Spray Dryer Digital Twin

Achieve production excellence with physical science-based digital twins

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Food & Beverage Industries

Today’s challenges and opportunities

Empowered Consumers

High Quality Demand and Cost Pressure

Sustainability & Responsibility

Emerging Markets and Global Setup

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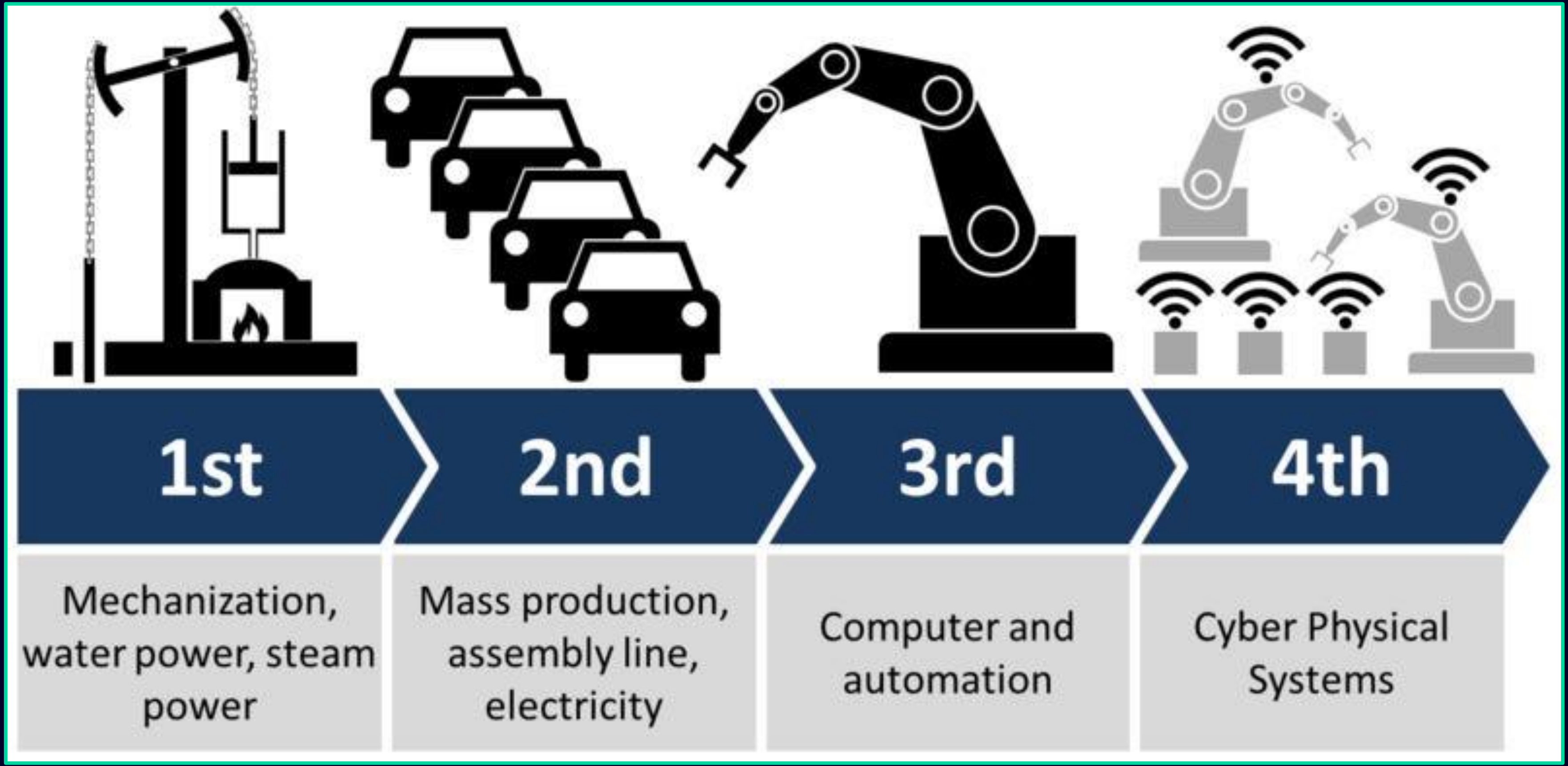
The F&B Industry is evolving again to meet these challenges

Process automation & optimisation is one of the biggest focus areas for innovation by food manufacturers, with 73% of manufacturers investing in the area



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How organizations are affected by the current challenges in the food and beverage industry

STATUS QUO IS INSUFFICIENT

to achieve <u>production excellence</u> in a <u>rapidly changing market</u>

due to the high degree of (manual) iteration in the innovation process across the food & beverage lifecycle

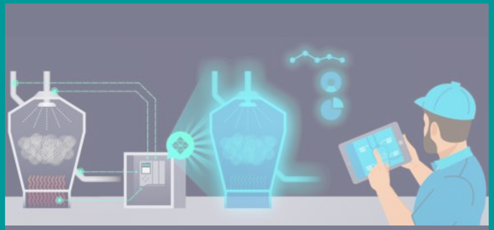
DIGITAL TRANSFORMATION

is required to achieve business objectives

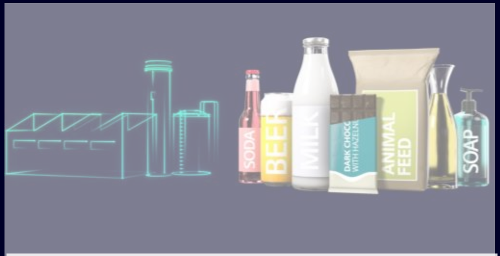
Our mission for food & beverage

"Achieve **production excellence** for a **sustainable** future"

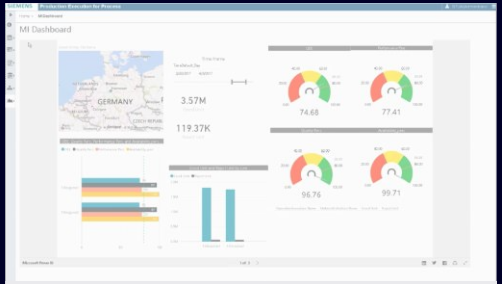
through the rapid configuration, calibration and deployment of science-based, data-calibrated digital twins



Digital twin of production



Digital twin of product



Digital twin of performance

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gPROMS – The Benefit of a Single Integrated Environment

Providing a unified approach to digital design and digital operations

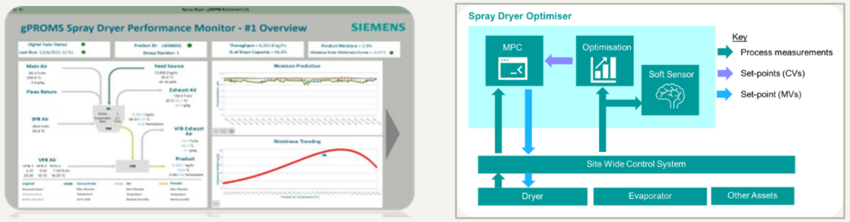
Digital Design

Desktop and web tools for true digital design

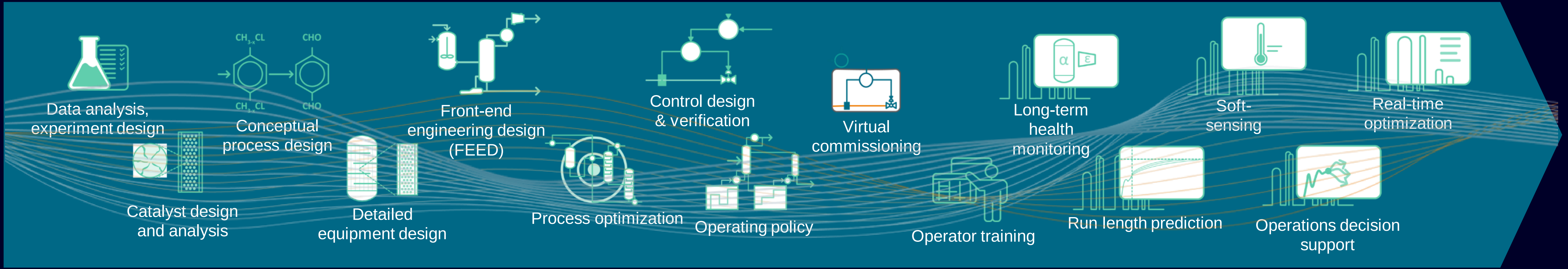
Accelerated innovation. Optimized process designs. Reduced experimentation.

Digital Operations

Model-based applications for real-time operations decision support



Optimized operation. Better control. Better-informed operators.



R & D ENGINEERING DESIGN OPERATIONS

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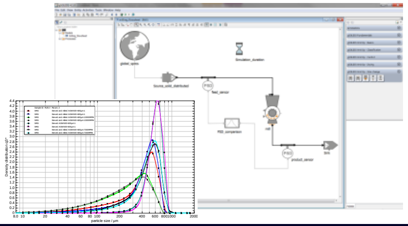
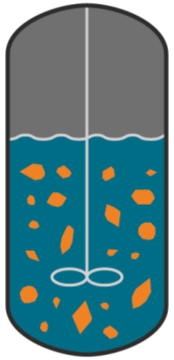
Delivering value to the F&B Industries

Optimisation of the batch recipe
for pharma-grade lactose
to **reduce time by 44%**

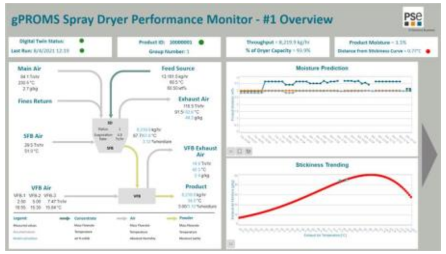
Significantly **reduced time and cost required** for experimentation and **minimised the risk** associated with **scale-up** of mills



Designing crystallizer modifications resulting in a **25% increase in filtration capacity**



Siemens' spray dryer optimizer enabled a **5% product moisture uplift** and **30% product variation reduction above** existing APC solution



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Working towards our mission with the food & beverage industry
Siemens' co-creation ecosystem

Food Centre of Excellence

NIZO
FOR BETTER FOOD & HEALTH

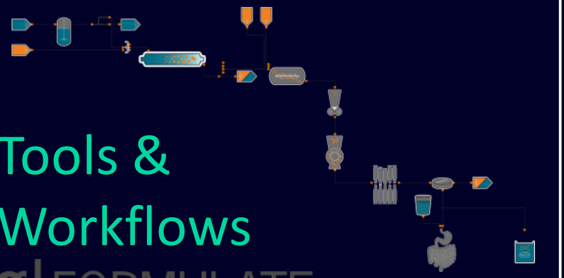
PSE
A Siemens Business

Food Advisory Board: coordination, & industry adoption

DANONE
FrieslandCampina
Nestlé
Abbott Nutrition
Avebe
Unilever

SPSE experience in, and developments for, other industry sectors

Tools & Workflows



g|FORMULATE

gPROMS g|PROPERTIES

Collaborative R&D

The University of Nottingham

DIDCOM
Formulated Products

DPTC
DAIRY PROCESSING TECHNOLOGY CENTRE

van hall larenstein
university of applied sciences

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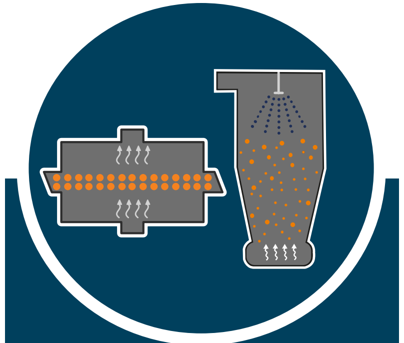
Digital Twins for the Dairy Industry

Dairy Manufacturing Applications

- ✓ Troubleshooting
- ✓ Monitor operating envelope
- ✓ Predict product attributes
- ✓ Enable real-time optimisation



MULTI-STAGE DRYING

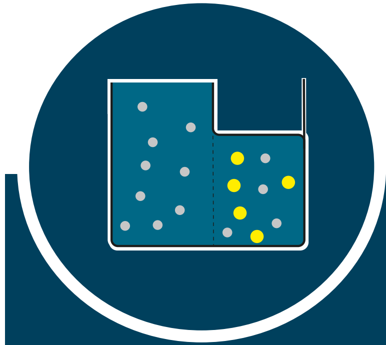
Maximise **drying capacity** & **throughput**

Reduce **fouling** due to stickiness

CRYSTALLIZATION

Meet **product quality attributes**

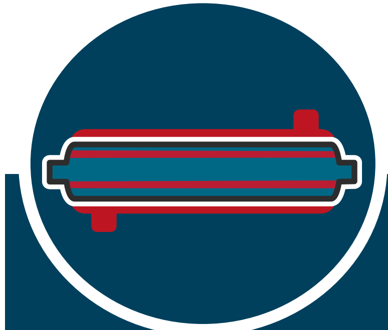
Reduce **batch time**



MEMBRANE FILTRATION

Reduce **fouling** & maximise **throughput**

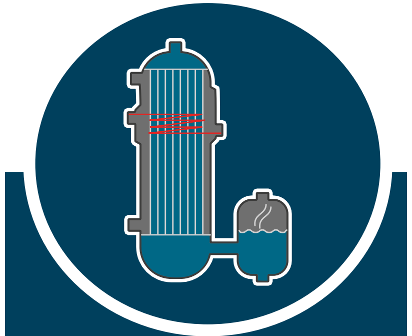
Optimize **configuration** & **control strategies**



HEAT TREATMENT

Ensure **product safety**

Increase **product quality**



FALLING FILM EVAPORATORS

Avoid **product fouling** in evaporator tubes

Reduce **energy consumption**

SEMI-HARD CHEESE MANUFACTURING

Troubleshoot **process interruptions**

Maximise **batch yields**

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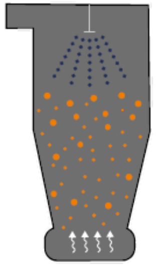
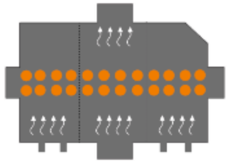
Spray Drying Process Models – Overview

- The spray drying model library can be used for single-stage and multi-stage dryers with internal and/or external fluid beds
- Models for cyclones, bag filter units etc. are also available to complete flowsheets
- The models are frequently used in the dairy industry for troubleshooting and optimisation purposes:
  - For example, the model can capture particle drying and product stickiness, helping users identify optimal operating conditions to ensure product quality and desired drying capacity

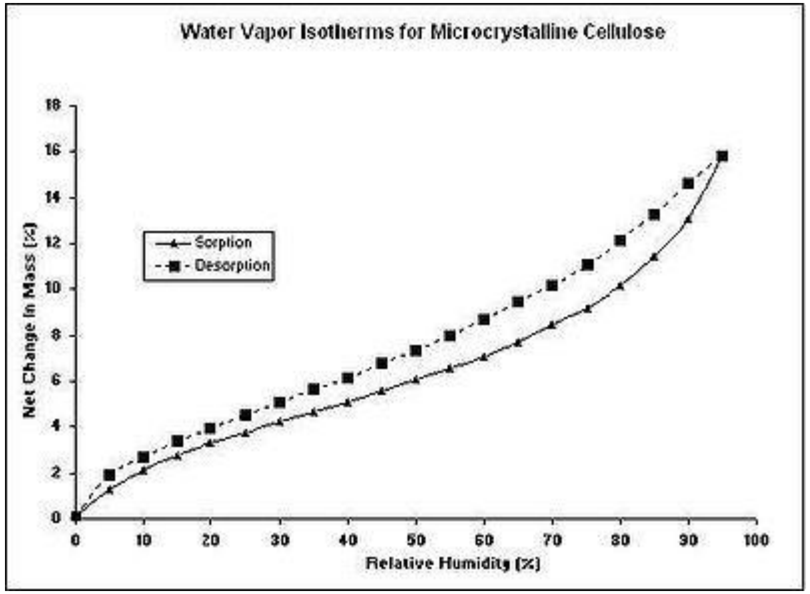
- **Spray drying library features the following:**
- Equilibrium based spray dryer
- Kinetic based spray dryer
- External fluid bed dryer
- Cyclone, baghouse etc.





Drying – sorption isotherm

- Sorption isotherm is **key** to a successful drying model
  - It defines the equilibrium moisture that can be achieved at the conditions
  - Typically measured using DVS (Dynamic Vapour Sorption)
    - Chamber with controlled environment, set humidity, measure change in mass
    - Typically want the 'desorption' curve
  - Experimental data can be fit to GAB isotherm
  - Does temperature matter?
    - Yes, they can be temperature dependent
      - But typically measured at 25^{o}C
    - Isotherms at multiple temperatures can be entered



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Near equilibrium calculation

$$X_{po} = X_{ao} + \Delta X$$

X_{po} – equilibrium moisture content of outlet dry air (kg/kg)
X_{ao} – moisture content of outlet dry air (kg/kg)
ΔX – difference from equilibrium (kg/kg)

- At equilibrium, ΔX = 0
- Equilibrium is not always reached due to atomization and residence time effects, hence near equilibrium can be considered
- For a given product and a given spray dryer, the difference from equilibrium is a function of dry solid content of feed, as this influences the atomization behaviour

$$\Delta X = A_x \left(DS_c - DS_{c,ref} \right) + B_x$$

A_x, B_x – product and dryer dependent parameters
DS_c – dry solids content of feed (kg/kg)
$DS_{c,ref}$ – reference dry solids content of feed (kg/kg)

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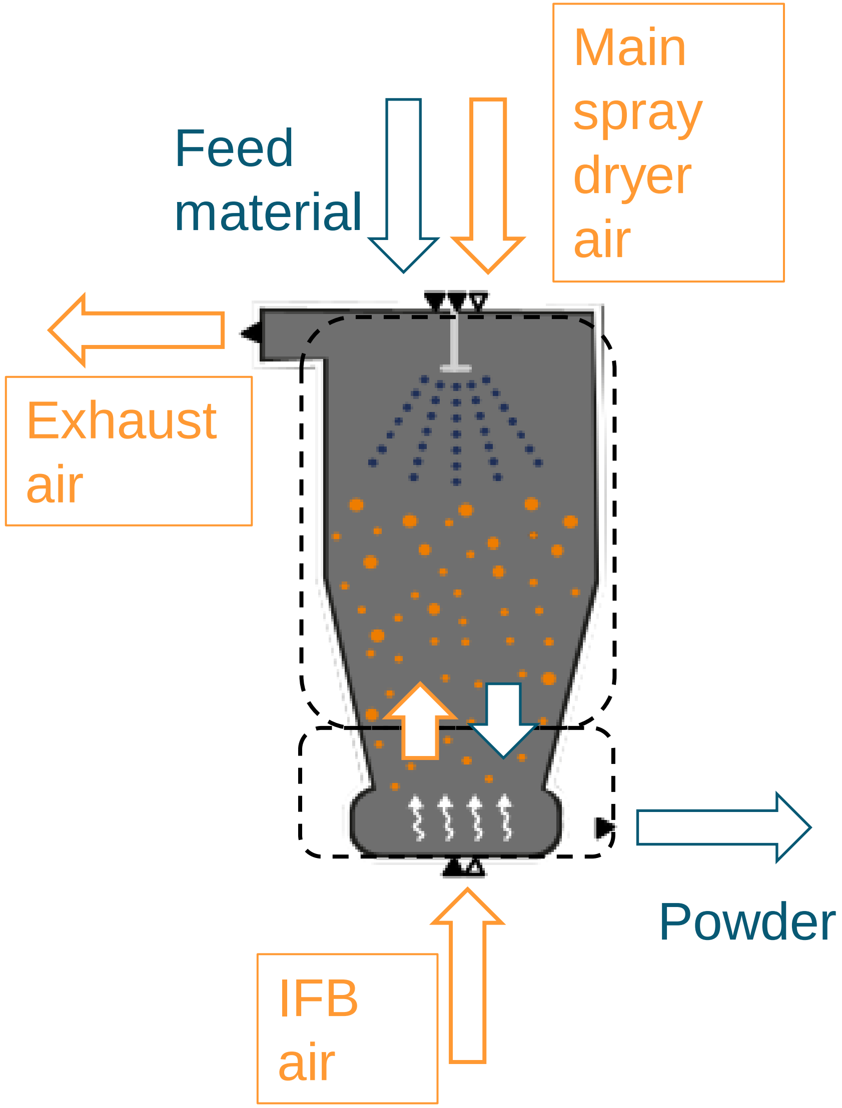
Internal fluid bed

- Internal fluid bed (IFB) can have an additional inlet air flow that passes through the bed and is mixed with the air in spray drying chamber

- The overall model is flexible and can be configured to include the IFB as a separate compartment.

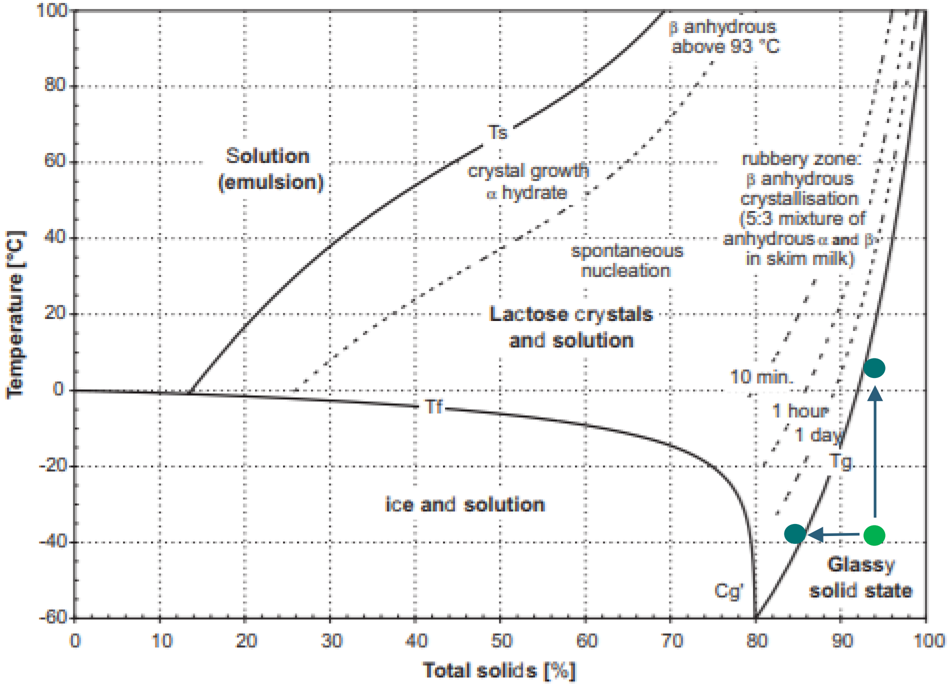
- Alternatively, the IFB compartment can excluded for either:
  - Non-IFB spray dryer installations
  - Model simplification



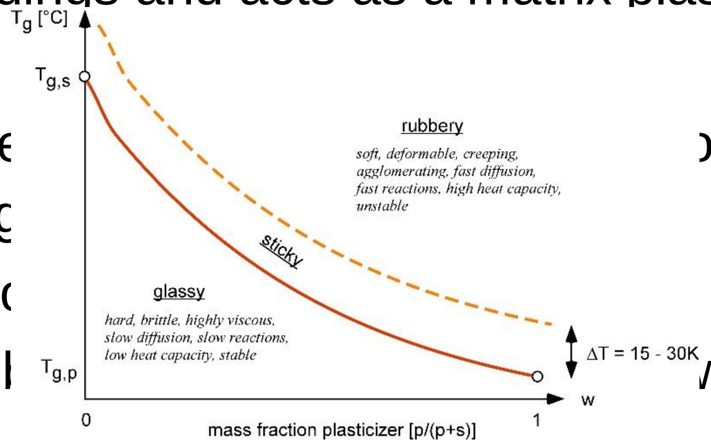
Material characterisation – glass transition temperature, T_g

- What is a glass?

- Mechanical p ... ent of a liquid
  - Meta-stable ... ent
  - Contains w ... undings and acts as a matrix plasticiser
- **Glass transi**
  - Temperatur ... nate ... a visco-elastic rubb ... l ag
  - Can be des ... ssic
  - Indicator of ... prol ... wanted agglomerat
  - Therefore, i ... ss temperature curve *particularly in dairy industry as feeds that are high in lactose are prone to sticking*



G.Vuataz, *The phase diagram of milk: a new tool for optimising the drying process*, Lait 82 (2002), 485-500, Fig. 12



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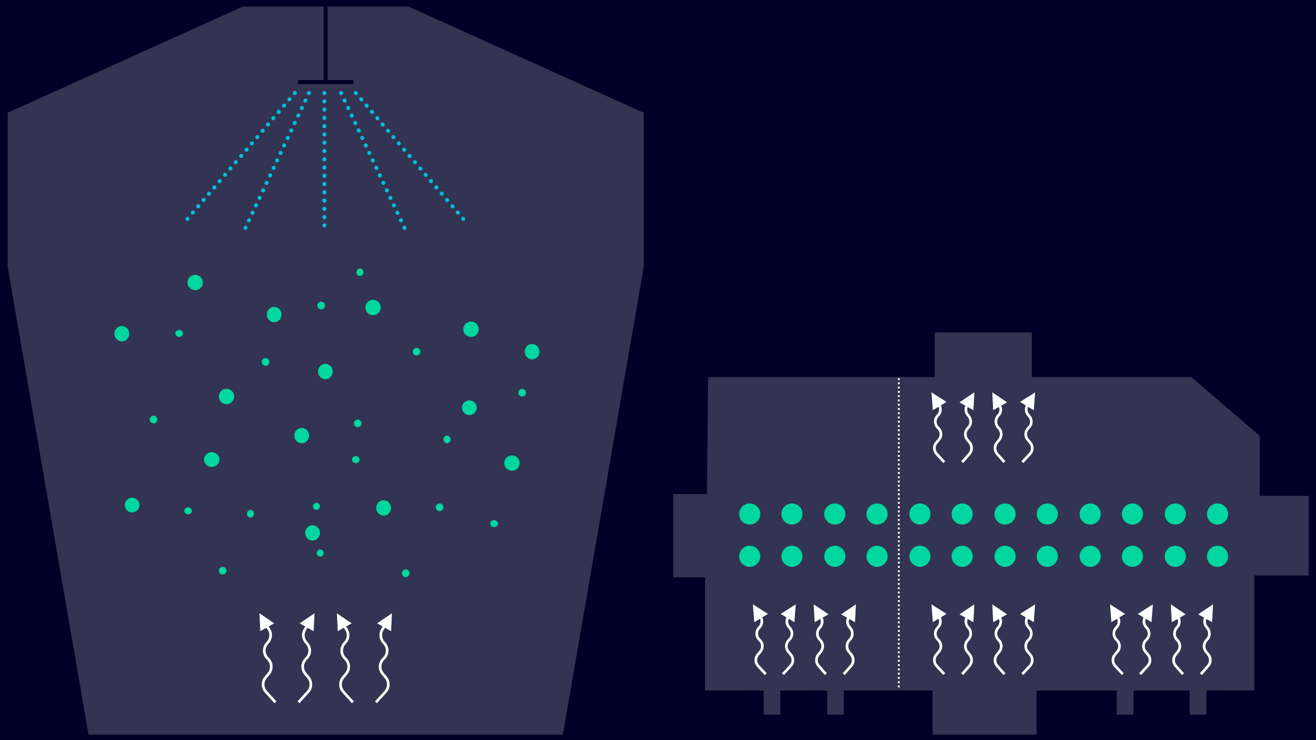
Spray Dryer Digital Twin Use Case

Spray drying

is a method of producing a dry powder from a liquid or slurry by rapidly drying with a hot air.



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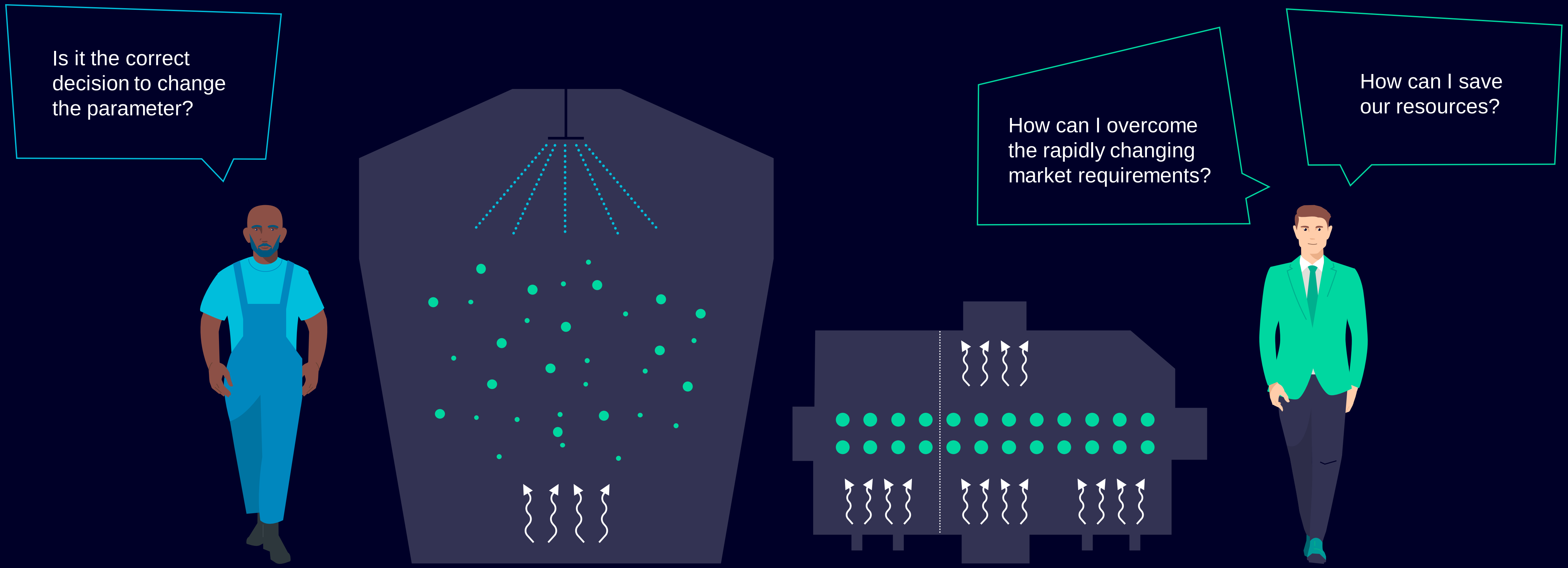
Spray Drying
Why is it important?



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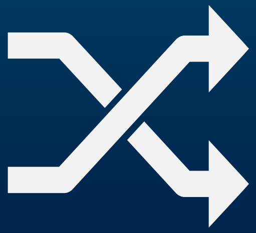
Spray drying in dairy today
Why is it important?

Increase Productivity

Support
operator decisions

More Flexibility



Overcome
rapidly changing
market requirements

Reduce Cost

Save
our resources

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Key questions in spray drying

How can I increase the moisture content in the powder?
By reducing variability in the process and operating at conditions that bring the powder moisture closer to the upper limit.

How can the throughput be increased?
By operating under the best conditions possible, subject to product and process constraints.

How can I save energy?
By running the spray dryer closer to the powder moisture specification, typically the drying temperature can be reduced and therefore energy savings can be achieved.

How can factory trials be reduced?
By capturing deep process knowledge
to accelerate determination of optimal operating parameters for new product introductions.

How can I avoid downtime due to caking?
By reducing variability in the process and operating in a safe region where the powder does not become sticky.

Example pain points and loss

Over drying of product beyond upper limit
= 0.5 wt.%
€650 k per annum operating loss

Inefficient energy usage (over drying etc.)
= up to 10% total usage
€50 k per annum operating loss

Lost throughput opportunity during peak milk
= up to 10% additional for 2 – 3 months
€200 k per annum lost revenue

Additional factory trials to introduce new products
= 1 – 2 per annum
€100 k per annum operating loss

Variations in product moisture
= +/- 20 – 30%

EXAMPLE
7.5 te/h product multi-stage dryer producing dairy products operated **without** support of process digital twins (e.g., APC, operator decision support etc.)

Unplanned stoppages (blockage etc.)
= 2 days per annum
€100 k per annum operating loss

In summary

Over €1 m untapped productivity bonus per annum on a typical dairy spray dryer*

* Numbers based on following parameters: Product value 2500 EUR / te; Spray dryer throughput: 7.5te/h powder; Operating profit margin: 10%; 80% spray dryer utilization annually; 0.03 EUR / kWh gas cost

Our solution
Siemens Spray Dryer Optimizer

Increasing productivity bonus through increased integration

Operator process training

Operator decision support

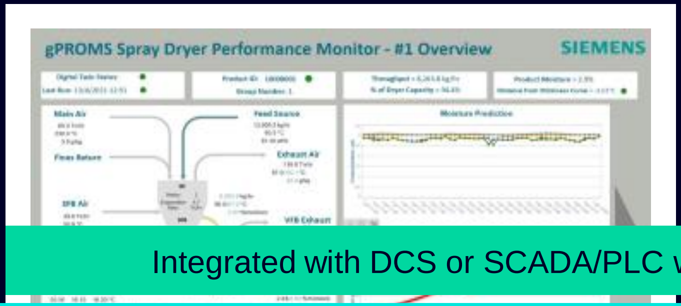
Monitoring

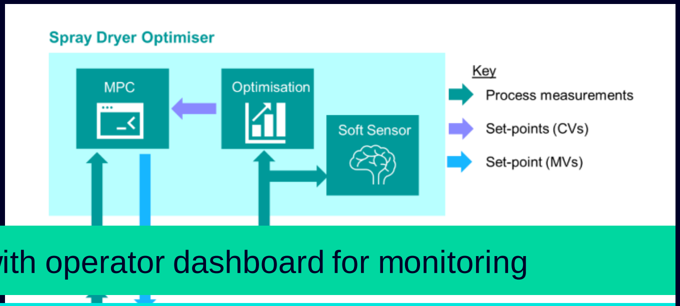
Real-time optimization

Advanced Process Control

Siemens Spray Dryer Optimizer

Internet browser-based Independent of spray dryer





Integrated with DCS or SCADA/PLC with operator dashboard for monitoring

Underpinned by the same process digital twin for your spray dryer

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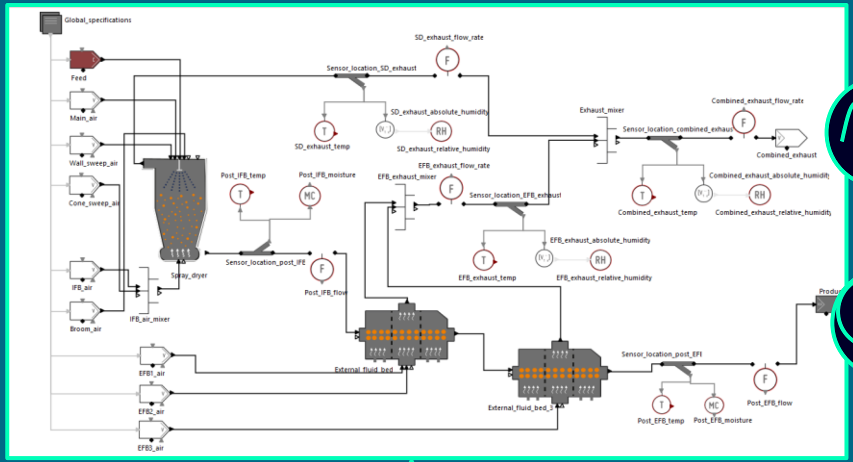
Digital Process Twins
At the heart of spray dryer operation …

CAPTURE DATA…

APPLY PHYSICAL SCIENCE-BASED MODEL

Measurement	F	T	S	H	P
Feed	✓	✓	✓		
Main SD air	✓	✓		✓	
Wall sweep air	✓	✓		✓	
Cone sweep air	✓	✓		✓	
IFB air	✓	✓		✓	
Broom air	✓	✓		✓	
EFB 1 air	✓	✓		✓	
EFB 2 air	✓	✓		✓	
EFB 3 air	✓	✓		✓	
SD chamber					✓
EFB chamber					✓



Simulation

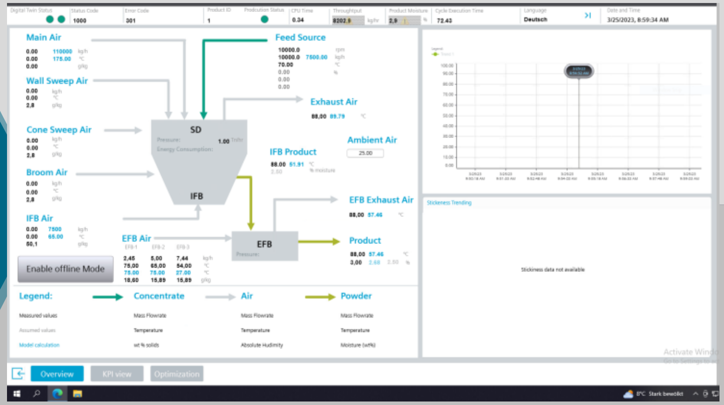
Optimization

Model calibration

Performed offline with historical plant data to ensure accuracy

…CREATE VALUE

Soft sense
Predict current values of unmeasured KPIs



Optimize
Calculate optimal conditions to run the plant

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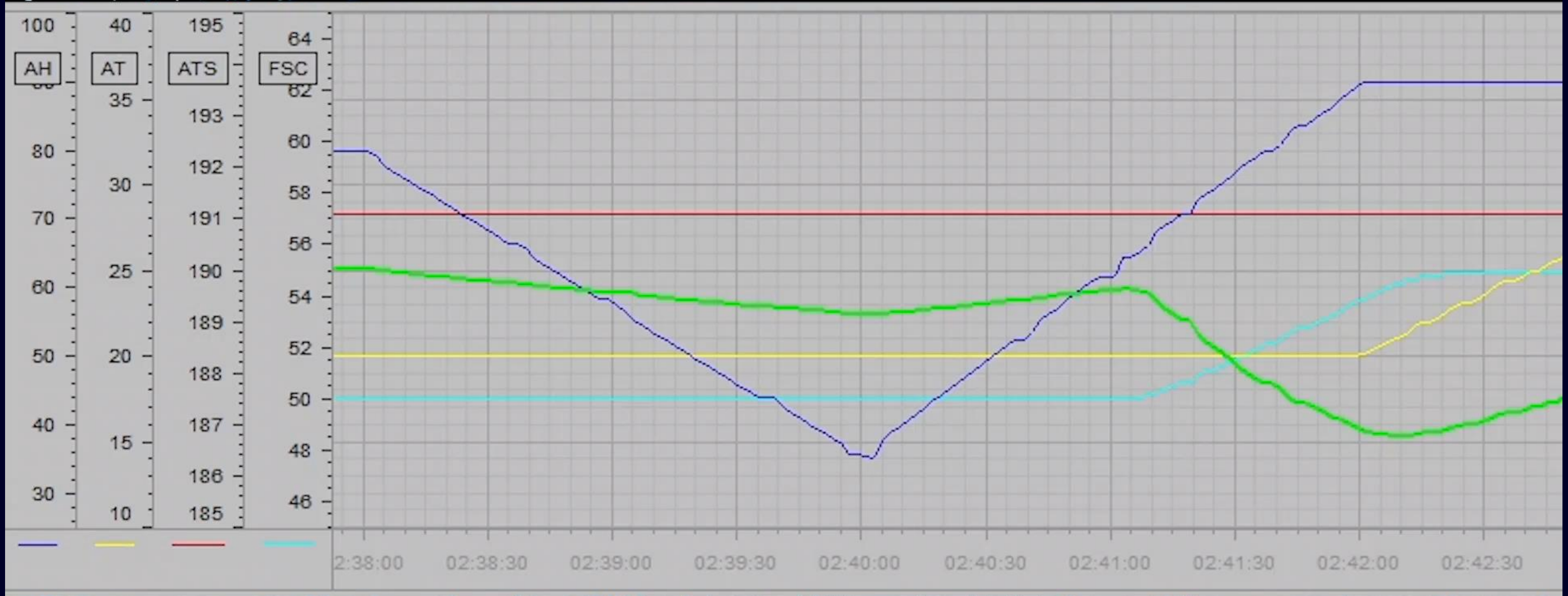
Spray dryer optimization – How it works



Improve Quality

Challenges

- Environmental parameters like humidity, air temperature, product parameters can influence product moisture content and therefore also the product quality

Solution

- Calculation of ideal process parameters in all situations
- Closed-loop implementation to continuously optimize production

Benefits

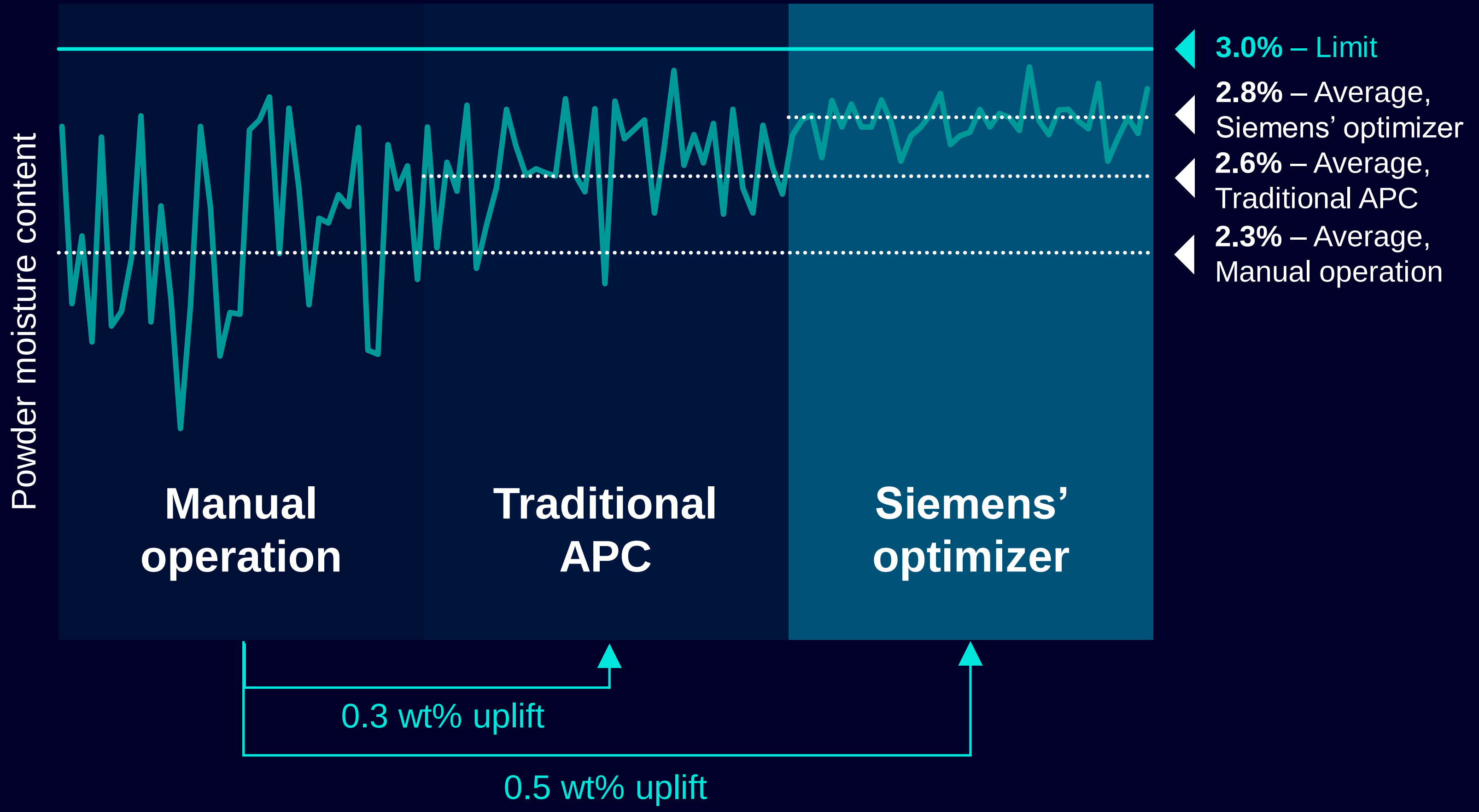
- Consistent product quality by maintaining ideal moisture content and output rate

Why physical science-based vs. data-driven or AI? – A customer perspective

*We did look at **data-driven** modelling approaches, but the data scientists found it **difficult** to generate robust models as they were **missing** what happens inside the spray dryer. Whenever an existing product moved beyond the calibration boundary, or a new product was introduced, **the model was not accurate anymore***

*I think the benefit of the **physical science-based model** is that we calculate the mass and energy balances within the spray dryer and can **properly predict the unit operation behavior***

The next generation of APC
Reducing variability and increasing performance



Siemens Spray Dryer Optimizer

Benefits compared to traditional APC systems:

- Reduces variability in powder moisture content
- Uplifts moisture (wt.%) closer towards the limit
- Prevent decay of performance over time as the models can better capture the complexity of spray drying

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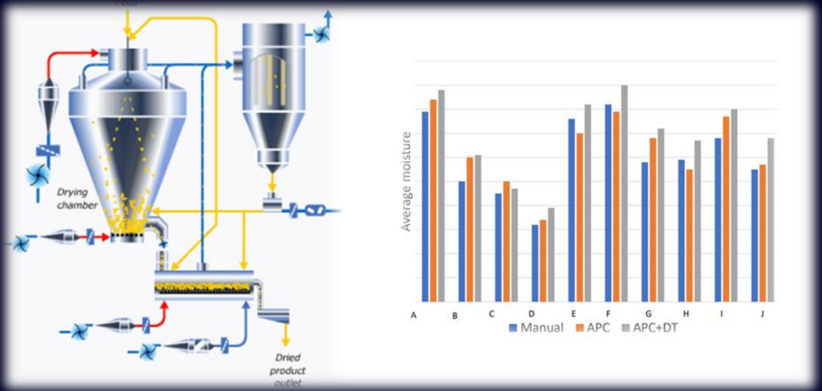
Siemens spray dryer optimizer: A Danone case study

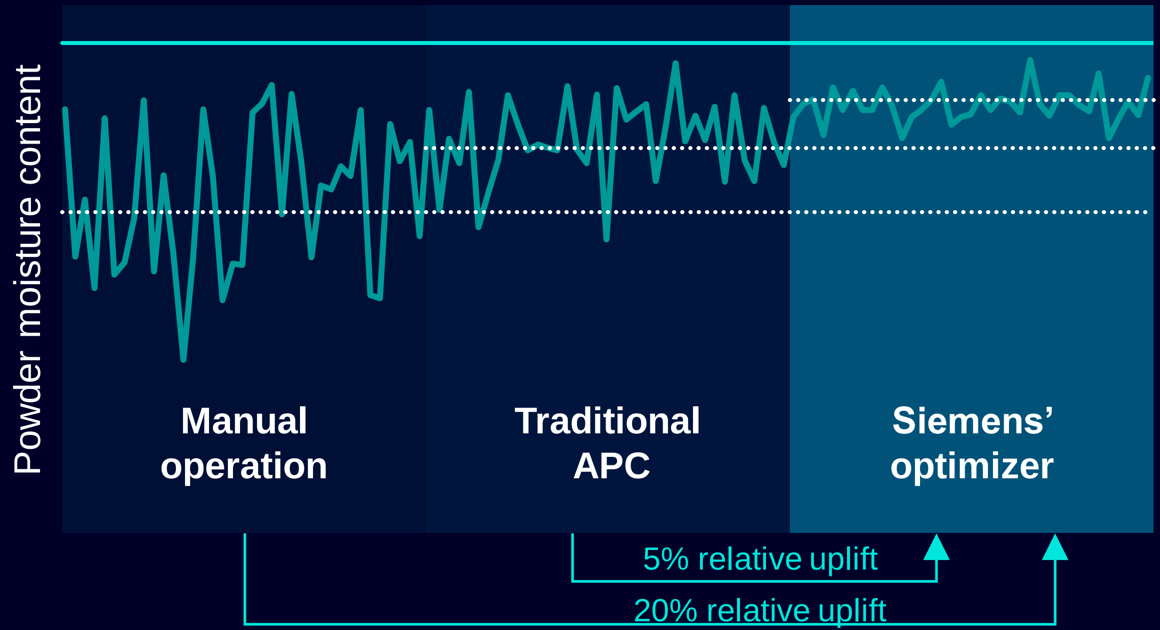
Customer Challenges

- Improve operating margins for infant formula manufacture:
  - Uplift product moisture
  - Reduce energy usage
- Achieve improvements for a large, evolving product portfolio

Our Solution

- Configure and calibrate physical science-based digital twin of spray drying process
- Deploy digital twin as a soft sensor on a plant within APC system
- Use for real time optimization and control





Customer Benefits

- 5% increase in product moisture content*
- 30% reduction in product moisture variability*
- Reduction in energy usage due to moisture uplift

ROI < 6 months

*Compared to previously employed data-driven APC at the factory

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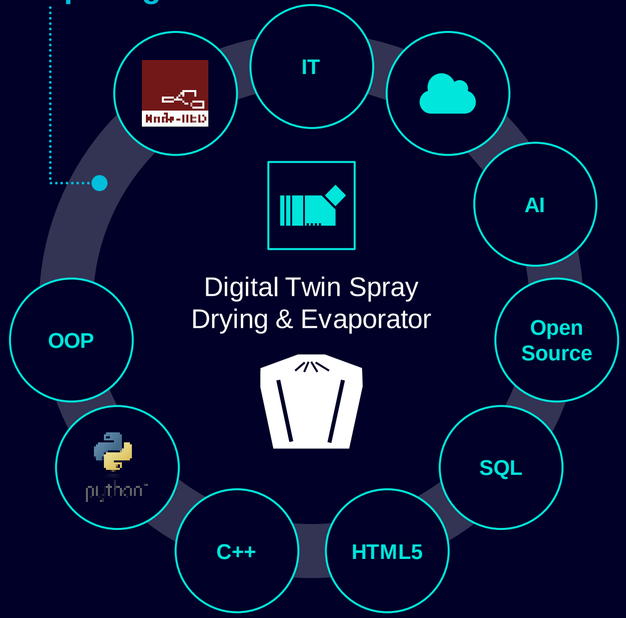
The next level of dryer improvement is determined by data and the ability to utilize software more effectively for its analysis

Extended spray dryer functionality

with new advanced functionality for machine -related data collection, processing, storage & visualization for e.g., condition monitoring, alarm management.

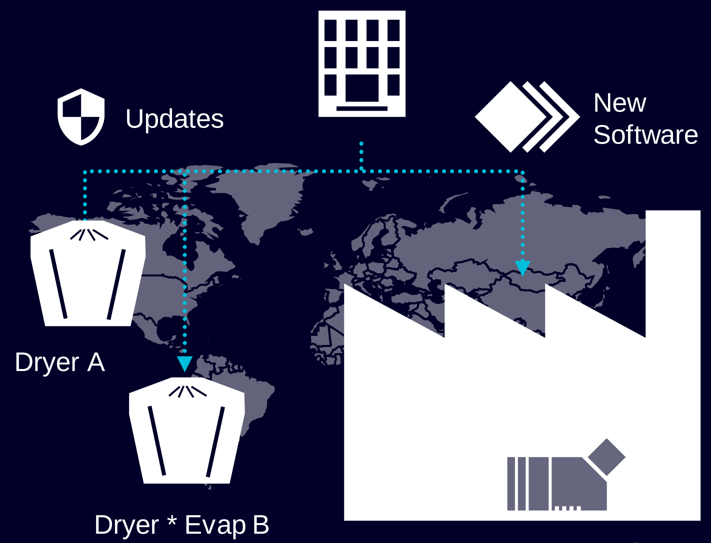
Edge Computing



Remote Software and optimization Management

Reduced time to market for spray dryer software during operations with centralized device-, application- & security management.

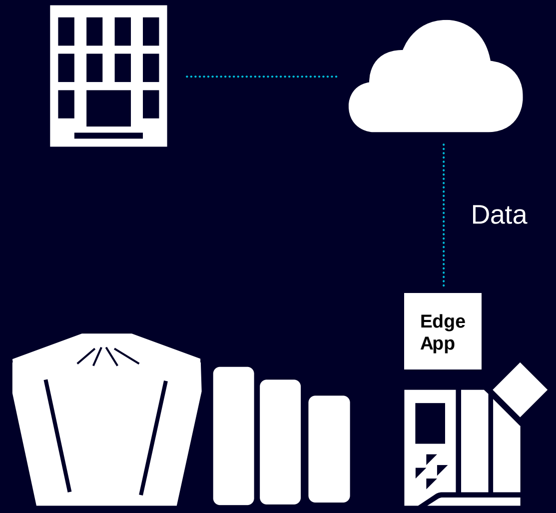
Dairy company



IT-Integration

Flexibility to integrate machine data into cloud and IT-systems of any kind for advanced analysis and optimization.

Dairy Company



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Thank You

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