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Let's Solve Water

November, 2019

Neural networks: teaching your treatment works to be smarter.

Xylem – A Global Water Technology Company Based in the USA

WE ARE A WATER INDUSTRY LEADER WITH GLOBAL REACH …

- Leading global water technology provider
- Approximately 16,800 global employees
- Headquarters: Rye Brook, NY; ~350 global locations
- Doing business in 150+ countries on 6 continents
- $5.2 billion in combined sales in 2018

…UNIQUELY POSITIONED TO HELP OUR PARTNERS SOLVE THE WORLD'S WATER CHALLENGES

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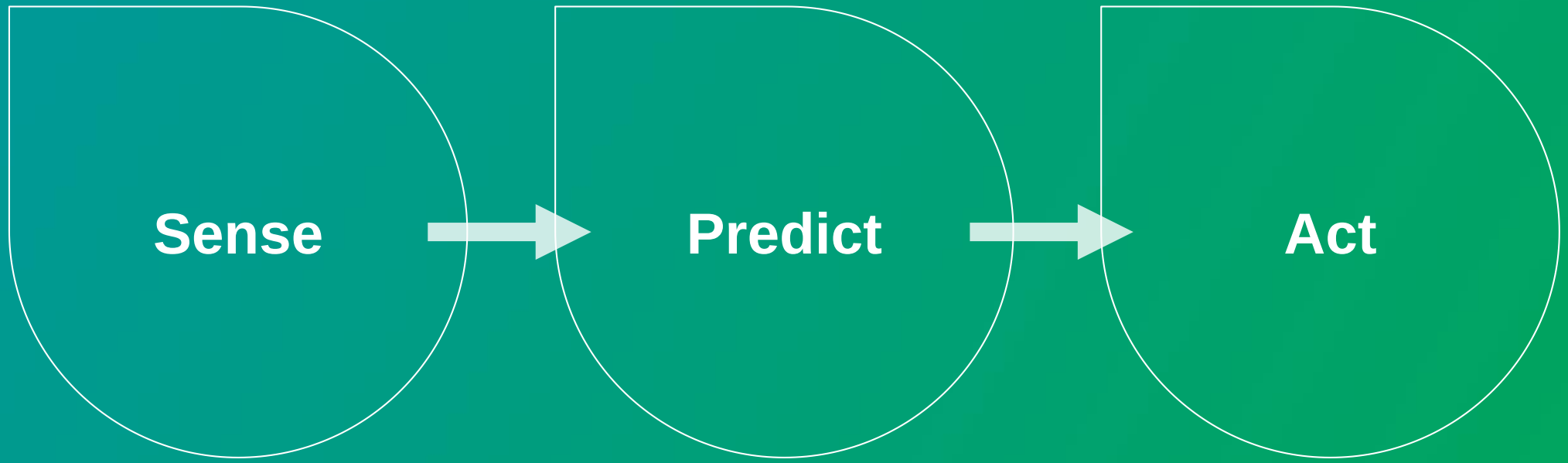

- Sensor networks
- Data management
- Structured / Unstructured data

- Digital Twin
- AI-enabled anomaly detection
- Predictive modeling

- Decision algorithms & recommendations
- Visualization & control

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BLUX

Wastewater Applications

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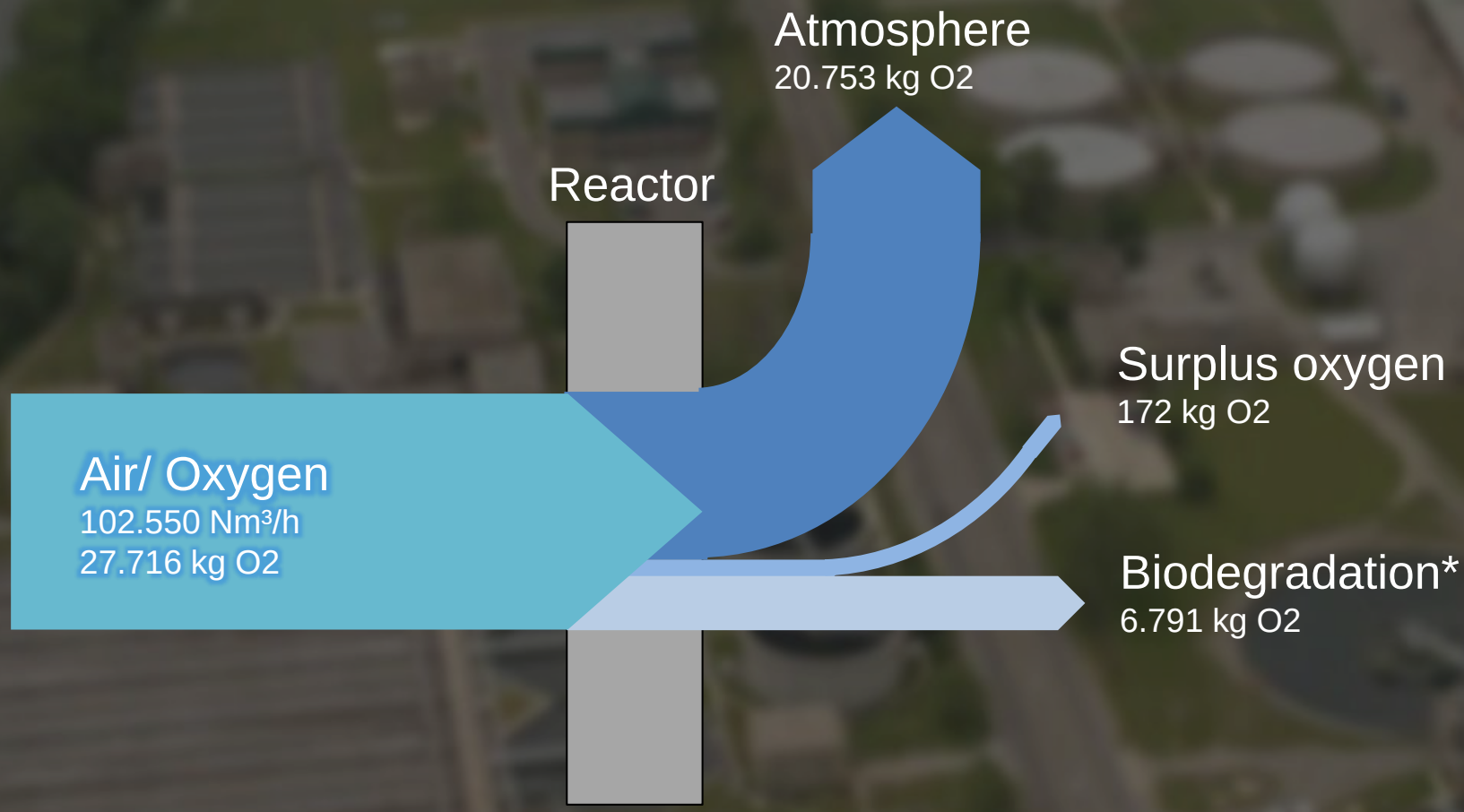
Objective:

Optimize energy and chemical usage while increasing compliance margins.

Efficiency of aeration



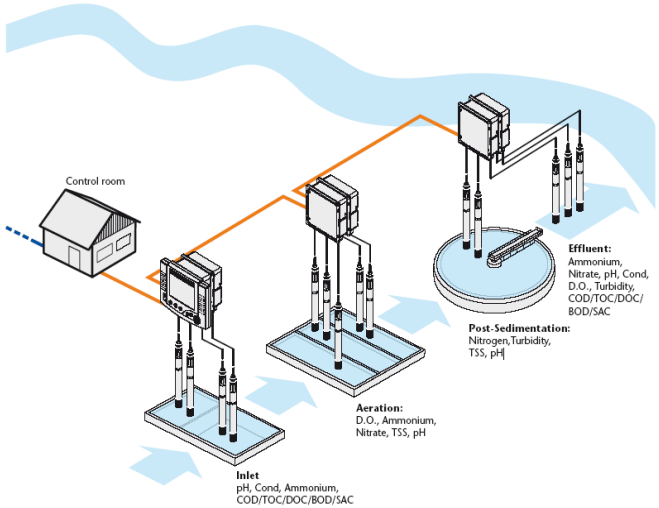
*without nitrification

Blue Infrastructure:

Control the urban water and wastewater system to improve the environment while saving ratepayers money

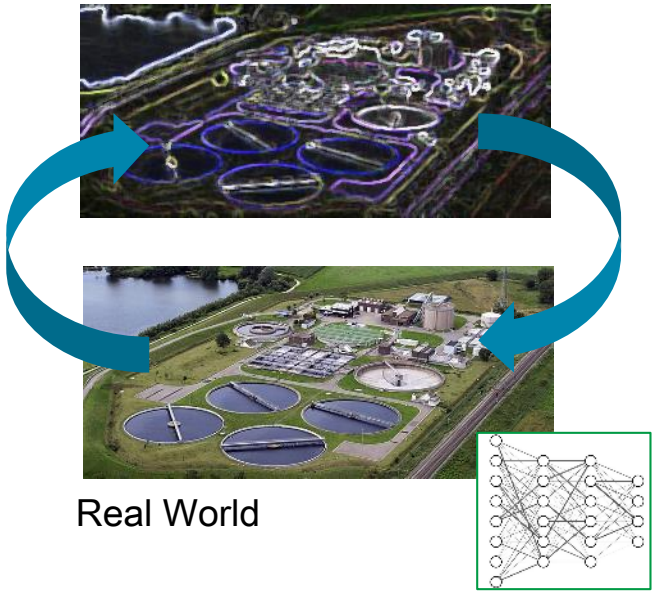
Data-Driven Process Optimization

Advanced Sensing



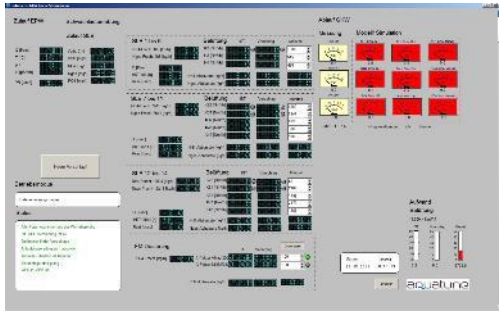
Machine Learning

Digital Twin



Real World

Dynamic Control



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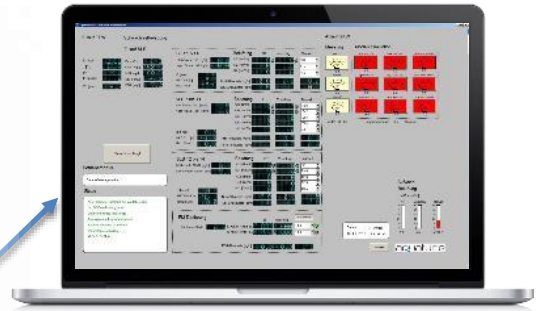
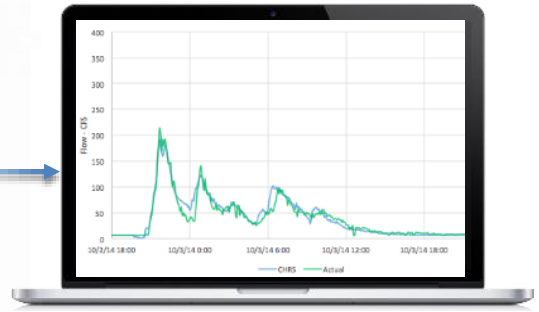
Act: Optimize

Run 1000s of scenarios
Reduce energy/chemicals
Automatic/guidance mode
Increase compliance margin



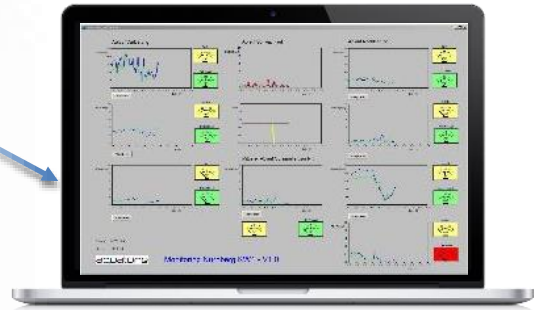
Predict: Create Digital Copy

Assimilate last 12-36 months of history
Run real time models
Recalibrate model on demand



Sense: Turn On the Lights ™

Data Collection
Real Time Alerts
Full SCADA Integration



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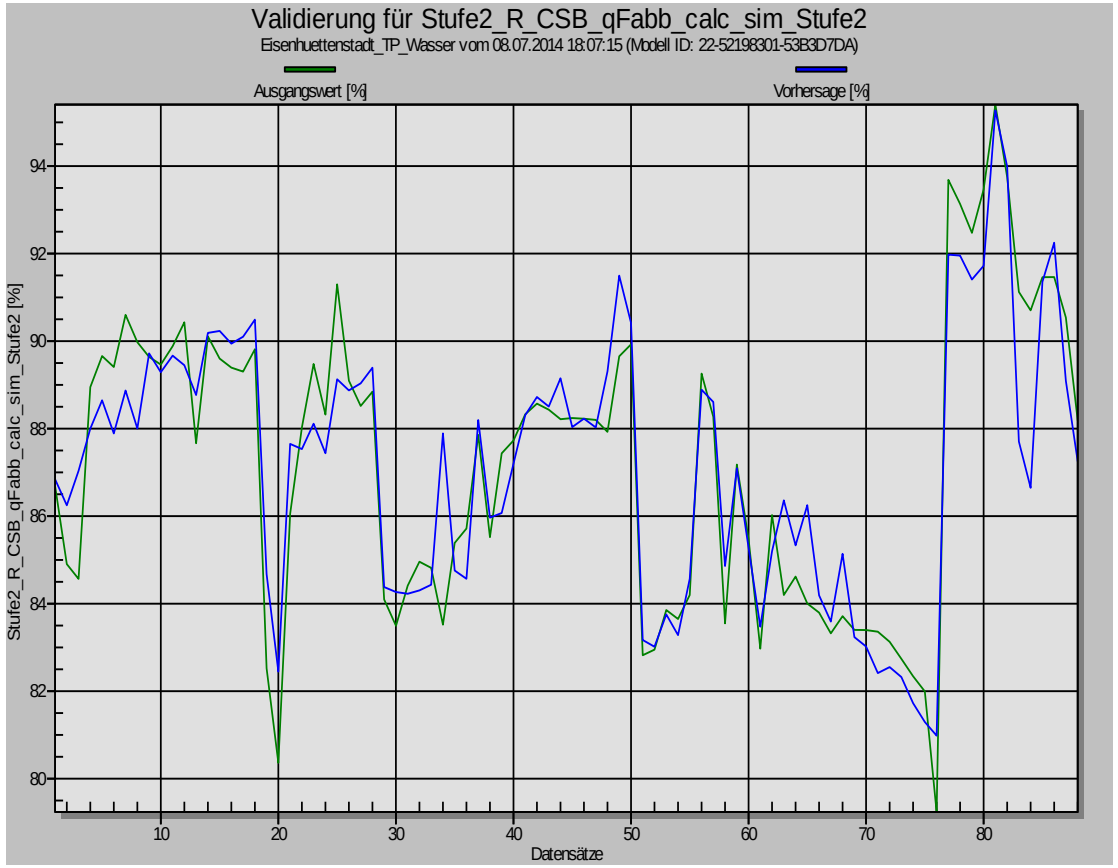
Predict: Cognitive Process Modeling



Digital Copy

Real World

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Predict: Cognitive Process Modeling

ANN-Model

Influent quantity

Temperature

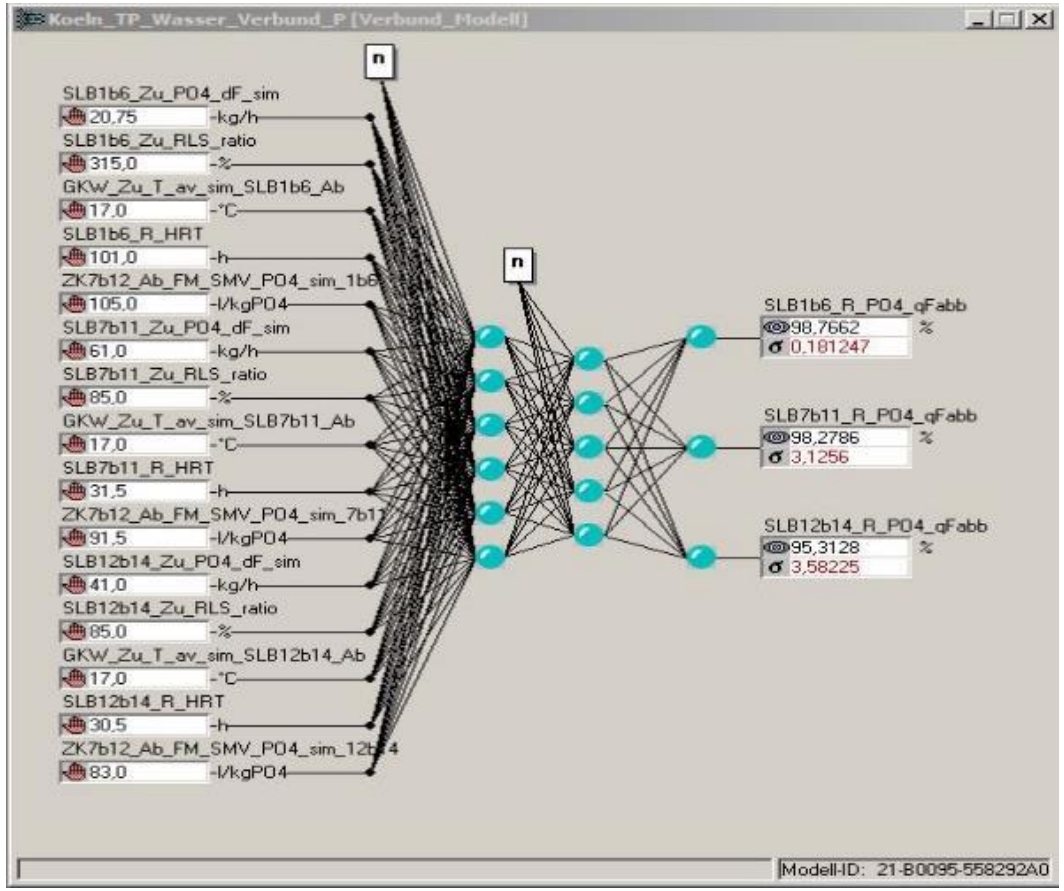
Loads

Total Solids

Aeration Intensity

Recirculation

Dosings



empirical, data driven

Degradation Rates

Effluent Concentrations

Energy Consumption

Efficiency

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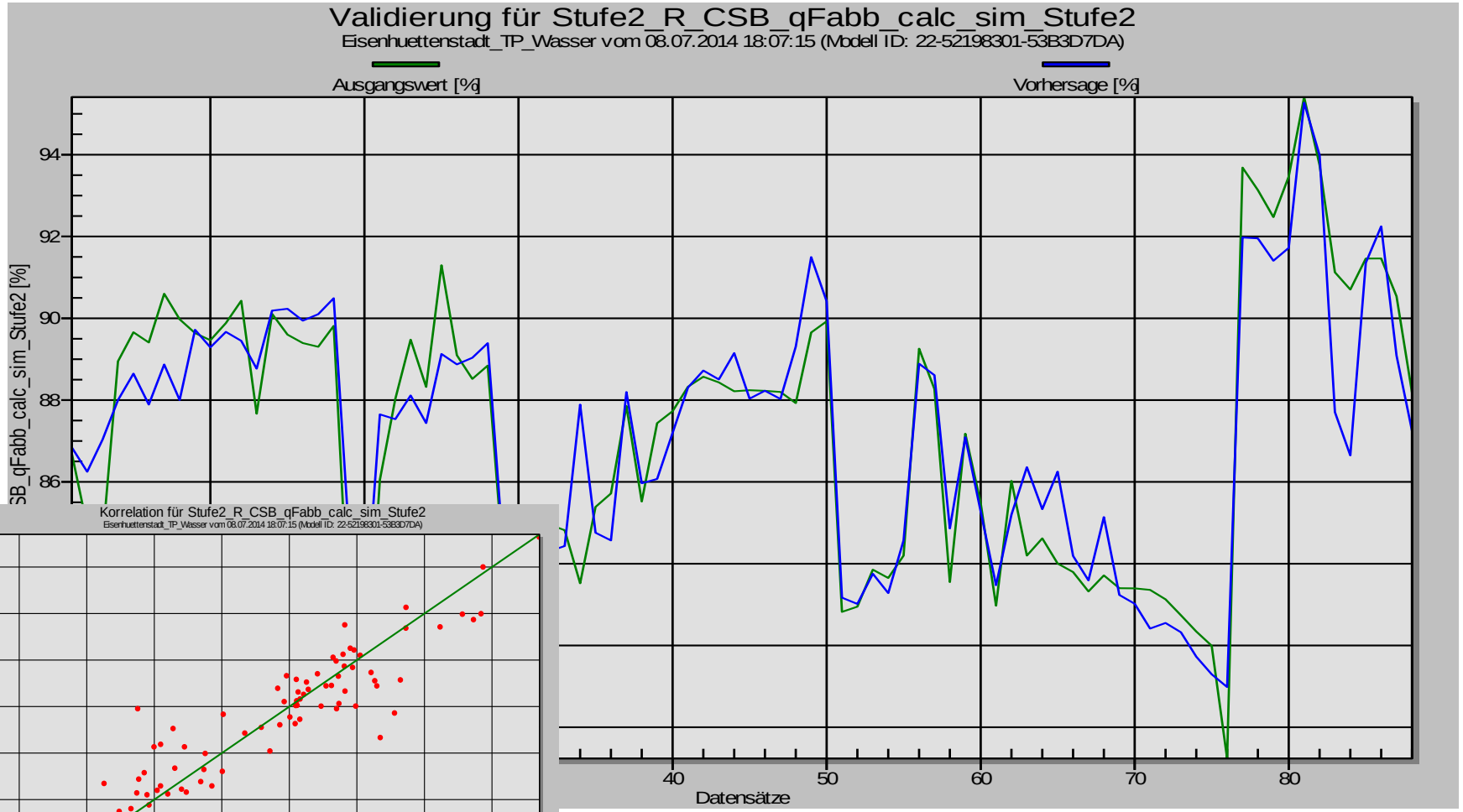
Predict: Cognitive Process Modeling



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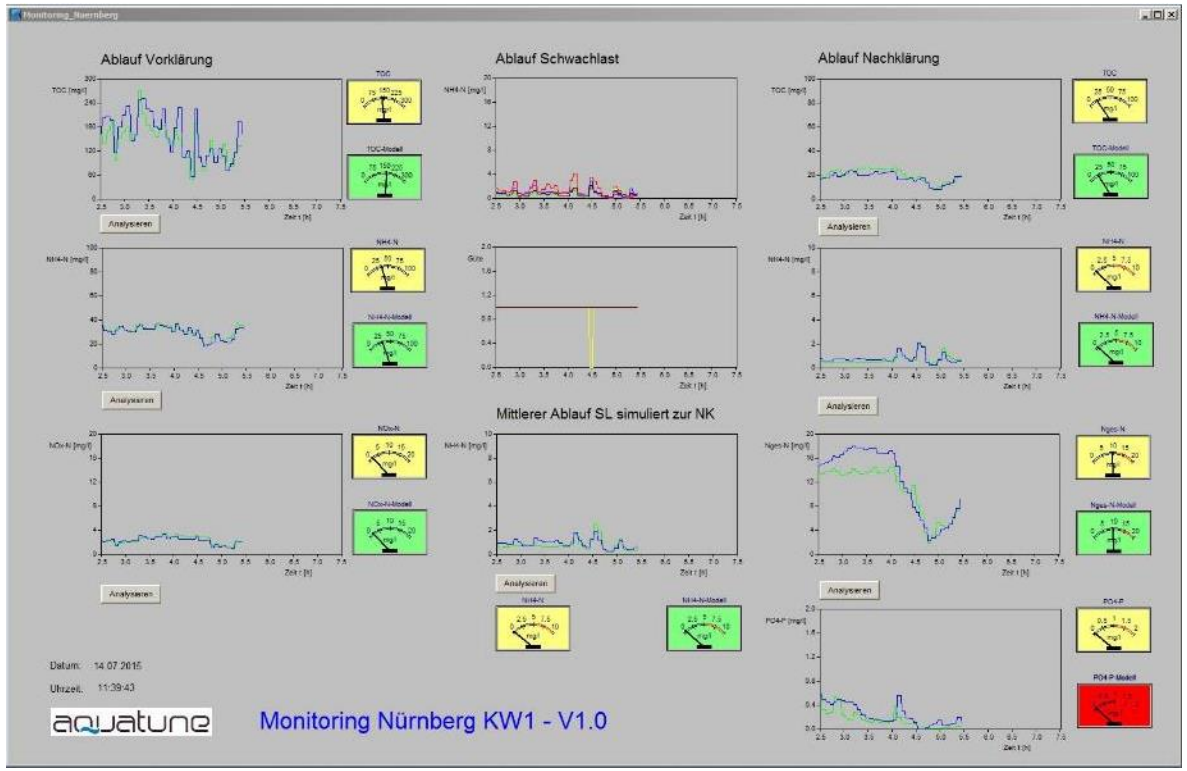
Predict: Cognitive Process Modeling



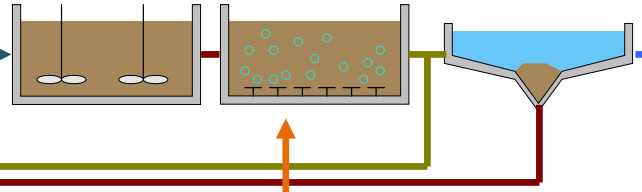
Digital twin can provide alerts when:

- Plant has abnormal operation.
- Sensor has issues.

Real Plant

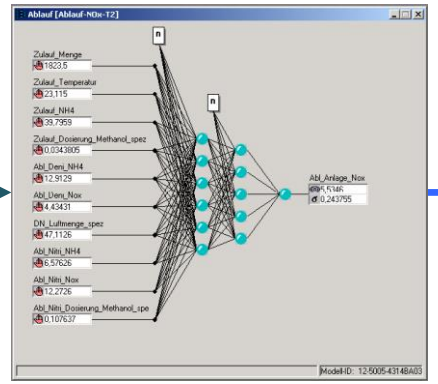
Input Data:
- Oxygen Demand
- Nitrogen
- Phosphorus

Setpoints:
- Aeration
- Recirculation
- Precipitant
- Flocculant
- Dosages
- a.s.o.
- ….



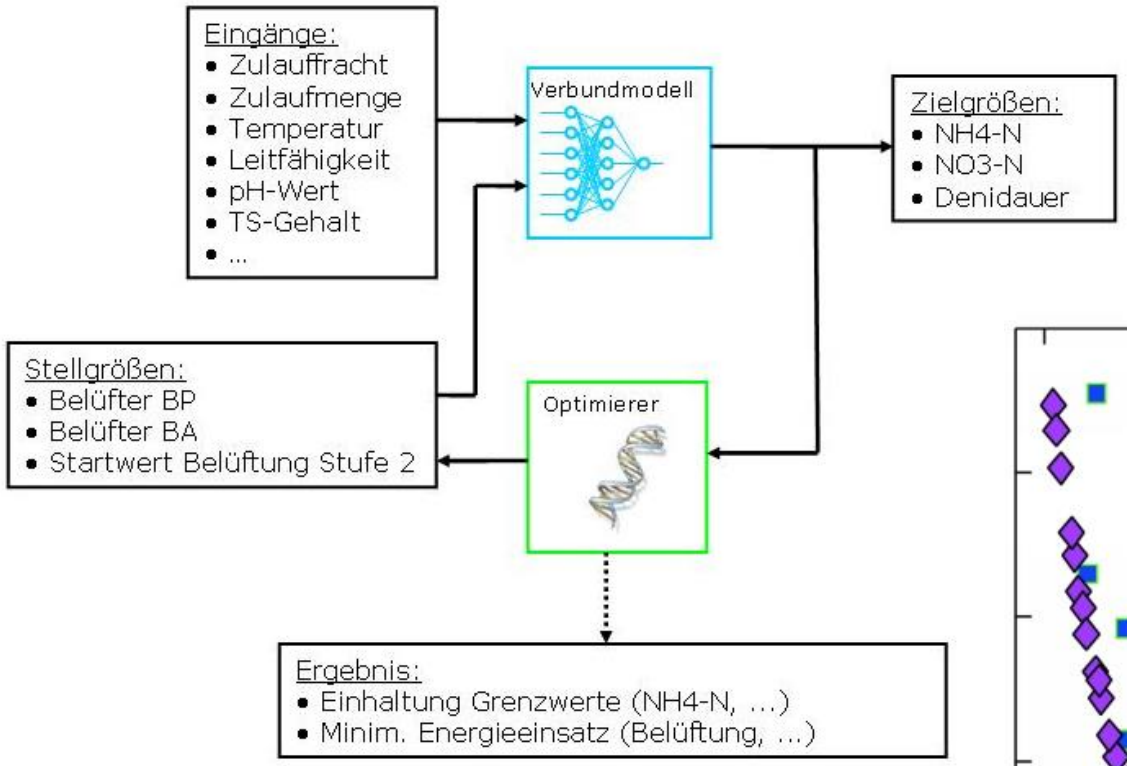
Effluent Data:
- Oxygen Demand
- Nitrogen
- Phosphorus

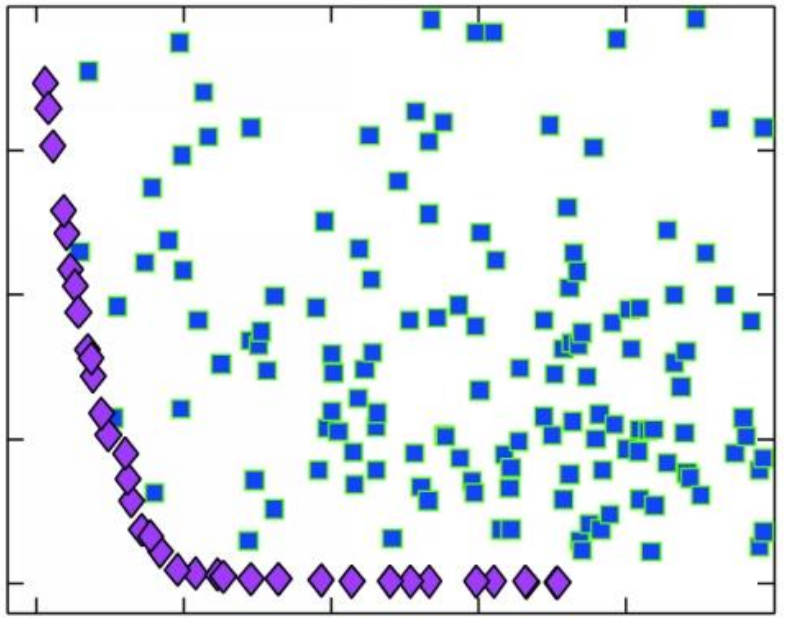
Simulation (Artificial Neural Network)



Prediction:
- Oxygen Demand
- Nitrogen
- Phosphorus

Optimize Process





- Genetic Algorithm
- Runs thousands of scenarios
- Selects the ideal control settings
- Recommends incremental changes

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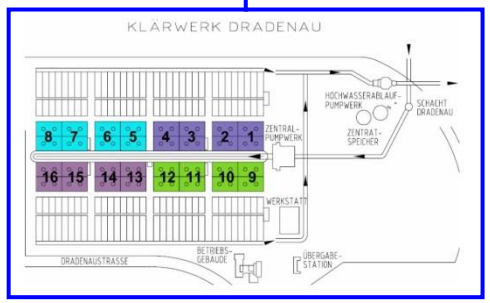
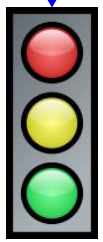
Optimize Process

Load-
Detection



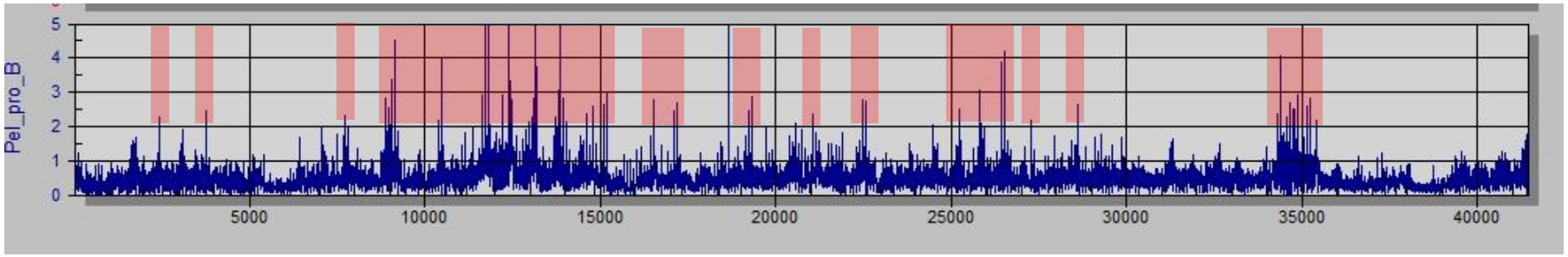
Saving-
strategy

Load-
strategy

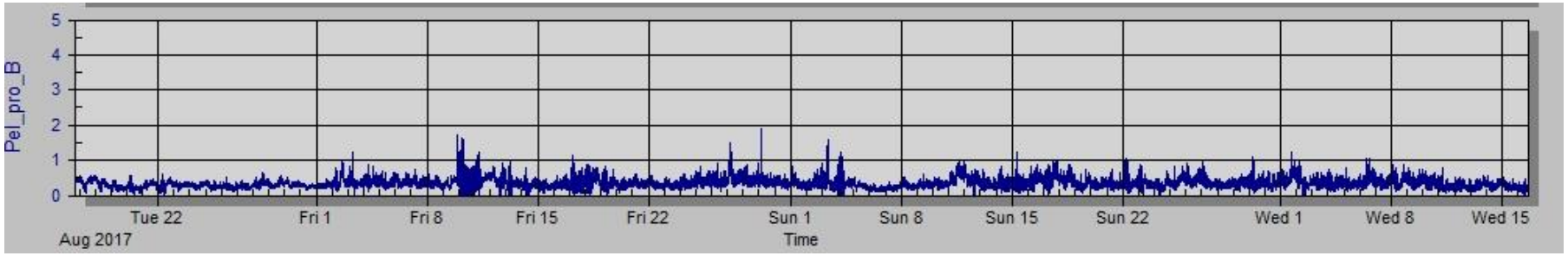


Key Performance Indicator: Specific Energy (kWh/kg)

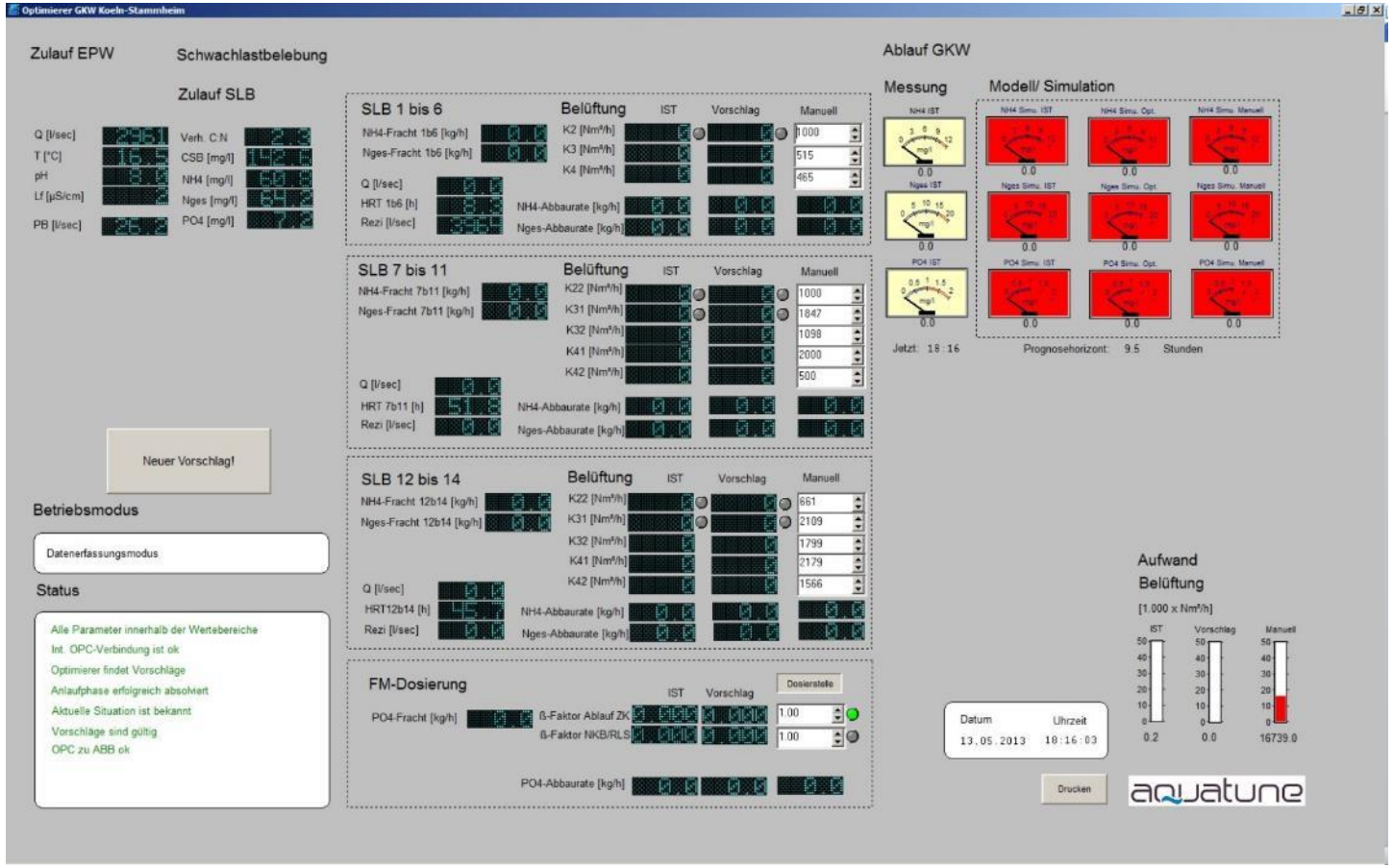
Before Optimization



After Optimization



Optimize Process



- Customized for each plant objectives
- Guidance mode / Automatic mode
- Periodic learning makes model more accurate

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Possible Optimization Strategies for Wastewater Applications

Which parameter is limiting the success?

- **Oxygen**: -> Increase aeration intensity
- **Retention time (HRT):** -> Increase aeration volume
- **Nutrient:** -> Start dosing of methanol (or similar)
- **Acidification**: -> Increase retention time in hydrolysis

Which effluent parameter is more critical?

- **Ammonium**: -> Increase nitrification
- **Nitrate**: -> Reduce aeration intensity and increase volume of denitrification

Which boundary conditions are in force?

- **Increased dissolved phosphorous**: -> Watch O2, NO3, PO4 in last cascade -> inc. aeration
- **Anaerobic growth of sludge**: -> Restrict sludge loading

Which loadings are expected (BLU-X collection systems)?

- Increase biodegradation to establish buffers for the event
- Reduce use of resources under dry weather conditions
- Active control of collection system.

Case Study: Cuxhaven WWTP

Problem

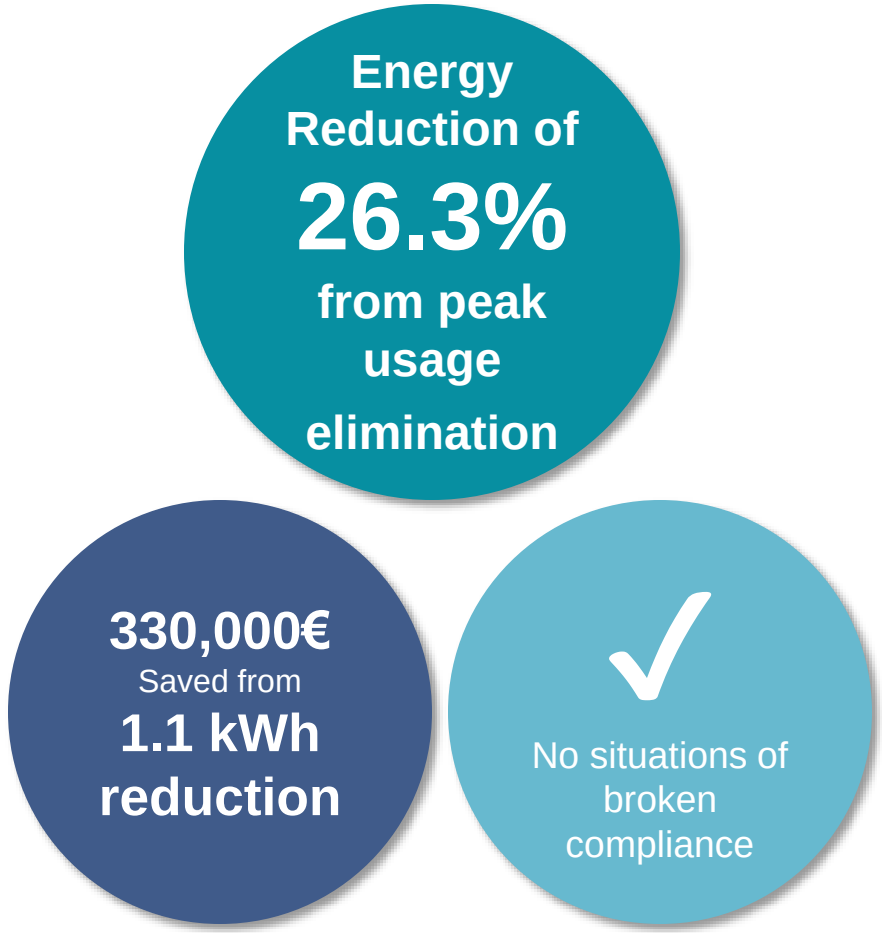
Reduce energy consumption for aeration for 5 parallel biological tanks while complying with legal effluent concentrations

aquatune Solution

Build models of the carbon-, nitrogen- and phosphorous-elimination processes to create optimization strategy.

Calculate the best setpoints for the aerators in each zone

Due to a lack of live sensors, create “virtual analyzers” using ANN’s to calculate estimated incoming carbon, nitrogen and phosphorous loads



Drinking Water Applications

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Possible Optimization Strategies for Drinking Water Applications

Find optimum dosings

- Optimize dosing of coagulants
- Optimize dosing of coagulation aids

Reduce losses and make optimum use of tariffs and of renewable energies

- Hydraulic losses are proportional to flow squared
- Activate pumps when energy is cheap
- Activate pumps when renewable energy is available
- Manage levels of elevated tanks according to consumption predictions

Find optimal timing for backwashes

- Find the best compromise between productivity and energy costs
- Find the best timing for chemical enhanced backwashes (CEB)

Reduce water losses by leakage detection

- Use Neural networksfor the fast detection of unnormal situations (for example leakages)

Intelligent process control by use of artificial neural networks (ANN) and genetic algorithms during treatment of Danube river water

Rudi Winzenbacher[1], Jörg Gebhardt[2], Silke Müller[2]

[1] Zweckverband Landeswasserversorgung [2] aquatune – Dr. gebhardt & Co GmbH

Zweckverband Landeswasserversorgung

Background

- The operation of coagulation-sedimentation plants used for river water treatment is quite ambitious, particularly with regard to the necessary dosage of coagulant (e.g. Fe^{3+}) and coagulant aid (CA).
- Typically the dosages are estimated according to the experience of many years and are corrected manually. This results in an excess consumption of treatment additives (preventive higher dosing, „human control inertia") and in stress for the operation crew.

Conclusions / Outlook

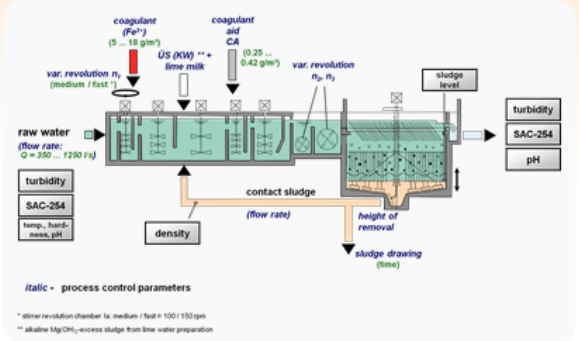
- By use of an intelligent process control based on ANN modelling a situation-specific full-automatic operation mode can be realized.
- Necessary prerequisite is that the modelling system is fitted close enough to real plant characteristics.
- A higher teatment efficiency is possible (potential savings of approx. 10 %).
- Future works including ANN re-training has to be done to enhance system reliabiltiy for a wider range of operation conditions.

Pre-treatment of Danube river water at Langenau Waterworks

Coagulation-sedimentation in a compact flocculation plant

Raw water quality:

turbidity = 2 … 500 FNU
SAC-254 = 2 … 30 m^{-1}



Outlet quality:

turbidity < 0.7 FNU
SAC-254 < 6 m^{-1}

- Treatment of approx. 30 Mio. m^3/a
- 11 control parameters, e.g. $ß_{Fe}$ (5 … 18 g/m^3) and $ß_{CA}$ (0.25 … 0.42 g/m^3)
- Costs of treatment additives (2011): 1,044 €/t Fe 2,600 €/t CA

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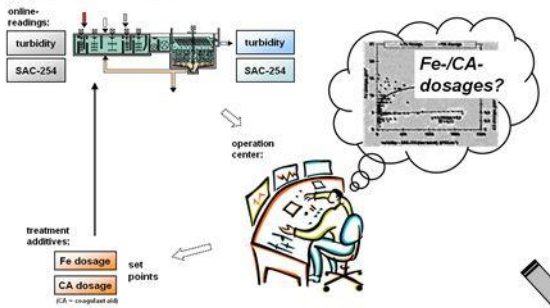
The way to an intelligent process control

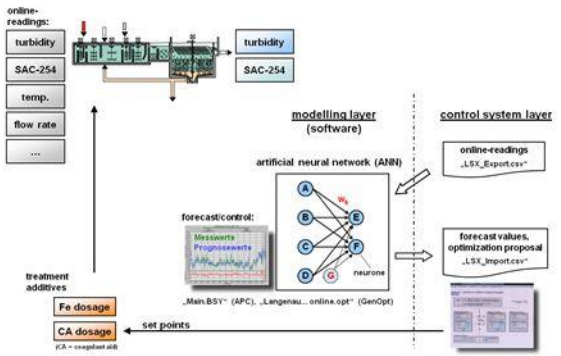
Conventional control of the coagulation-sedimentation step (until 2009) …



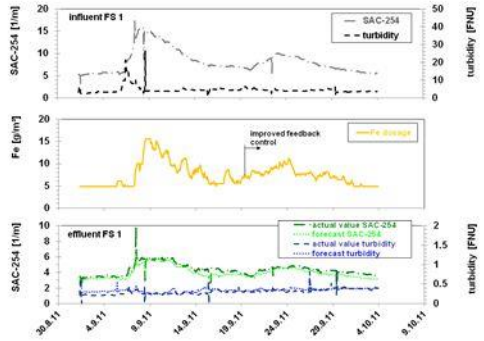
Realization steps:

- Compilation and analysis of process data (2005-2008)
- Building, training and validation of ANN-models
- Formulation of the optimization task in terms of a target function and constraints
- Analysis of crucial online parameters
- Test phase with ANN-re-trainings and alterations for improved consideration of model uncertainties

… and new control system with ANN and genetic algorithms (since 2011)



Result:



How it works:

- Optimization server pemanently gets online-measured values
- The ANN which has learned plant behaviour from historical data simulates the process with varying Fe/CA dosages
- The best solution chosen by a genetic optimization algorithm is issued to the supervisory control system

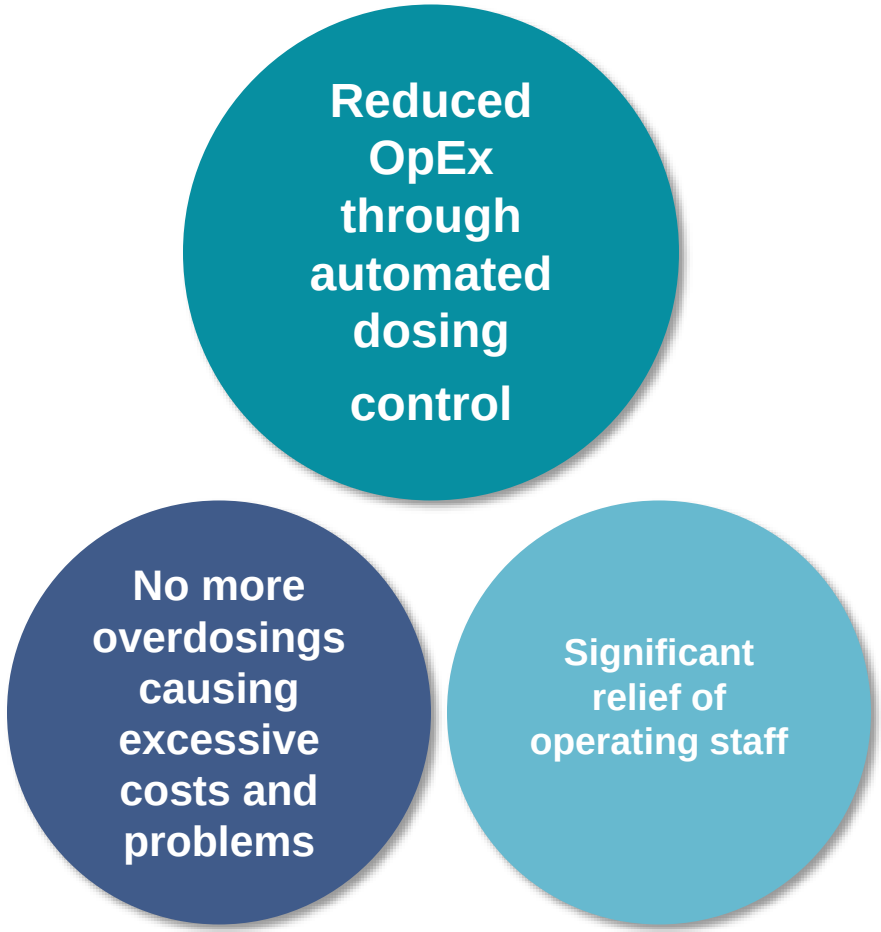
Results: Langenau Waterworks

Problem

Determine the optimal of coagulant (Fe^{3+}) and coagulant aid (CA).

aquatune Solution

Create an online optimization system for drinking water treatment system to minimize consumption of chemicals and maximize compliance.



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