Thursday 21st May 2020

Gain efficiency in your wastewater water plant while maintaining the highest process output

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Agenda

Wastewater Treatment

- Short introduction to Plant and Processes
- Typical Energy Usage

Looking at the Secondary Biological Treatment Process

- Potential for Optimisation
- Aeration Plant Performance
- CFD Modelling
- Bjegemark, A Case Story with CFD

Control Optimisation

- How To Do It?

Data Driven Site Wide Performance

- Smart Infrastructure
- Optimisation Strategies

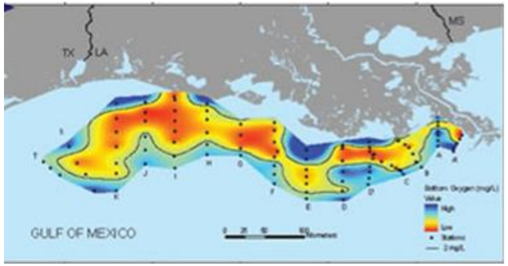
Why Do We Need to Treat Wastewater

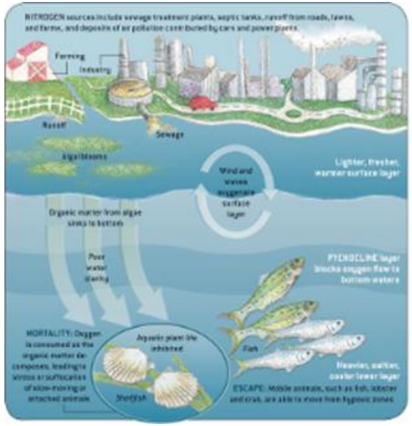
Protect Nature (recipient)

- Low Oxygen Level (BOD)
- Eutriphication (N, P)

Protect Human Health and Maintain Water Body Quality

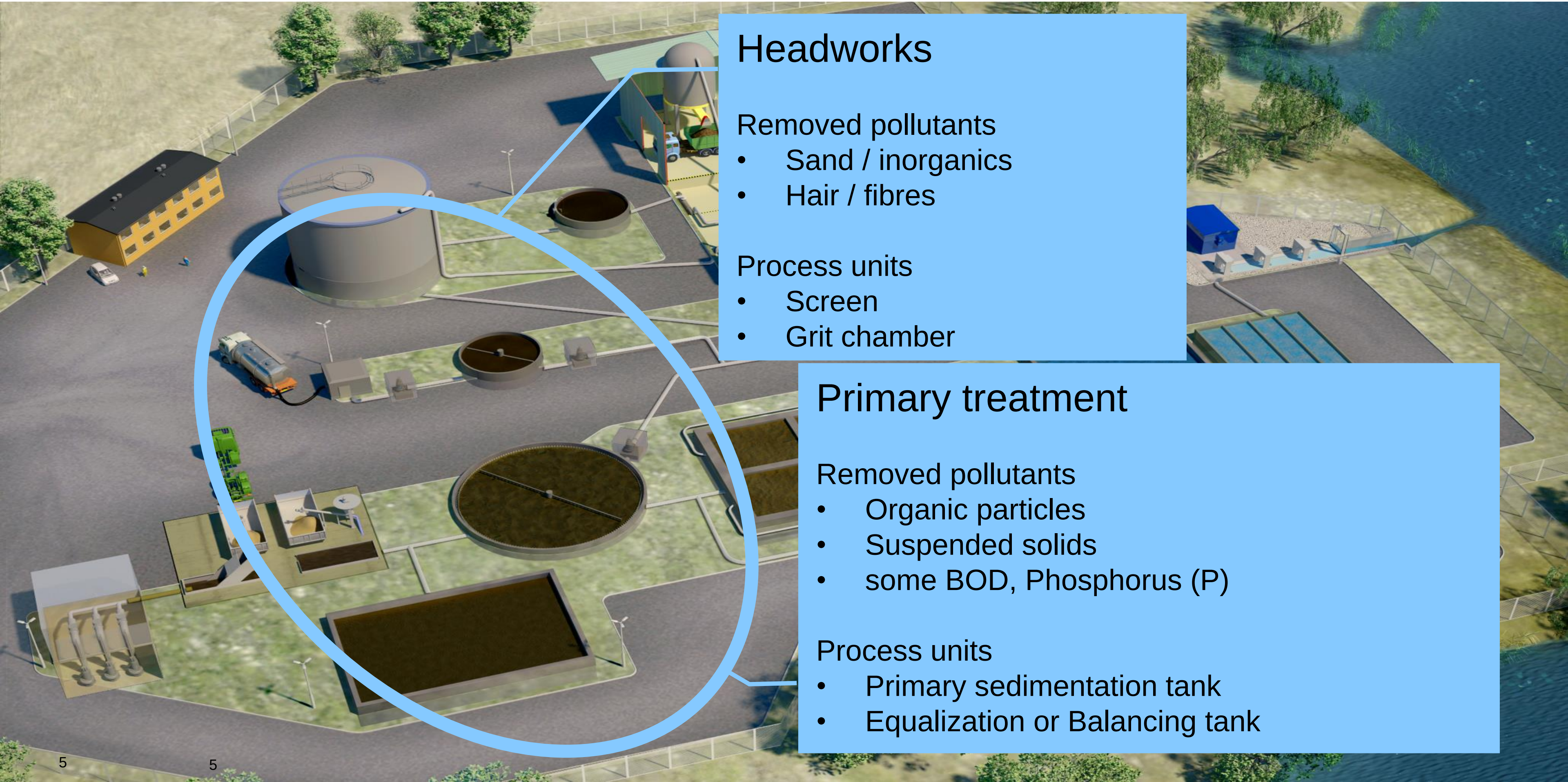
- Visible pollution in the water body and along shore lines and beaches (Aesthetic issue)
- Pathogenic organisms (bacteria, viruses)





A Typical Wastewater Treatment Plant

Wastewater Treatment



Headworks

Removed pollutants

- Sand / inorganics
- Hair / fibres

Process units

- Screen
- Grit chamber

Primary treatment

Removed pollutants

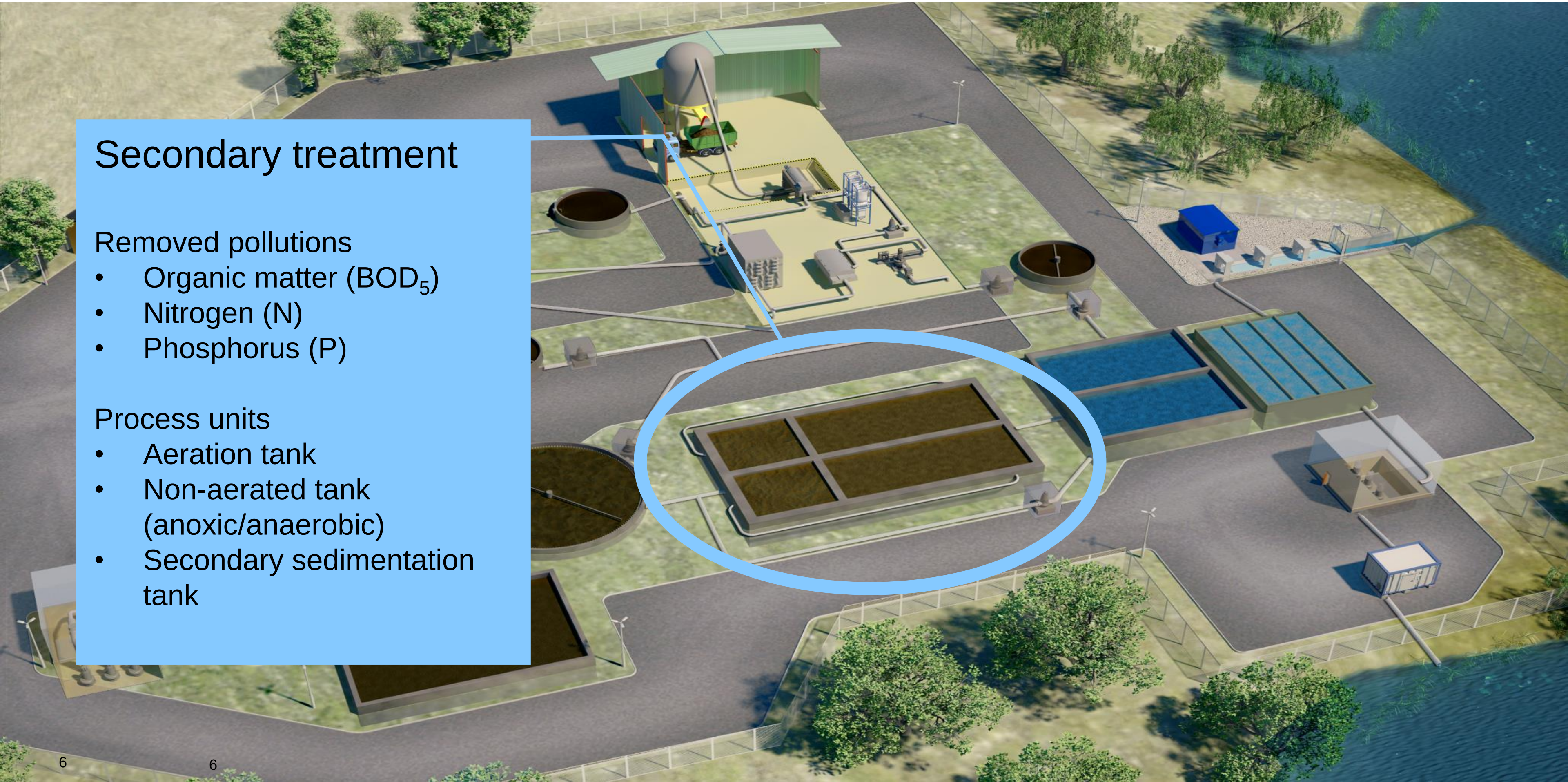
- Organic particles
- Suspended solids
- some BOD, Phosphorus (P)

Process units

- Primary sedimentation tank
- Equalization or Balancing tank

5

Wastewater Treatment



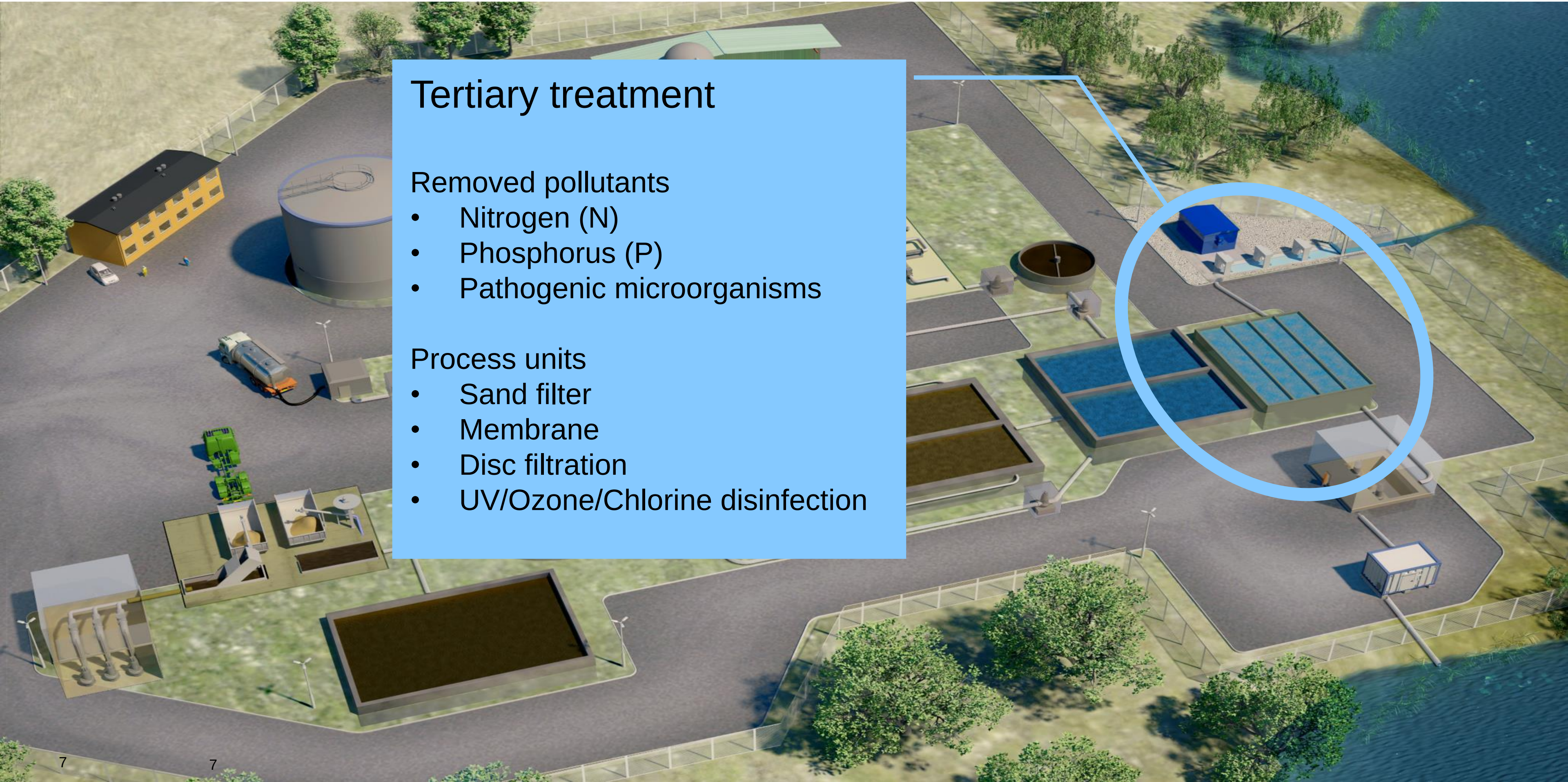
Secondary treatment

Removed pollutions
- Organic matter (BOD_5)
- Nitrogen (N)
- Phosphorus (P)

Process units
- Aeration tank
- Non-aerated tank (anoxic/anaerobic)
- Secondary sedimentation tank

6

Wastewater Treatment



Tertiary treatment

Removed pollutants

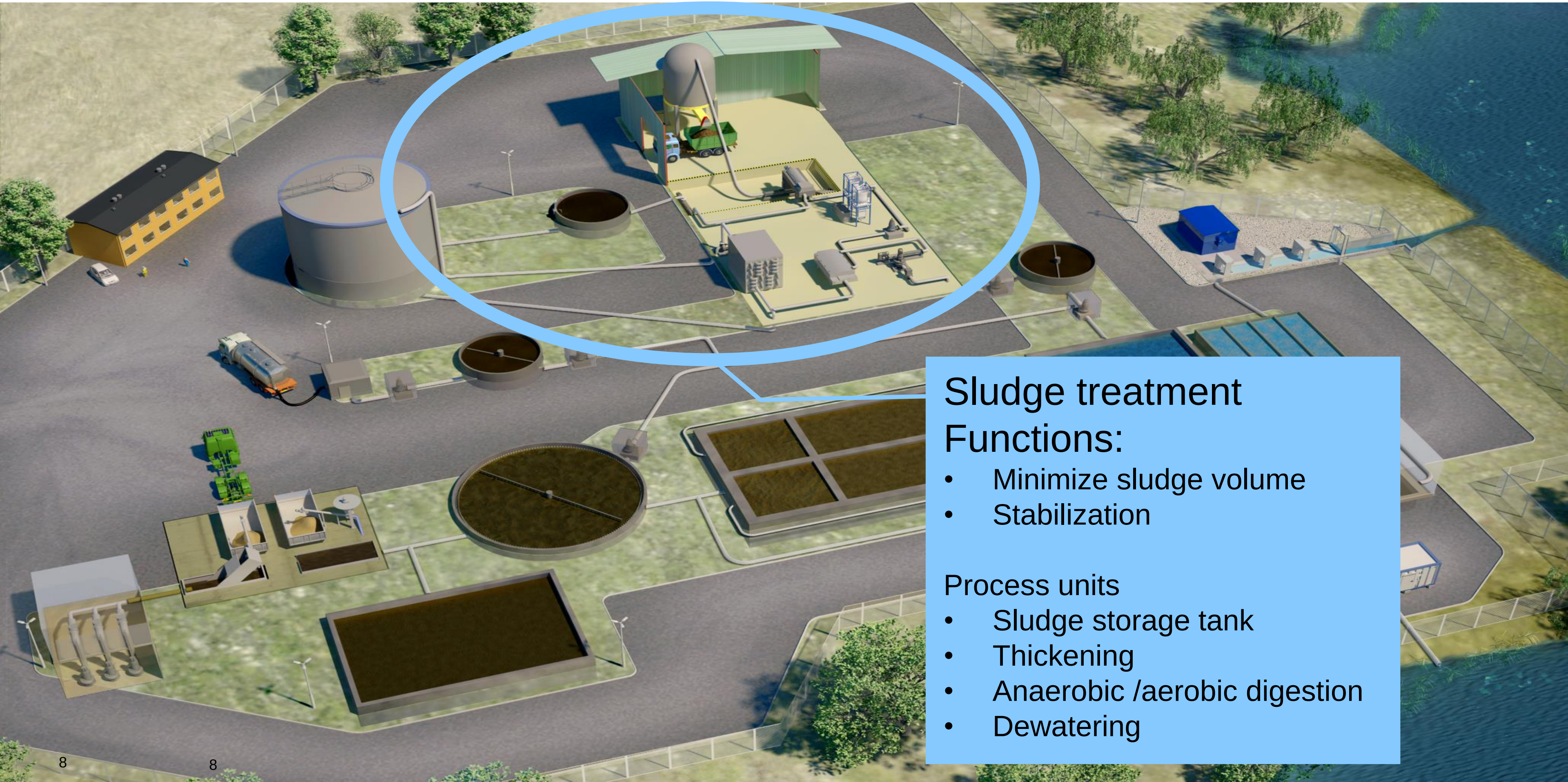
- Nitrogen (N)
- Phosphorus (P)
- Pathogenic microorganisms

Process units

- Sand filter
- Membrane
- Disc filtration
- UV/Ozone/Chlorine disinfection

7

Wastewater Treatment



Sludge treatment

Functions:

- Minimize sludge volume
- Stabilization

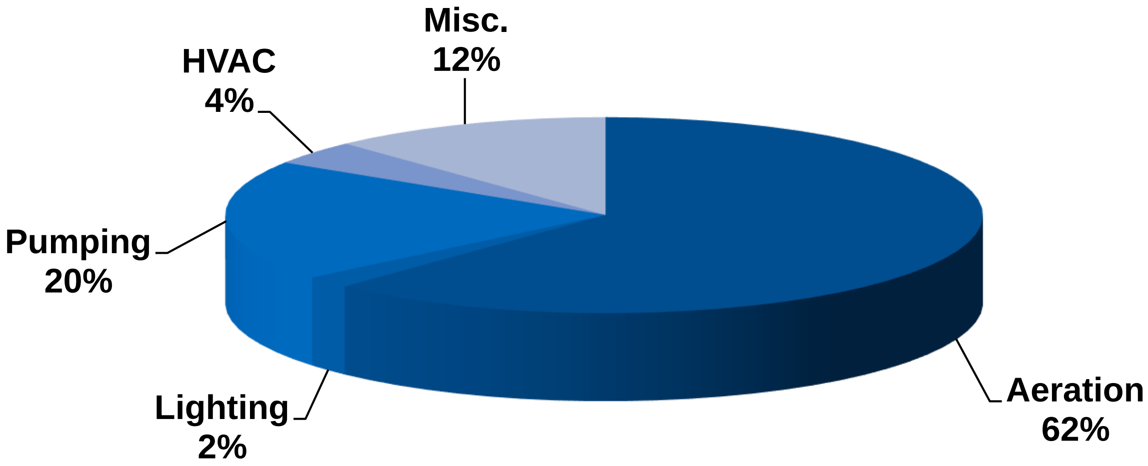
Process units

- Sludge storage tank
- Thickening
- Anaerobic /aerobic digestion
- Dewatering

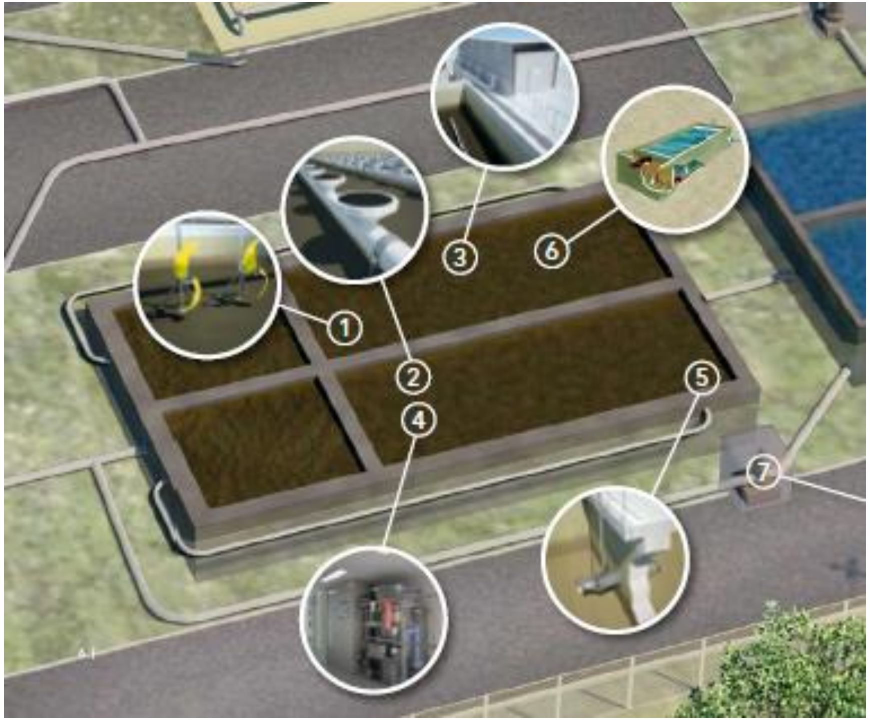
8

Typical Energy Usage

Aeration System can account for 50-75% of Plant Energy Usage



Wastewater Treatment



1. Mixing in secondary treatment. Homogenization in anoxic and anaerobic stages of the process.
2. Aeration in oxic stage of the process for BOD-removal and nitrification
3. Aeration using blowers
4. Complete standardized ozone system for odor removal or sludge disintegration
5. Recirculation of mixed liquor from oxic zone to anoxic zone for denitrification
6. Biological treatment (SBR), complete biological system with all treatment steps within a single tank
7. Return activated sludge pumping

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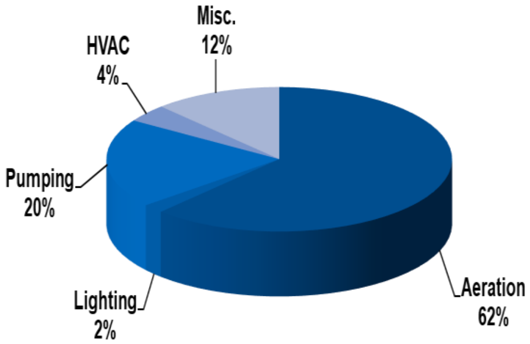
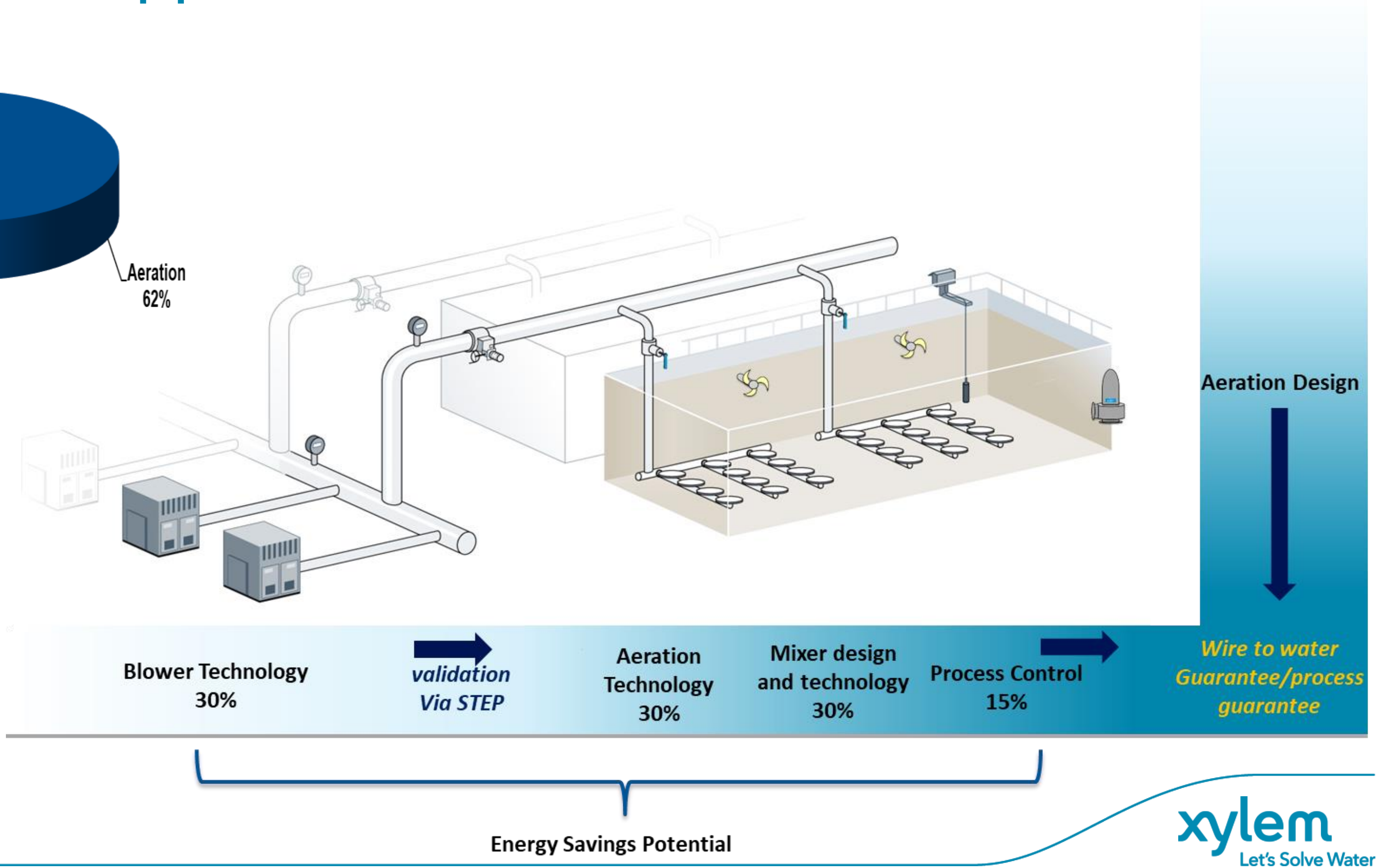
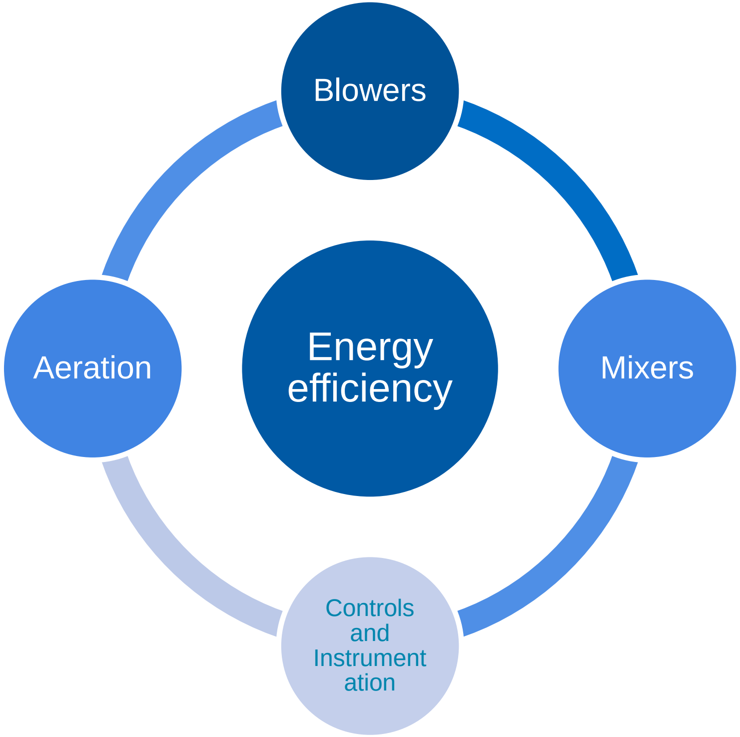
Looking at the Secondary Biological Treatment Process

A Systems Approach





Why Look at Aeration, Blowers & Mixers as a System

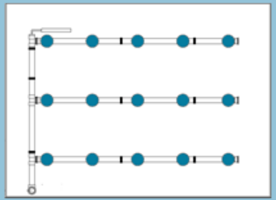
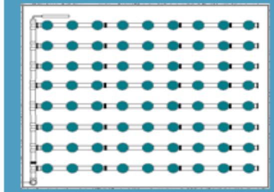
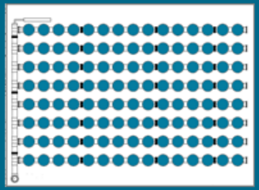


<u>Benefits</u>

- Risk minimisation.
- Increased efficiency
- Lower total cost of ownership
- Functional guaranties
- Simplicity and peace of mind
- Simple interfaces for contractor / consultant end users
- Potential wire to water guarantees

Optimising Principle of Oxygen Transfer Efficiency through Diffuser Density

	Low cost installations	Medium cost installations	High cost installations
Oxygen requirement	1,000 kg/h	1,000 kg/h	1,000 kg/h
Diffuser coverage	10 %	15 %	20 %
Oxygen transfer efficiency [SOTE]	32 %	34.5 %	37 %
Required airflow	10,300 Nm3/h	9,600 Nm3/h	9,000 Nm3/h

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Potential for Aeration Optimisation with Blower Design

Wastewater treatment blower and aeration combination design

Description (for 2 tanks)	Option 1 Cheap system	Option 2 energy Optimized system
Aeration grid design **Tank floor surface: 2 x 4598.16 m2** **Water depth: 3.65m** **Max. AOR: 927 kgO2/h** **alpha factor: 0.5**	6396 no of diffusers 70420 Nm3/h 592 mbar	15768 no of diffusers 41290 Nm3/h 411 mbar
Blowers design	MAX400-C060T1 - 6 pcs (5+1)	MAX300-C040T1 - 4 pcs (3+1)
Total power consumption	1,560 kW	708 kW
Total investment cost	€ 1,019,099.00	€ 788,769.25

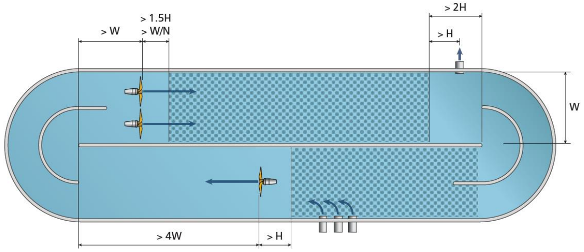
23% ON INVESTMENT

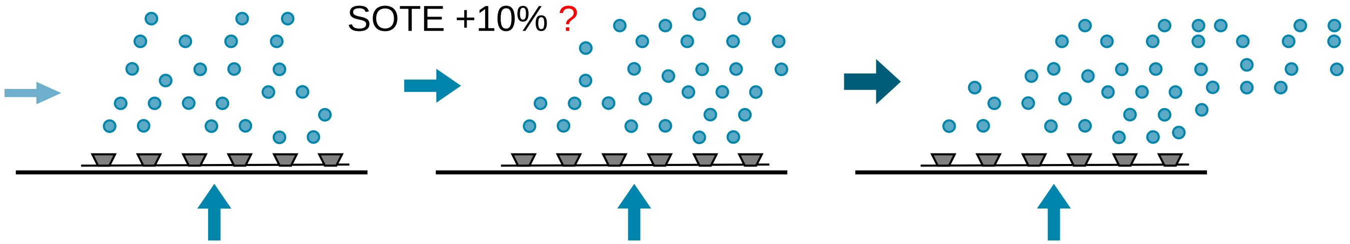
55% POWER SAVINGS

Combining Mixing & Aeration in Oxidation Ditch Design

Optimized combination of aeration and mixer design is vital for the total efficiency

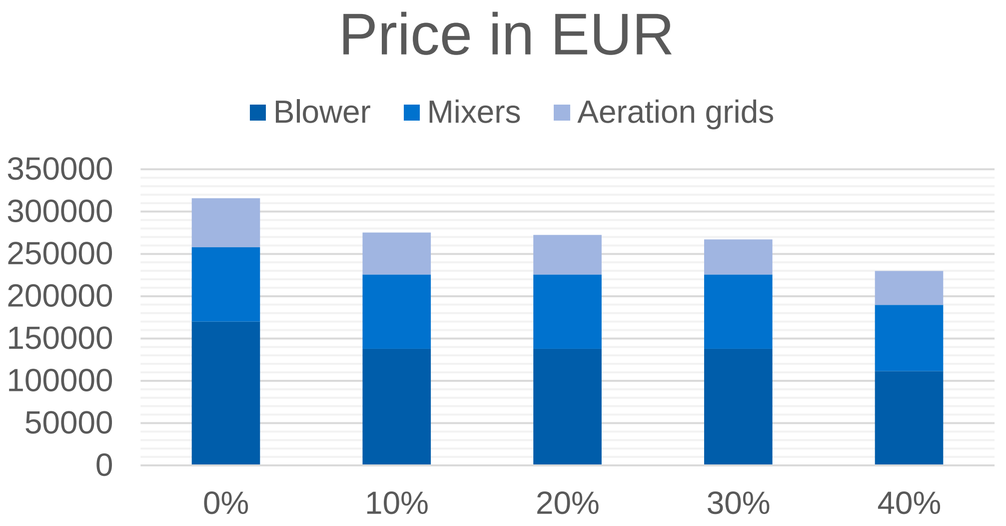
- **Flow high enough to overcome losses caused by aeration**
- **Optimize bubble retention time in the water**
- **Minimizing local energy losses with optimized placement of mixers and aeration**





Design Example

Capital savings, 100,000 PE WwTP



DESIGN OPTIMISATION LEVEL		0%	10%	20%	30%	40%
Aeration grids	EUR	57900	49599	46755	41400	40125
Mixers	EUR	87837	87837	87837	87837	78100
Blower	EUR	170100	137900	137900	137900	111550
Total	EUR	**315837**	**275336**	**272492**	**267137**	**229775**
% savings			**13%**	**14%**	**15%**	**27%**

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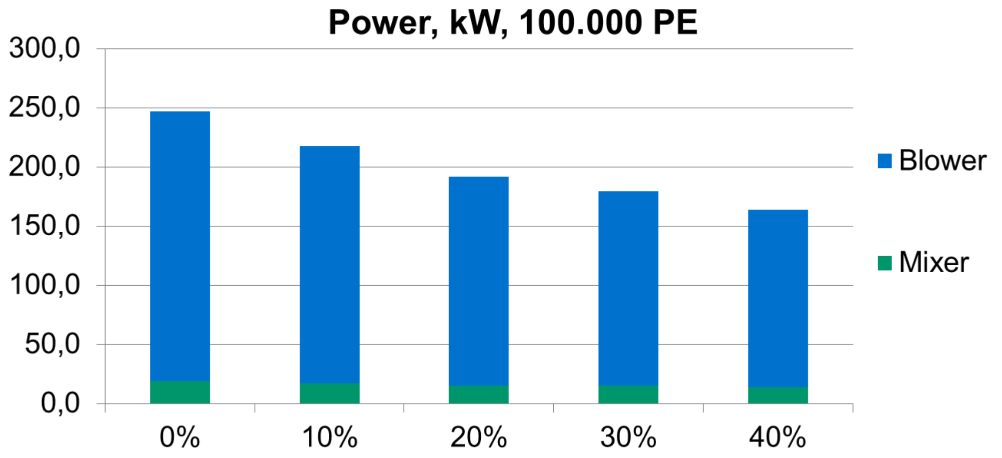
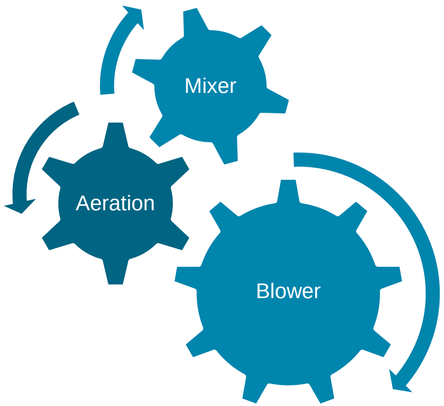
Design Example

Energy savings, 100,000 PE WwTP

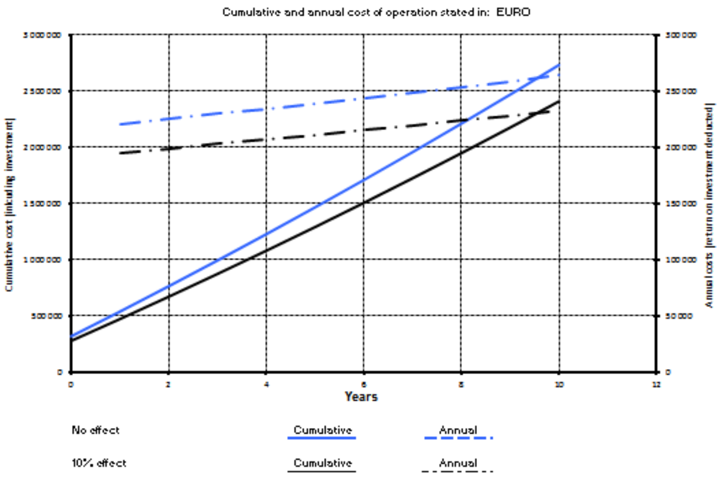




TOTAL POWER		0%	10%	20%	30%	40%
Mixer	kW	18,7	17,2	15,0	15,0	13,6
Blower	kW	228,2	200,6	176,6	164,6	150,0
Total power	kW	**247**	**218**	**192**	**180**	**150**
% savings mixer			8%	20%	20%	27%
% savings blower			12%	23%	28%	34%
% savings on total			**12%**	**22%**	**27%**	**39%**

Design Example

Example for 10% systems improvement over 10 years

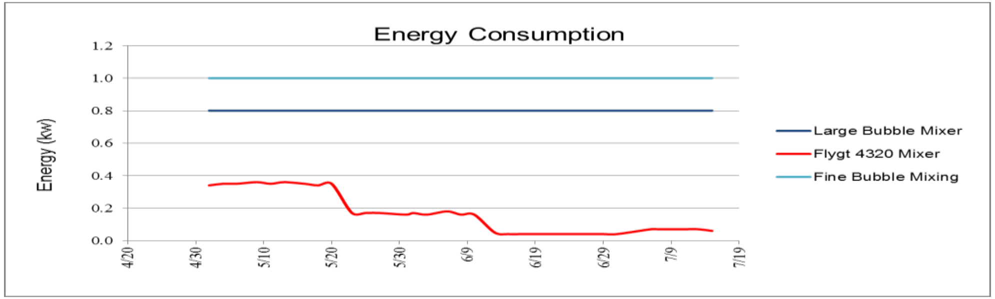


- Total Investment cost is 13% lower then a standard design.
- Energy savings over 12% / year
- 10 years of operation - 254 040 EUR in Energy cost.

Analysis based on	**No effect**	**10% improvemnt**		
Inflation rate	2	2	%	
Electricity price	0,10	0,10	EURO	/ kWh
Total input power	247	218	kW	
Investment cost	315 837	275 336	EURO	
Annual electricity cost (base year)	216 372	190 968	EURO	
Other annual costs (base year)	0	0	EURO	

Oxidation Ditch Refurbishment Trends

Identifying design trends with plug flow and pulsed aeration mixing with close to full floor coverage



Electric energy input over time for three different mixing technologies as measured between end of April to mid-July at South Shore Water Reclamation Facility.

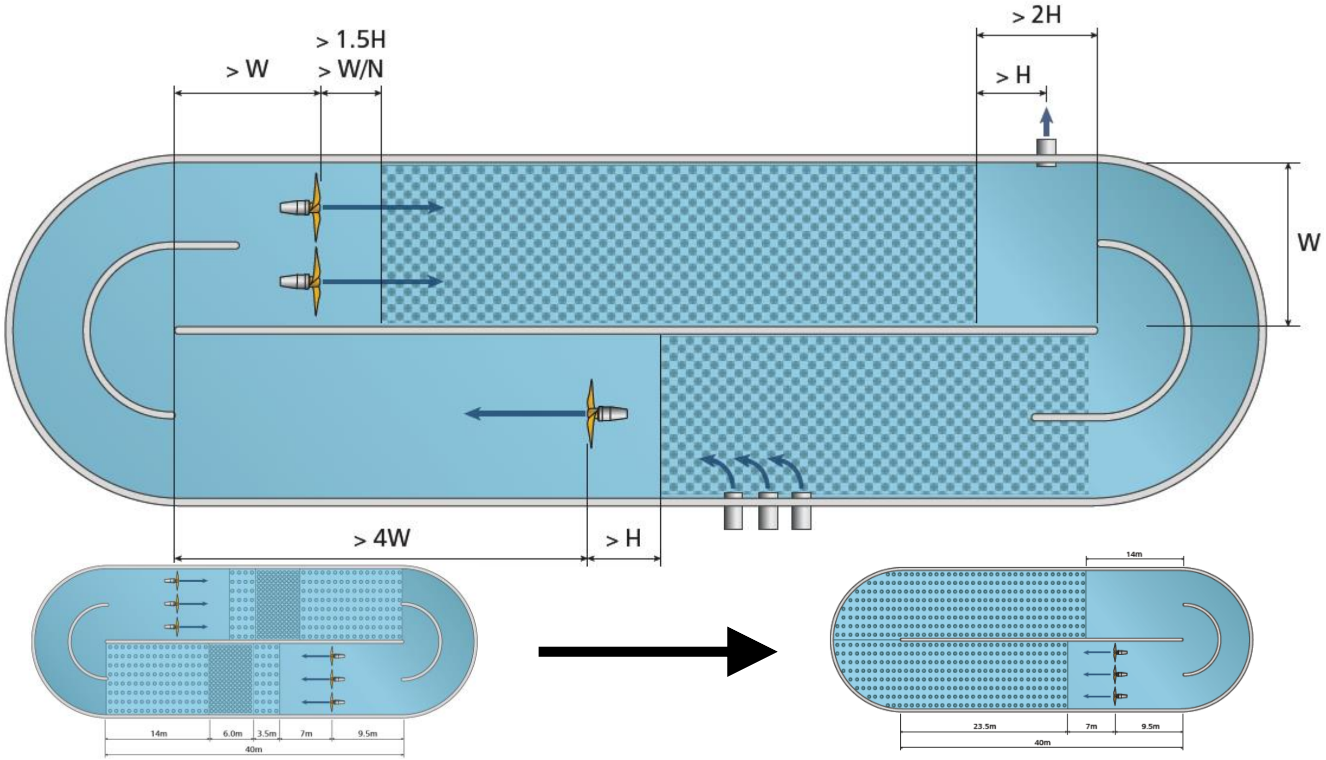
Report by Magnus Fahlgren

Observations

- More expensive upgrade
- Energy saving not better
- Process results same
- Could mean bigger blowers then needed as a result.

Mixing & Aeration Design Principles

Knowledge is key



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Summary for Oxidation Ditch Opportunity

Key is the ability to optimise aeration and mixing with blower technology to given process demands

Resulting in increased potential for

- Optimised System Solution
- Reduced Investment Cost
- Increased Efficiency
- System works well

Optimised System Case Story with CFD
Bjegemark, Denmark

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Bjegemark WwTP

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Bjegemark WwTP, Highlighting the Potential

Products in scope

Turbo Blower	Sanitaire TurboMAX
Aeration system	Sanitaire diffusers
Mixers	Flygt 4320 adaptive**.**
Control system	

P**roject based on below evaluation criteria**

30% 15 year LCC evaluation
30% Price
30% Quality of solution
10% Reference

CFD analysis conducted showed that:

There is a potential for additional savings of 25-30%.
Position of Mixers was moved based on CFD results.

Results from Bjergemark site after operating for about 3 months.

- Energy cost 145 000 kWh/ months just
  - Extrapolated to 580 000 kWh/y
    - Compared to the guarantee value of 950 000 kWh/y

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Bjegemark WwTP, Bidder Evaluation

5 bidders for the project

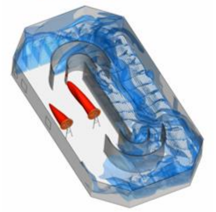
	5	3	4	2	1
Point på "Totalpris" [30% vægtning]	0,0 x 30%	5,4 x 30%	0,0 x 30%	2,6 x 30%	10,0 x 30%
El-forbrug over 15 år [30% vægtning]	6,6 x 30%	6,6 x 30%	7,8 x 30%	4,8 x 30%	10,0 x 30%
Point på "Kvalitet og løsning" [30% vægtning]	7,5 x 30%	7,1 x 30%	7,8 x 30%	10,0 x 30%	5,4 x 30%
Reference og organisation [10 % vægtning]	5,6 x 10%	3,3 x 10%	2,8 x 10%	10,0 x 10%	0,0 x 10%
Samlet point sum	4,8	6,1	5,0	6,2	7,6

Bjegemark WwTP, Summary of Scope

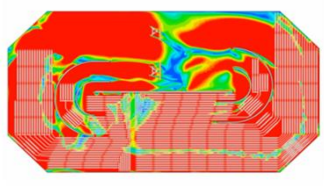
- Analyzed 6 various design proposals
- High resolution transient analysis used to confirm the chosen design
- Evaluation criteria:
  - ✓ Bulk flow velocity
  - ✓ Sedimentation risk evaluation
  - ✓ Air entrainment risk on the mixers evaluation
  - ✓ Excessive turbulence fluctuation evolution.

In this case Mixers were moved based on CFD findings.

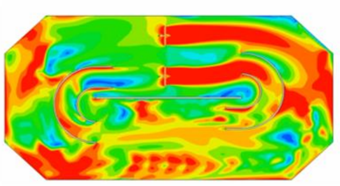
Air plumes and mixer



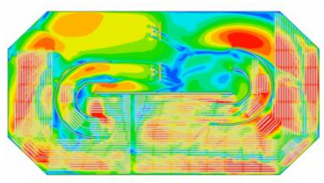
Wall shear stress @ bottom

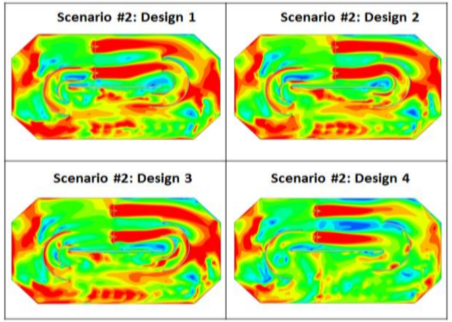


Velocity magnitude @ mixer height



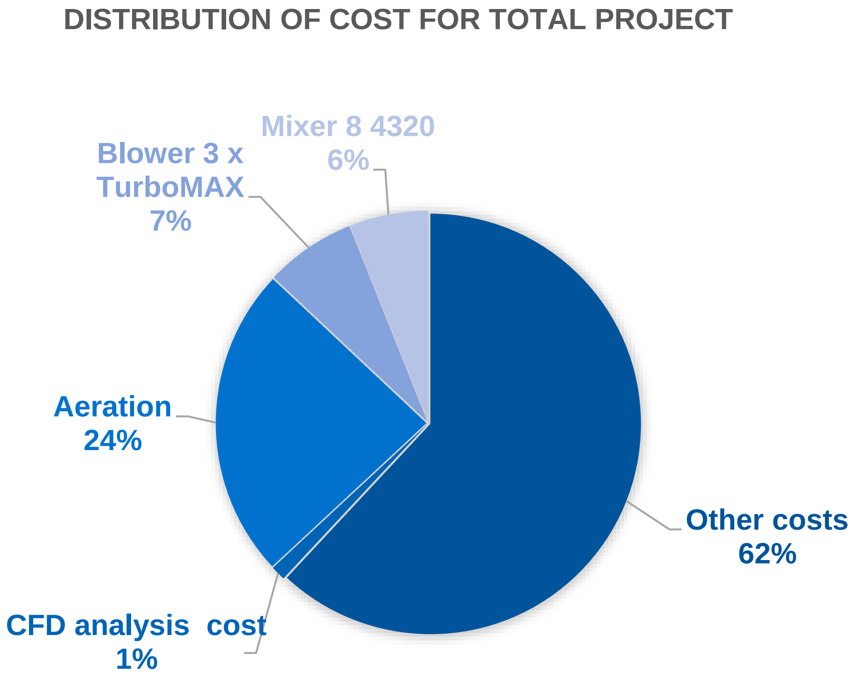
Velocity magnitude near the bottom





Bjegemark WwTP, CFD Cost

CFD Cost in relation to project size



Up to -30% Saving due to CFD

<u>CFD = 1% of total cost</u>

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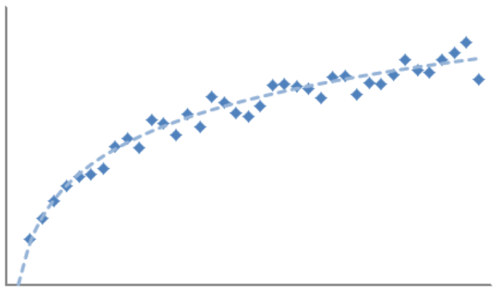
Knowledge is Key

Commonly used test standards:

- US American Society of Civil Engineers (ASCE)
- European EN 12155 standard

We know that test standards are not up to date and don't work well in ox-ditches.

Gamble if passing a test or not!



Aeration Test Standards

EN 12255-15 and DWA-M209 revision on going

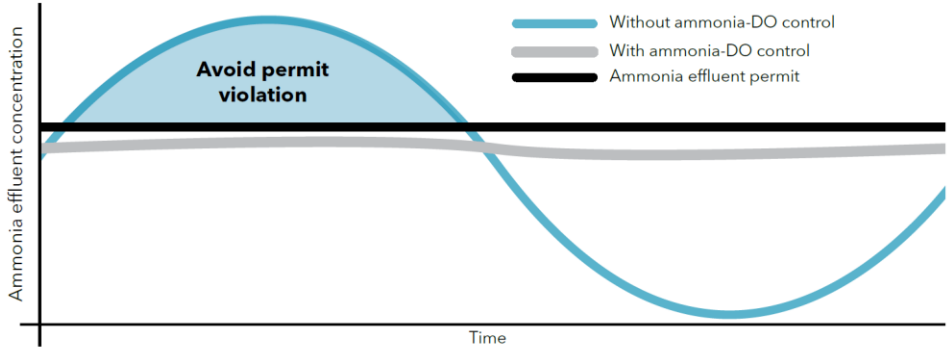
Addressing issues with	Now impacted by up to*
Mixing – not full floor coverage (ditches in particular)	-25%
Prep method (sulphite, N_2/O_2)	±3%
Temperature & sulphite	-15%
Loss of cobalt	-15%
TDS	-5%
Liquid volume	±1%
Effective depth	-8%
Blower performance (inaccurate flor to power)	-5%

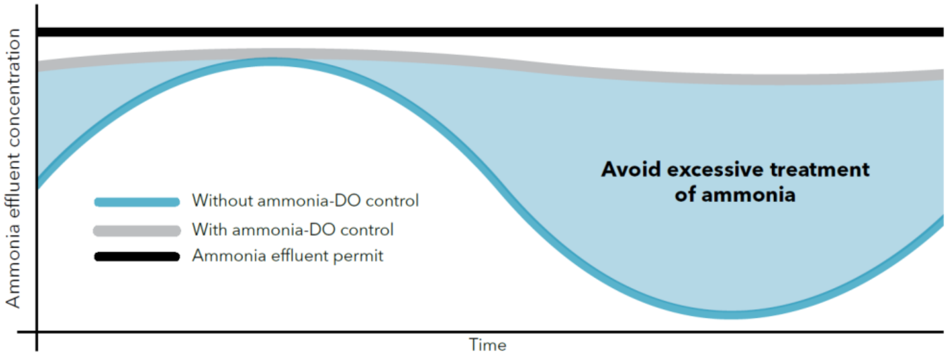
**All values above are approximate and should not be taken as absolute values and based on Oxidation ditch testing mainly.*

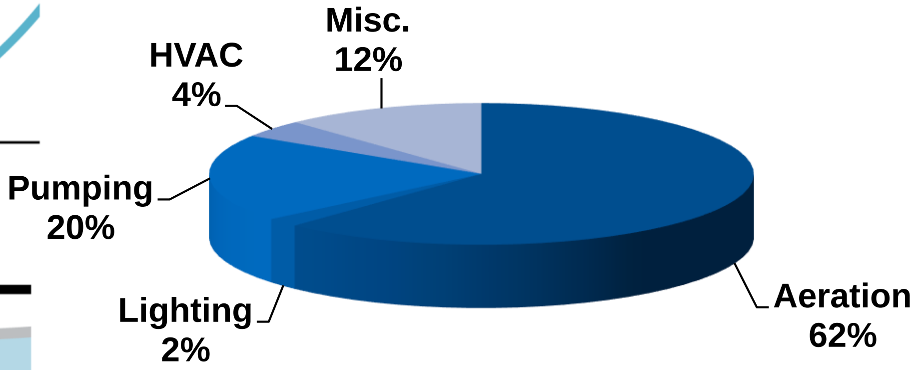
Control Optimisation

The importance of good data

Why Do It?







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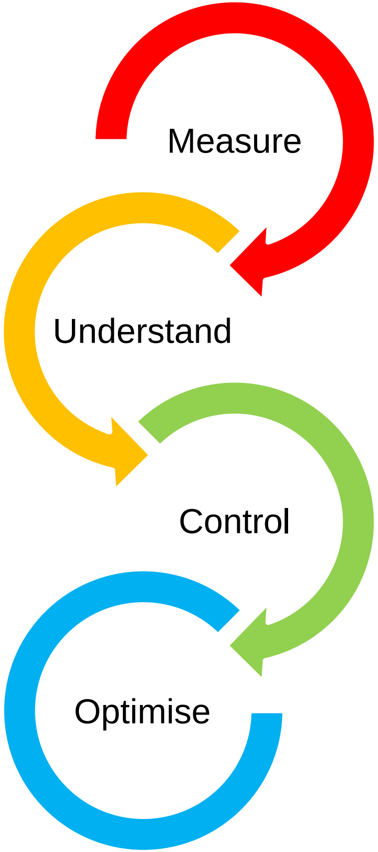
How To Do It? Nitrification

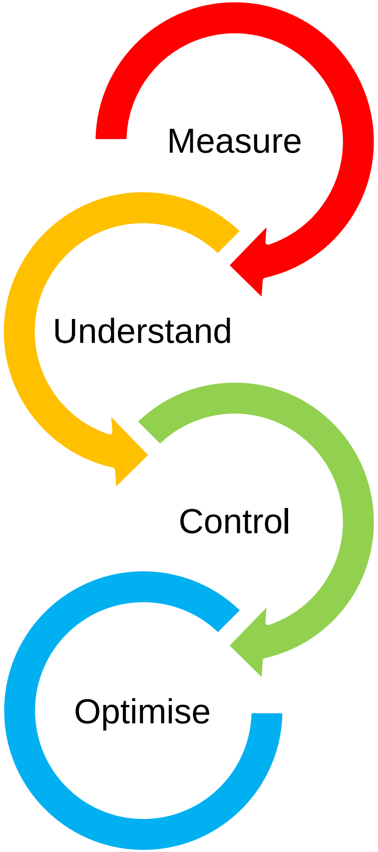


Ammonia using VARiON probe, Dissolved oxygen using FDO probe, MLSS using ViSolid probe

Ammonia is the hardest contaminant for the bacteria to break down (nitrification). Other contaminants will be digested first. By controlling against Ammonia, you effectively treat all other contaminants as well.

Dynamic adjustment of dissolved oxygen set point based on incoming and mid-process ammonia levels

How To Do It? Nitrification/Denitrification



Ammonia and Nitrate using VARiON probe, Dissolved oxygen using FDO probe, ORP using Sensolyt probe with PtA electrode, MLSS using ViSolid probe

Ammonia is the hardest contaminant for the bacteria to break down (nitrification). Other contaminants will be digested first. By controlling against Ammonia, you effectively treat all other contaminants as well.

Dynamic adjustment of dissolved oxygen set point based on incoming ammonia levels

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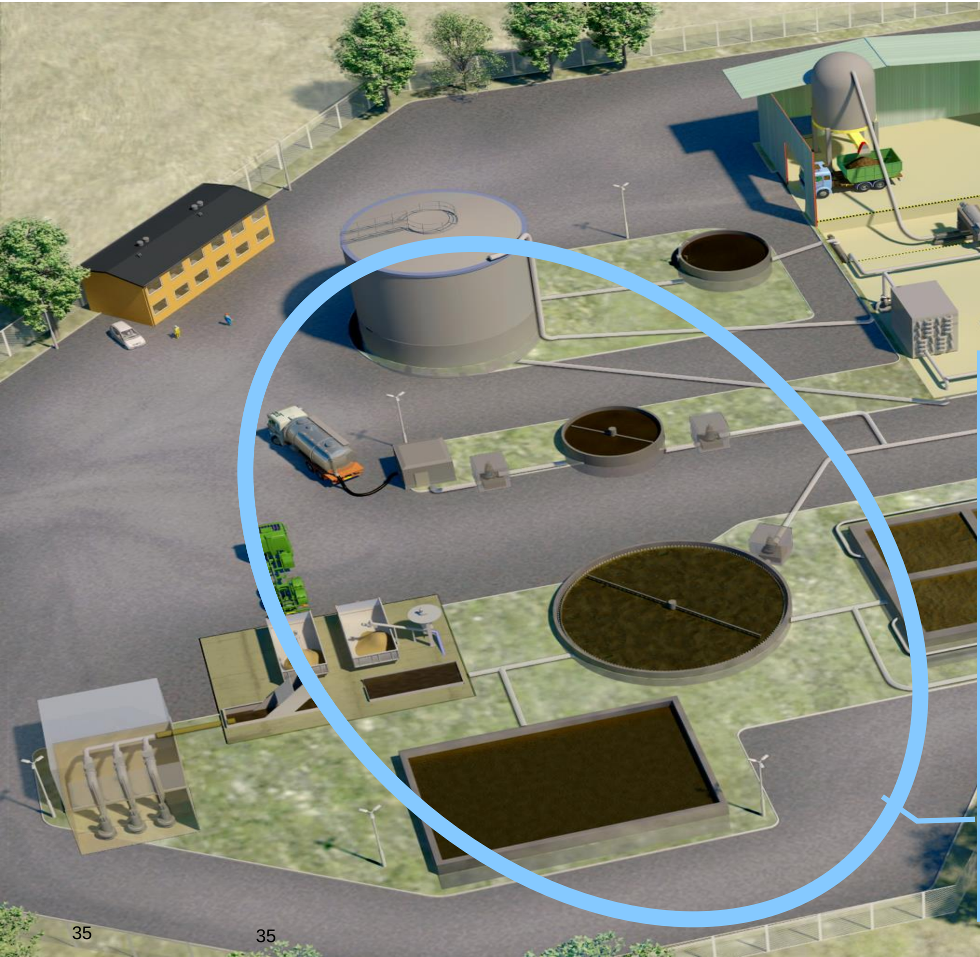
Primary Treatment Control



Primary treatment

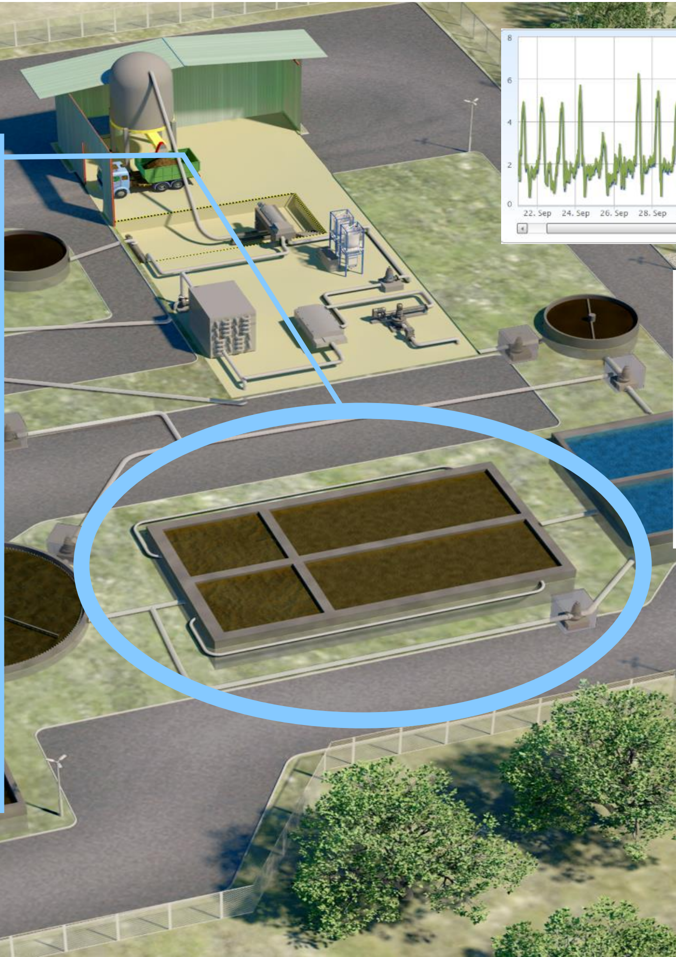
- Ammonia (Crude)
- Phosphate (Crude)
- COD (Crude)
- ORP (Crude)
- Sludge Blanket (PST)
- Inline Solids (Settled)
- Ammonia (Settled)
- Phosphate (Settled)
- COD (Settled)
- Turbidity (Settled)

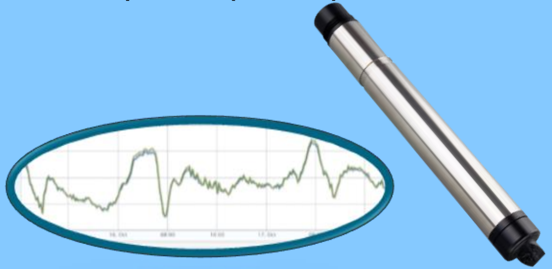
35

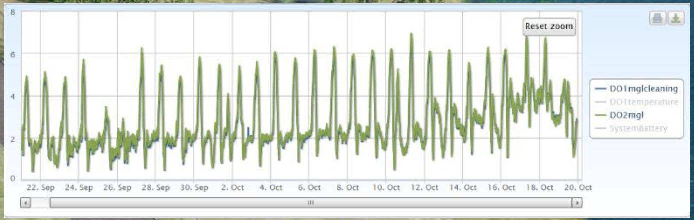
Secondary Treatment Control

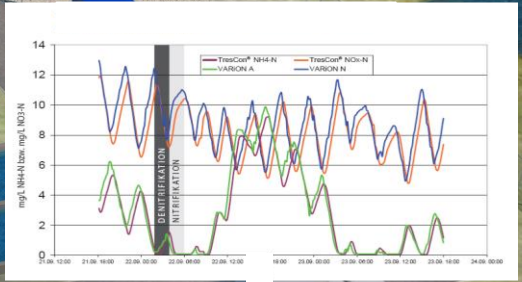
Secondary treatment

- Solids (RAS, Aeration, Outlet)
- Ammonia (Aeration)
- ORP (Anoxic Zone)
- Dissolved Oxygen (Aeration)
- Nitrate (Anoxic Zone, Aeration)
- Phosphate (Outlet)



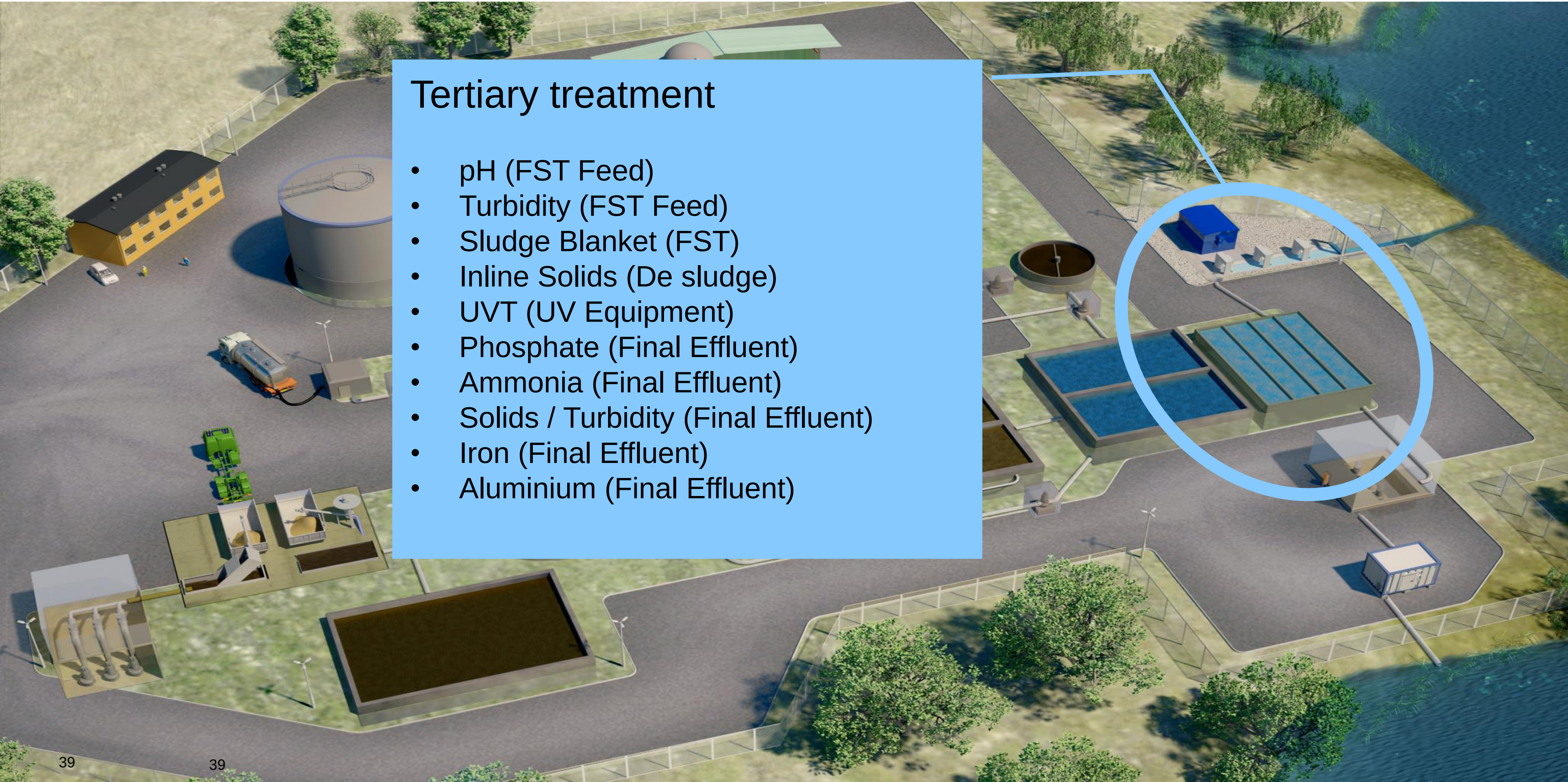






37

Tertiary Treatment Control



Tertiary treatment

- pH (FST Feed)
- Turbidity (FST Feed)
- Sludge Blanket (FST)
- Inline Solids (De sludge)
- UVT (UV Equipment)
- Phosphate (Final Effluent)
- Ammonia (Final Effluent)
- Solids / Turbidity (Final Effluent)
- Iron (Final Effluent)
- Aluminium (Final Effluent)

39

Key Questions to Consider

1 • Is the plant/basin operated with continuous aeration?

2 • Is the nitrogen load in inflow highly dynamic (high or low peaks)?

3 • Is aeration control based on DO measurement?

4 • Is the DO concentration adjusted automatically?

5 • Is the DO concentration adjusted based on ammonia?

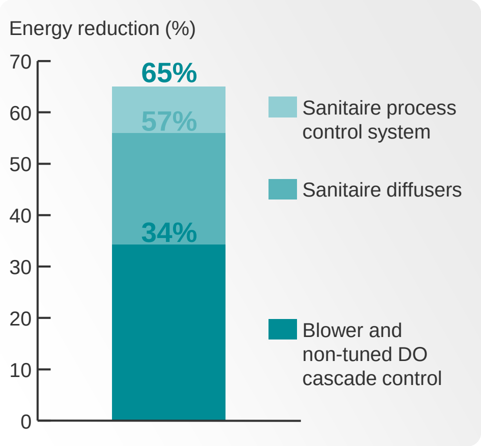
6 • Does the plant have difficulty in meeting consents for ammonia or nitrate?

7 • What is the payback time required for any investment in optimisation?

Control Optimisation Case Story

Optimising the dissolved oxygen (DO) profile @ Sternö WwTP

APC optimizes Sanitaire aeration system, including blower air pressure, actual airflow to the basin and secures minimal pressure loss over the valves by applying Most-Open-Valve logic.



65%

The amount of energy savings due to a new blower, new aeration grid and new APC system at the Sternö wastewater treatment plant in Sweden.

AMMONIA REDUCTION:

	Increased reduction of ammonia [%]
Cold water period (Jan – April)	20
One year operation	9

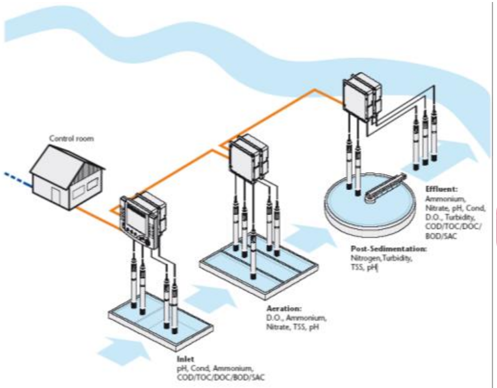
Real Time Digital Optimisation


Objective:
Optimize energy and chemical usage while increasing compliance margins.

Smart Infrastructure

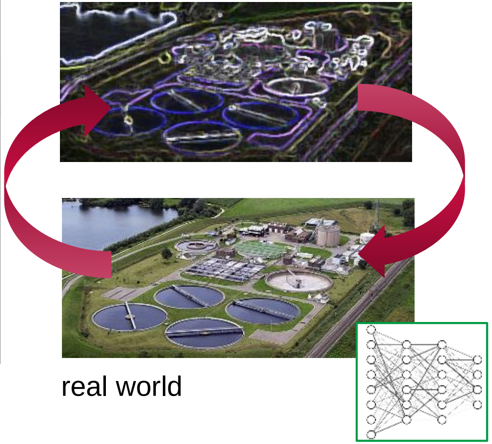
Data-Driven Process Optimization

Advanced Sensing



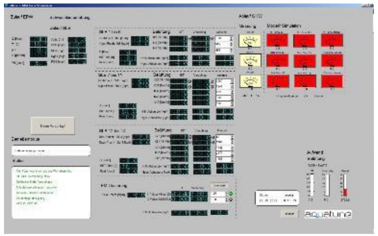
Machine Learning

digital twin



real world

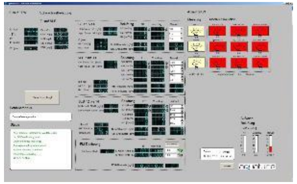
Dynamic Control



Smart Infrastructure

Tier 3: Optimize

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

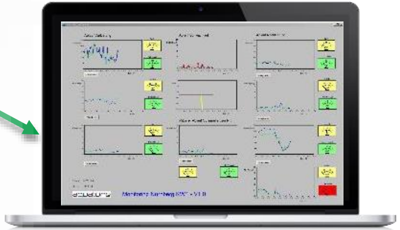


Tier 2: Create Digital Copy

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

Tier 1: Turn On the Lights™

Data Collection
Real Time Alerts
Full SCADA Integration



xylem
Let's Solve Water

Results: Cuxhaven WwTP

BLU X

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

Energy Reduction of
26.3%
from peak usage elimination

330,000€
Saved from
1.1 kWh reduction

✓
No situations of broken compliance

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Let’s Solve Water

Results: Stadtwerke Trier WwTP

Problem

Determine the optimal combination of set points for water pumps servicing elevated tanks to reduce energy usage

Aquatune Solution

Create an online optimization system for drinking water system to minimize consumption of external energy and maximize the use of renewable energy

Develop 24-hour prediction system for water consumption in different zones

Support development of automatic system for supply control in the elevated tanks.

Reduced OPEX through automated pump control

Pumps operating at optimal level to optimise energy usage

Project expanding to other water network zones for optimisation


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Let's Solve Water
THANK YOU!