The Art of Scaling Innovation

Model-based Process Improvement and Control of Solvent Switches

Sam Wuyts
Synthetics Drug Substance Technology and Innovation Senior Principal Scientist

Johnson&Johnson

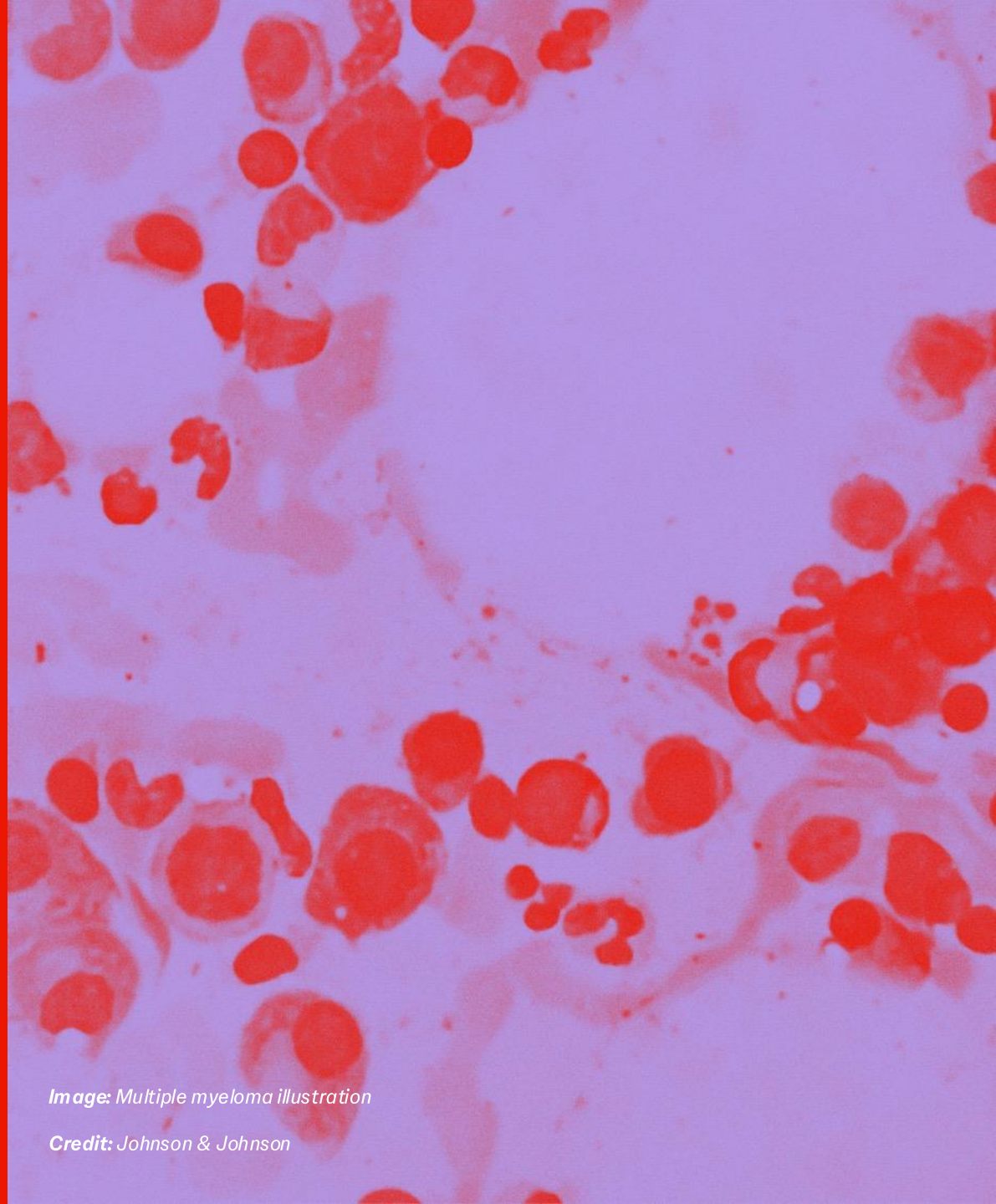


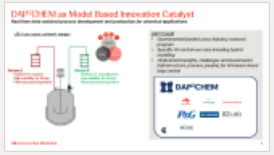
Image: *Multiple myeloma illustration*

Credit: *Johnson & Johnson*

Agenda

Introduction

Model based optimization and control as part of J&J digital strategy **01**



DAP²CHEM as innovation catalyst **02**

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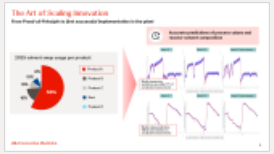


Successful PoP to implemented use case **03**

Implemented use case to Innovation Program **04**

Next Steps

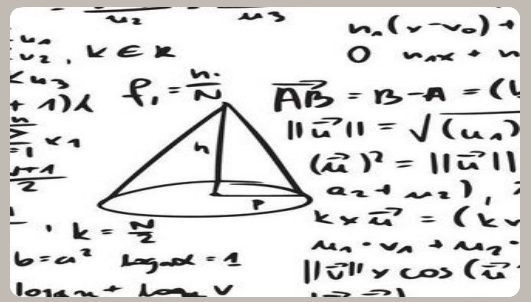
The self-optimizing plant and efficient learning **05**

Model based optimization and control: best process developed & executed

- Digitize knowledge
- Predict scale up
- Optimize process dynamically
- Integrate Quality

A Map

Draw a map & find the best route

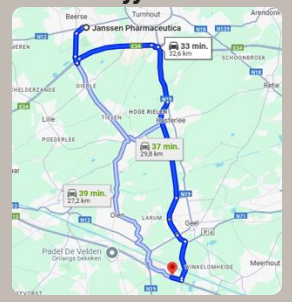


Process model

A GPS

GPS suggests best route

Offline



Online / Realtime

Model based optimization

A Car

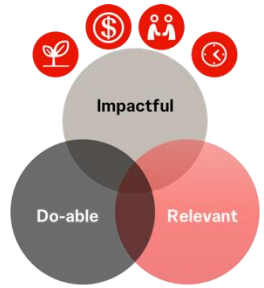
Self-driving car

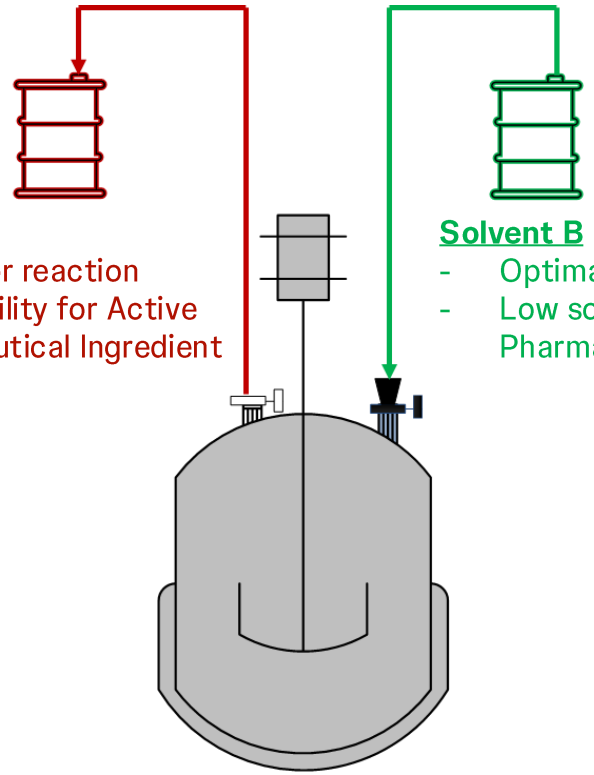
Closed loop control

DAP²CHEM as Model Based Innovation Catalyst

Real time data assisted process development and production for chemical applications

J&J use case: solvent swaps





Solvent A
- Optimal for reaction
- High solubility for Active Pharmaceutical Ingredient

Solvent B
- Optimal for crystallization
- Low solubility for Active Pharmaceutical Ingredient

DAP²CHEM

- *Governmental funded cross-industry research program*
- *Specific AI-control use case including hybrid modeling*
- *Understand benefits, challenges and investments (infrastructure, process, people) for AI-based closed loop control*

DAP²CHEM

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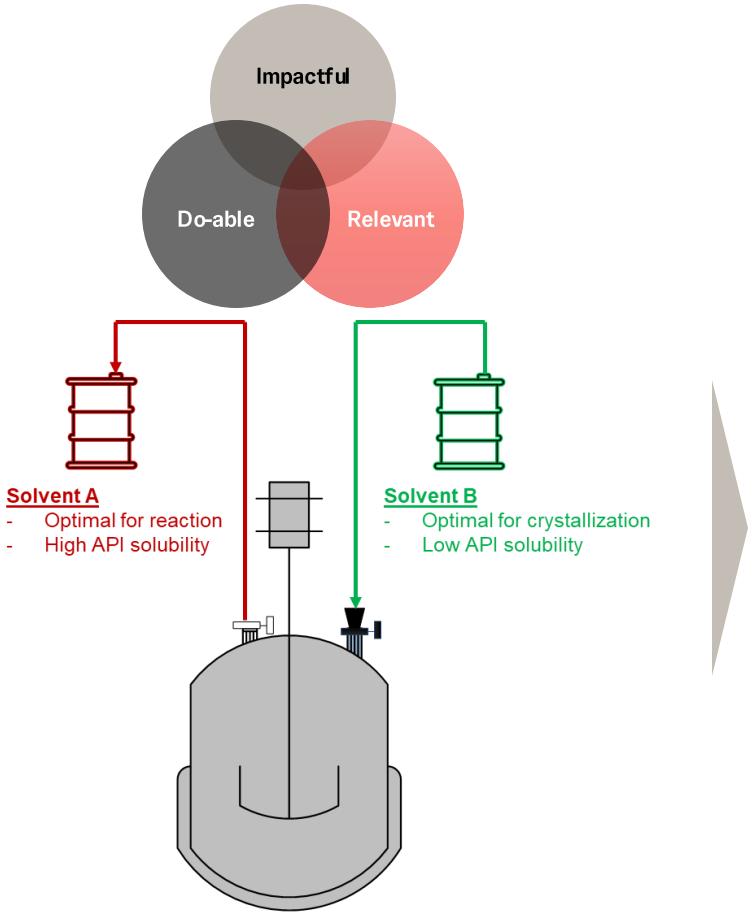
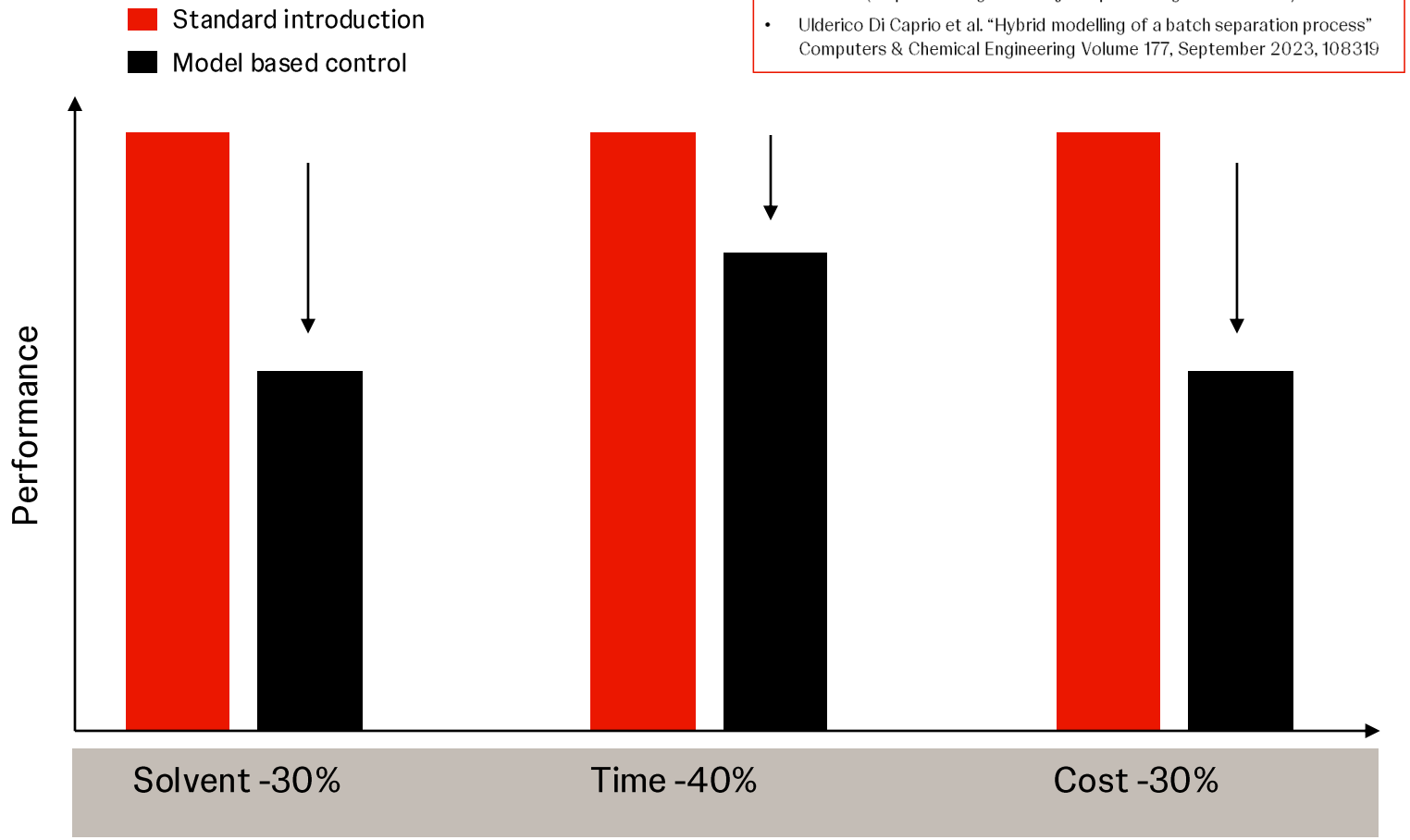
DAP²CHEM as Model Based Innovation Catalyst



Results of pilot plant PoP



Publications

- Elmaz, Furkan, et al. "Reinforcement learning-based approach for optimizing solvent-switch processes." Computers & Chemical Engineering 176 (2023): 108310. (https://doi.org/10.1016/j.compchemeng.2023.108310) ·
- Ulderico Di Caprio et al. "Hybrid modelling of a batch separation process" Computers & Chemical Engineering Volume 177, September 2023, 108319

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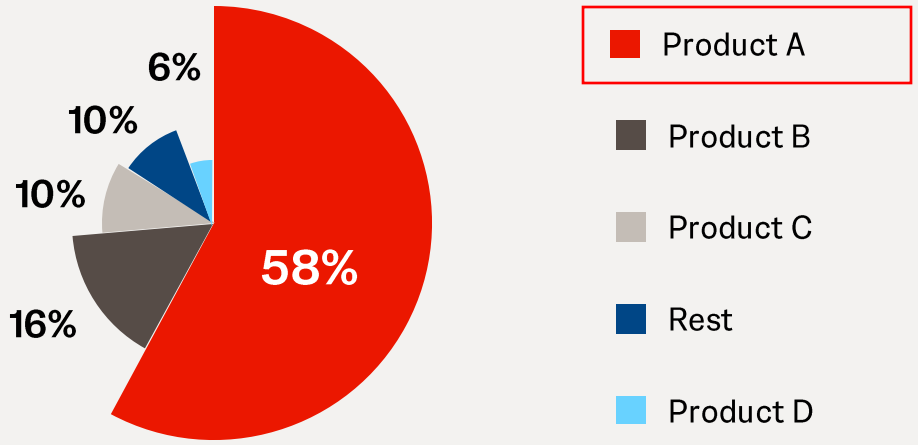
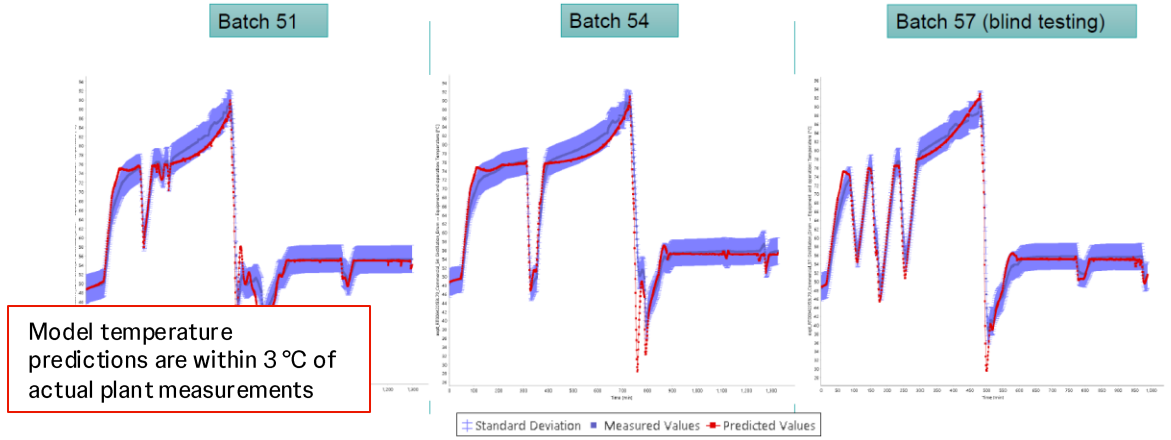
From Proof-of-Principle to first successful implementation in the plant

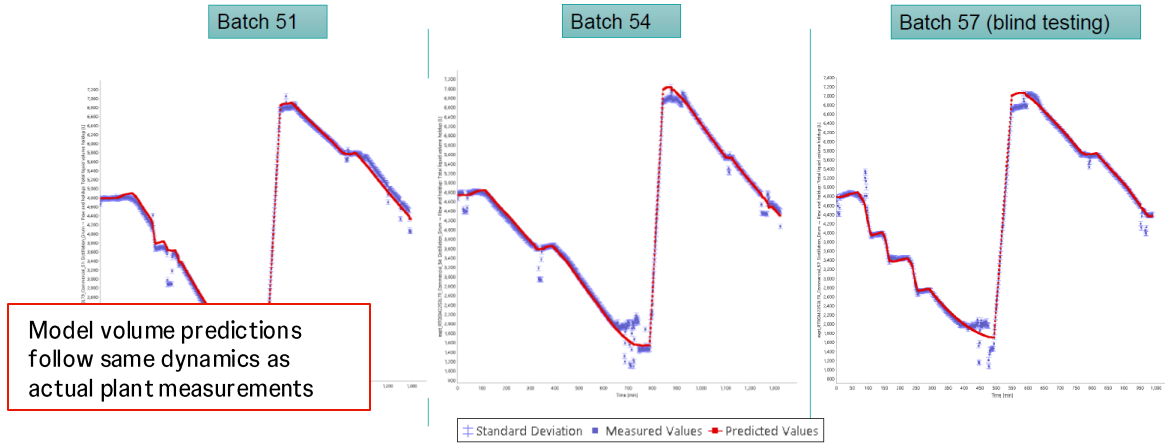
2025 solvent swap usage per product



Accurate predictions of process values and reactor solvent composition



Model temperature predictions are within 3 °C of actual plant measurements



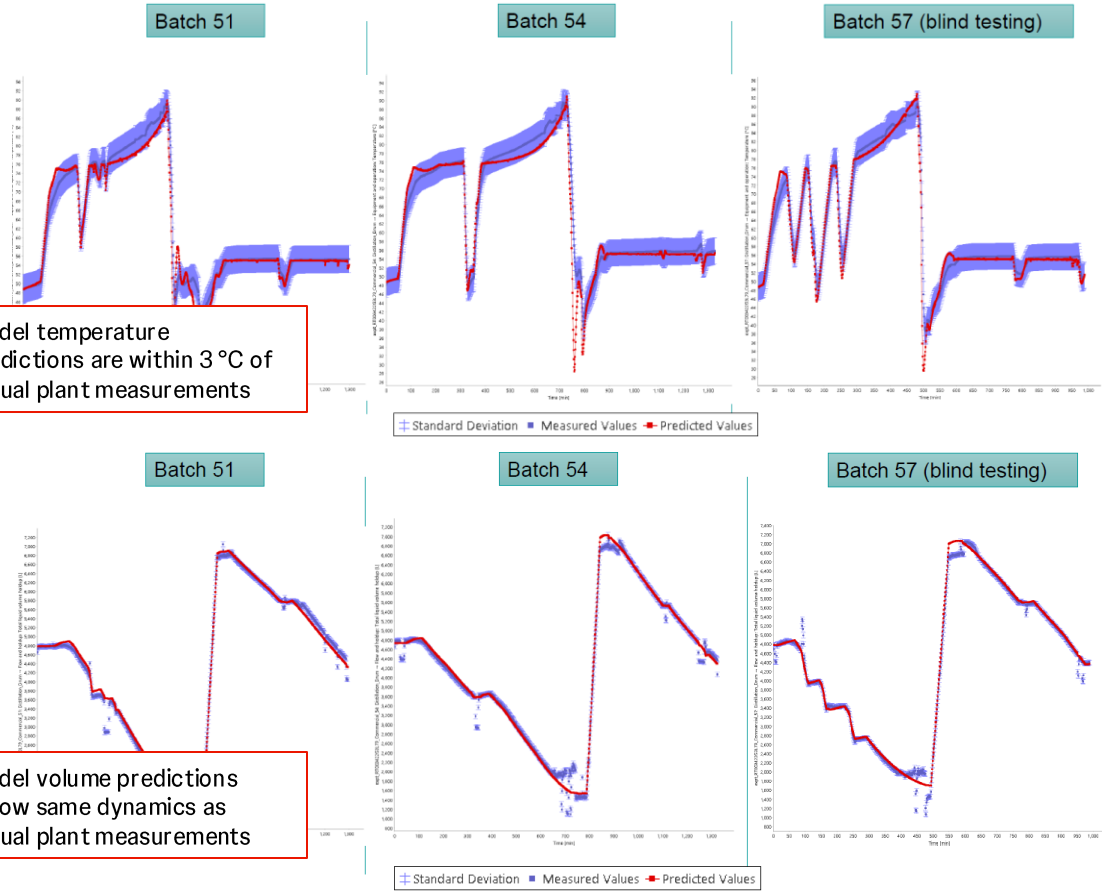
Model volume predictions follow same dynamics as actual plant measurements

The Art of Scaling Innovation

From Proof-of-Principle to first successful implementation in the plant

Ongoing need for experimental validation!

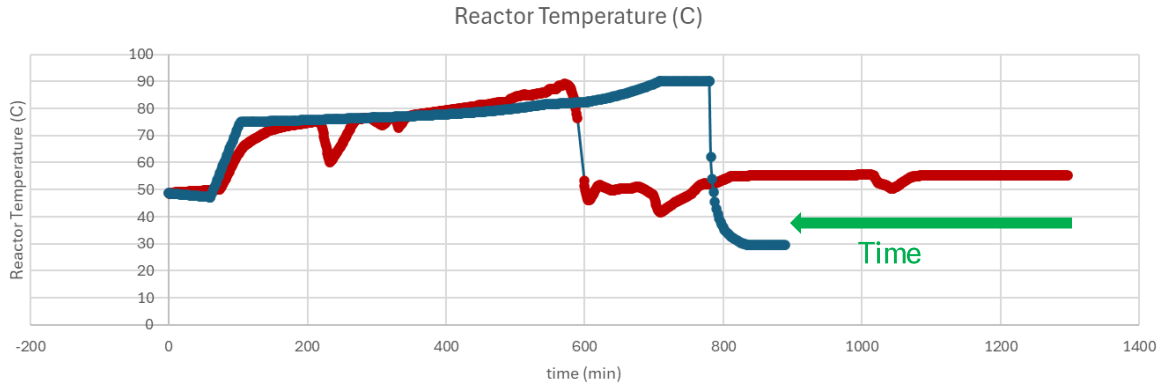
Accurate predictions of process values and reactor solvent composition

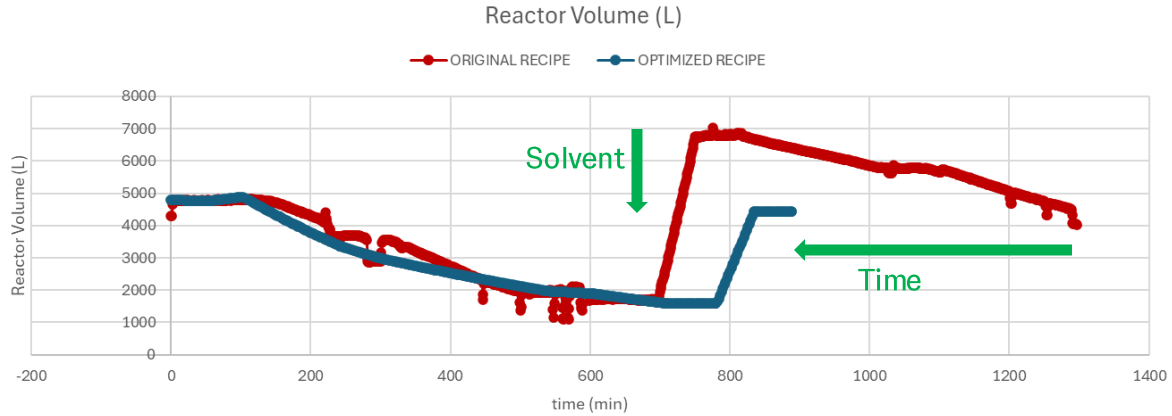


Model temperature predictions are within 3 °C of actual plant measurements

Model volume predictions follow same dynamics as actual plant measurements

Optimization leading to solvent and cycle time reduction





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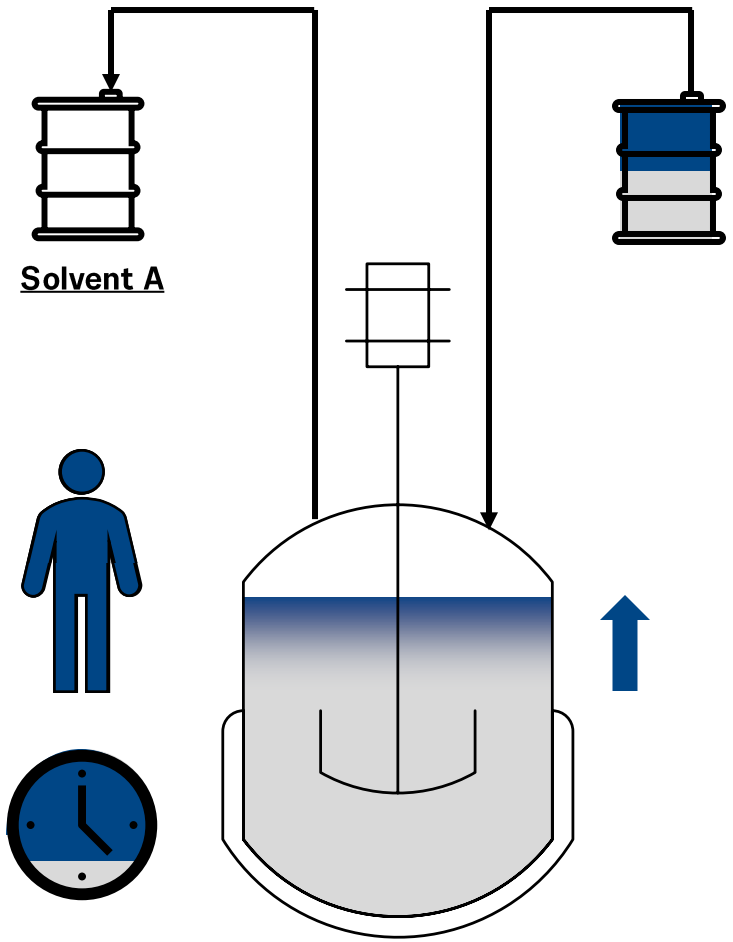
Model based optimization enabled improvement cascade



€2MM yearly savings

1. **Solvent** reduction
2. **Cycle time** reduction
3. **Labor** efficiency
4. **Batch scale-up**
5. **Autonomous operation**

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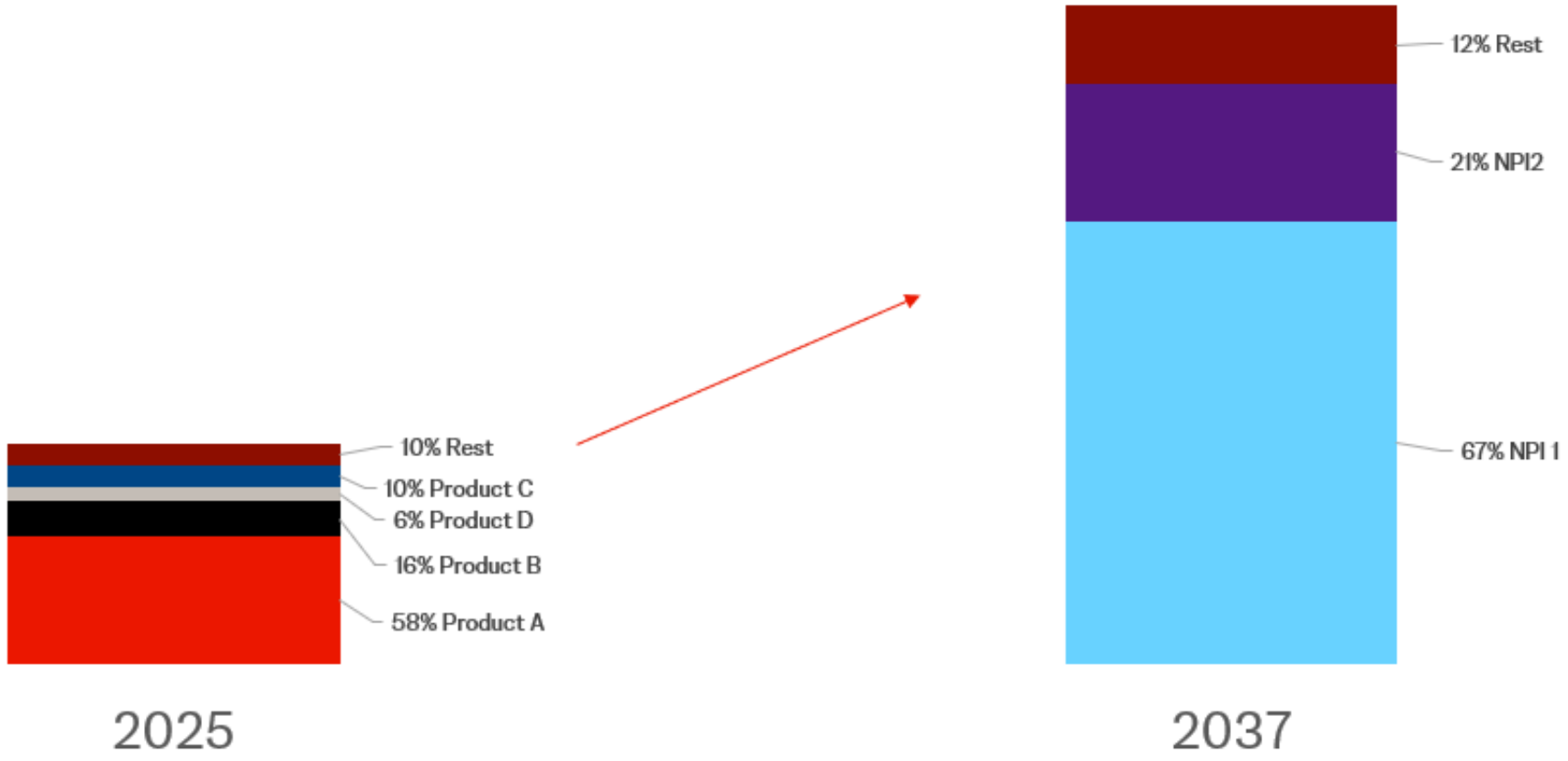
From first successful implementation in the plant to Innovation Program



Factor 3 increase in solvent demands for solvent swaps!

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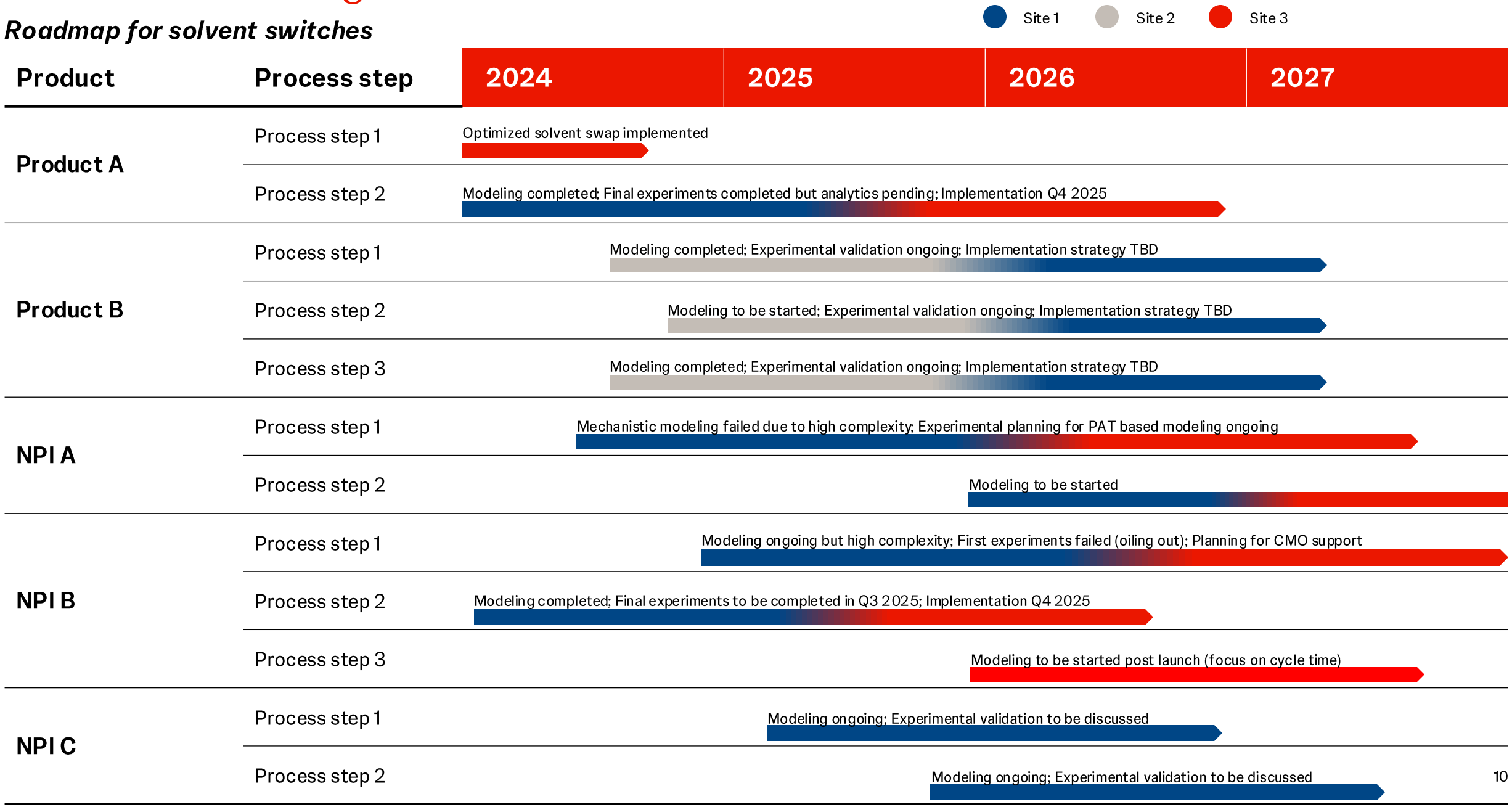
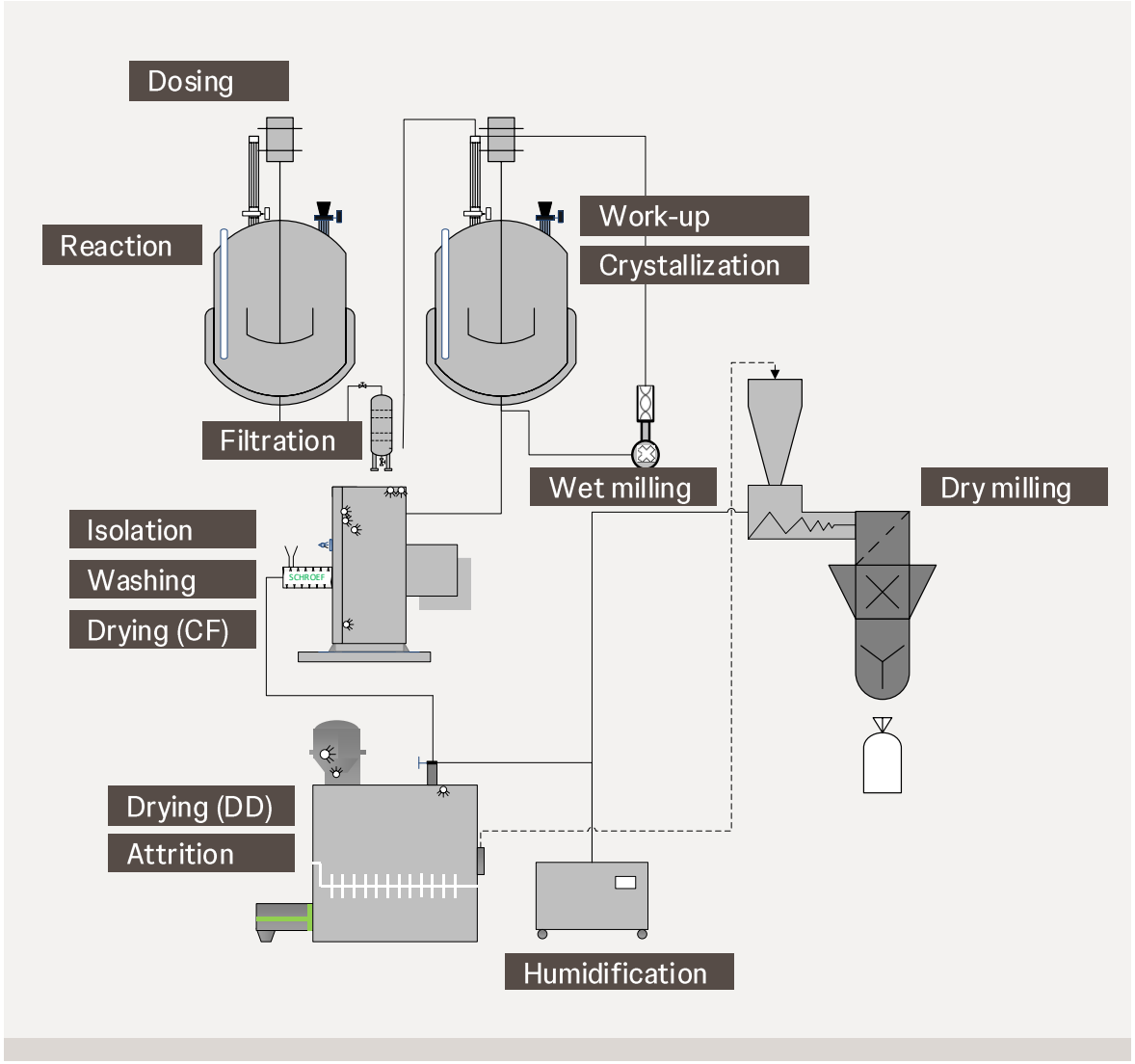
Roadmap for solvent switches

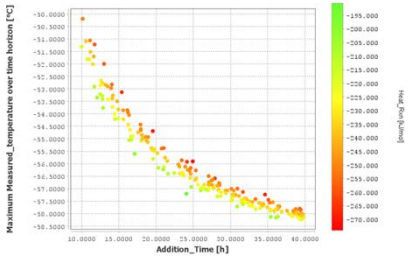


Next steps – the self-optimizing plant

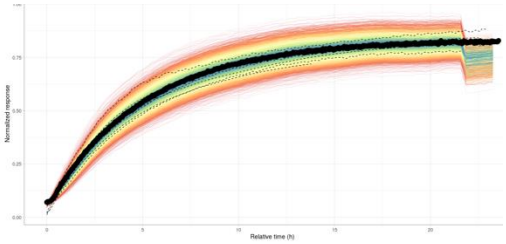
Expansion over unit operation portfolio



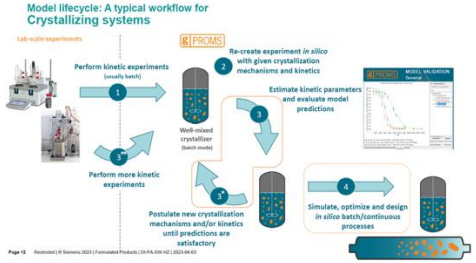
Cryogenic dosing



Reaction fingerprinting



Wet milling model



(Post) drying

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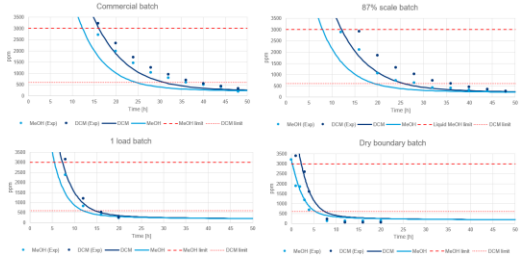

Centrifugation

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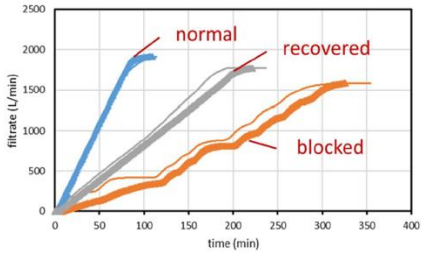
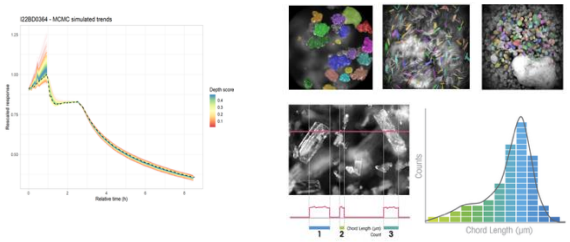


Crystallization fingerprinting



Thank you!

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Innovative Medicine