
  - Potentially large number of optimization decisions (fuel selection, equipment on/off, routing)
  - Mixed continuous/discrete decisions
- gPROMS Utilities finds a way through the maze by applying rigorous optimization technology, taking into account demands, prices and availability, to find the economically optimal operating profile for any situation.
- >2–5% energy improvement for ‘already optimized’ plant
- 10–15% energy improvement for unoptimized plant

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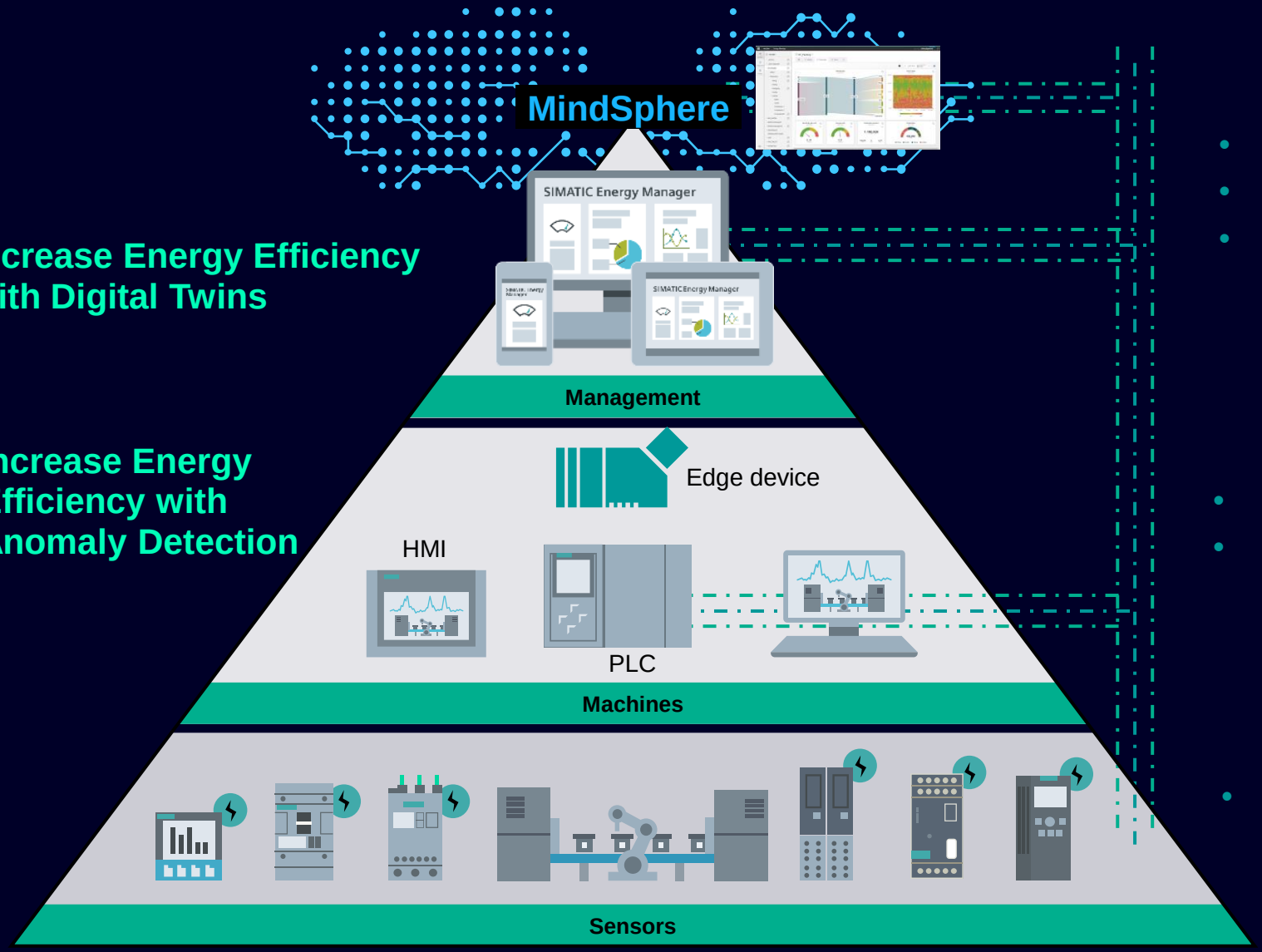
Energy management at different levels



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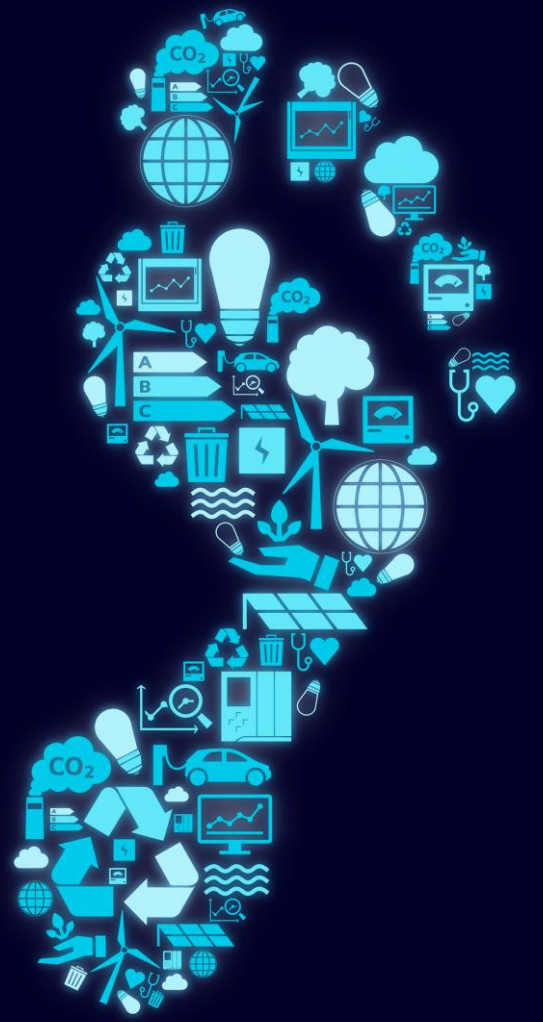
SIMATIC Energy Management
Reduce Your Carbon Footprint



siemens.com/simatic-energy-management

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