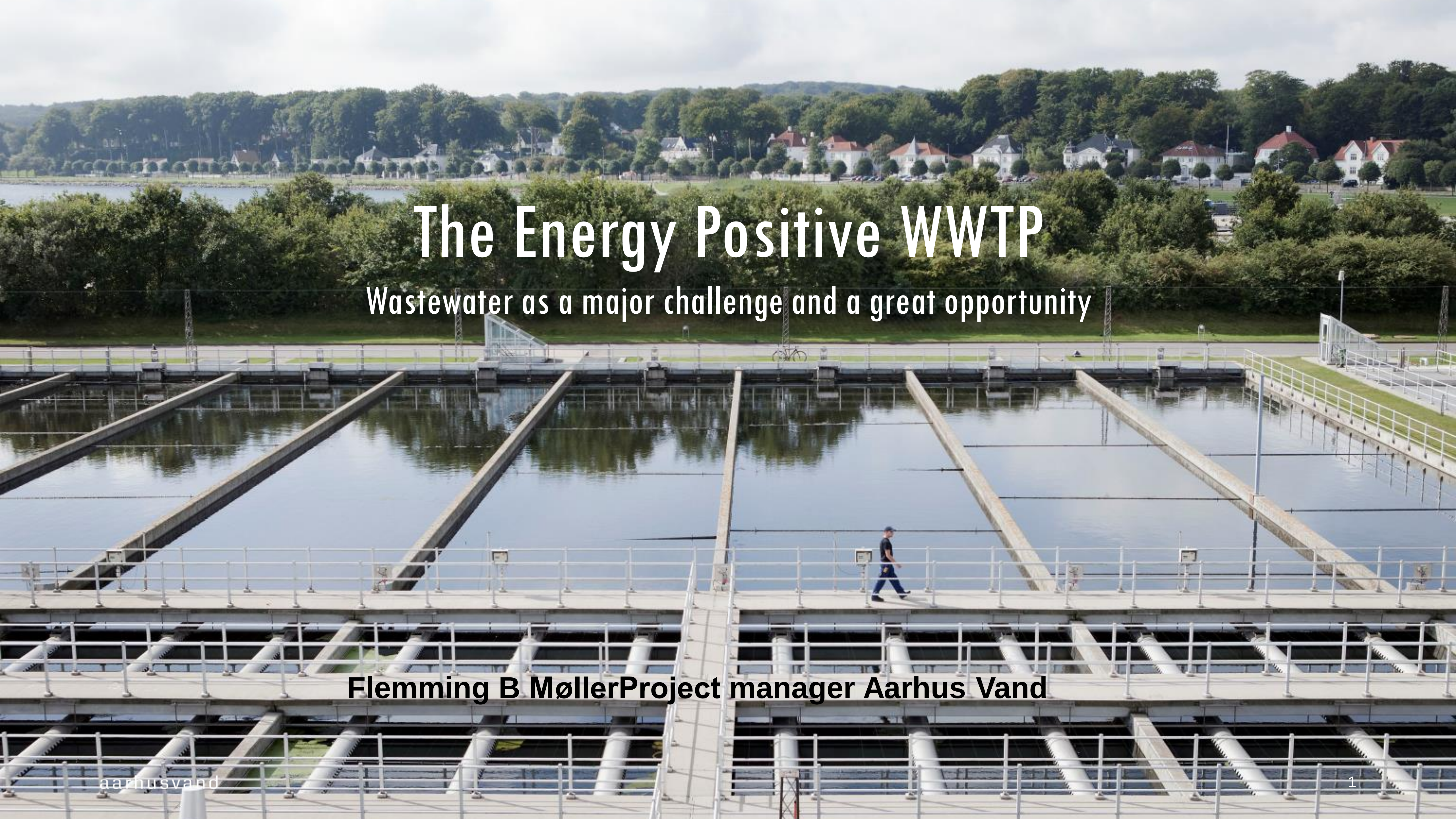


The Energy Positive WWTP

Wastewater as a major challenge and a great opportunity

Flemming B MøllerProject manager Aarhus Vand

Who am I?

Flemming B. Møller

- Aarhus Vand (Aarhus Water Company Ltd, Denmark)
- 2000-2013 Operational Manager
- 2013-2014 Project Manager for implementation
- 2014-2016 Projekt manager in Chicago for the WTA (Water Tecnologi Alliance) at the Danish trade counsil
- 2016-present Project manager at Aarhus Vand

- Marine Engineer
- Diploma in Maintenance Management

Agenda

1. **Introduction**
    - Energy and ressource strategy 2020
2. **Marselisborg WWTP – from energy consumer to producer**

Key Performance Data – Aarhus Water

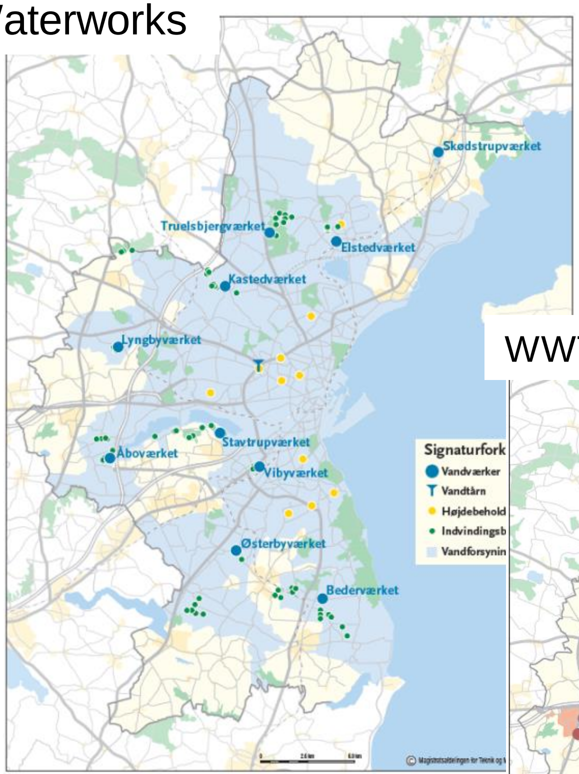
We deliver 15 mill. m³ *drinking water* per year

- 8 waterworks
- 90 boreholes (100 % groundwater)
- 1,450 km water pipes
- 275,000 people are connected

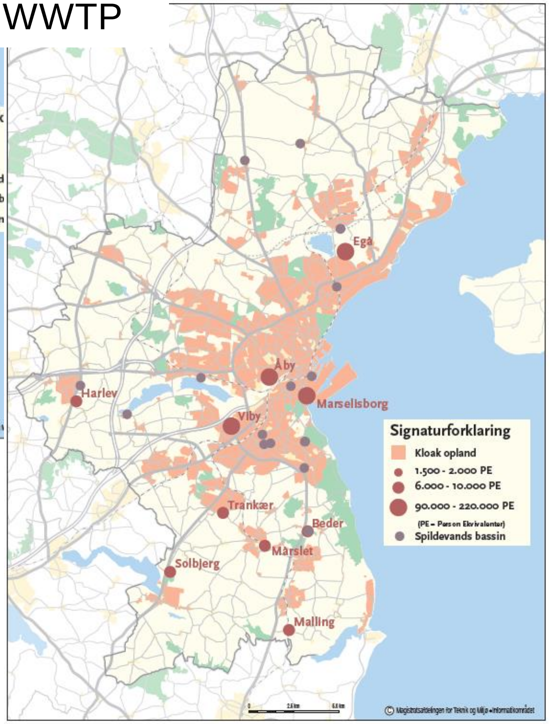
We transport and treat 35-40 mill. m³ *wastewater* per year

- Service area of 11.600 ha
- 4 wastewater treatment plants
- 140 pumping stations
- 2,800 km sewage pipes
- Storm/wastewater detention basins approx. 120,000 m³
- 26 % is combined sewers
- 335,000 people are connected
- Industry pollution 36,000 PE
- Total loading: 450,000 PE

Waterworks



WWTP



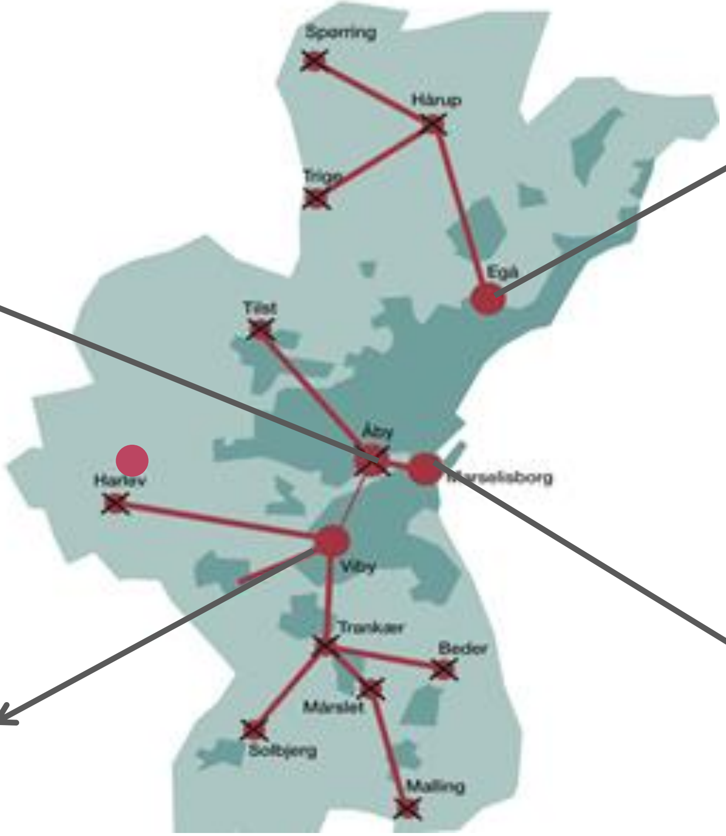
Master Plan – Wastewater Treatment, Phase 1 2006-2016

Aaby WWTP

84,000 PE (14 MLD)

Egå WWTP

120,000 PE (28 MLD)



Viby WWTP

83,000 PE (23 MLD)

Marselisborg WWTP

200,000 PE (26 MLD)

Master Plan – Wastewater Treatment, Phase 2 2017-2025

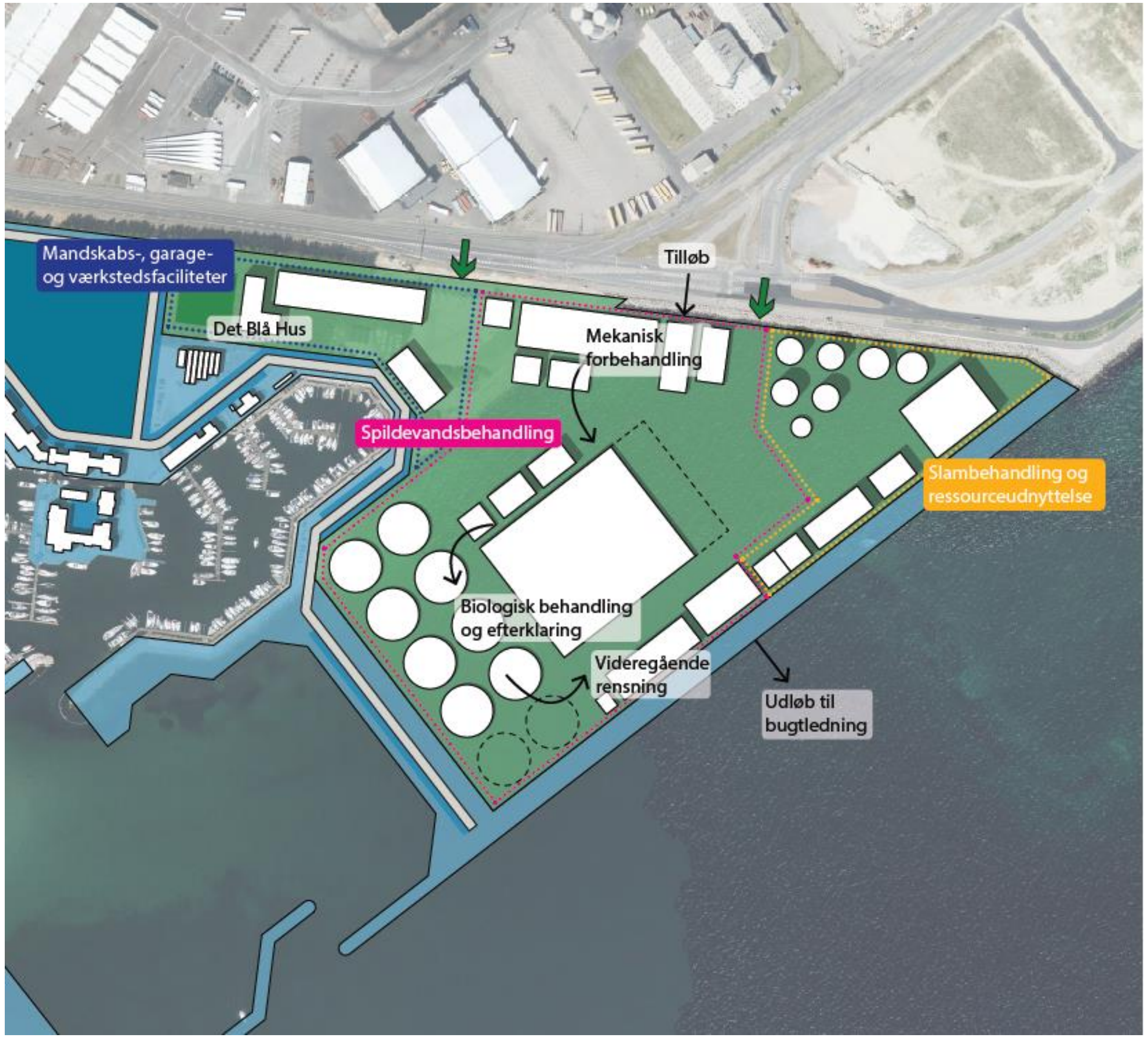
Egå WWTP

120,000 PE (28 MLD)

Marselisborg WWTP

480,000 PE (73 MLD)

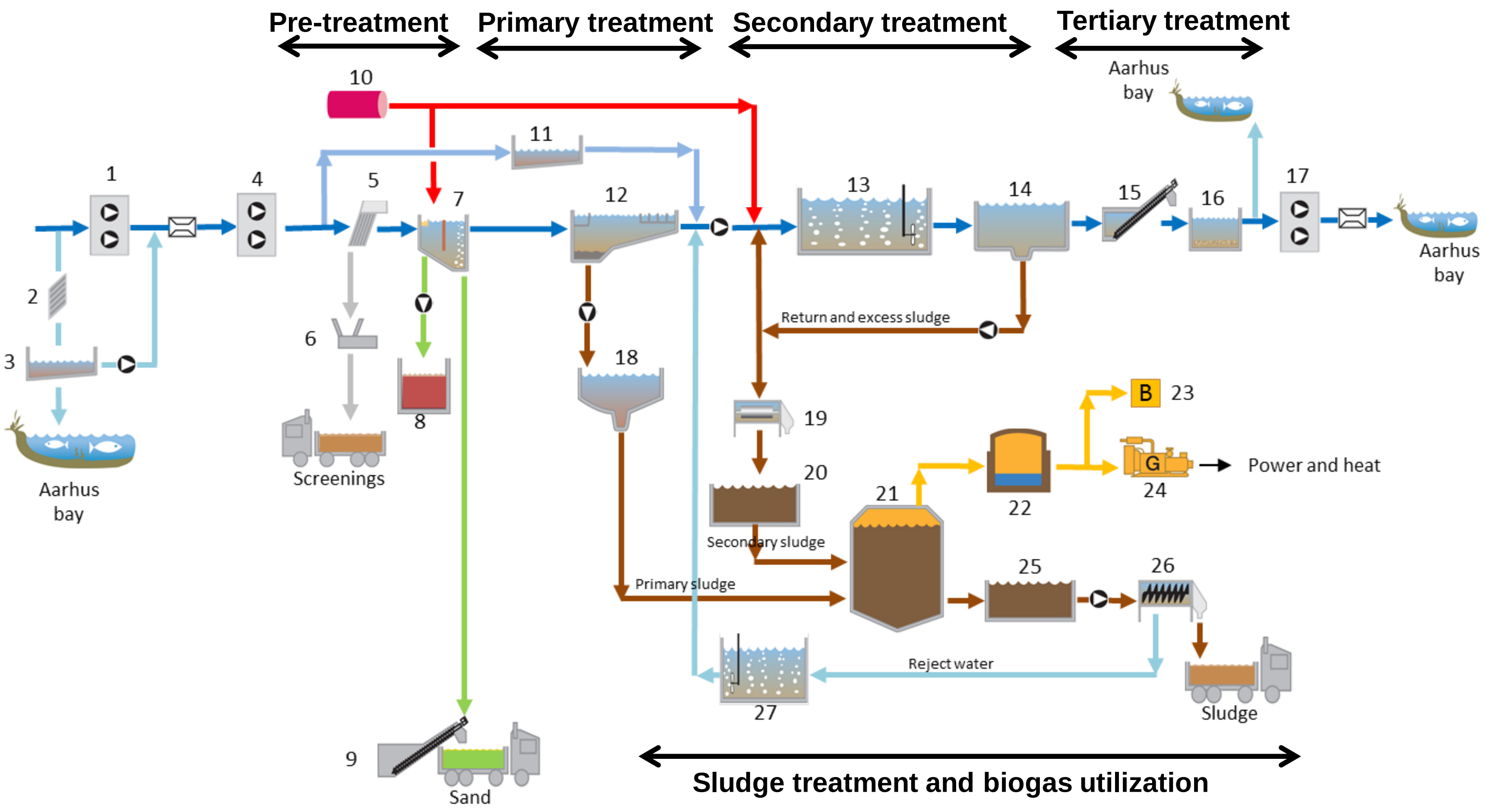
Marselisborg ReWater 480.000 Pe



Energy and ressource strategy 2020

Vision	**We recycle valuable resources in a circular economy while considering environment, the whole water cycle and our business economy. We produce more energy than we consume. We are aware of our effect on greenhouse gasses and are CO_2-neutral.**		
Goals 2030	**CO_2-neutral**	**Net energy producing**	**50% phosphor recovery**
Goals 2020	**40% reduction in CO_2 emissions (carbon footprint)** **higher than 70% nov 2020 ☺**	**Energy self sufficiency electricity and Heat 55%** **55% nov 2020 ☺**	**35% phosphor recovery of P in inlet**

Marselisborg WWTP – Main Flow Diagram



- Primary water flow
- Secondary water flow
- Sludge
- Biogas
- Sand and grease
- Screenings
- Chemicals
- Pumps
- Flow meters

aarhusvand

1: Catchment area pumps
2: Coarse screen
3: Overflow basin
4: Inlet pumping station
5: Inlet screen
6: Screening press
7: Grit chamber & grease trap
8: Grease tank
9: Sand washer plant
10: Chemical tank (PIX dosing)
11: Overflow tank
12: Primary clarifiers
13: Biological tanks (Nitrification/denitrification)
14: Secondary clarifiers
15: Intermediate pumping station
16: Sand filters
17: Outlet pumping station
18: Sludge thickeners
19: Sludge pre-dewatering
20: Sludge buffer/thickeners tanks
21: Anaerobic digesters
22: Gas storage tank
23: Gas boiler
24: Gas motors (CHP)
25: Homogenizing/storage tanks
26: Final sludge dewatering
27: DEMON® Anammox side-stream

Marselisborg Wastewater Treatment Plant

Maximum capacities:

- Maximum capacity 220,000 PE_{BOD}
- Peak flow 1400 l/s

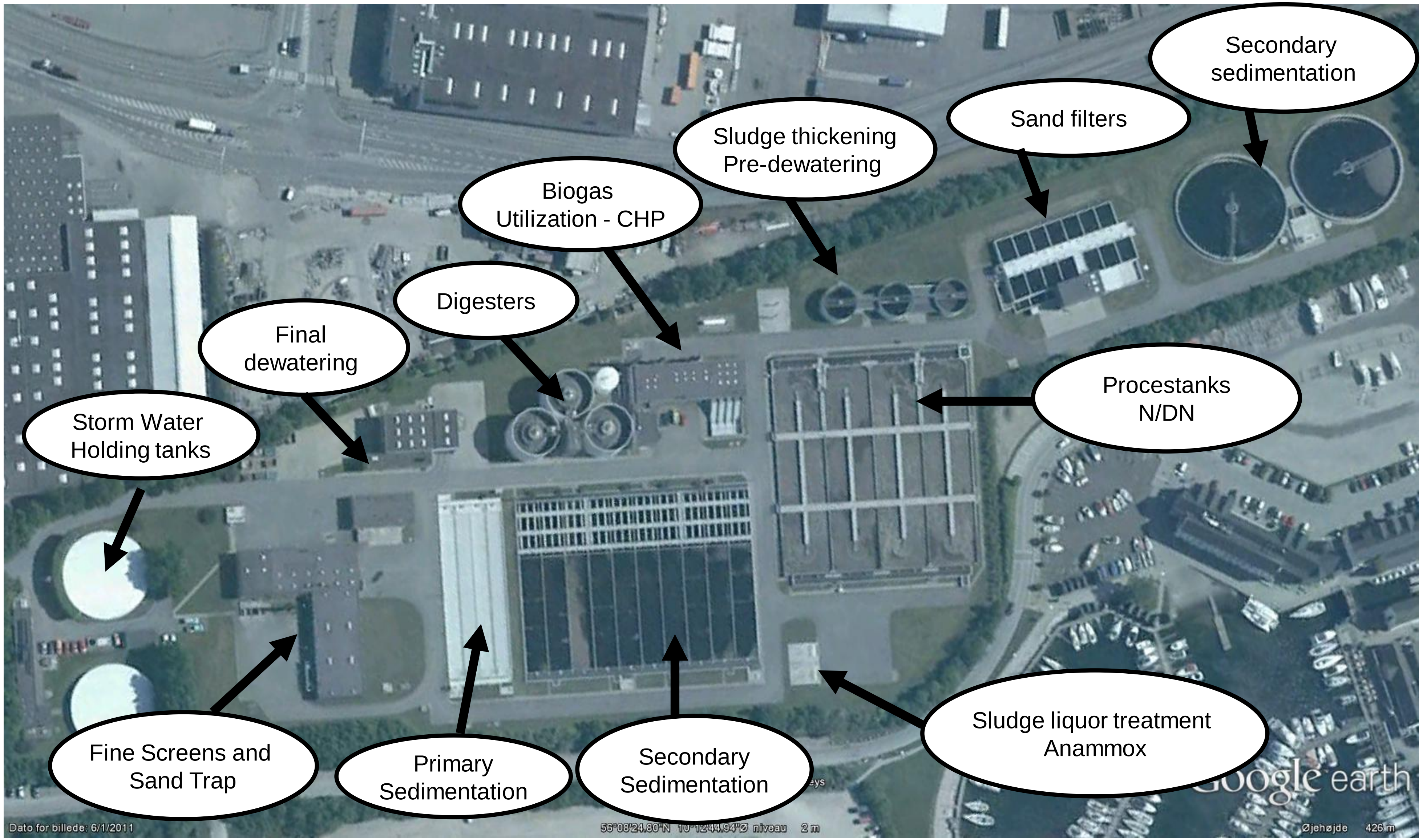
Wastewater mix:

- Industrial loading approx. 10% of total organic loading the rest is from house holds
- No co-digestion of organic waste

Effluent requirements:

Marselisborg WWTP		Limits
Total N	mg/l	**8**
Total P	mg/l	**0.8**
COD	mg/l	**75**
TSS	mg/l	**20**

Marselisborg WWTP – overview and design/load



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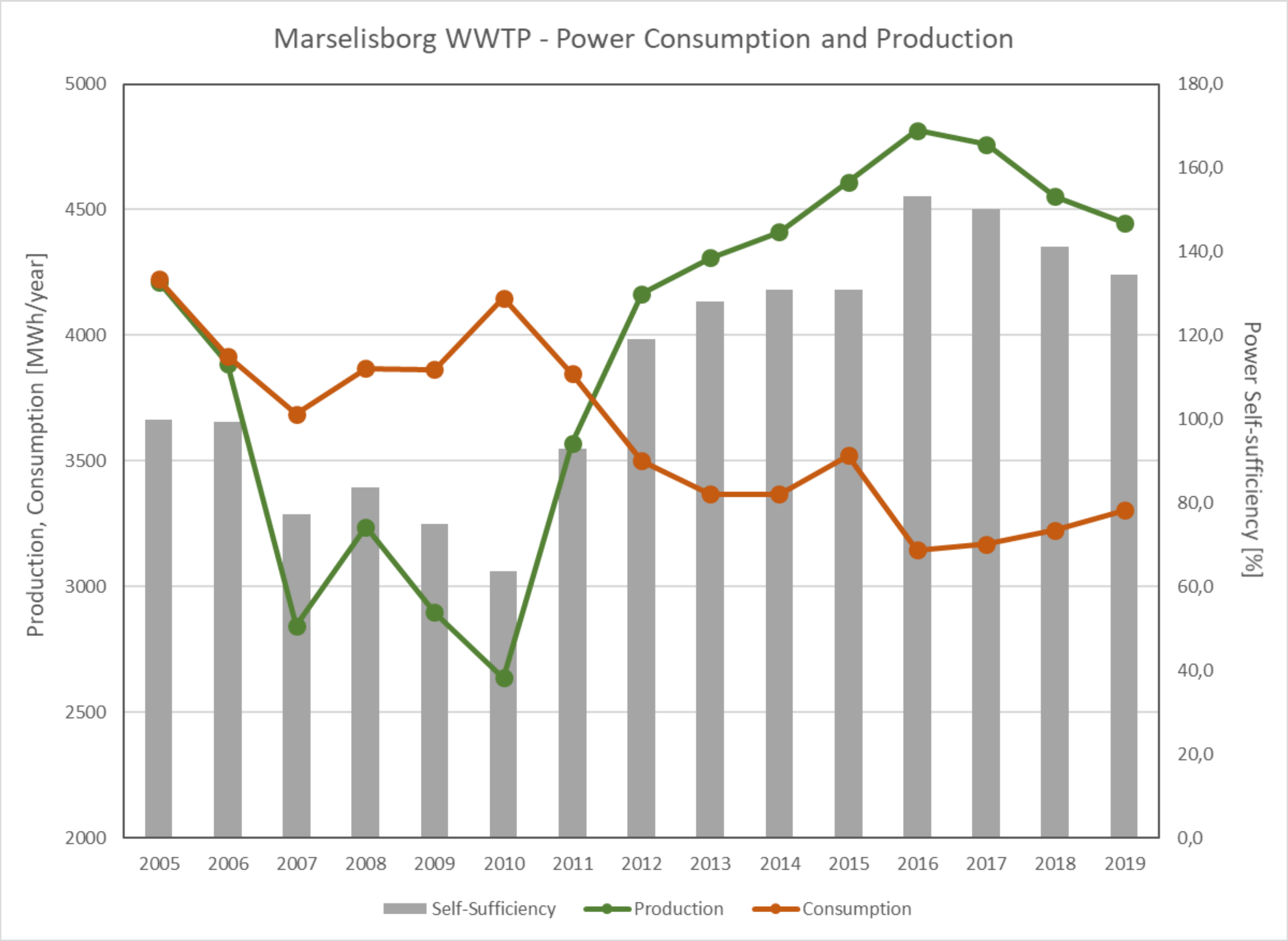
Power Consumption and Production Marselisborg WWTP: 2005 - 2018



2016 result – power only:

Production*: 4815 MWh/year
Consumption: 3146 MWh/year

Self-sufficency: 153 %

*) no external carbon source

Excess Heat approx. 2500 MWh/year
Is exported to district heating

➔ **Over all self sufficiency > 230 %**

Steps of optimization at Marselisborg WWTP

1) **Process Optimization**
    - Biological Nitrogen and Phosphorus removal
    - Clarifier control (increased hydraulic capacity during rain)
    - Software, Sensors and VFDs (controllability)
2) **Component Optimization**
    - Turboblower
    - Centrifuge
    - Gas engines (CHPs)
3) **New Processes**
    - Simultaneous Nitrification/Denitrification
    - Sidestream De-Ammonification
    - Mainstream Nitrite-shunt

Proces optimization

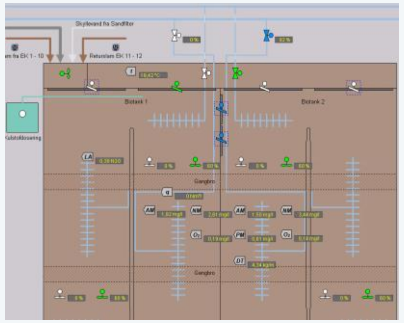
N-removal controlled with NH_4-online sensors

Key data:

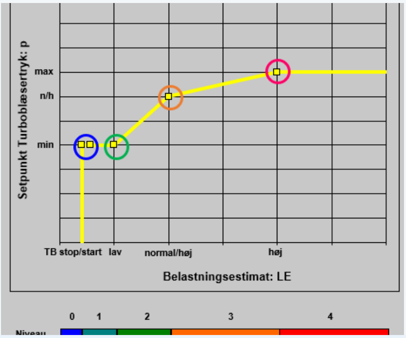
- Control of blowers according to estimated NH4-load
- Controlling sludge age (N/DN)
- VLT control – return sludge, etc.
- Reduction of electricity consumption ~700.000 kWh/year ~ 61.000 €/year

VLT Control of return sludge

Ammonia sensors



Ammonia estimate

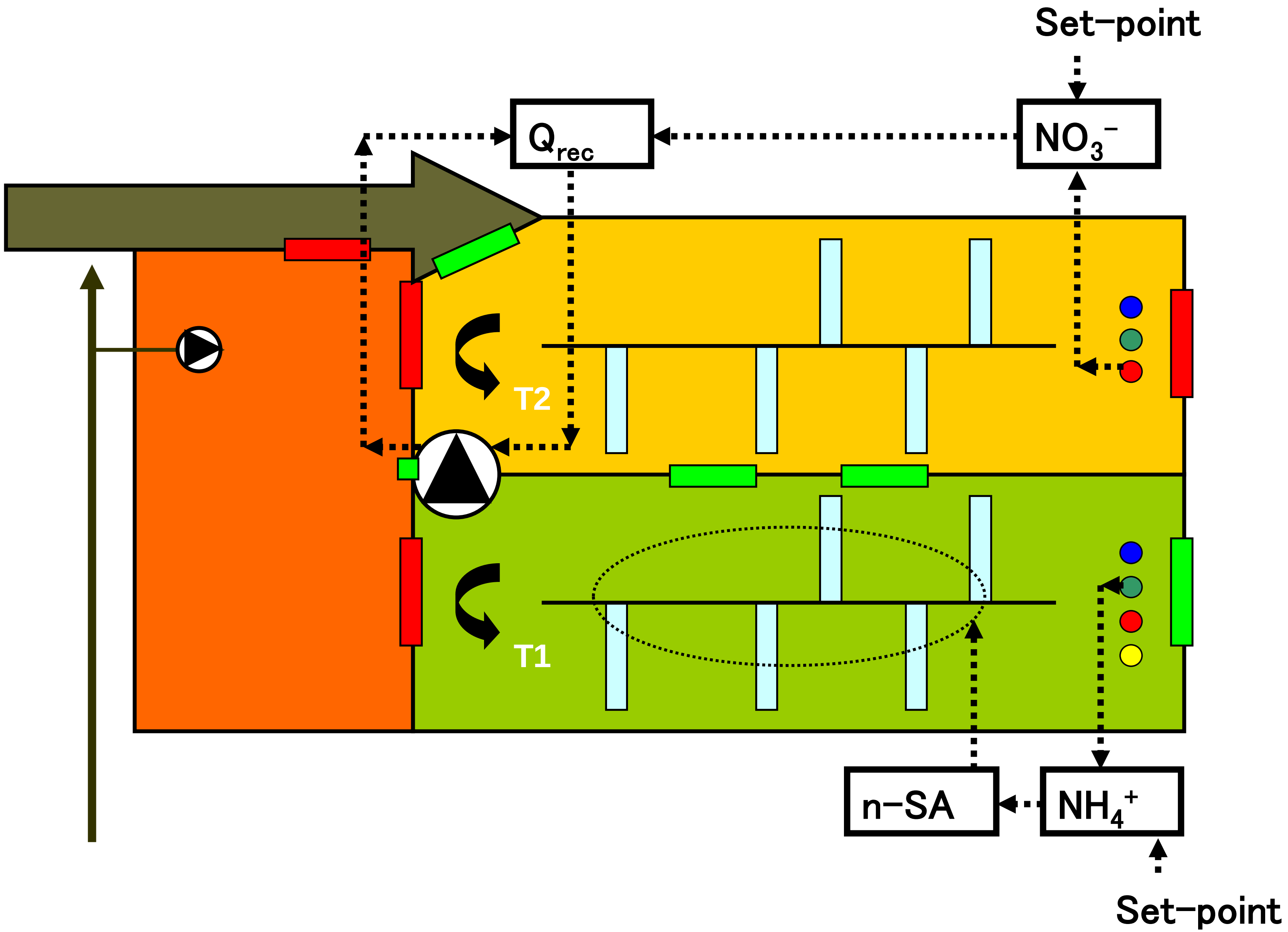


Control of blower

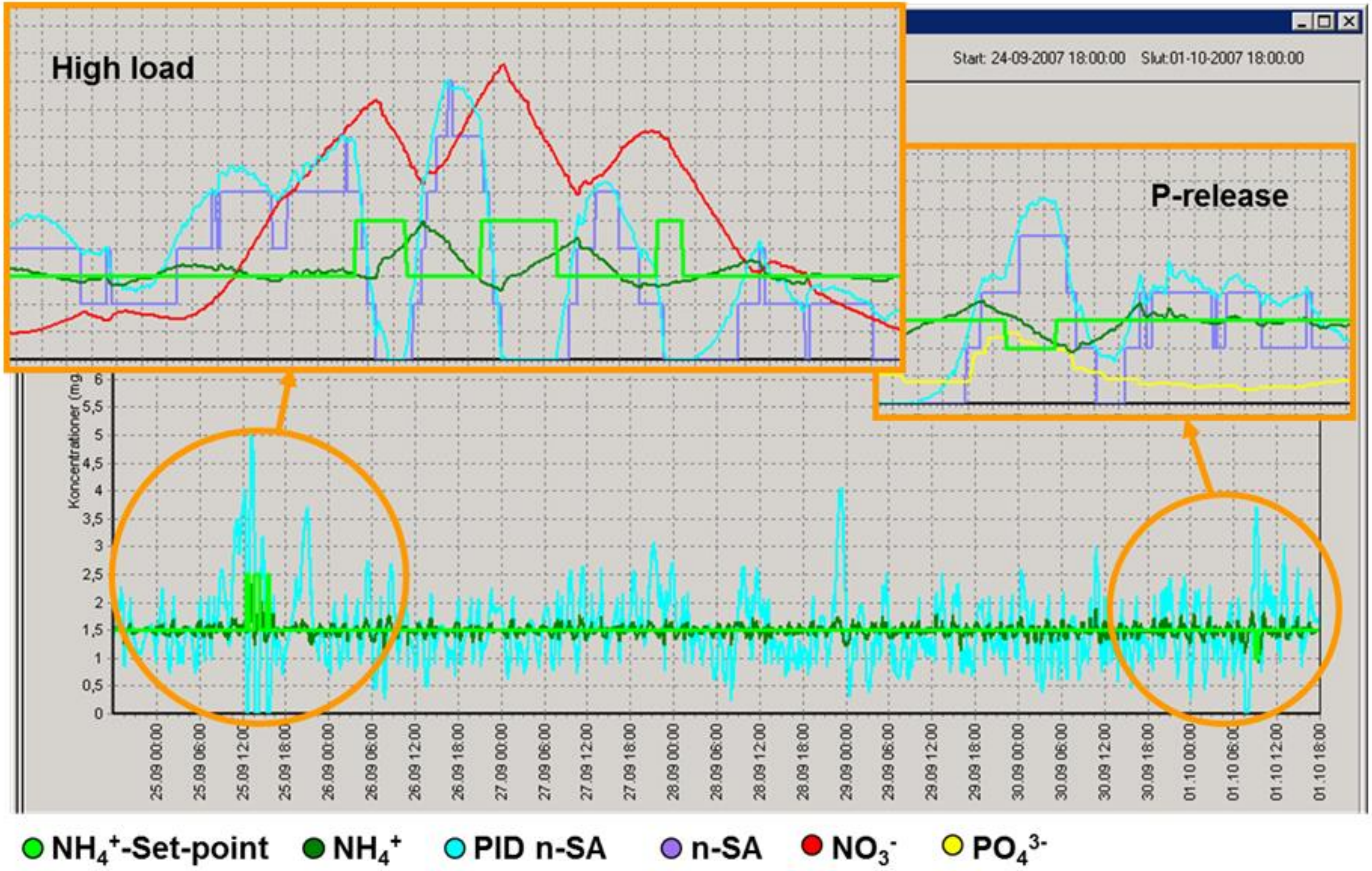
Business case:

- Investment ~ 400.000 €
- Reduction of electricity consumption ~ 61.000 €/year and reduction in WW tax ~ 114.000 €/year
- Pay back time (ROI) ~ 2-3 years

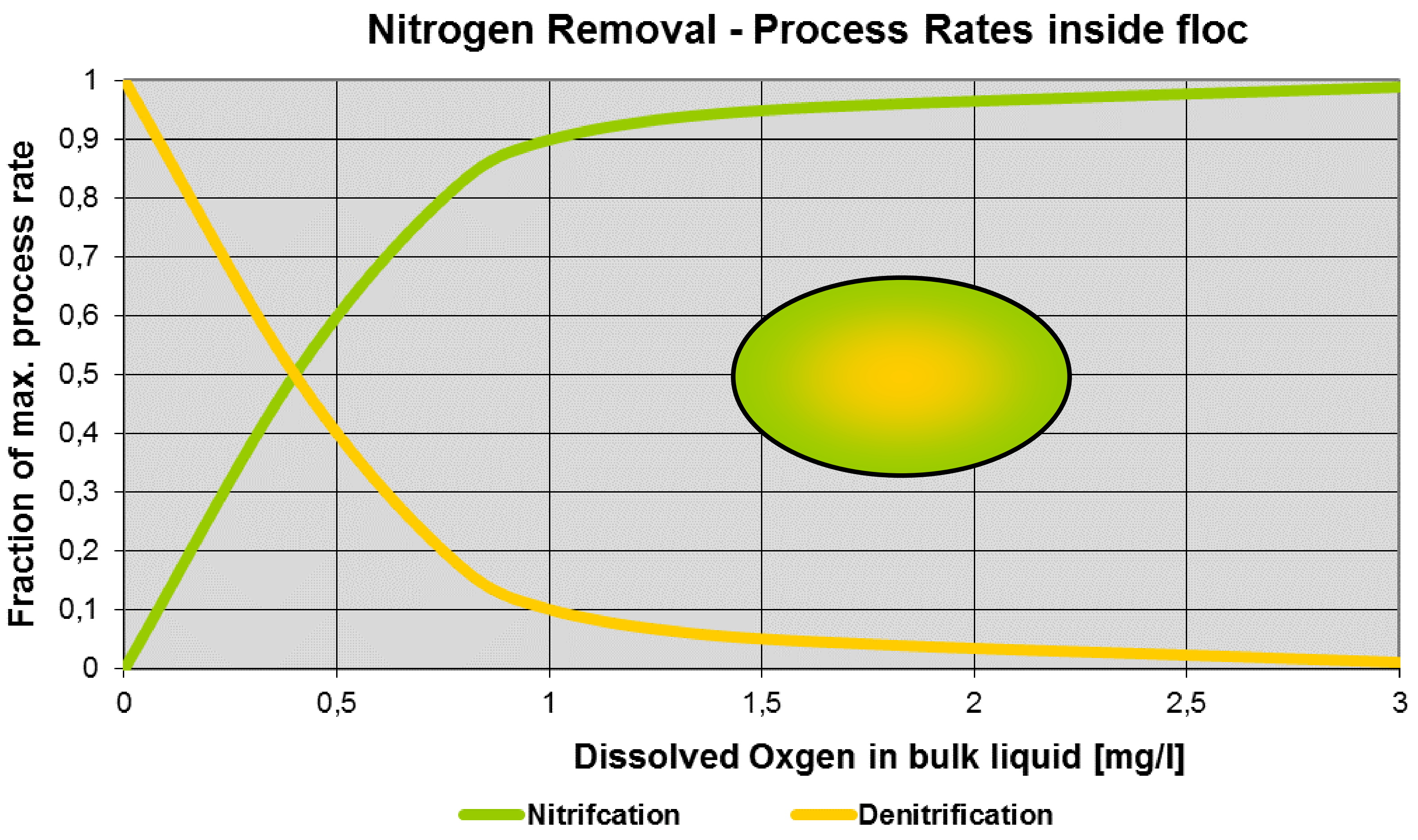
Aeration / recirculation



Direkte ammonium kontrol



Simultaneous Nitrification/Denitrification



Control of blower using Ammonium load estimate – no DO control

- Reduction of Ammonium without increase in Nitrate
- Dissolved Oxygen always less than 0.5 mg/l

Areation controls

Improved efficiency of the aeration

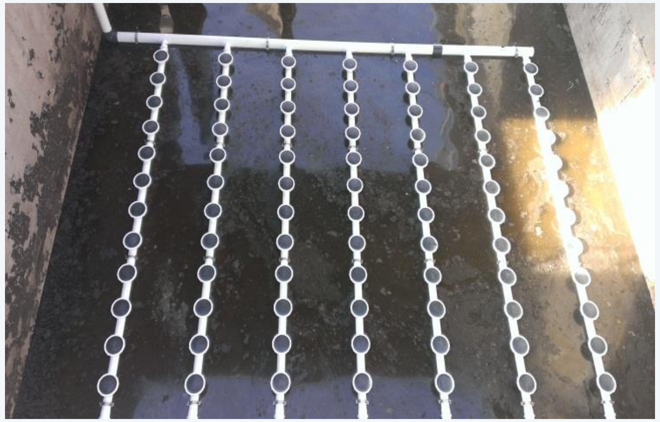
Key data:

- Replacement of HV Turbo blower with a Turbo Compressor and implementing new membranes on the diffusors
- Reduction in power consumption: 300.000 kWh/year

HV Turbo blower - 1992

ABS HST Compressor

New membranes - fine bubble aeration



Business Case:

- Construction costs: 250.000 €
- Reduction in power costs ~ 26.000 € per year
- Pay back time (ROI): ~ 10 years

Implementation: 2011-12

Blowers at Marselisborg wwtp

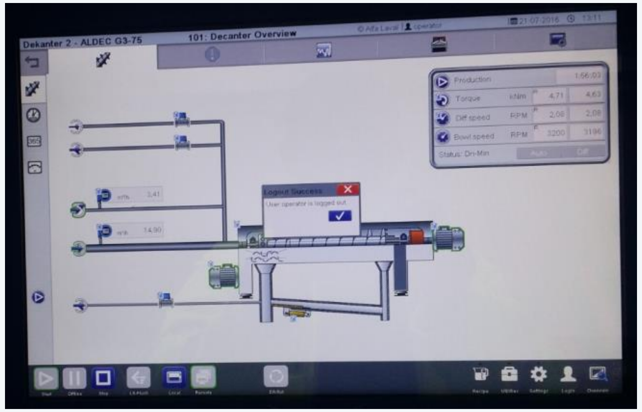
Replacement of old final dewatering unit

Key data :
- Replacement of old centrifuge with new energy efficient
- Reduction in power consumption 60.000 kWh/year
- Reduced operation costs

Alfa-Laval, 550 series

Alfa-Laval, G3 Centrifuge

Automatic control

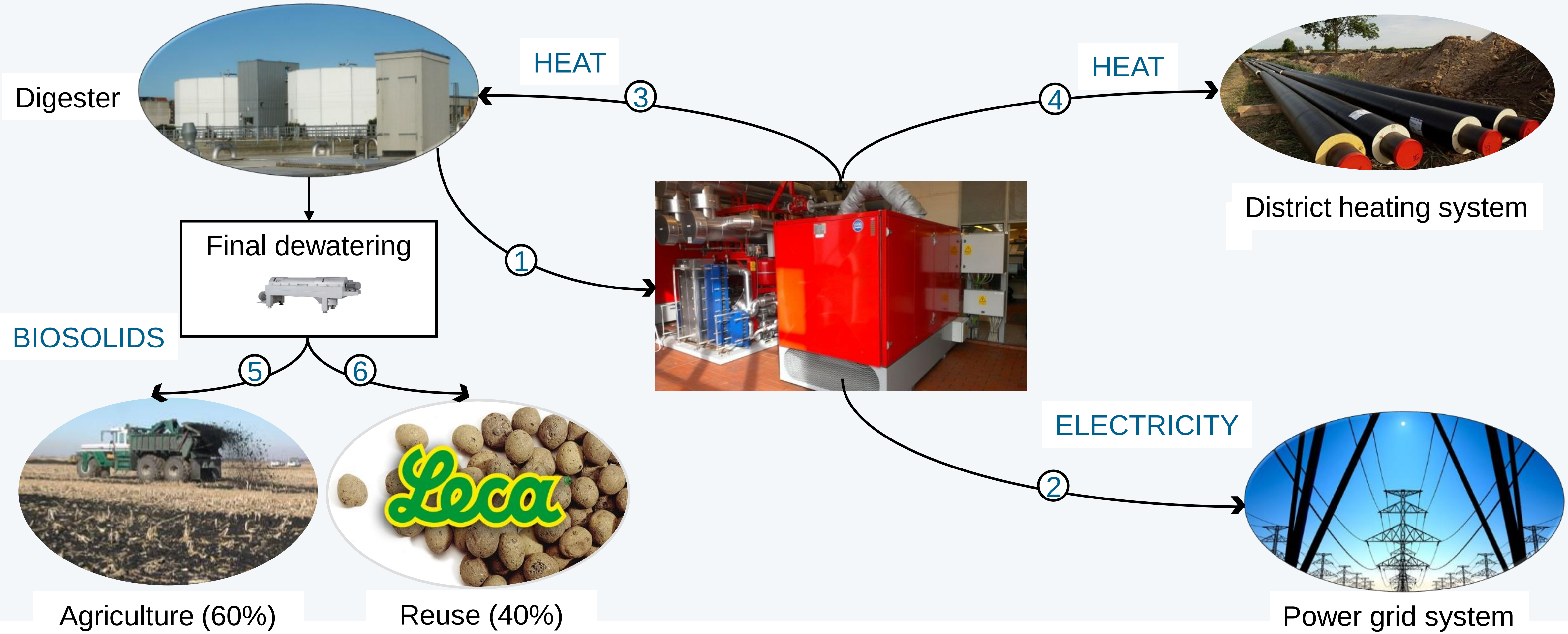


Business Case:
- Investment costs : 216,000 €
- Reduction in power consumption ~ 6,000 € per year and reduced OPEX ~ 47,000 € per year
- Pay back time (ROI) ~ 4 years

Implementation: 2016

Optimized energy production

Improved biogas utilization



Optimized energy production from biogas

Key data for the project:

- Phase 1: Replacement of 3 old gas engines with two high efficiency – 2 pcs 250 kW – CPH units
- Electricity production (additional production): approx. 1 mio. kWh/year

New gas engine

- Power efficiency 38-39%
- Surplus heat efficiency 50-55%
- Total efficiency 88-94%

Business Case:

- Investment costs: 1.271.000 €
- Income from sold electricity ~ 154.000 €/year
- Pay back time (ROI): 8 years

Implementation: 2010-2012

Optimized energy production from biogas

Key data :

- Phase 2: New CHP and gas treatment
- Power production (surplus production) 900,000 kWh/year

Gas engine installation

Gas treatment, activated carbon

New gas engine:

- 1 pcs. 355 kW CHP biogas motor
- Power efficiency: 40%

Business Case:

- Investment: 3,2 mill. DKK. (430,000 €)
- Power production (surplus production), ~ 138.000 €/year
- ROI approx. 3-4 year

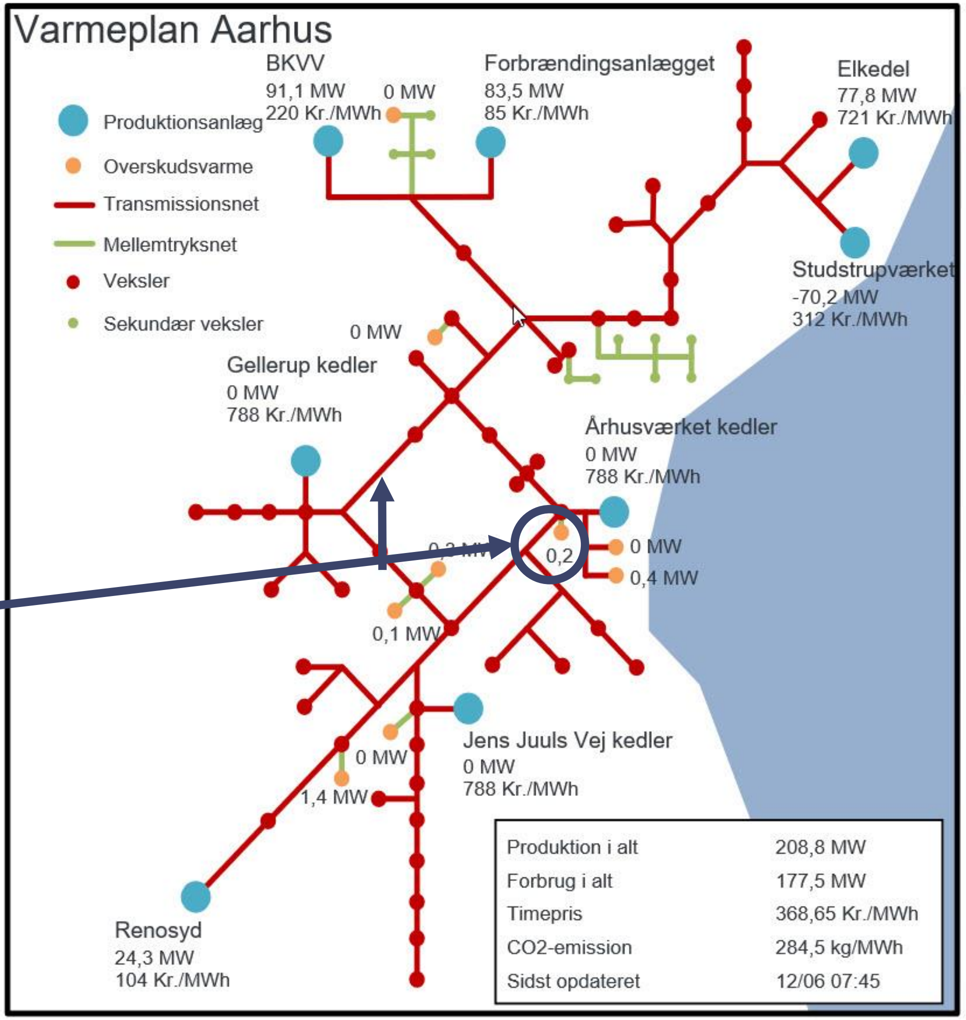
Implementation: 2015

Solution at Viby WWTP

Smart grid, district heating system in Aarhus

Key data :

- Surplus heat from the gas engines is used for district heating



Key data for the project:

- Construction costs	166.000 €
- Annual Income (sale)	33.000 €/year
- Pay back time (ROI)	5 years

Summary of energy optimization

Activity	Saving (-) Additional Production (+) KWh/year	Investment €	Reduced, OPEX Savings/sales € per year	ROI (Simple)
Reduction of energy consumption				
Process optimization	-700,000	400,000	175,000	2.3
Improved aeration/new blower etc.	-300,000	250,000	26,000	9.6
Replacement of final dewatering (centrifuge)	-60,000	216,000	47,000	4.6
Sludge liquor treatment	-50,000	400,000	85,000	4.7
Increasing energy production				
Replacement of old gas engines	1,000,000	1,271,000	154,000	8.3
New gas engine and gas treatment	900,000	430,000	139,000	3.1
Surplus heat for district heating	2,500,000	166,000	33,000	5.0
Total		**3,133,000**	**659,000**	**4.8**
Total, Reduction in power consumption	-1,110,000			
Total increase in energy production	**4,400,000**			
- power	**1,900,000**			
- heat	**2,500,000**			

OPEX for WW service in Aarhus Vand reduced ~ 3.6 %

Savings = reduction of power consumption and waste water taxes

Sales = supply of power and excess heat to external power and district heating networks

Marselisborg P-recovery plant

Official opening in January 2019

Struvite - From problem to ressource

The problem

- Gray irritating material in pipes etc. in sludge treatment processes

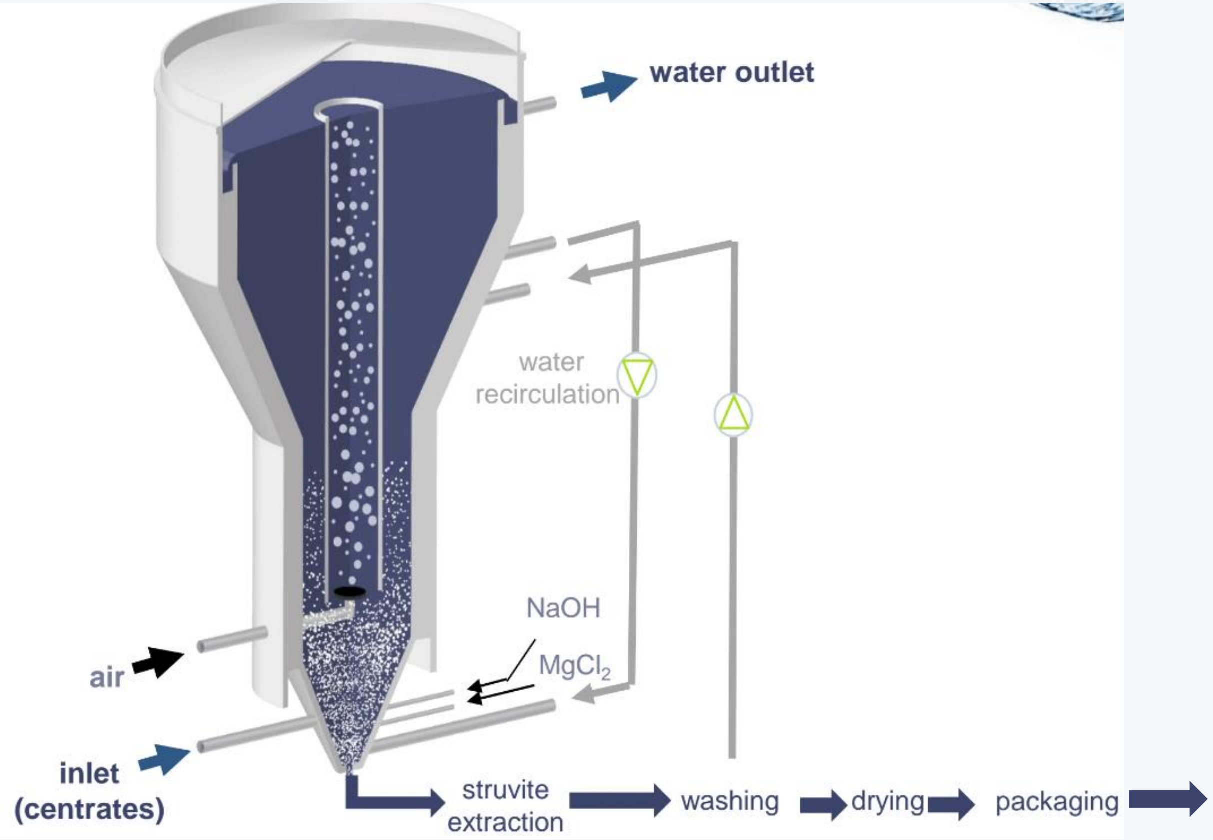
$$Mg^{2+} + HPO_4^{2-} + NH_4^+ + 6H_2O \rightarrow MgNH_4PO_4{,}6H_2O + H^+$$

magnesium + phosphorous + ammonium + water → struvite + acid

The ressource

12.6 % P, 5.6 % N, 10 % Mg   a premium fertilizer!

The Proces Nutrient recovery at Marselisborg WWTP

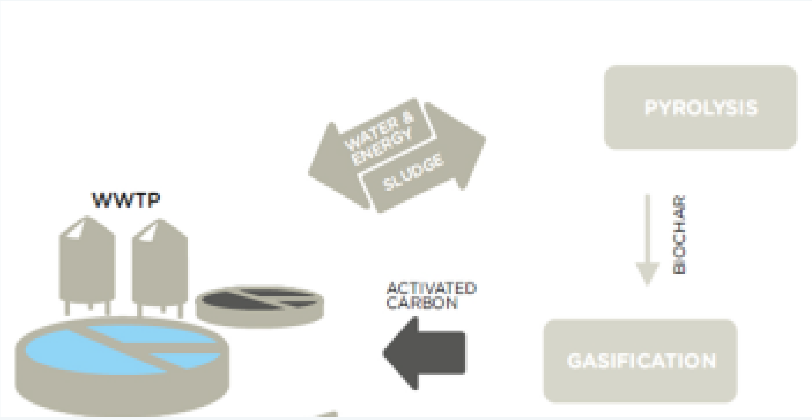


Operational benefits from P-recovery

- The internal phosphorus load is removed (more cleaning capacity)
- Blockages / uncontrolled struvit clocking are significantly reduced (less maintenance costs)
- Sludge amount is reduced (reduced costs for sludge disposal)
- Less consumption of chemicals for P-removal in wastewater (saving)
- Less energy consumption for wastewater treatment (less power consumption)
- Sales of "PhosphorCare" generates revenue

Circular resource utilisation of residual sludge

- Development of **unit to produce activated carbon from biochar**
- Application sent to MUDP in Denmark
- Approved September 2018



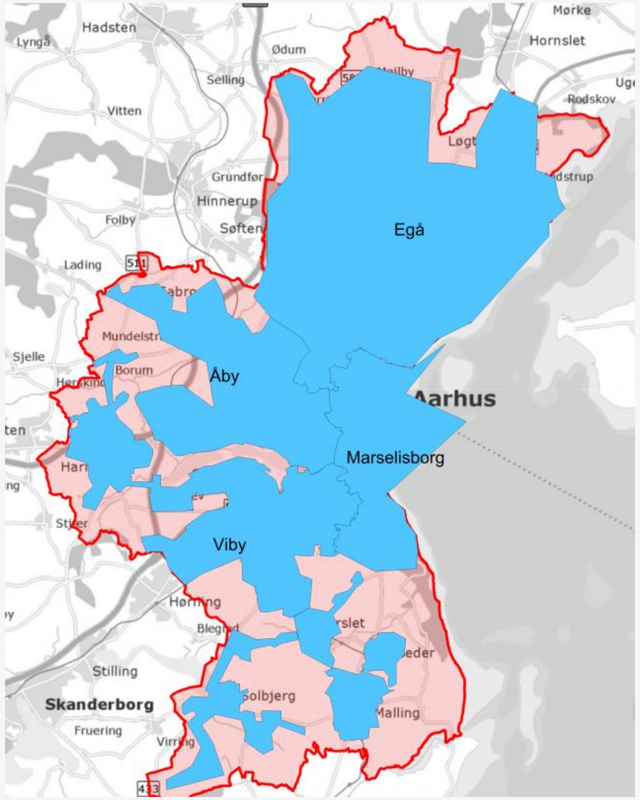
Ansøgningsskema 2018 til
MUDP
Grøn Innovationspulje

1.1 Hovedoplysninger

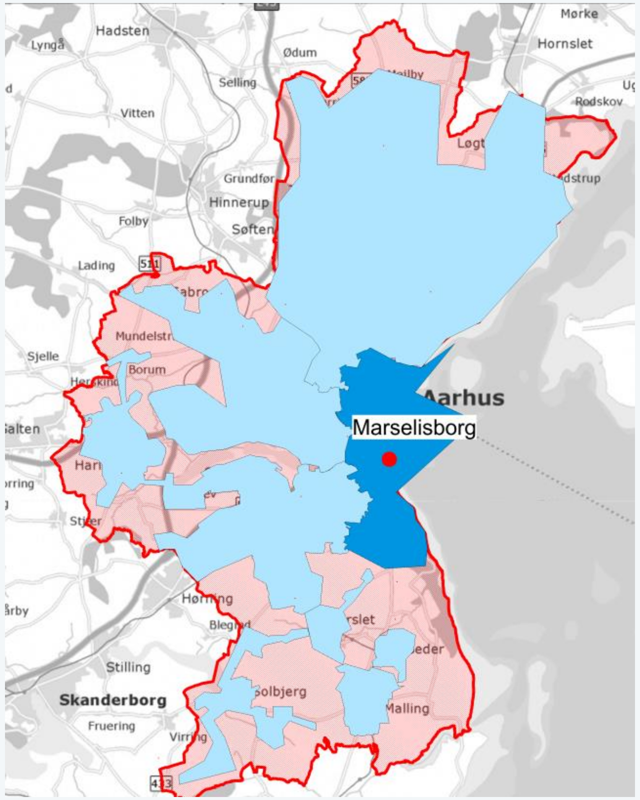
Projektet	**Oplysningerne anføres i denne kolonne**
Angiv hvilket hovedemne projektet omhandler: (sæt ét kryds)	*Opslag 2018 med* ***ansøgningsfrist 7. maj 2018 kl. 12.00:*** [ ] Klimatilpasning og Vand [ ] Reduceret belastning af natur og miljø [X] Bedre ressourceeffektivitet
Projektets titel:	Circular resource utilization of residual sludge: Development of unit to produce activated carbon from biochar.
Kort beskrivelse af hovedformål med projektet, der må bruges ved offentliggørelse (max.10 linjer):	This project develops and tests a technology for cost-effective improvements of the environmental sustainability of waste water treatment by upcycling of residual sludge into activated carbon. Residual sludge will be transformed into high value activated carbon to be applied on-site while simultaneously reducing greenhouse gas emissions and environmental impacts related to organic pollutants and micro plastics.

Project participants: AguaGreen ApS, Aarhus Vand A/S, VandCenterSyd og DTU KT RISØ

Energy self-sufficient and carbon footprint at Marselisborg catchment area. 200.000 people



Aarhus Water Service Area



Marselisborg Catchment Area

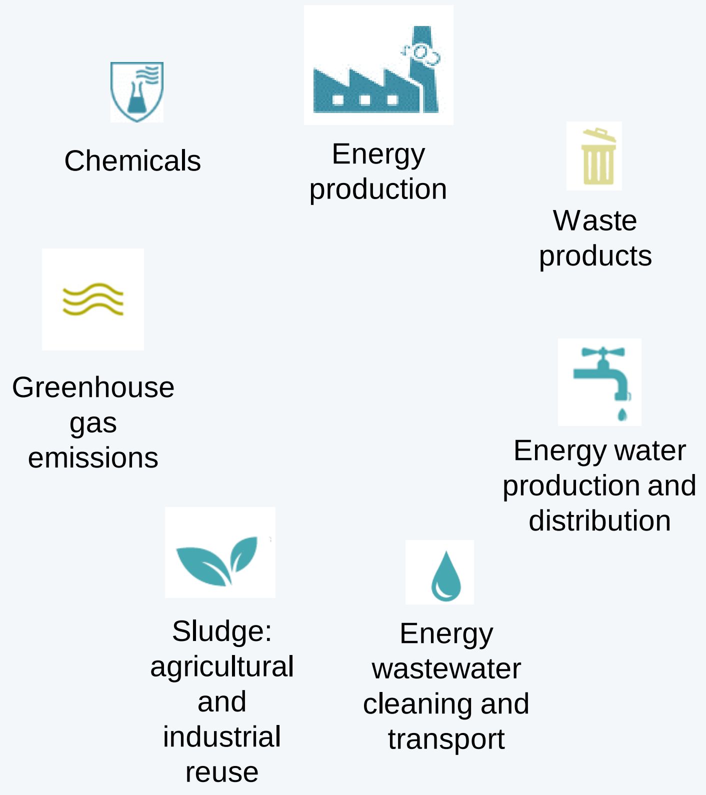
Catchment area Marselisborg

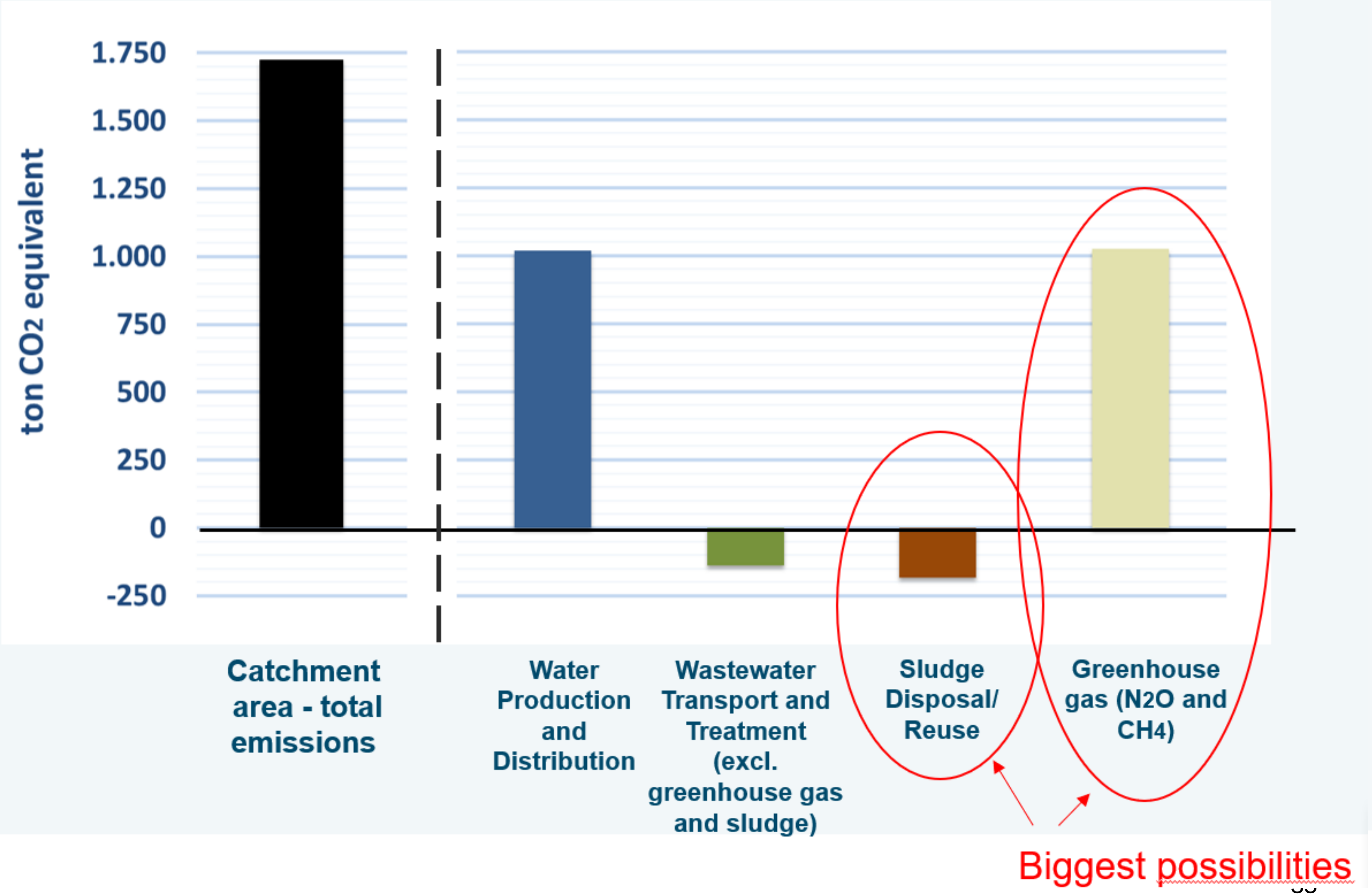
ENERGY SELF SUFFICIENCY			2014	2015	2016	2017	2018
Amounts	Water production and dist.	[mill. m^3]	5,8	6,0	6,1	6,3	6,3
	Wastewater treated	[mill. m^3]	10,5.	12,0	11,2	10,6	9,2
Power Consumption	Water treatment and distribution	[GWh]	3,1*	3,2	3,6	3,7	4,1
	Wastewater Transport	[GWh]	0,7*	0,8	0,8	0,6	0,5
	Marselisborg WWTP	[GWh]	3,4	3,5	3,1	3,2	3,3
	Total	[GWh]	7,2	7,6	7,5	7,4	7,9
Energy Production	Power production, sold	[GWh]	4,4	4,6	4,8	4,8	4,6
	Heat production, sold	[GWh]	2,1	2,2	2,6	2,4	1,9
	Total	[GWh]	6,5	6,8	7,4	7,2	6,5
Energy self sufficiency (heat and power)	Marselisborg WWTP	[%]	192	194	234	227	196
	Catchment Area Marselisborg	[%]	90	90	99	96	82

* Estimated on basis of the specific energy consumption found in 2015

Specific energy consumption		2014	2015	2016	2017	2018
Water treatment and distribution	[kWh/m^3]	0,53	0,53	0,59	0,59	0,65
Wastewater Transport	[kWh/m^3]	0,07	0,07	0,07	0,06	0,05
Marselisborg WWTP	[kWh/m^3]	0,32	0,29	0,28	0,30	0,36

CO_2 emissions included in the model for Marselisborg catchment area (MCA* 2018)





Summery

REDUCTION OF CONSUMPTION (from 2005 to 2016) 1.1 GWh ~ 25% (Netto 34%)

Thank you for your attention!

Contact Details:
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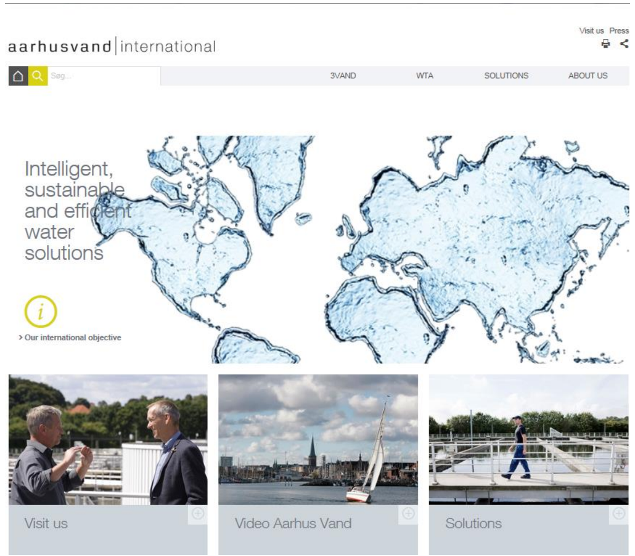
E-mail: FBM@aarhusvand.dk

http://www.aarhusvand.dk/international/



Reference:
Obtaining 150% Electricity Self-sufficiency at a Wastewater Treatment Plant, WEFTEC 2017 - Manuscript