Intro and objectives

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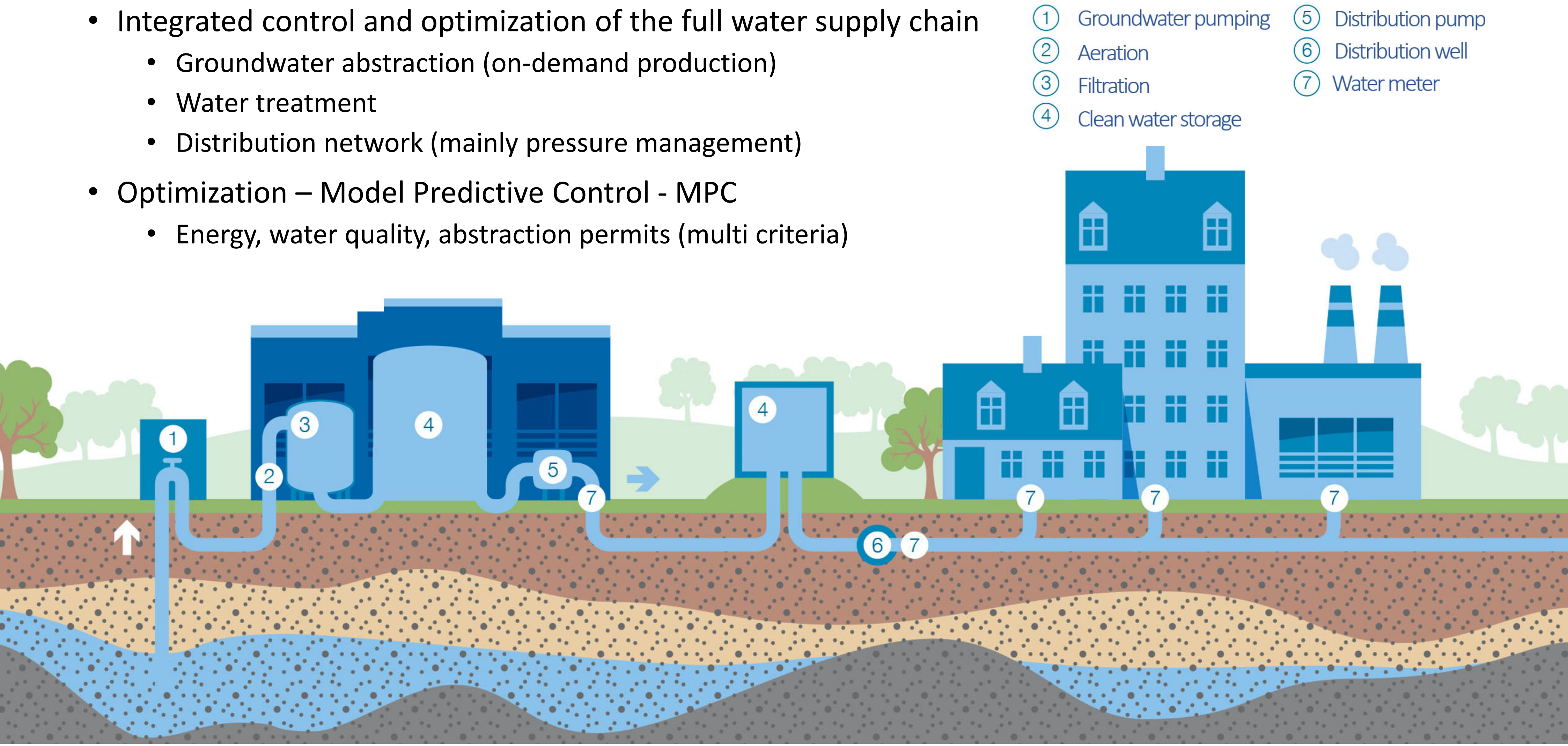
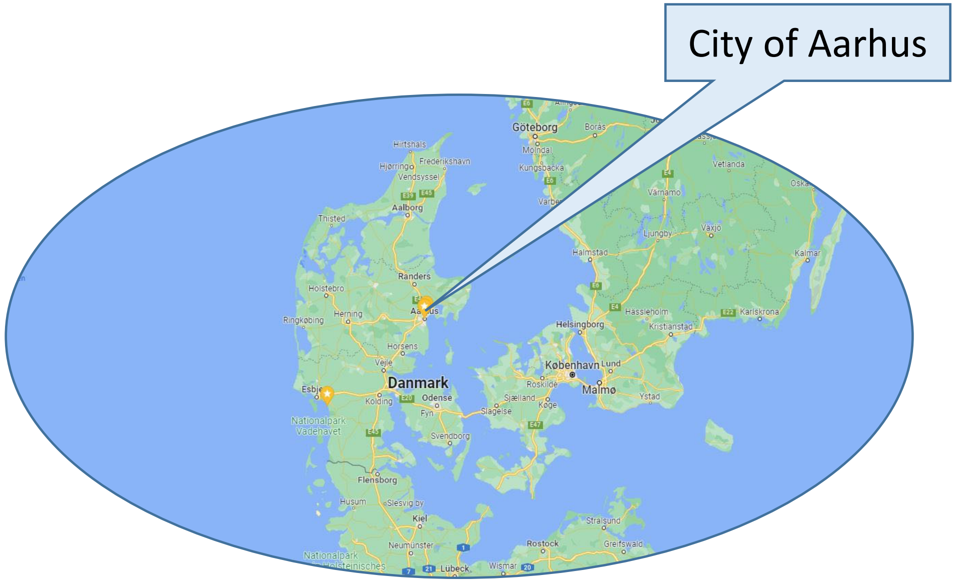
- Integrated control and optimization of the full water supply chain
  - Groundwater abstraction (on-demand production)
  - Water treatment
  - Distribution network (mainly pressure management)
- Optimization – Model Predictive Control - MPC
  - Energy, water quality, abstraction permits (multi criteria)



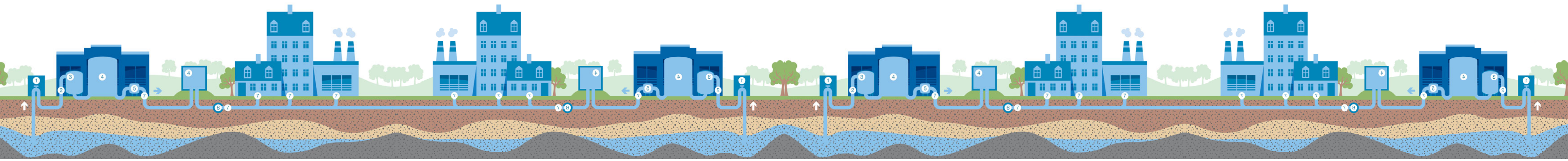
The physical system



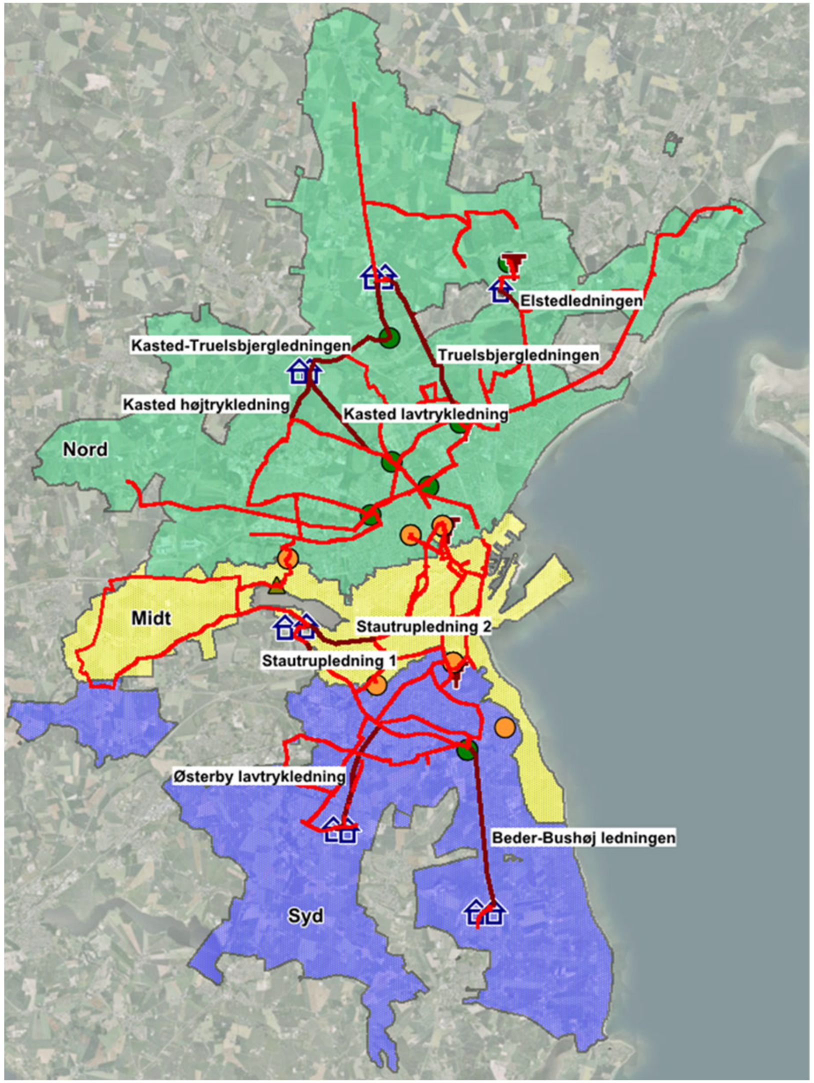
a few facts....

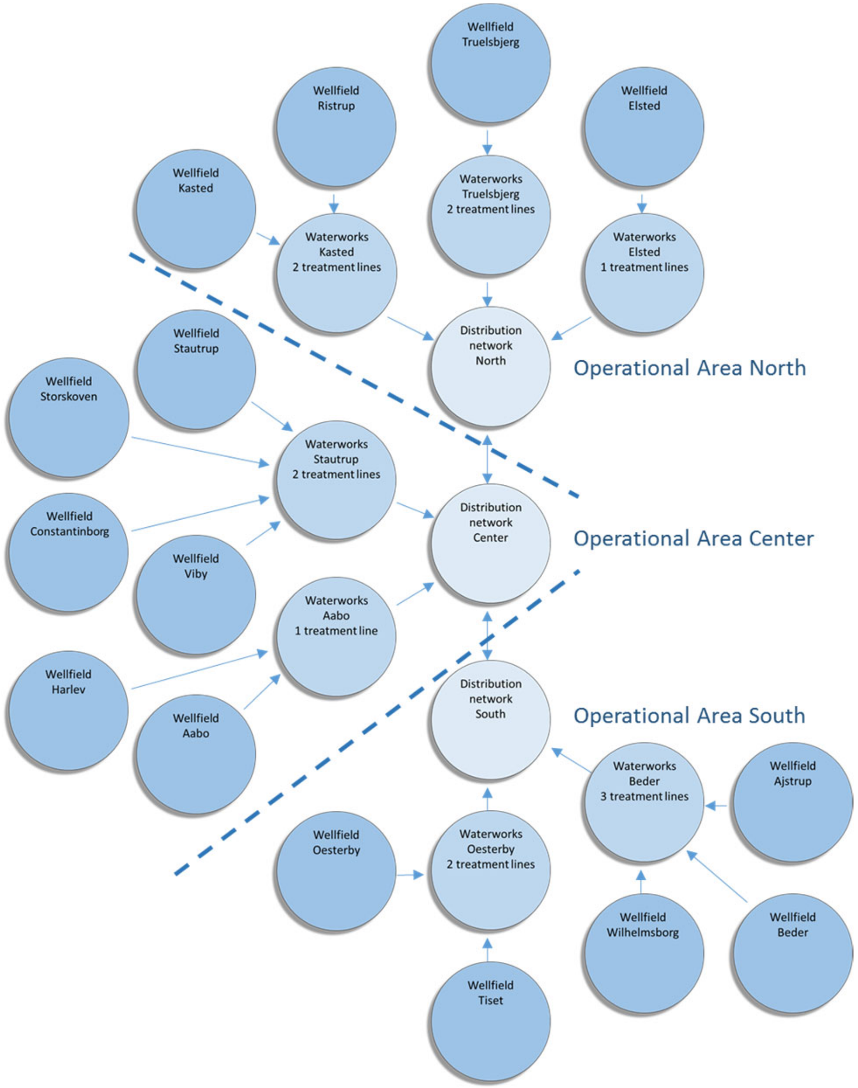
- Aarhus Water is a publicly owned water utility
- 3 operational areas
- 336.000 water customers
- Annual turnover 110 million USD
- 15 million m3 (4000 million gallons), 9 water works, 100 wells, 1500 km pipes
- Unaccounted-for-water is around 4-6%

- Wastewater treatment: 35 million m3/year, 4 treatment plants, 150 pumping stations, 2200 km pipe, 25% combined sewers, 70.000 m3 retention storage

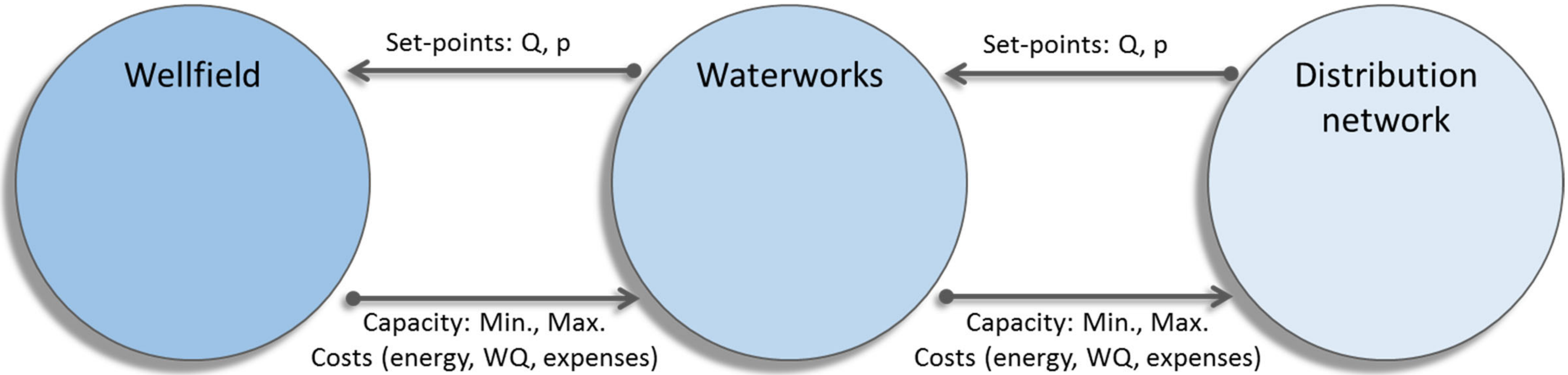


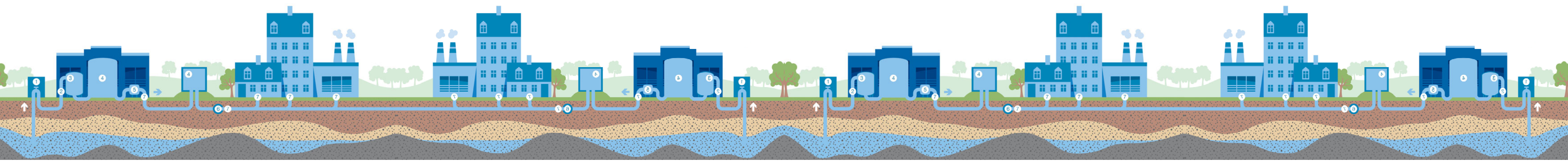
Managing the physical system



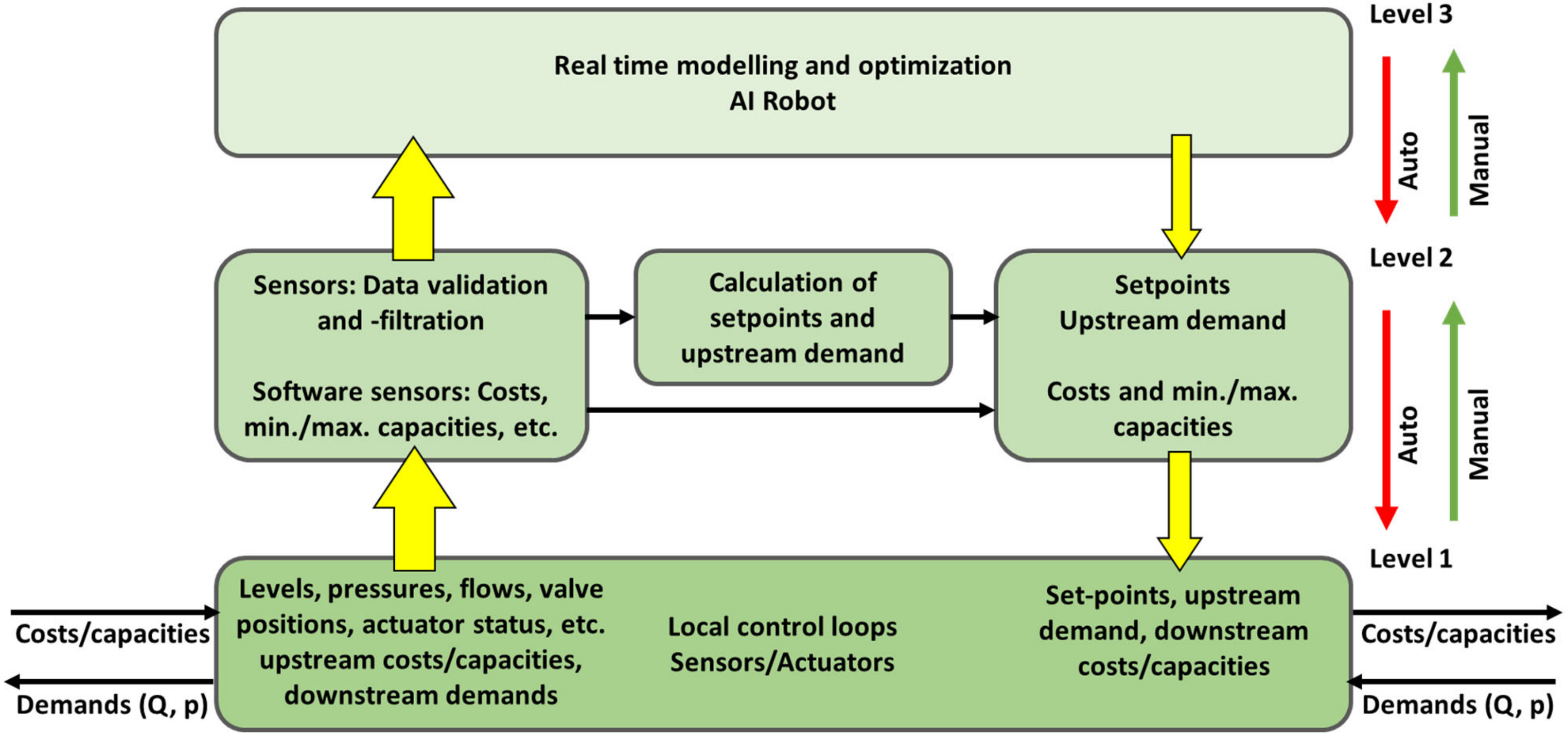


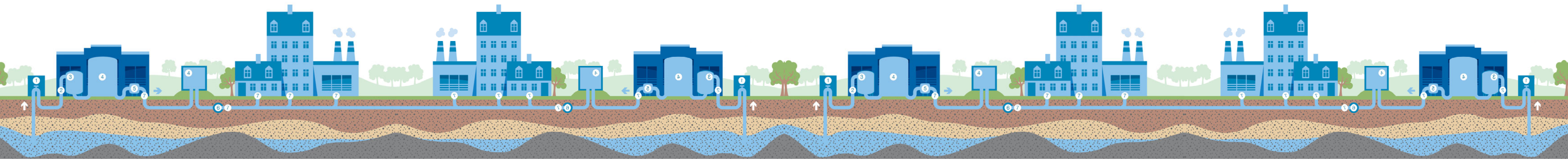
Concept: Demand Driven Water Supply



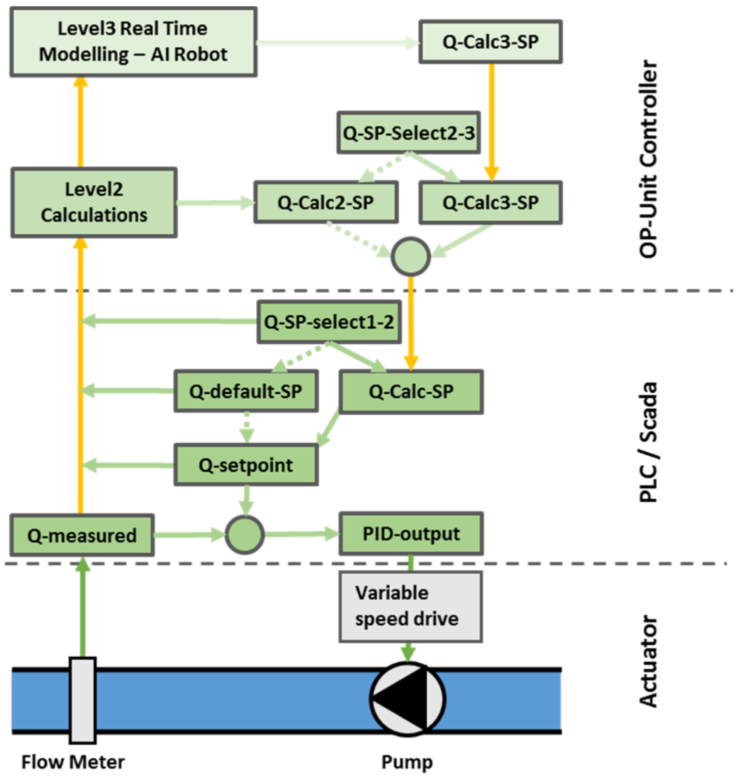


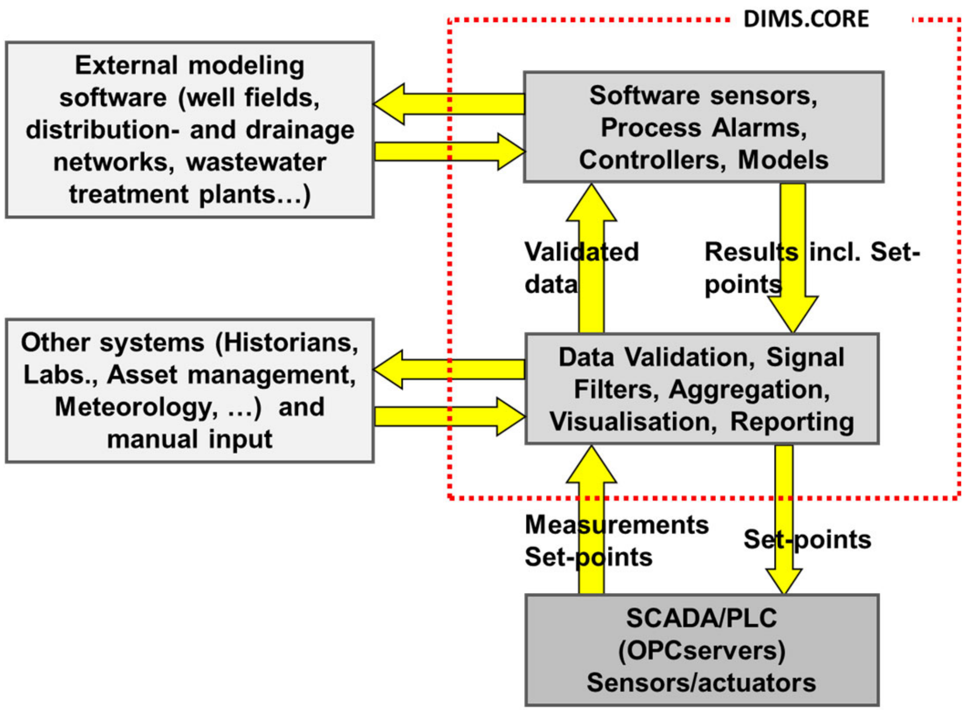
Internal structure of the operational units

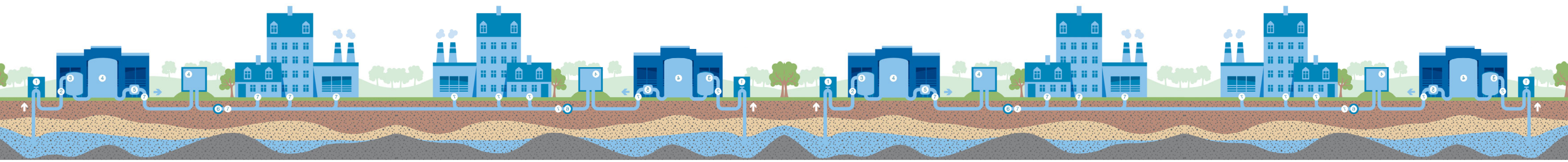




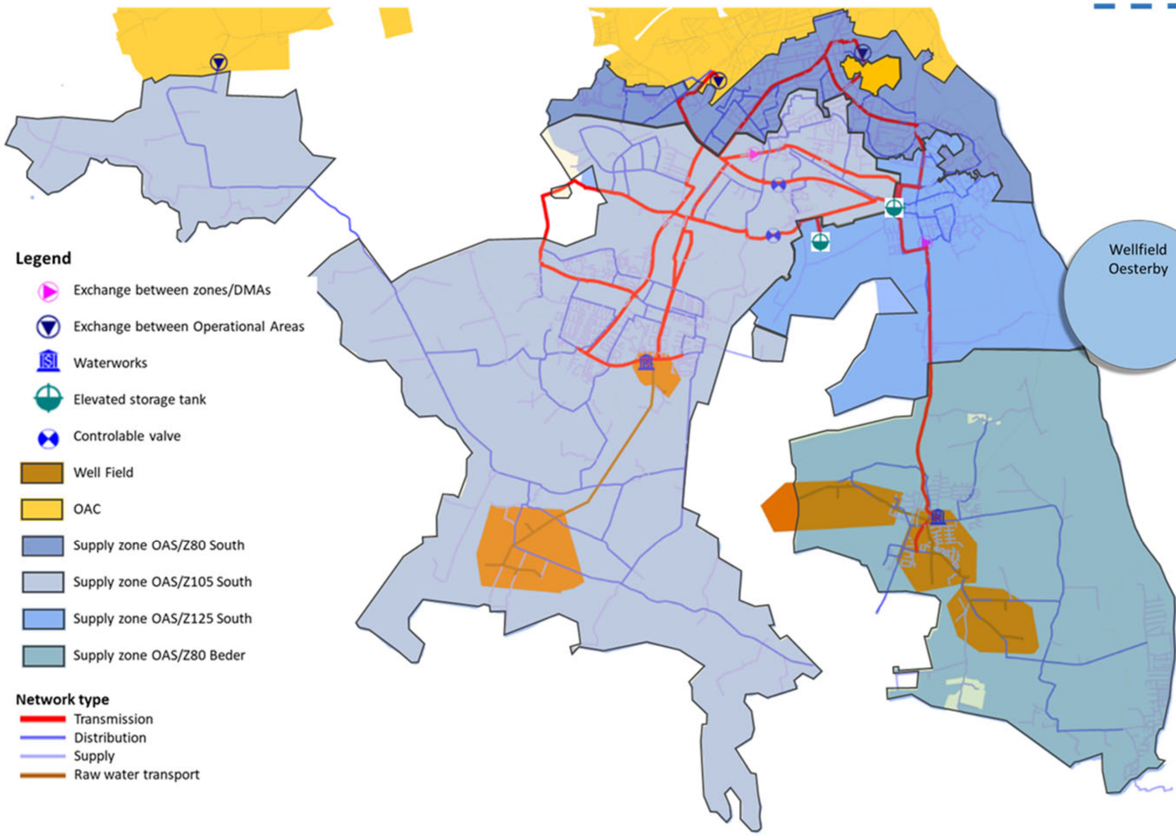
Automation platform – layered structure

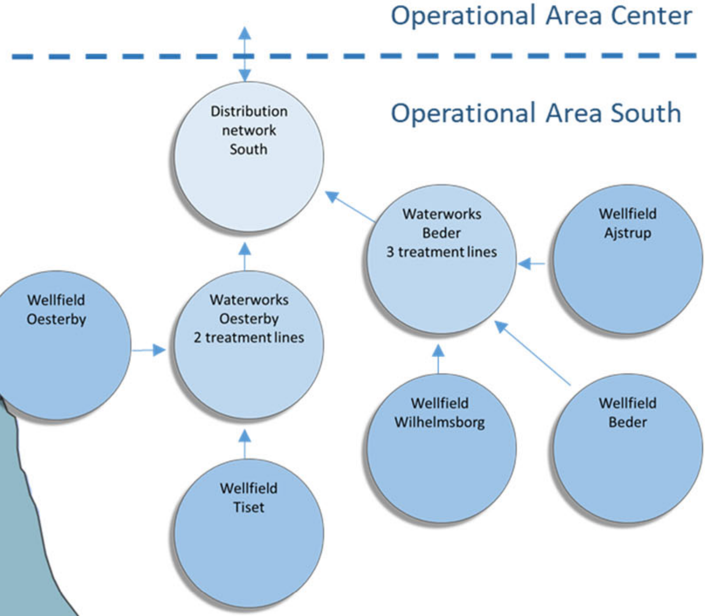


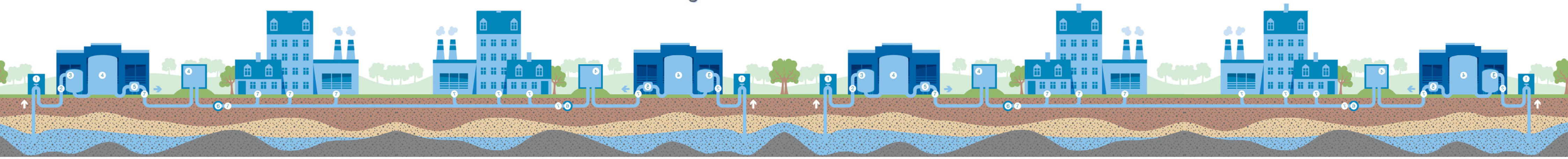




Operational Area South







Demand forecast

Prediction:

7 days into the future for each minute is calculated every hour....

Q_{-n}: This minute - n weeks back in time
Q_{-1}: This minute - last week
Q_0: This minute
Q_1: This minute - next week

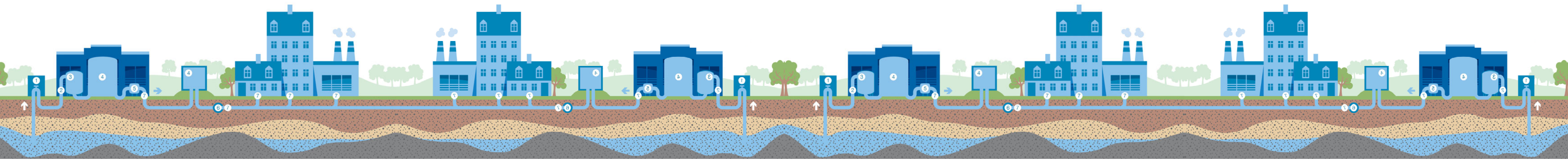
Discard:
$\mathrm{Max}(Q_0, Q_{-1}, \ldots., Q_{-n})$
$\mathrm{Min}\,(Q_0, Q_{-1}, \ldots., Q_{-n})$

$$Q_1 = (\qquad Q_k) \,/\, (n - 1)$$

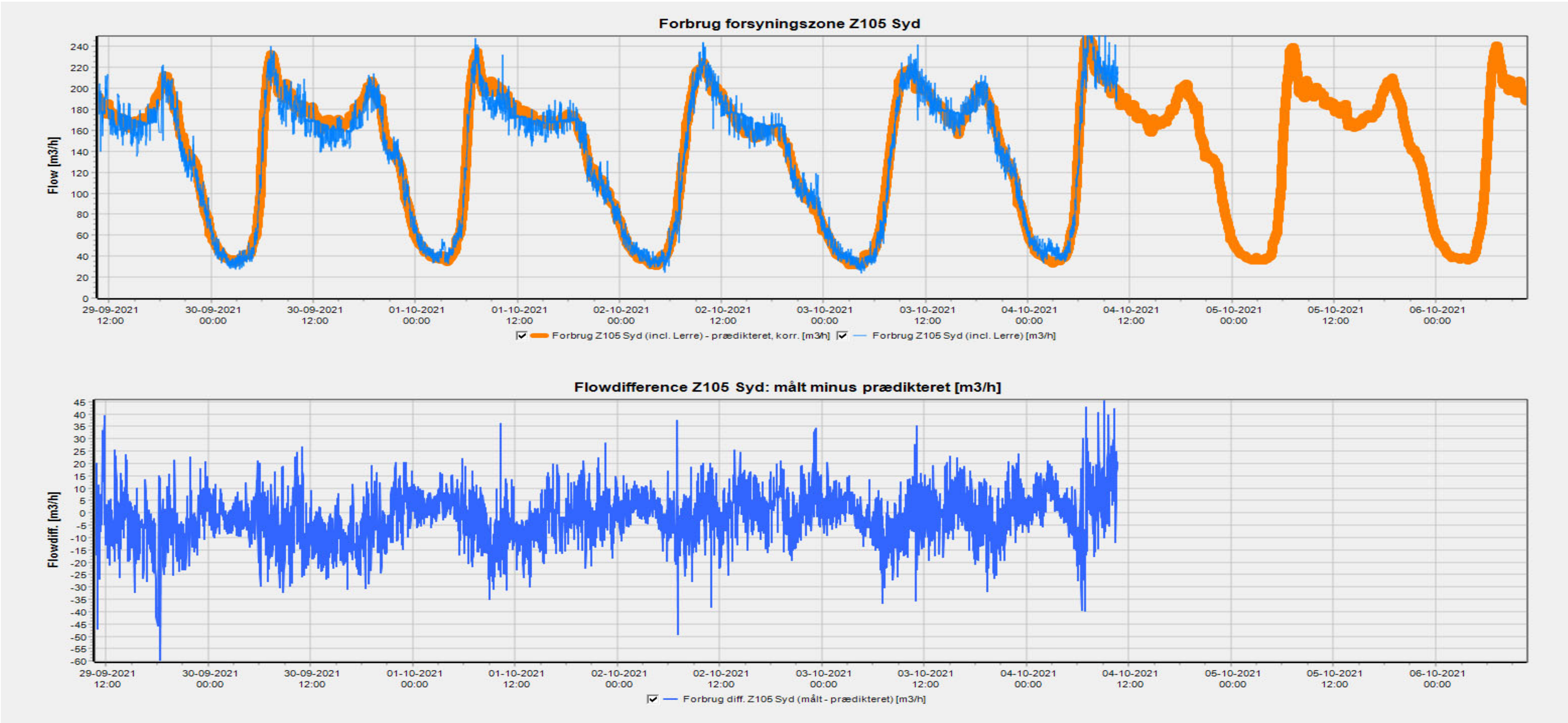
$$Q_{1,max} = \mathrm{Max}(Q_0, Q_{-1}, \ldots., Q_{-n+2})$$
$$Q_{1,min} = \mathrm{Min}\,(Q_0, Q_{-1}, \ldots., Q_{-n+2})$$

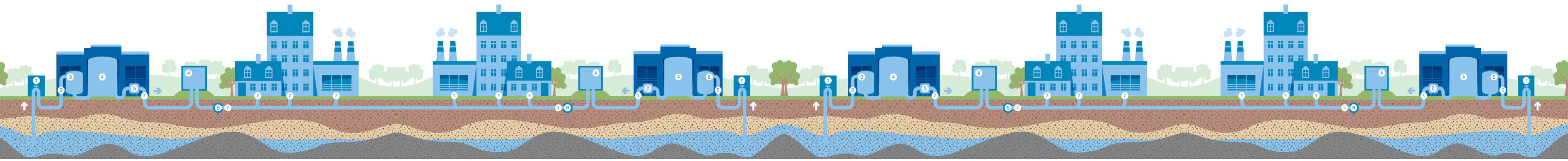
$$Q_{1,expfilt} = Q_{1,expfilt,old} + \varepsilon * (Q_1 - Q_{1,expfilt,old})$$

$$Q_{1,corrected} = \mathrm{TimeShift}\,(\varepsilon, Q_{1,expfilt})$$

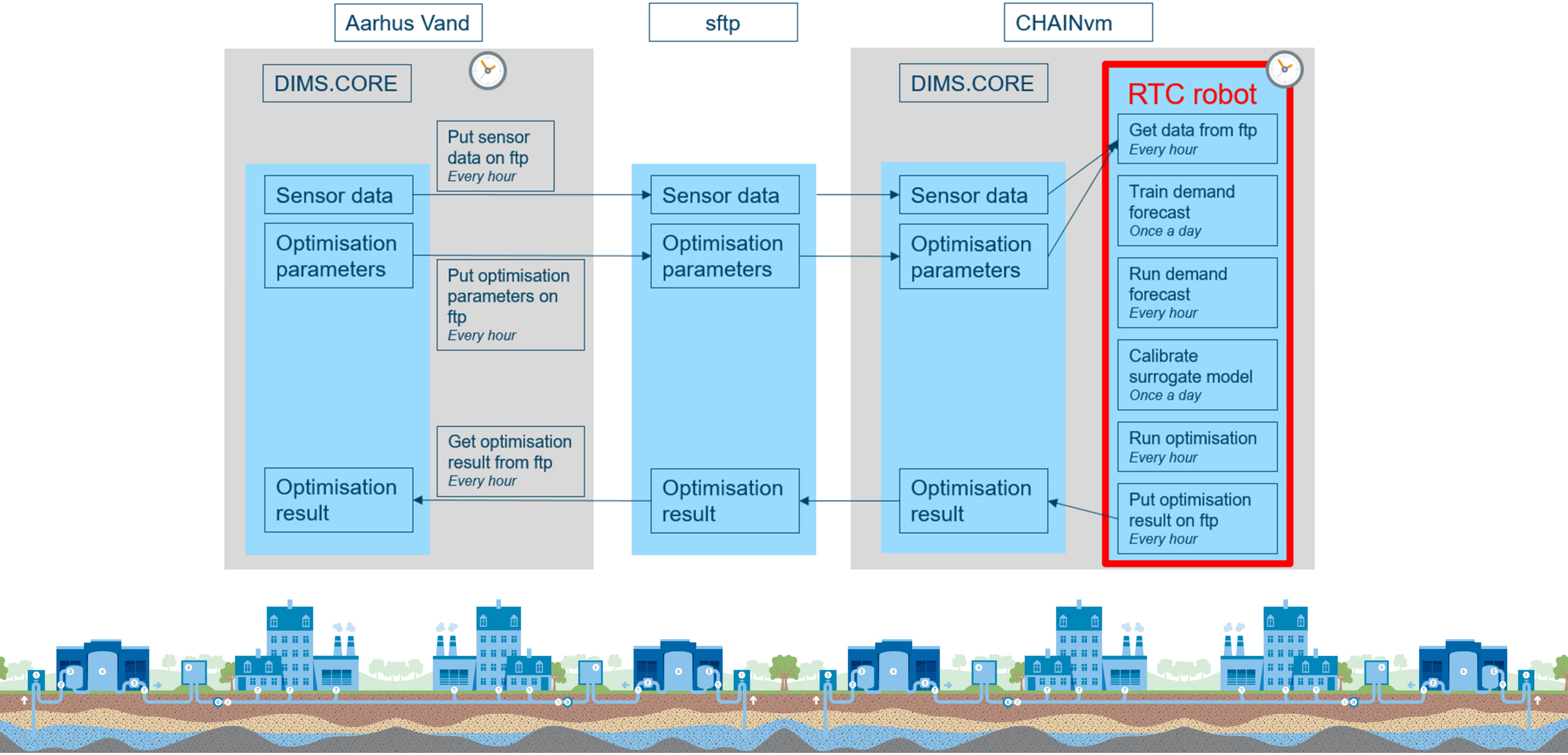


Demand forecast – 7 days ahead





Operations in the automated workflow



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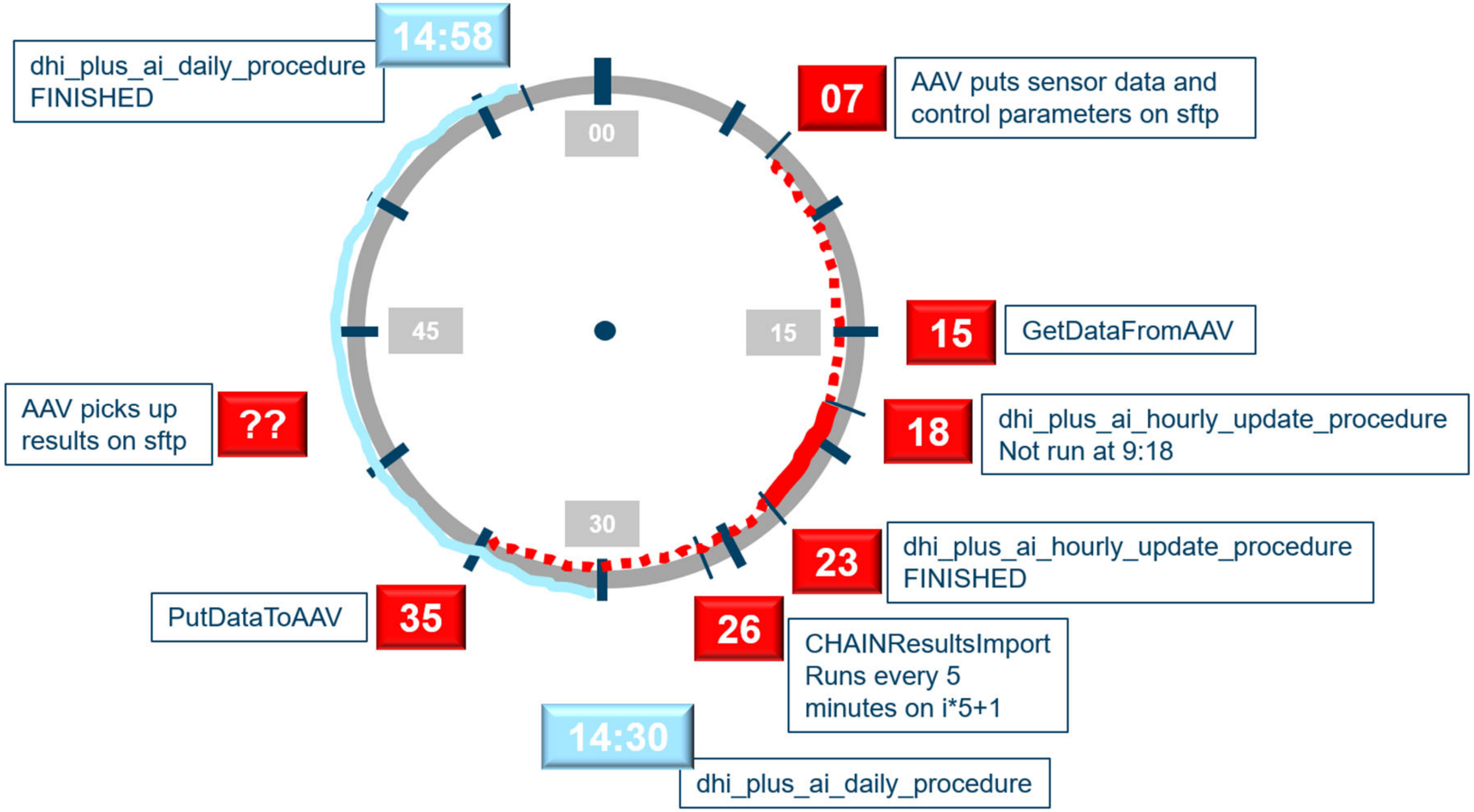
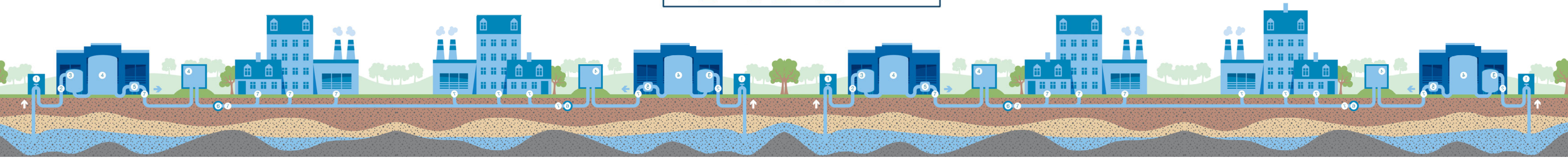
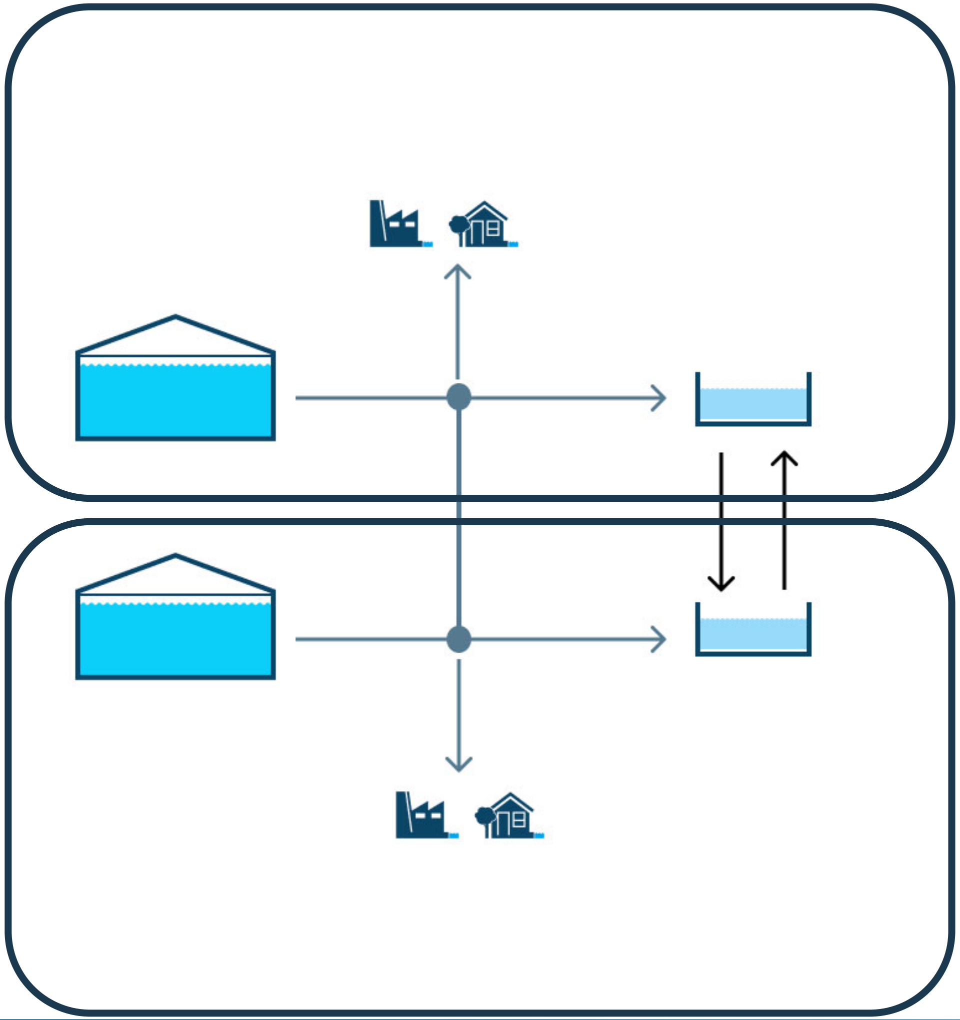




Managing a water distribution system

Model Predictive Control

- Proactive
- Coordinates subsystems



Rule-based control

- Reactive
- Isolated control of subsystems

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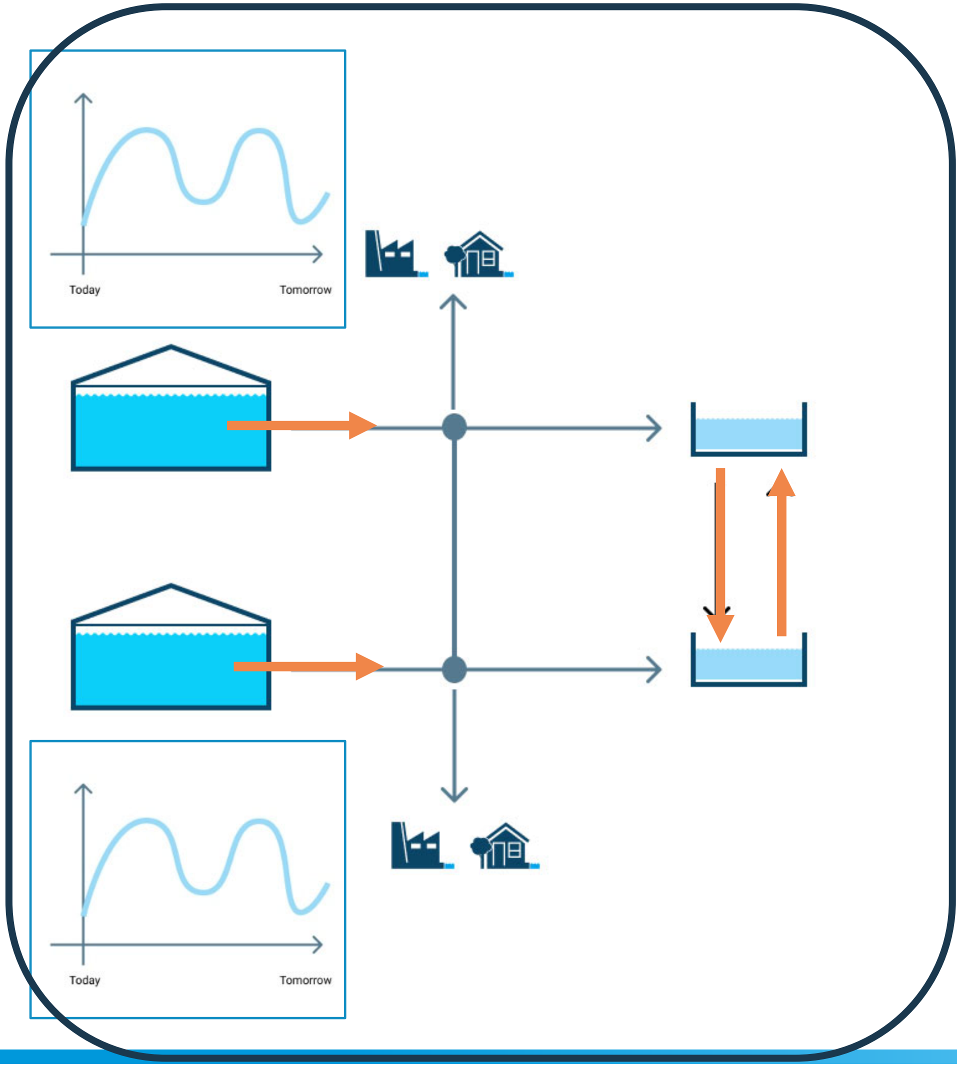

Rule-based control

- Reactive
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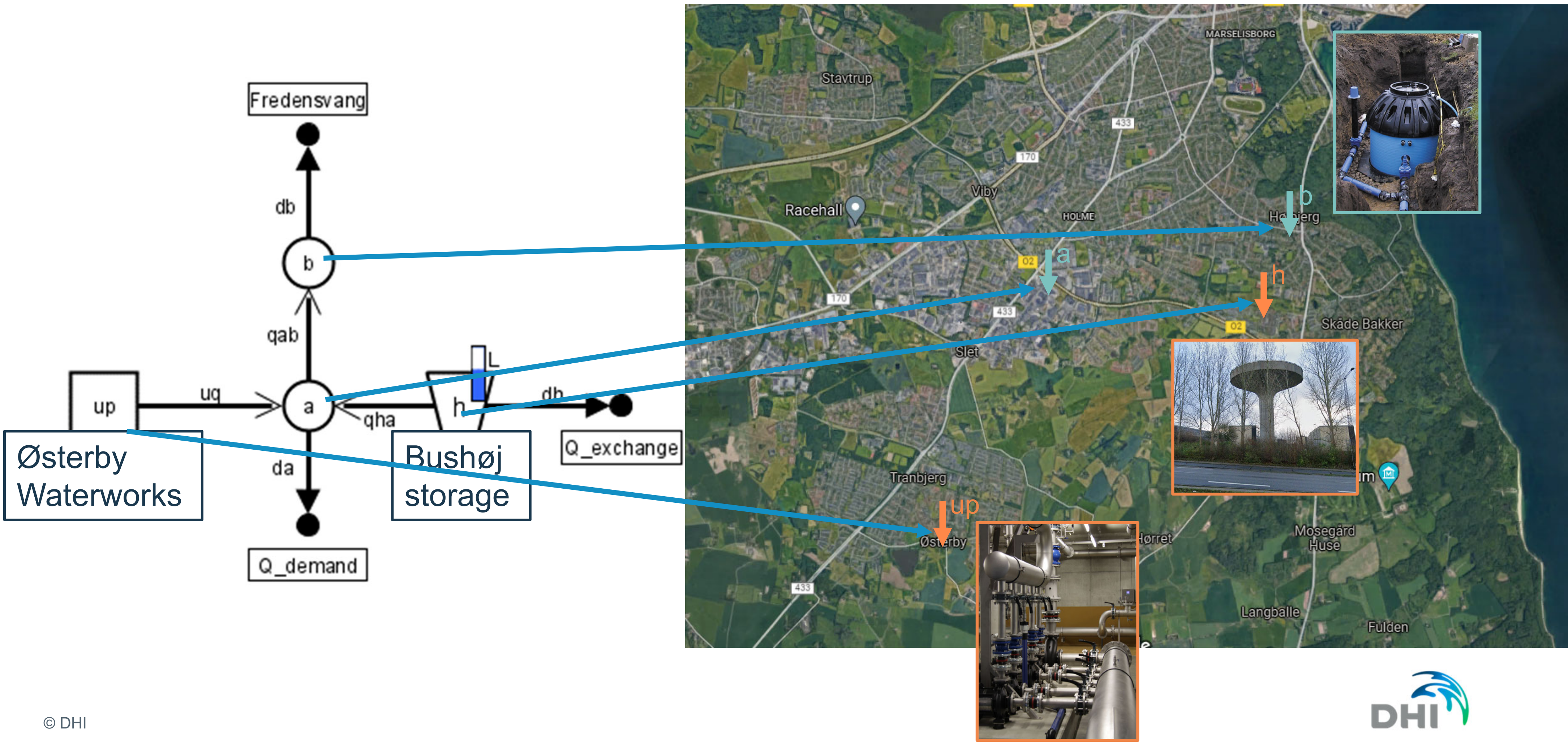
Model Predictive Control (MPC) for a pressure zone



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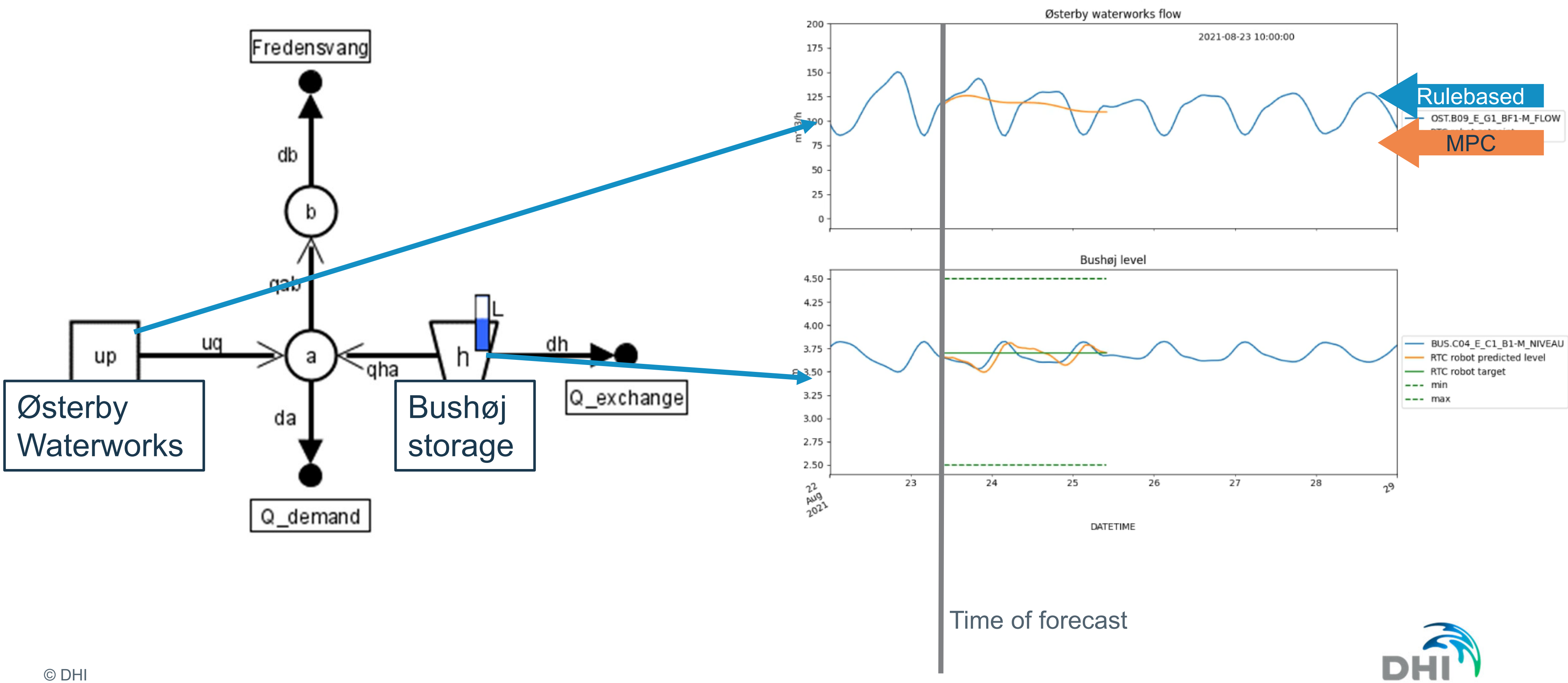

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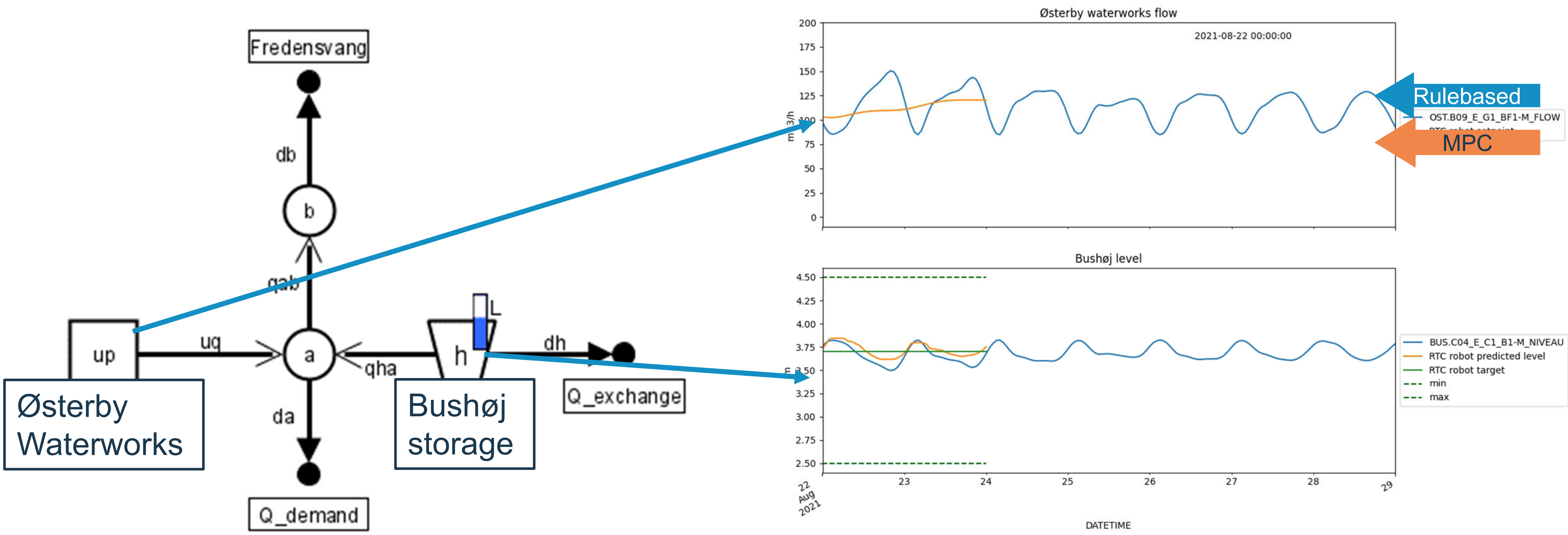

Conclusion and recap

- Successful demonstration of concept
- Optimization on energy and pressure
- Offline “shadow” optimizer – still being evaluated
- Concept scalable
- Fast optimization process

- Practical experience – initial focus on data- and workflow

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