

Presenter:

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# Billund Biorefinery

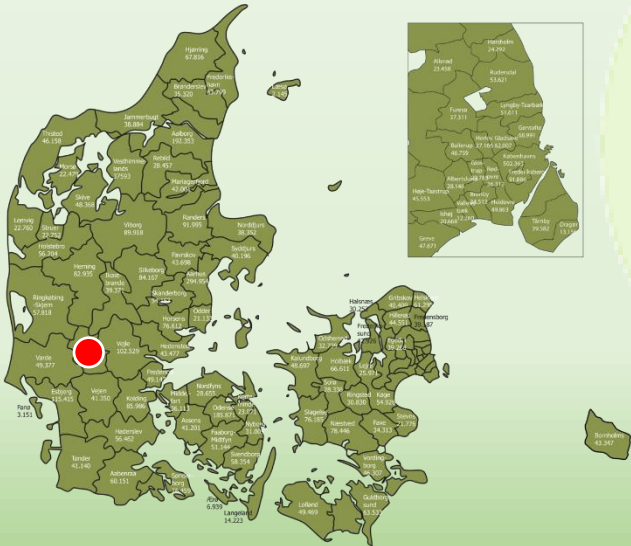
## WWTP contributes to Circular Economy

And from 17 SDG – we have selected 5



- Who are we?
  - Public utility company
  - Owned by the municipality of Billund
  - Consists of four companies
    - Billund Drinking Water
    - Billund Wastewater
    - Grindsted Wastewater
    - Billund Energy

} Billund Biorefinery



- What do we do?
  - Drinking water supply
  - Wastewater treatment
  - Treatment of Organic fraction of municipal solid wastes
  - Treatment of Industrial organic wastes
  - Energy production – both electricity and heat
  - Produce valuable products from waste streams from the municipality
  - Provide direct service to the customer – drinking water, sewerage, waste management
  - Provide consultation for other utility companies; national and international
  - Officially supported as a Lighthouse for Danish water technology
  - Strong collaboration with industries in the municipality - win-win strategy





# The Business plan in Billund Vand and Energy

## 1. Strong collaboration with Industries:

- Win-Win situation
- Complex economic agreement
- Extensive collaboration between operations teams



## 2. Reduction of costs

- We are strongly focused on reducing the costs due to regulations from the national government!
- **Therefore the Plan for Wastewater 2014-2035**
- Wastewater will reduce costs within 20 % ( $\approx$  3.8 million DKK or 520000 Euros or 600000 USD)
- Drinking water will reduce costs within 30 % ( $\approx$  1.3 million DKK or 173700 Euros or 200000 USD)
- Annual production of electricity and heat (green energy) worth at least 10 million DKK ( $\approx$  1.3 mill. Euros or 1.5 mill. USD)

**Have to reduce costs - Total Expenses - every year  
as announced annually by the government**

# Billund BioRefinery

Resource Recovery for the Future

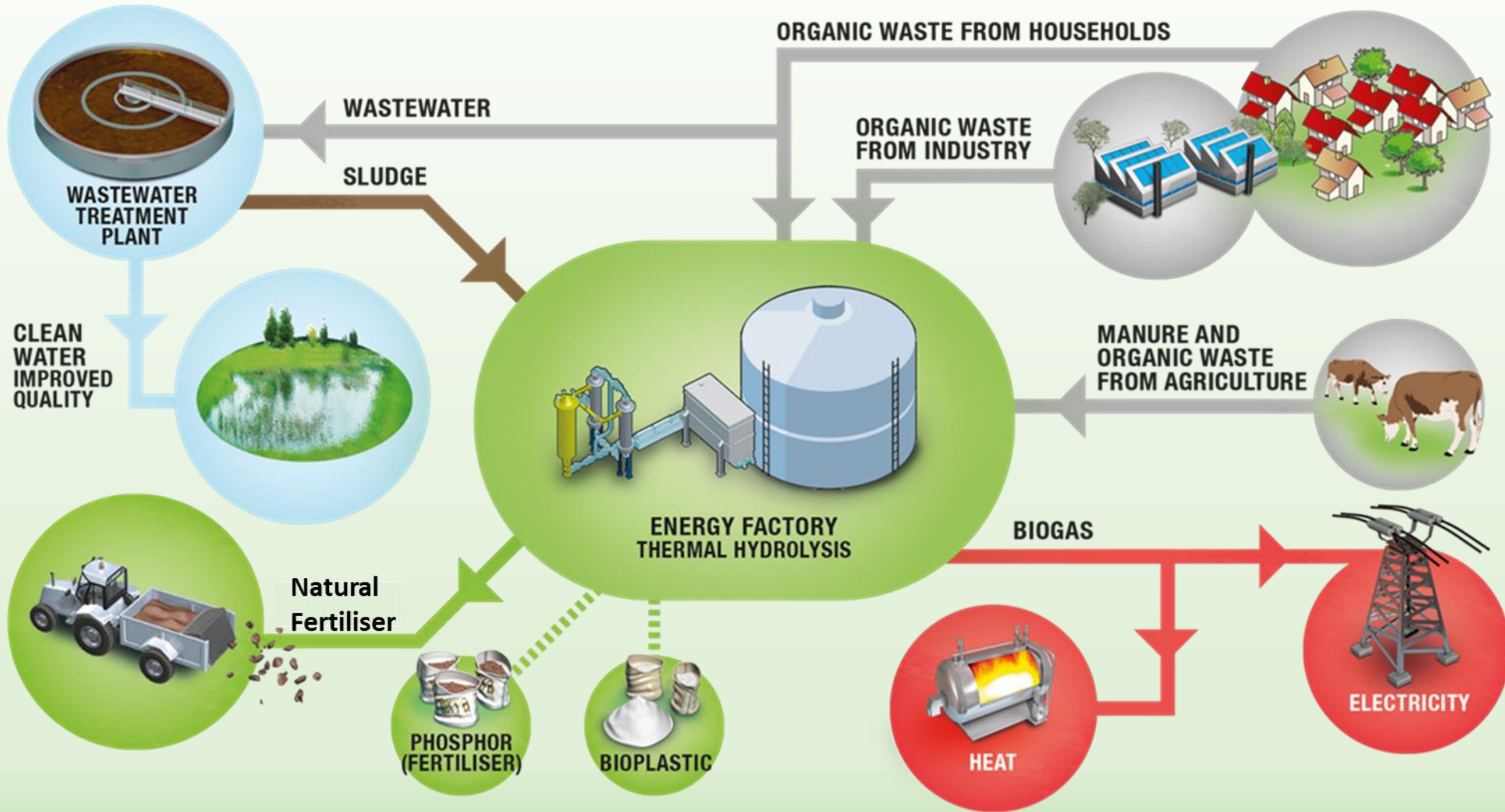


**Billund Biorefinery is a high profile project launched by  
Krüger-Veolia and Billund Vand A/S in a Public-Private partnership**



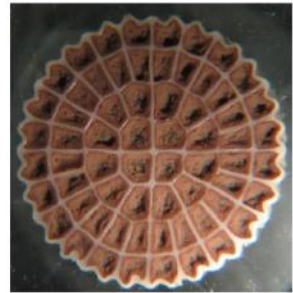
# A short history of BBR

- Grindsted wastewater treatment plant
  - Commissioned in 1996
  - Combined treatment of wastewater and organic wastes from WWTP, households and industries
  - One of the first in the world
- 2013 - A competition about defining the WWTP of the future – a lighthouse project by the Miljøstyrelsen
  - Governmental grant as reward for the best ideas
- Grant amount
  - 15 million DKK (≈2 million Euros or 2.3 million USD)
- Total budget
  - 72.5 million DKK (≈ 9.7 million Euros or 11.2 million USD)
- Public private partnership
  - Billund Vand A/S and Krüger-Veolia
  - Bilateral learning
- Add-ons to enhance existing biorefinery

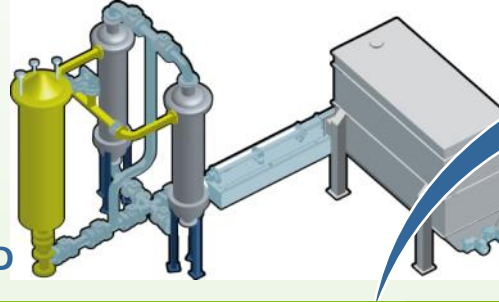
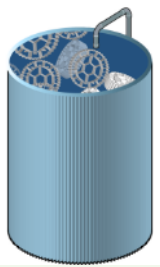




# A unique solution



Anita™ Mox



Exelys™ DLD

**An existing WWTP with co-digestion**



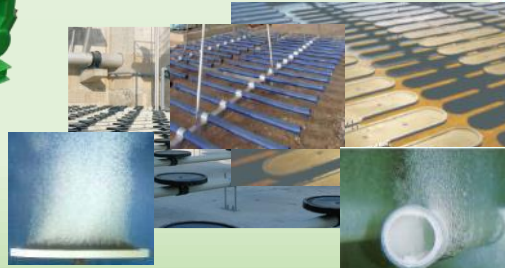
*New Technologies*

+

*Known technologies*



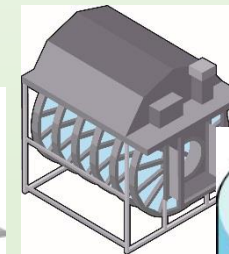
Energy production



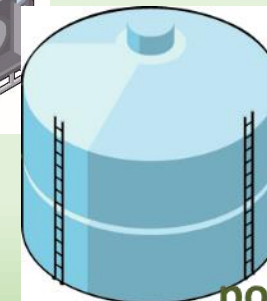
Energy efficient aeration



STAR/AQUAVISTA



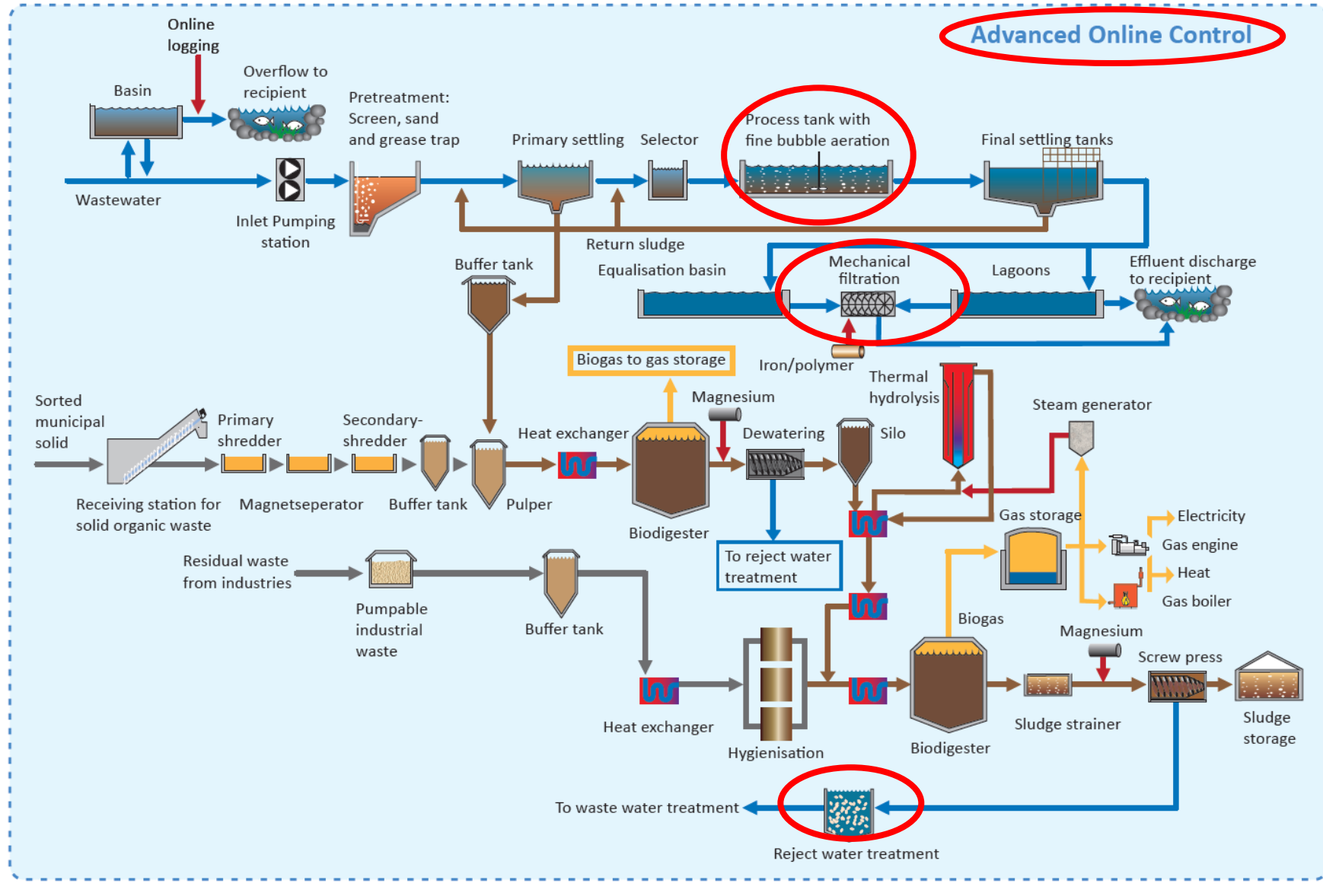
Filtration for polishing effluent  
+ cleaning stormflow



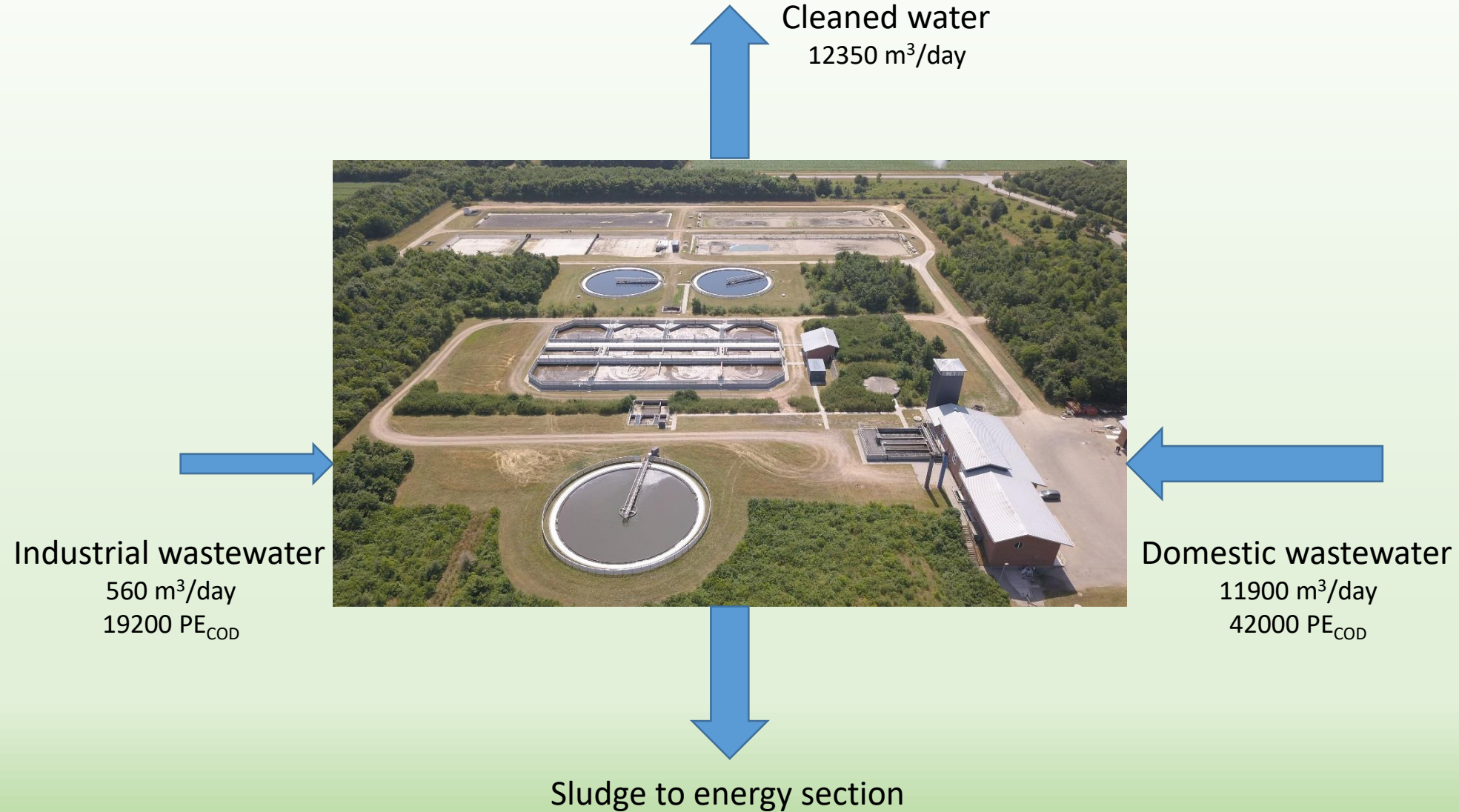
Anaerobic digestion

powered by

# Description of add-ons – Water recovery



# Water recovery





# Water recovery

## Quality of Effluent - regulation

Kontrolvariable	Grænse-værdi	Kontrolmetode
Flow (l/s)	430	Absolut (maks.)
BOD <sub>modificeret</sub> (mg/l)	10	Transportkontrol
COD (mg/l)	75	Transportkontrol
Total-P (mg/l)	1,5	Transportkontrol
Total-N (mg/l)	6	Transportkontrol
Ammoniak-kvælstof (mg/l)	2	Tilstandskontrol
Ammoniak-kvælstof (mg/l)	5	Absolut (maks.)
Suspenderet stof (mg/l)	15	Tilstandskontrol
Acrolein (µg/l)	0,02	Transportkontrol
Natamycin (µg/l)	2	Transportkontrol
Kviksølv (µg/l) – filtreret <sup>1)</sup>	0,18	Transportkontrol
Bly (µg/l) - filtreret <sup>1) + 2)</sup>	12	Transportkontrol
Cadmium (µg/l) - filtreret <sup>1) + 2)</sup>	0,9	Transportkontrol
Krom (µg/l) - filtreret <sup>1) + 2)</sup>	49	Transportkontrol
Kobber (µg/l) - filtreret <sup>1) + 2)</sup>	49	Transportkontrol
Nikkel (µg/l) - filtreret <sup>1) + 2)</sup>	40	Transportkontrol
Zink (µg/l) - filtreret <sup>1) + 2)</sup>	31	Transportkontrol
pH	6,5 – 9,0	Absolut (min/maks.)
Ilt	60 %	Absolut (min.)

## Actual quality

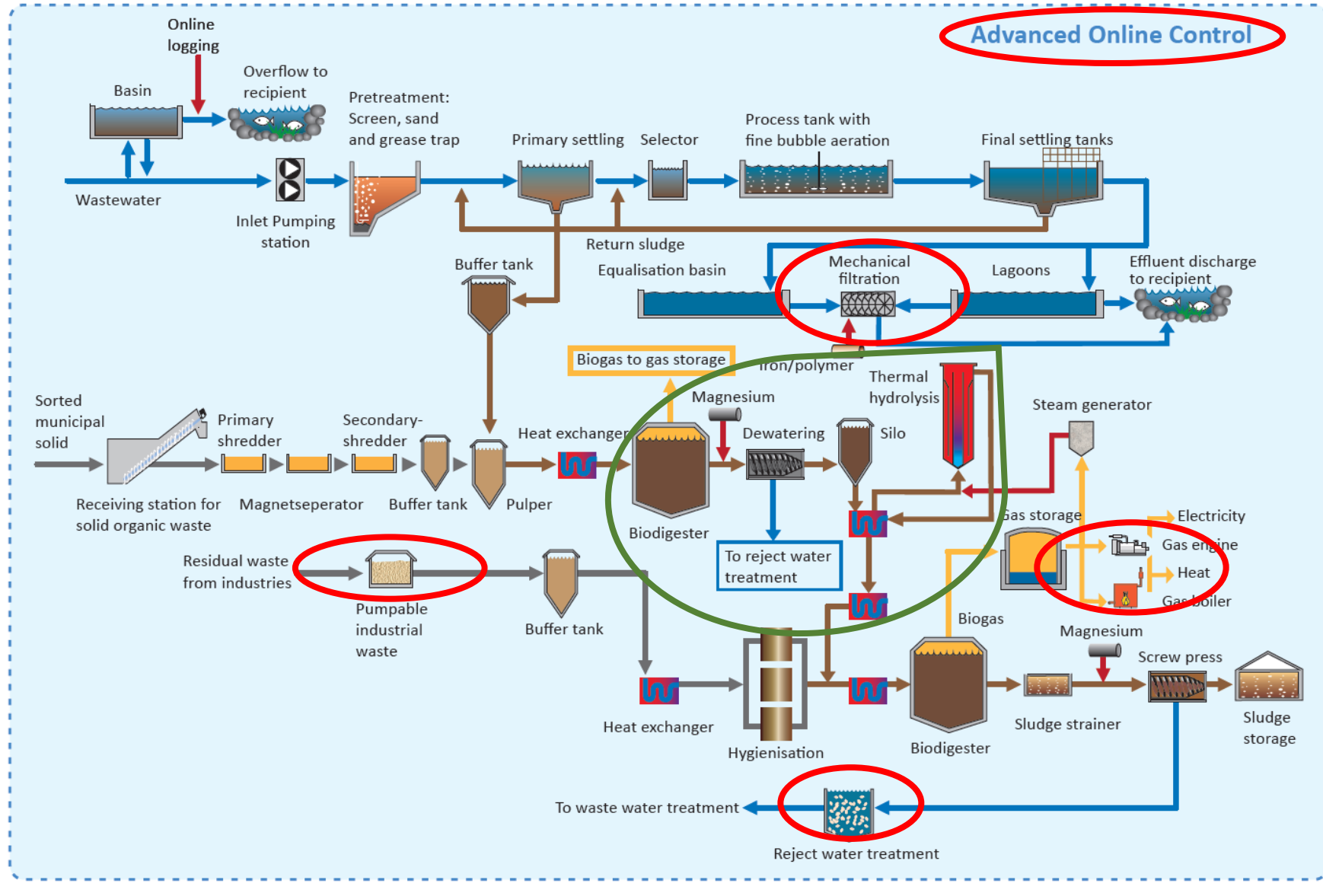
Data from 2017 to 2020	Regulation	Effluent	Removal efficiency %
COD mg/L	75	46	93
TN mg/L	6	4,7	92
TP mg/L	1,5	0,4	94
BOD mod mg/L	10	3,7	98
NH4 mg/L	2	1,3	97
SS mg/L	15	7,6	98

# Water recovery

- 4.5 million m<sup>3</sup>/ year cleaned water
- We pay pollutant taxes per kilogram of pollutant let out
  - Even if we are below the effluent limit!
  - Important to reduce pollutant load as much as possible
- A Hydrotech filter was installed as part of BBR
  - Eliminated the need for lagoons for polishing
  - Reduced SS load on the recipient during rainy season
  - Was shown to reduce measurable microplastics mass by 77%



# Description of add-ons – Energy recovery





# Source separated organic fraction of household wastes

*Sådan sorterer du:*

<b>Madaffald</b>	<b>Restaffald</b>
Alle madvarer - uden emballage	Mælke- og juicekartoner
Brød og kagerester	Bleer og hygiejnebind
Kød og pålæg	Plastikfolie og poser
Fedt og sovs	Aluminiumsbakker
Fisk og fiskeben	Staniol
Frugt og grøntsager	Konservesdåser
Kaffegrums og teblade med filter	Skruer og skruer
Afskårne blomster	Porcelæn og stentøj
Æggeskaller	Potteplanter
Aftøringspapir - køkkenrulle og lign.	Dyreexkrementer (inkl. kattegrus)
	Aske fra askebæger og brændeovn

Kildesorteret Husholdningsaffald



# Energy positive

Thermophilic, 55°C  
1500 m<sup>3</sup>  
Residence time: 13 days  
Sulzer mixer, recirculation  
Gaswasher  
**3200 Nm<sup>3</sup>/day (63 % CH<sub>4</sub>)**



***Digester***

Exelys  
Continuous thermal hydrolysis unit  
15 to 18% input DS  
160°C at 8 bars for 30 min



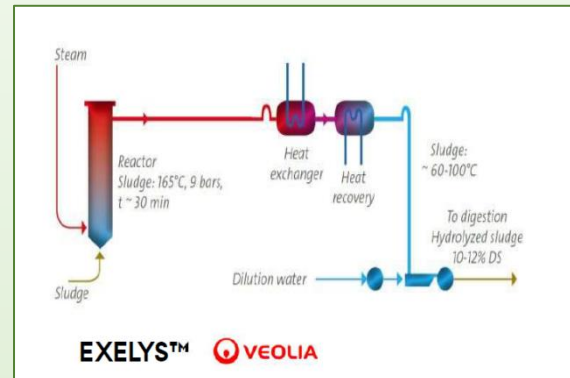
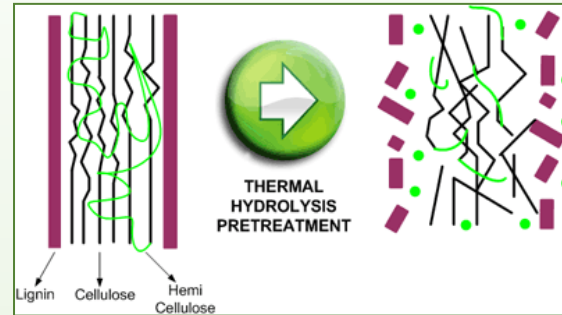
***Lysis***

Mesophilic, 37°C  
2800 m<sup>3</sup>  
Residence time: 27 days  
Halberg mixer, recirculation  
**6200 Nm<sup>3</sup>/day (69 % CH<sub>4</sub>)**



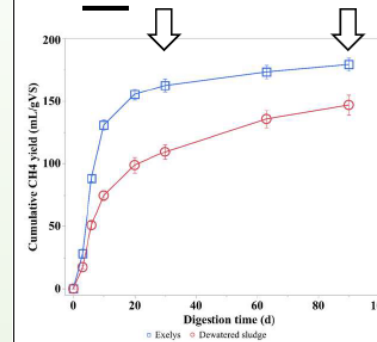
***Digester***

# DLD configuration with Exelys



Energy requirement:  
Biogas used for Exelys process heat: 270 to 300 m<sup>3</sup>/day

## -BATCH TEST



Tested date:

Sep. 2017 (Referring to CSTR)

Dewatered sludge DM. 22.6% VS 16.8% VFA 272.6 mg/L

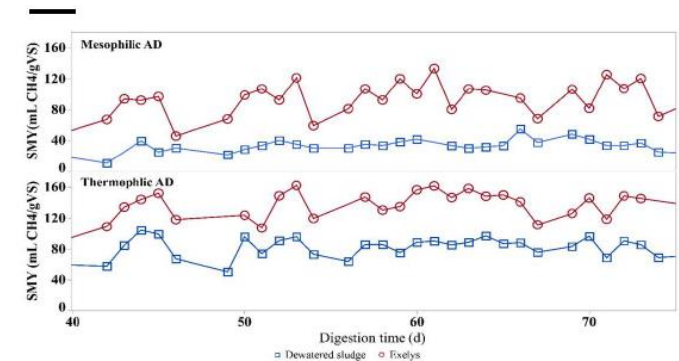
Exelys DM. 7.3% VS 5.1% VFA 1282.6 mg/L

Methane produced from Exelys sludge was **50%** more and **20%** more than dewatering sludge (Day 30 and 90)

Substrate	Experimental BHP 90 [mL CH <sub>4</sub> gVS <sup>-1</sup> ]	B <sub>0</sub> [mL CH <sub>4</sub> gVS <sup>-1</sup> ]	K [d <sup>-1</sup> ]	R <sup>2</sup>	RMSE
Dewatered sludge	146.83±4.55	140.37	0.06	0.9705	8.2975
Exelys™	179.36±2.97	175.33	0.11	0.9660	10.9837

Hydrolysis rate/constant was accelerated after EXELYs process

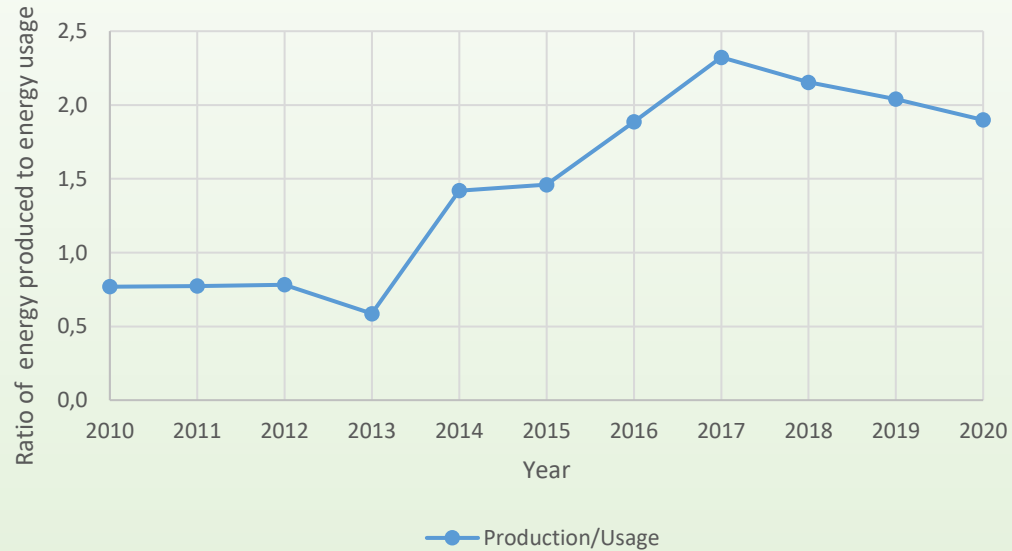
## -CSTR



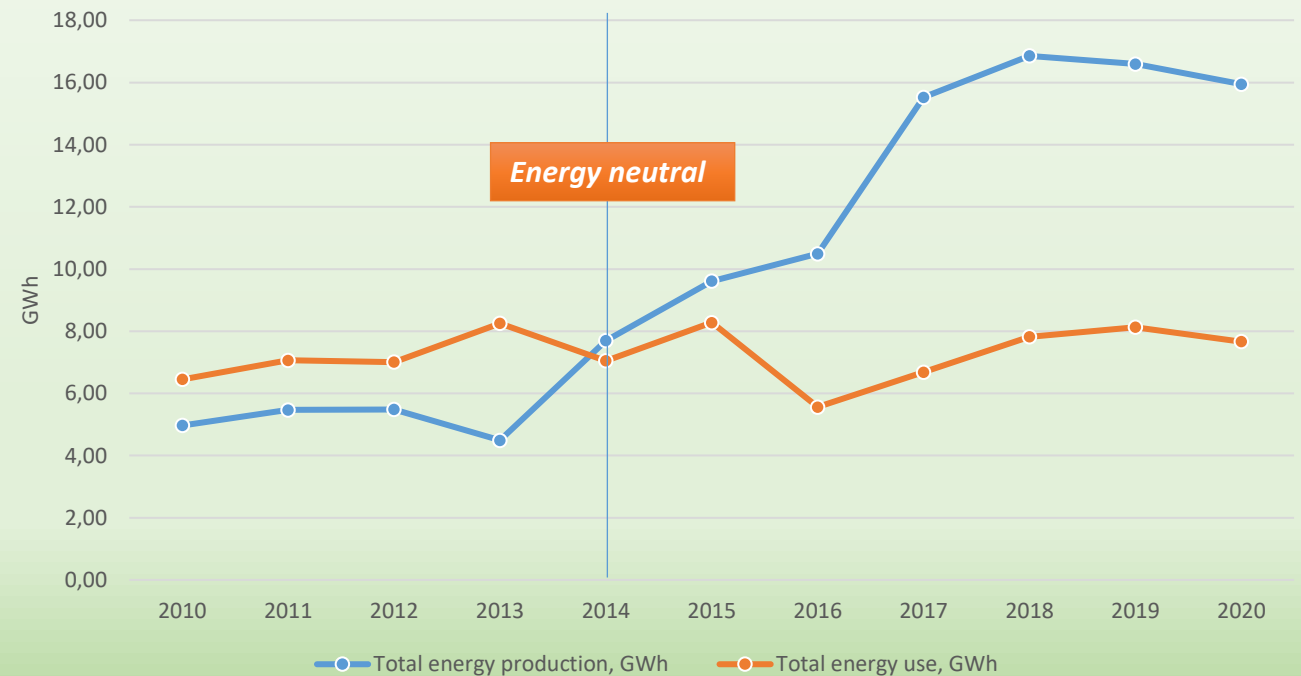


# Energy positive

Energy, ratio of Production/Usage



Annual energy production and usage



Biomass inputs	Per day, m3	2020, tonnes	Dry solids (%)
Waste activated sludge	50	71442	1.5 to 5%
Primary sludge	50	13003	5%
OFMSW	14	3623	32
Industrial wastes	45	7569	5 to 35%
Exelys treated digestate	40		7%

# Energy efficient reject water treatment

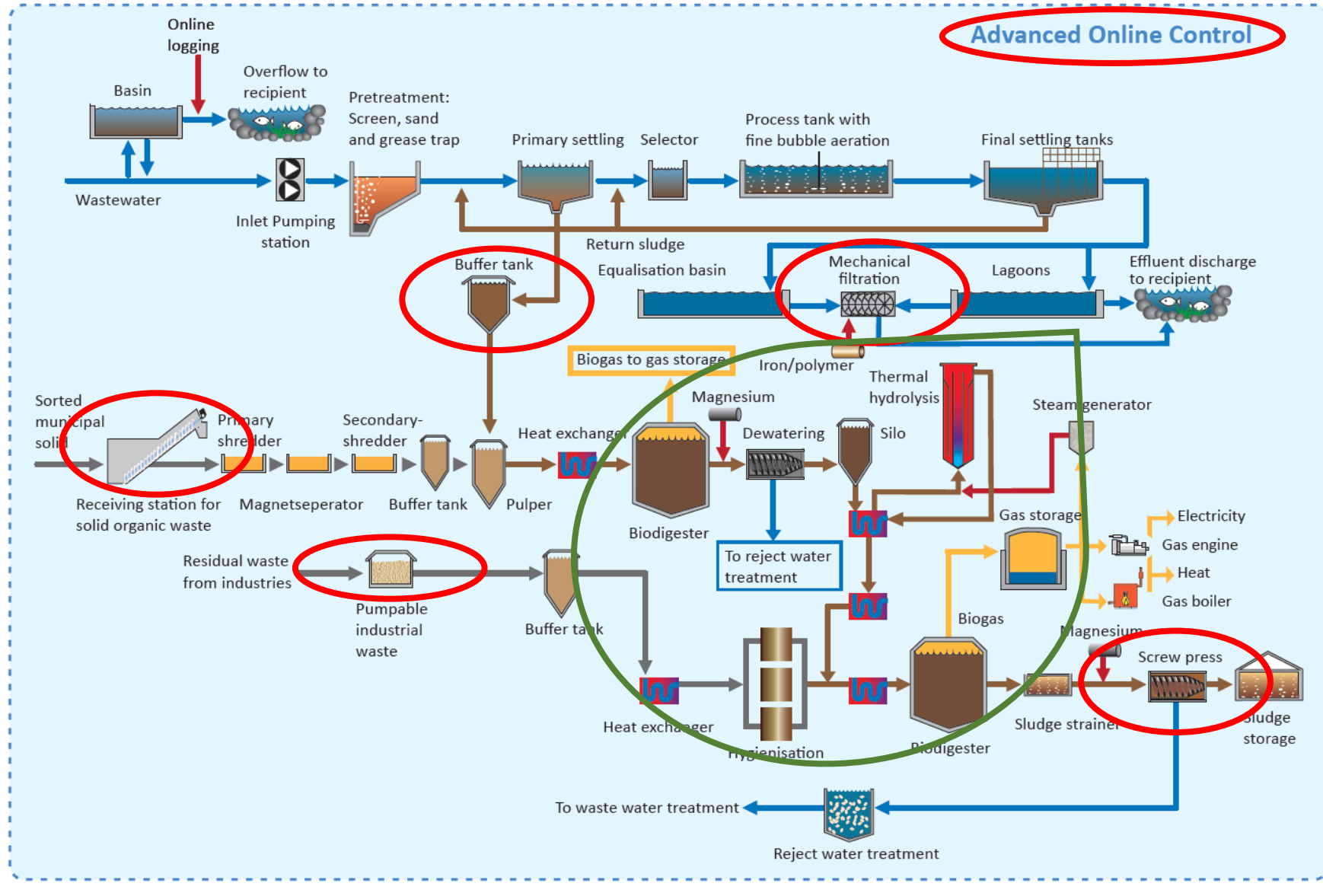


**AnitaMox™**

- Reduced internal load on wastewater treatment plant
- Removes upto 80% influent Nitrogen
- Reduced aeration requirement - by 50%
- Zero use of additional carbon
- Compact
- N<sub>2</sub>O considerations



## Processes– nutrient recovery



# Natural fertilizer

**2014: 4400 T /year**

**N-content 49 g/kgTS**

**P-content 29 g/kgTS**

**K-content 2 g/kgTS**

**2020: 4300 T /year**

**N-content 51.2 g/kgTS**

**P-content 27.4 g/kgTS**

**K-content 1.2 g/kgTS**

Fertilizer quality



## Natural fertilizer

- Quantity of natural fertilizer reduces drastically due to double digestion and thermal hydrolysis
  - Thermal hydrolysis shown to improve biogas yield by 50% thus reducing outlet solids
- Quality assurance starts at outlets of industries
- Natural fertilizer tested for 7 heavy metals, xenobiotics, plasticizers, PAH's and bacterial contaminants
  - Performed by an accredited third party
  - Results sent directly to Environmental Agency
- High value due to nutrient content



## BBR products (2020)

- Energy produced:

- Total 16 GWh/y
- Electricity 7.1 GWh/y
- Heat 8.9 GWh/y

- Energy utilized in the entire concern:

- Total 7.6 GWh/y
- Electricity 4.2 GWh/y
- Heat 3.4 GWh/y

- Energy production is more than 2 times than that used in the entire company

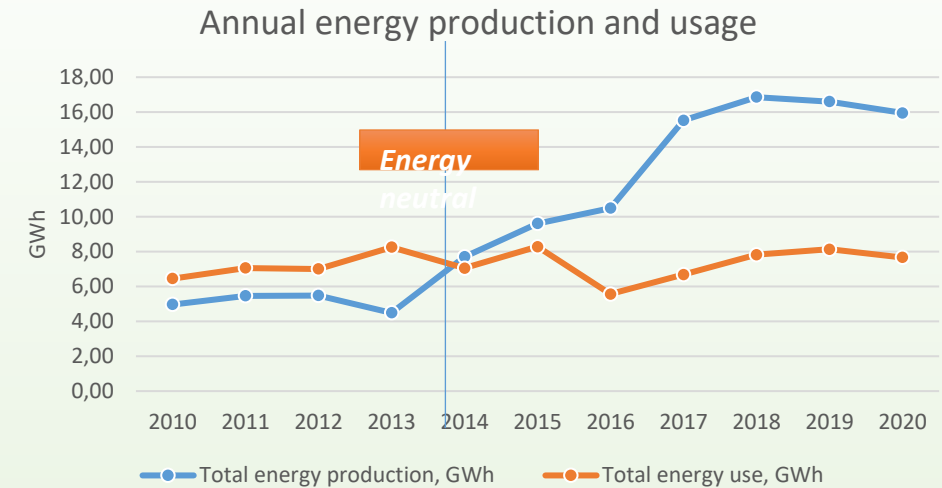
This includes the supply of drinking water, sewerage, wastewater cleaning and the production of energy itself

- Cleaned water:

3.8 million m<sup>3</sup>/y

- Nutrients

- Natural Fertilizer (24 % DS) 4300 ton/y
  - Nitrogen 51 ton/y
  - Phosphorus 27 ton/y
  - Potassium 1.2 ton/y

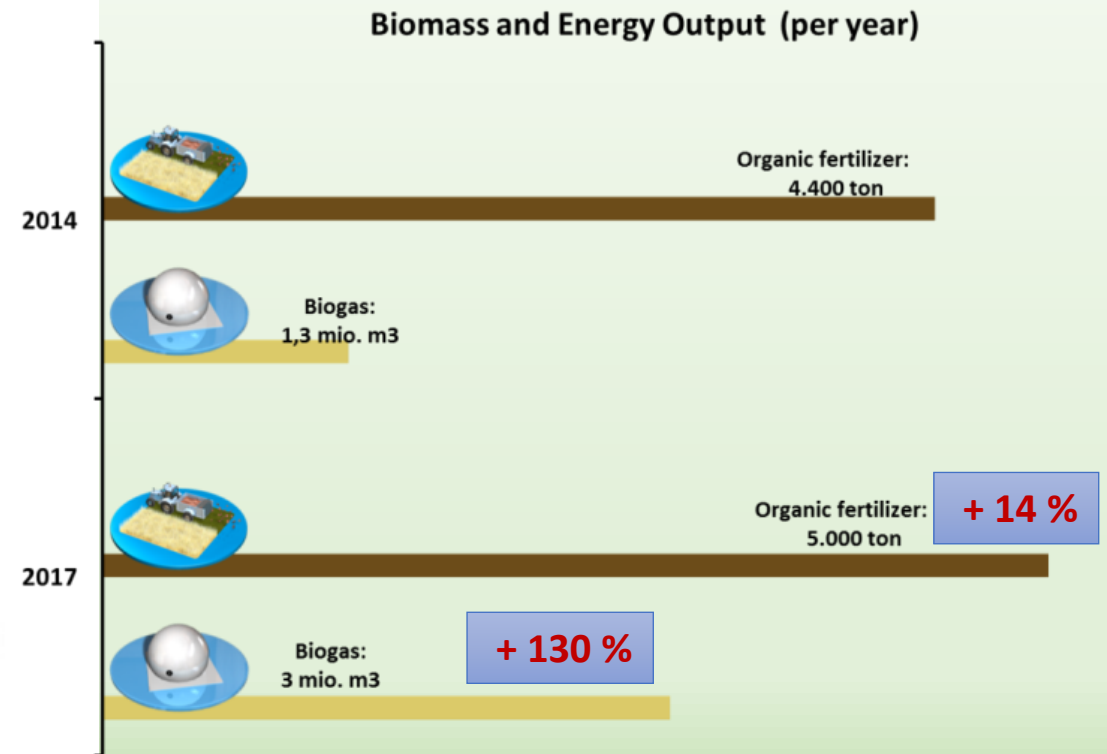
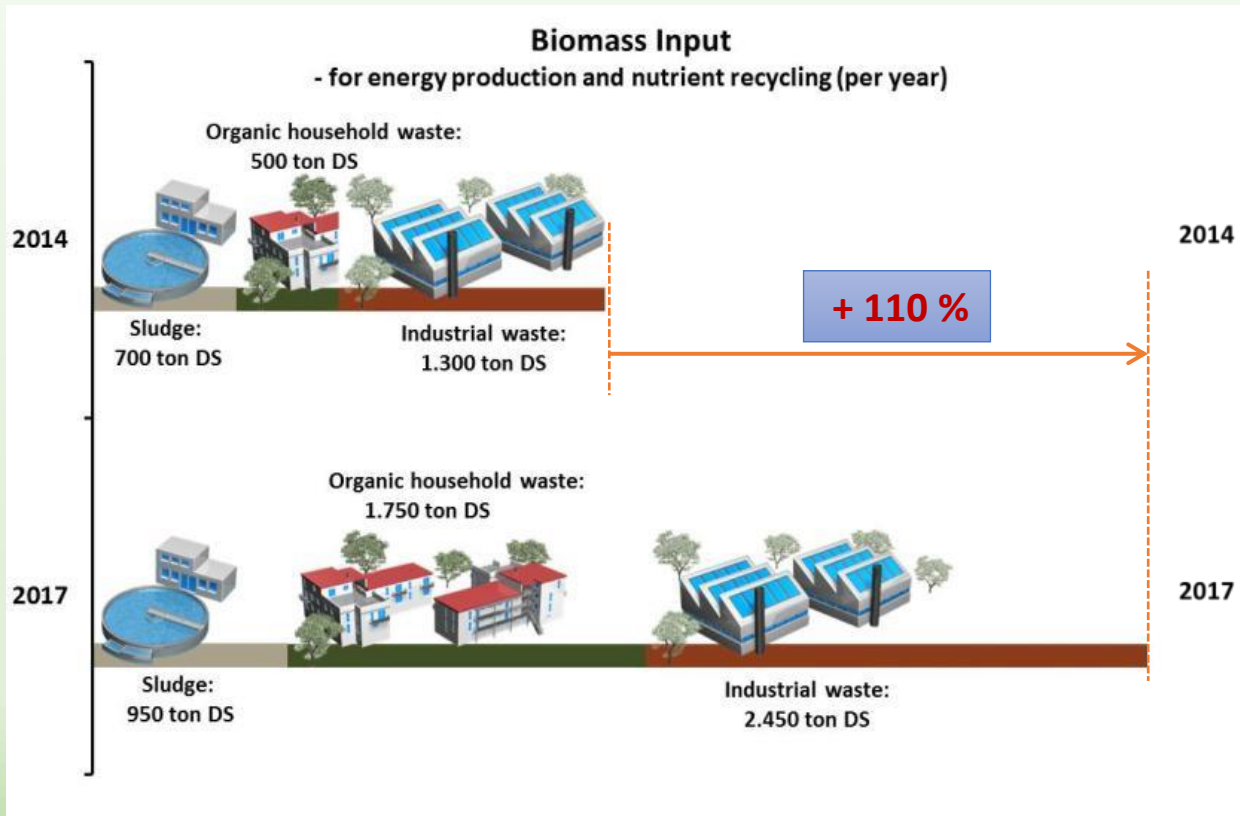


# BBR-Expected results



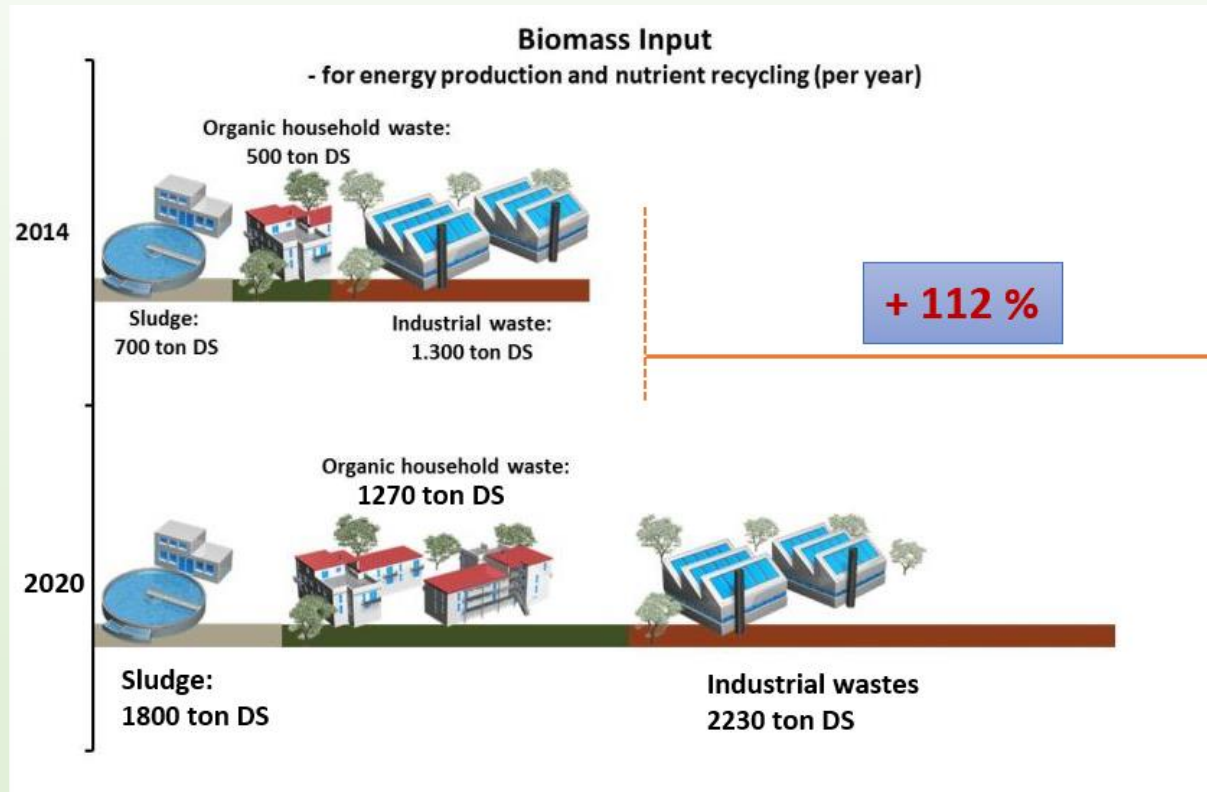
Residues as input

Valuable output

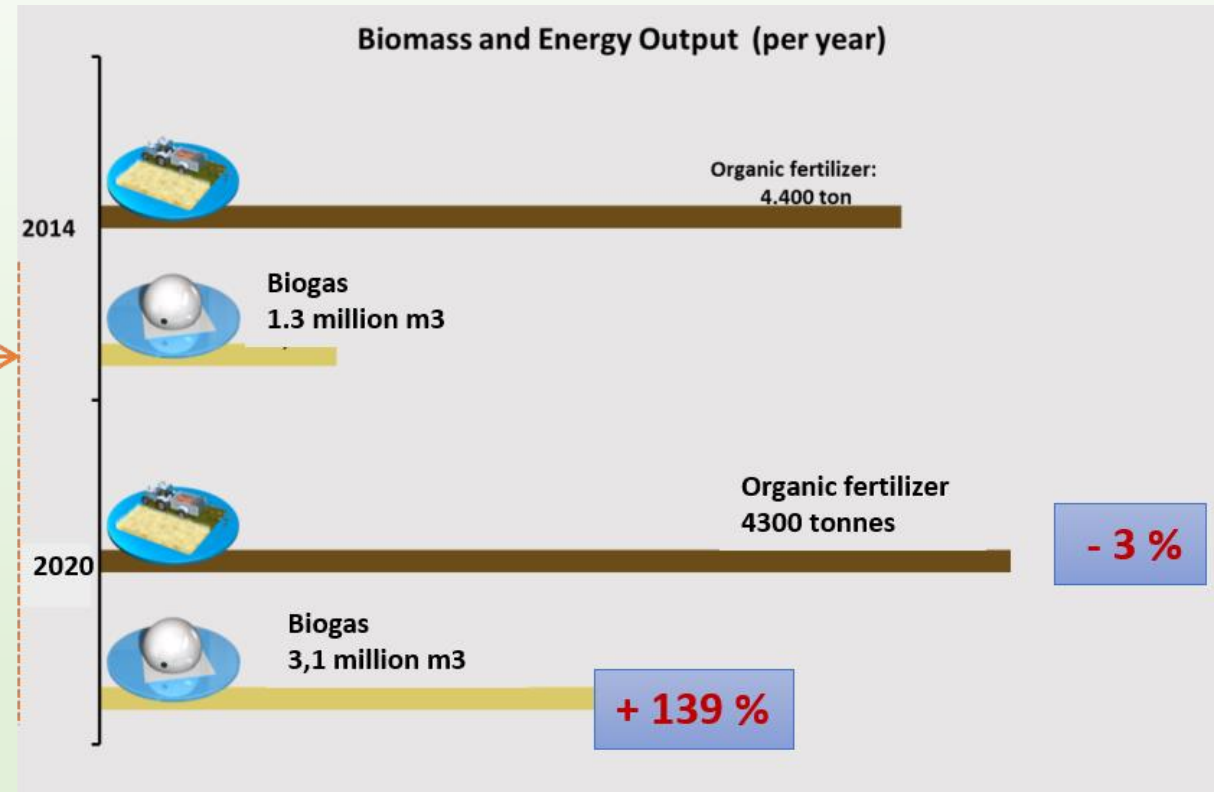


# BBR-Actual results

## Biomass input



## Valuable output



# What have we achieved?

## 1. Good performance in economy

- Best in class with regards to the Danish regulation of water and wastewater utilities.
- Wastewater treatment costs reduced by 20 % and costs of producing and distribution of drinking water by 30%.
- Drinking water costs is 0,3 Eurocents/m<sup>3</sup>

## 2. Good performance in effectiveness

- Waterloss below 2%.
- 0,3 leakages/10 km pipes
- Won 'Great place to work' Denmark, in 2017 and 2020

## 3. Good for the Environment

- The condition of the recipient has improved to 5 on a scale of 6, where 6 is without human impact
- Discharge from wastewater treatment plant better than regulatory requirements
- Recover 94% of influent Phosphorous





# Future plans

- Effluent quality
  - Pharmaceutical residues
  - Microplastic
  - Low concentration but high impact pollutants
- Energy production
  - GHG/climate neutral
  - Is production of energy the best use of resources?
  - Other products from recovered resources
  - Focus on phosphorous recovery
- Natural fertilizer
  - Pyrolysis a good option?
    - Loss of Phosphorous
    - Pathogens and Xenobiotics removed
    - Removal of Mercury and microplastics
    - Possibility of recovering energy and nutrients
    - Carbon sequestration

Energy neutral  
≠  
Climate neutral

Thank you for your attention

Best Regards,  
Chitra S Raju

