# Modelling and Simulation to Assess Industrial Symbiosis

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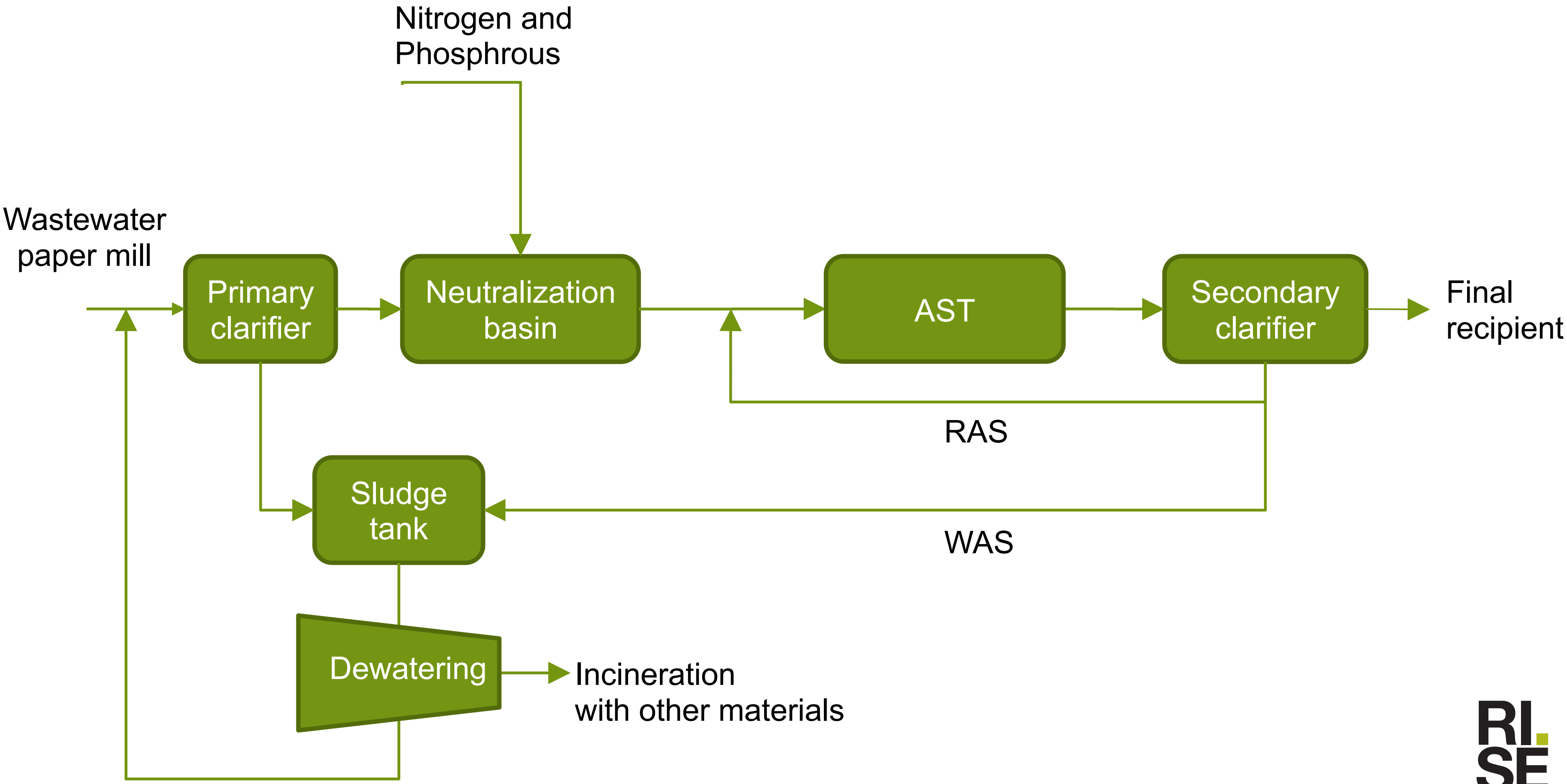
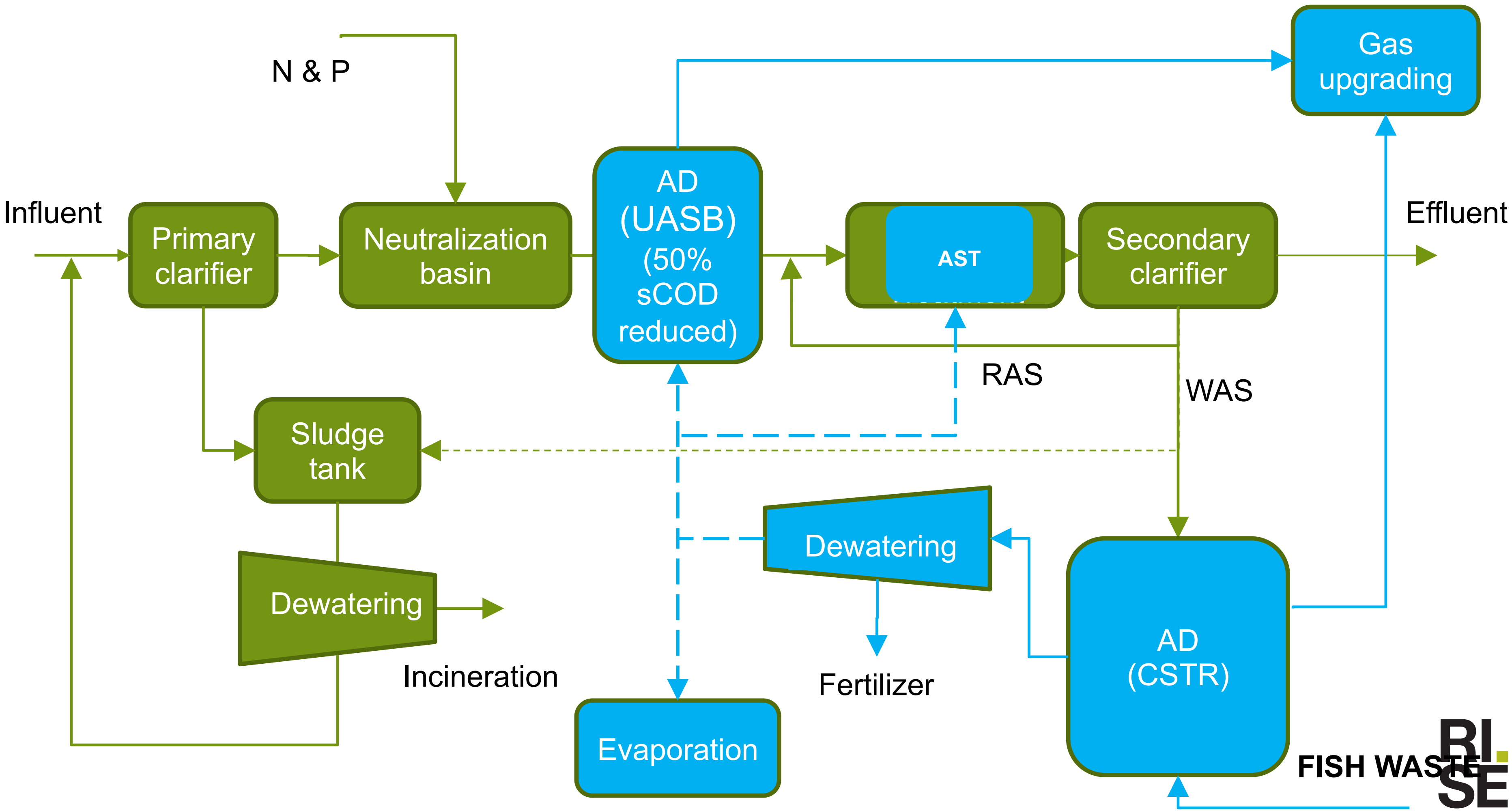

Nitrogen and Phosphrous
Wastewater paper mill
Primary clarifier
Neutralization basin
AST
Secondary clarifier
Final recipient
RAS
Sludge tank
WAS
Dewatering
Incineration with other materials



N & P
Gas upgrading
Influent
Primary clarifier
Neutralization basin
AD (UASB) (50% sCOD reduced)
AST
Secondary clarifier
Effluent
RAS
WAS
Sludge tank
Dewatering
Dewatering
Incineration
Fertilizer
Evaporation
AD (CSTR)
FISH WASTE

# Process Modelling

# Introduction

- The purpose of models is to reflect the real world system in order to understand them
- Model development must take a stance in the problem formulation for which the model will be used
  - The best model is the simplest one possible to address problem
- Models are useful but never correct

**The main problem in our field is to keep the main problem the main problem**

**– George Ekama**

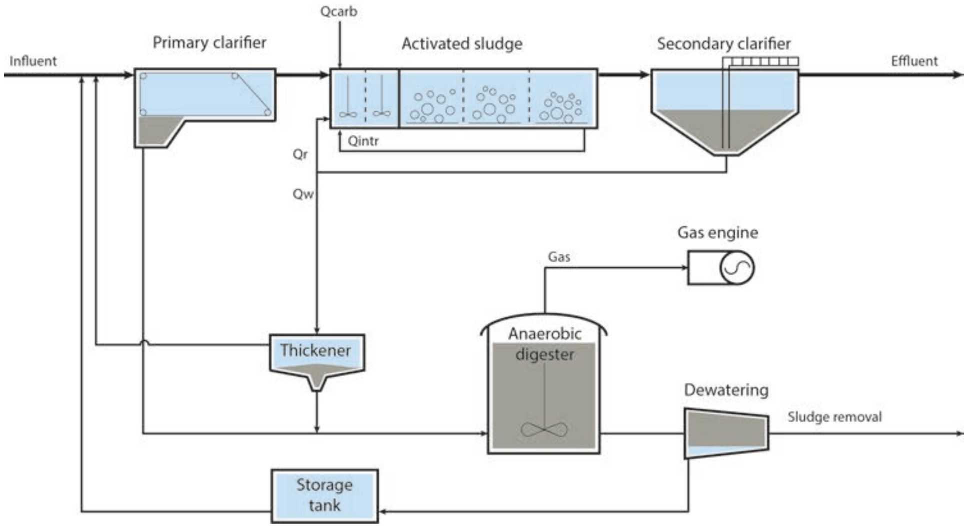
# Modelling goals

- WWTP modelling for developing process understanding
- Modelling for WWTP design
- Modelling for WWTP optimisation
- Modelling for WWTP control
- WWTP modelling for teaching/learning
- Digital Twins

# WWT
# Process Model

- Hydraulics
- Biological processes
- Chemical Processes

- Sub models
  - Activated sludge
  - Anaerobic digestion
  - Settling
  - Etc.
- Mathematical equations implemented in a computational software for simulations



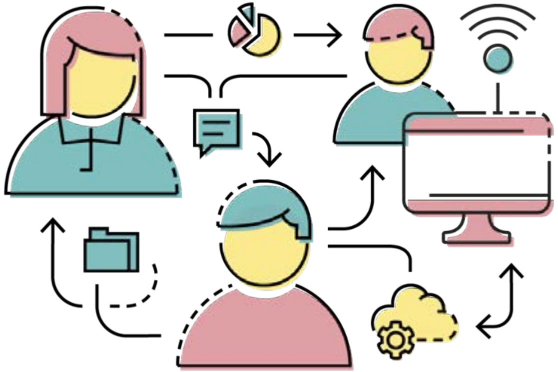
# Case Study – Skogn

# Aim and purpose of modelling

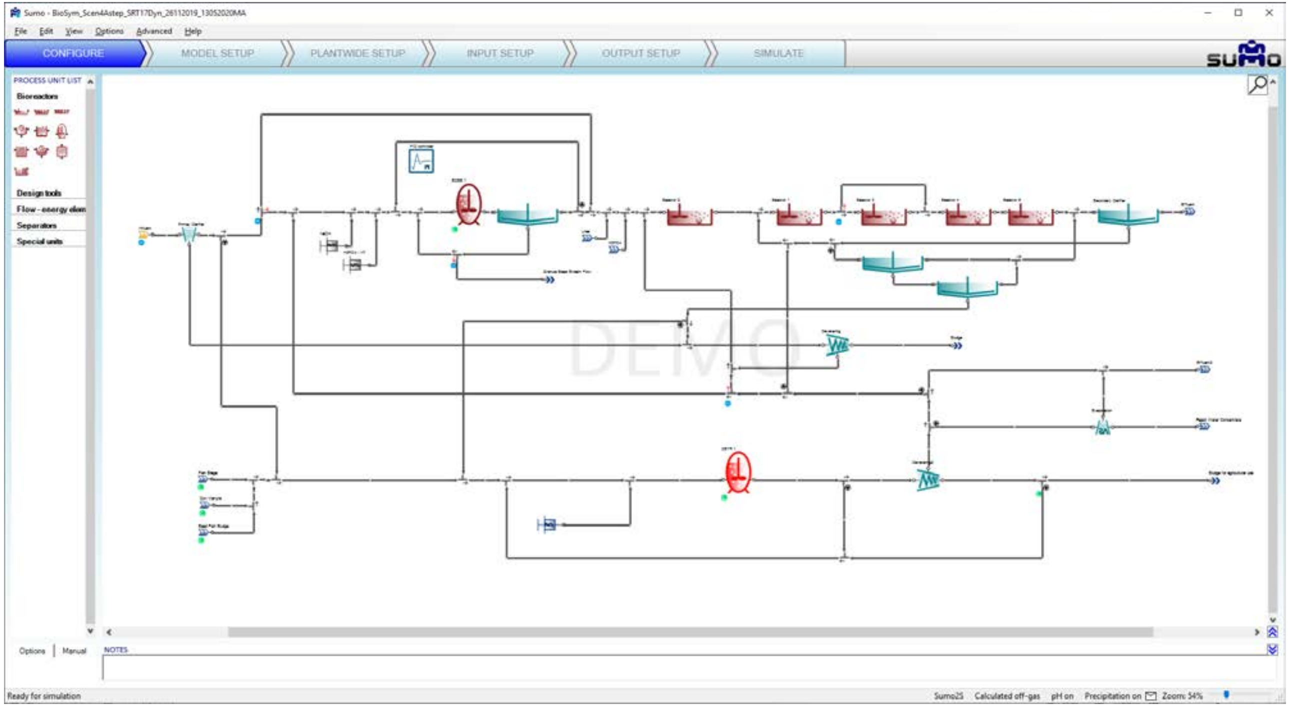
- Evaluate plant-wide impact of industrial symbiosis concept
  - Impact on effluent water quality
  - Evaluate plant operational strategies, incl. disturbances
  - Optimize nutrient additions
  - Optimize co-substrate mix
  - Communication purposes

# Model developments

- Physico-chemical modelling
- Sulfur conversion and reactions
- Granular anaerobic process
- (Methane oxidation)

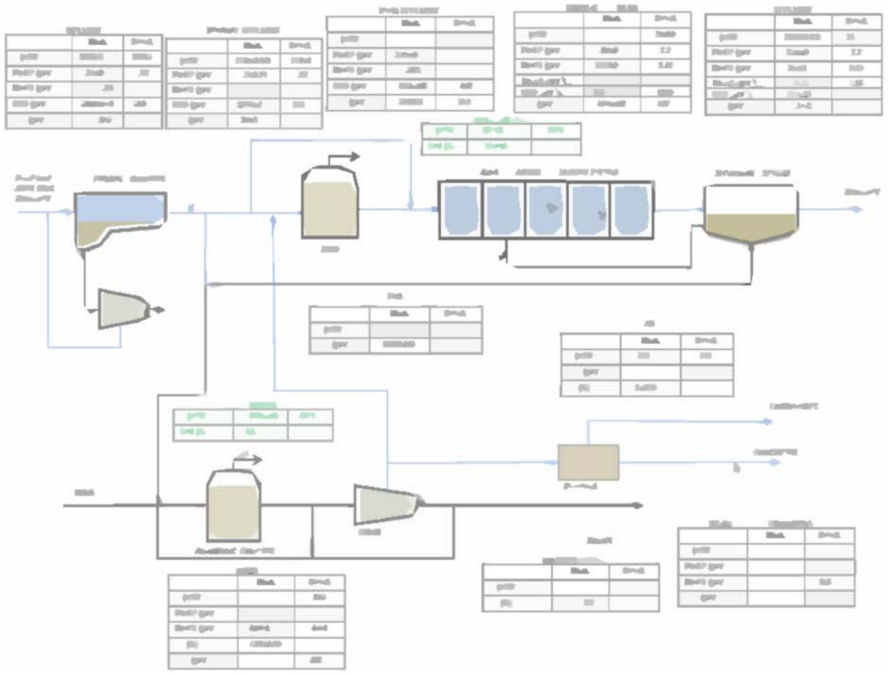


# SUMO modelling software



# Model calibration and validation

- Following Good Modelling Practice
- Thorough data collection campaigns
- Influent characterization
- Calibration of model parameters until criteria
- Validation on separate data set
- Static and dynamic



# Results

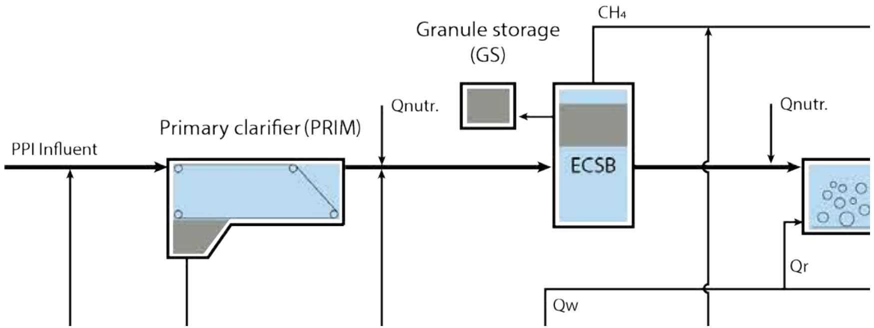
# COD load and characteristics

**COD fractionation – 7 variables**

- Volatile fatty acids (VFA)
- Readily biodegradable substrate (non-VFA)
- Slowly biodegradable substrate
- Soluble unbiodegradable organics
- Particulate unbiodegradable organics
- etc

**Transformation of COD**

- Mechanical separation
- Microbial growth on substrate (varying conditions)
- Decay and hydrolysis



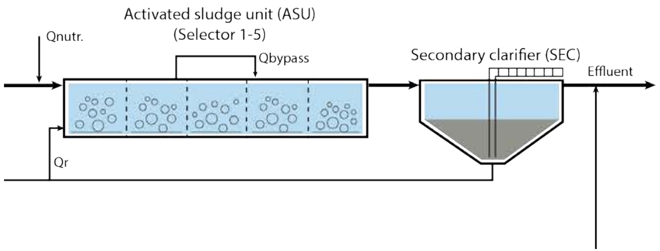
# Activated sludge operation

**Transformation of COD**

- Aeration requirement is reduced
- Operational strategy analysed, e.g. by-passing of Selector 3

Predicting

- Higher COD-content of WAS
- Lower fraction of COD in WAS is unbiodegradable
- → Biogas potential higher

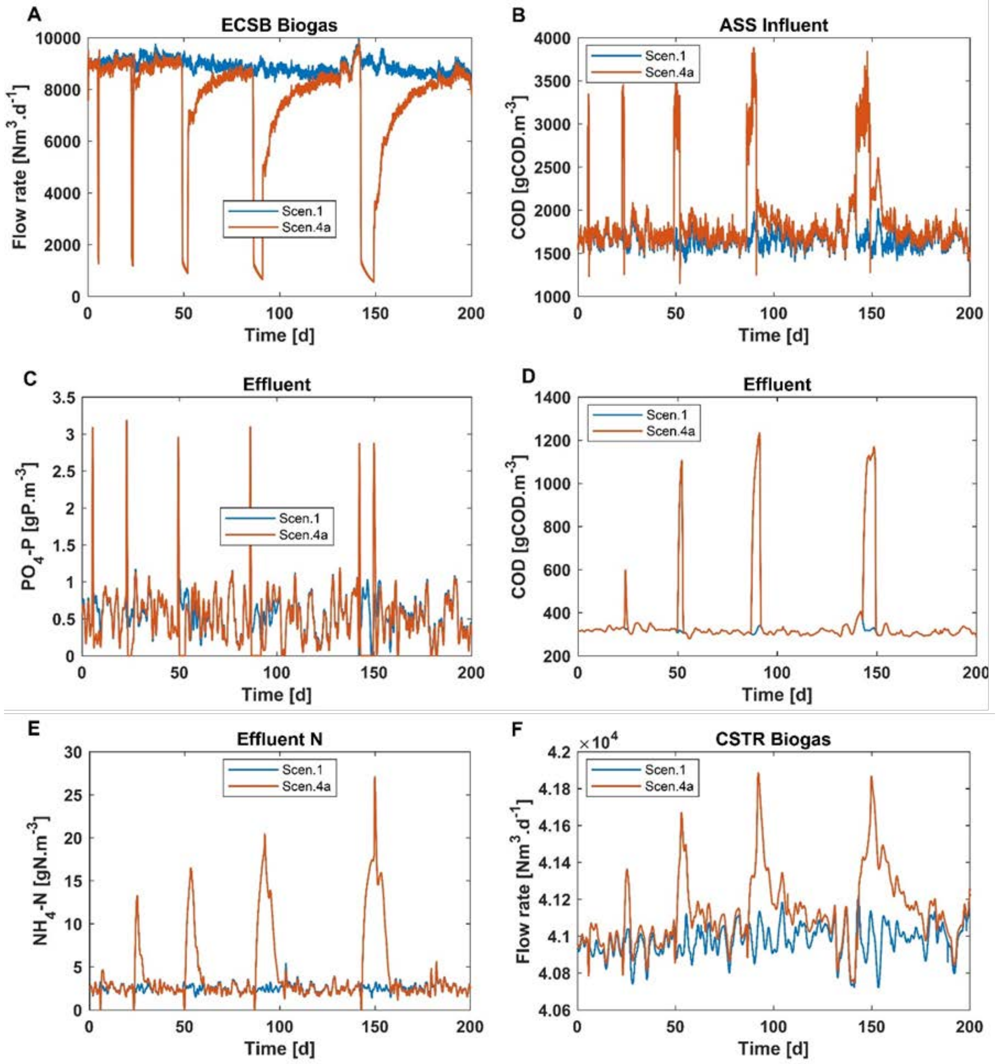


# Nutrient optimization

| Scenario | Nutrient dosing | | | | Effluent quality | | |
|---|---|---|---|---|---|---|---|
| | N reject water (kgN.d$^{-1}$) | P reject water (kgP.d$^{-1}$) | H3PO4 ECSB (kgP.d$^{-1}$) | H3PO4 ASS (kgP.d$^{-1}$) | N (kgN.d$^{-1}$) | P (kgP.d$^{-1}$) | COD (kgCOD.d$^{-1}$) |
| **Nutrient optimization** | -17 % | -18 % | -100 % | -100 % | Improved | Improved | Similar |
| **Nutrient optimization – reduced SRT** | -8 % | -2 % | -100 % | -62 % | Similar | Improved | Similar |

# ECSB bypass

- Disturbance case – short term bypass of primary effluent over ECSB to activated sludge
- Time for bypass: 0,5, 1, 3, 5, 7 days.
- 0,5 and 1 days – limited impact.
- 3, 5, 7 days – prolonged impact.



# Conclusions technical

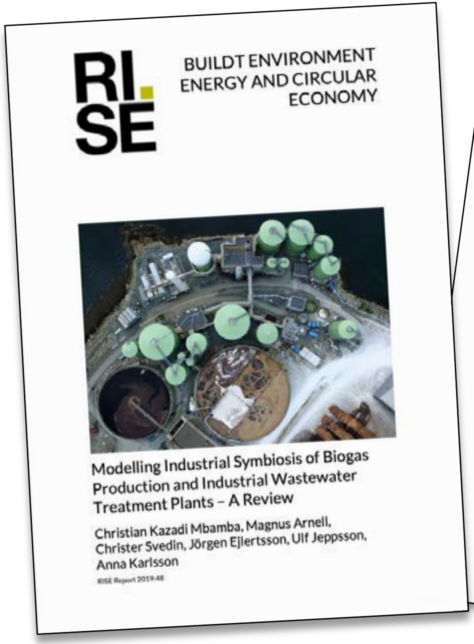
- Predict the characteristics of the COD to ASS as a result of adding an ECSB
- Assessment of operational strategy for ASS with reduced load
  - lower SRT and bypass of Selector 3 is possible
  - the lower load also means a reduced need of aeration in the ASS
- Predict how the sludge age in the ASS affect the biodegradable organics in the WAS
  - the slowly biodegradable COD is roughly doubled.
  - this indicate an improved biomethane potential of the WAS.
- Nutrient dosing optimizations identified and savings estimated
- Assessment of the effect of ECSB-bypass on the ASS at different time length
- Sulphur conversion processes shown and fate of S predicted

# Conclusions general

- Model developed in commercial platform with success
- Important output variables are predicted – averages and trends in simulated scenarios
- Simulations provided valuable process insights during commisioning of full-scale process
- Simulation results are valuable for communication with plant operations, contractors etc.
- Model adaptable to other plants through re-chatacterization and re-calibration

# Where to go from here…

- Literature review
- Project report
- Project website

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