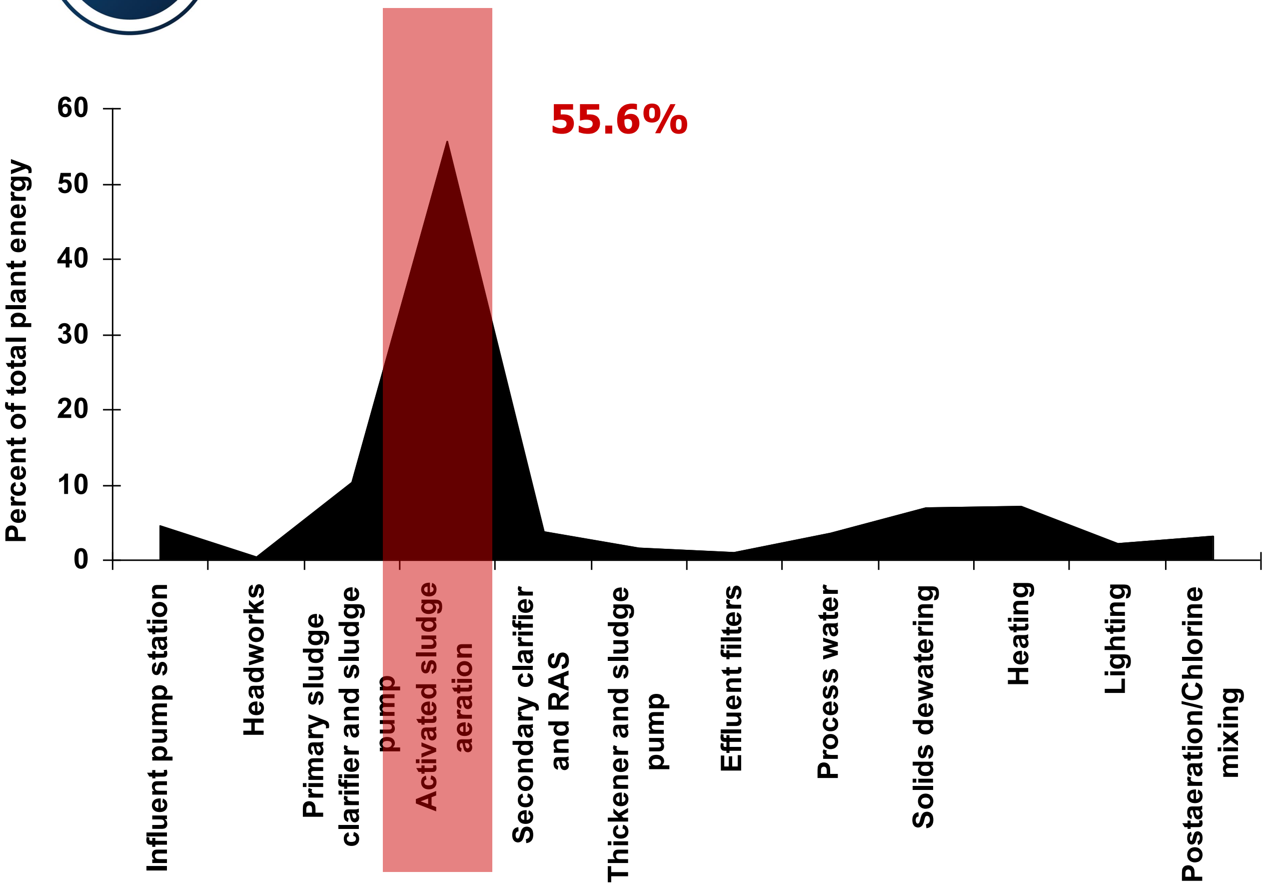
Anaerobic treatment of weak effluents at low temperatures

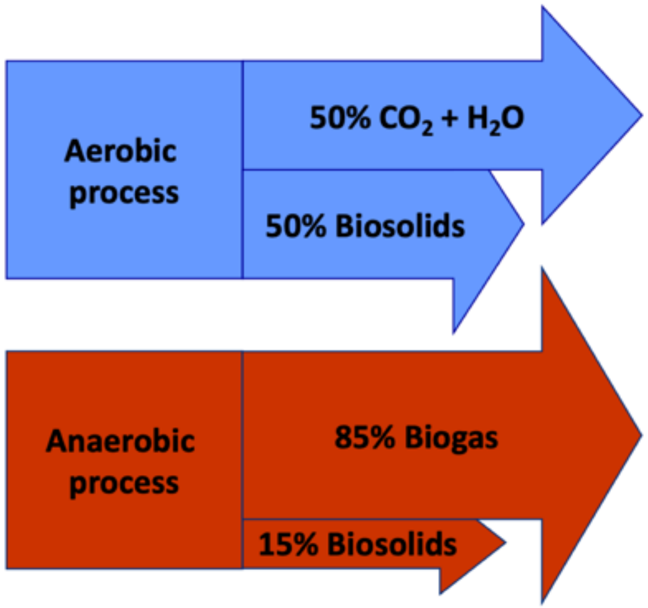
Professor Ana Soares

Cranfield University

Power consumption in wastewater treatment plants



Anaerobic vs. aerobic wastewater treatment



*Tchobanoglous, G., Burton, L.F. and Stensel, H.D. (2003) Metcalf & Eddy, Inc., McGraw-Hill Book Co, International edition.
*Young, D.F. and Koopman, B. (1991) Journal of Environmental Engineering-Asce 117(3), 300-307

Anaerobic digestion vs anaerobic treatment

Anaerobic treatment processes

Sludge:
High BOD + COD
High suspended solids (0.5- 6%)

↓

Anaerobic digestion

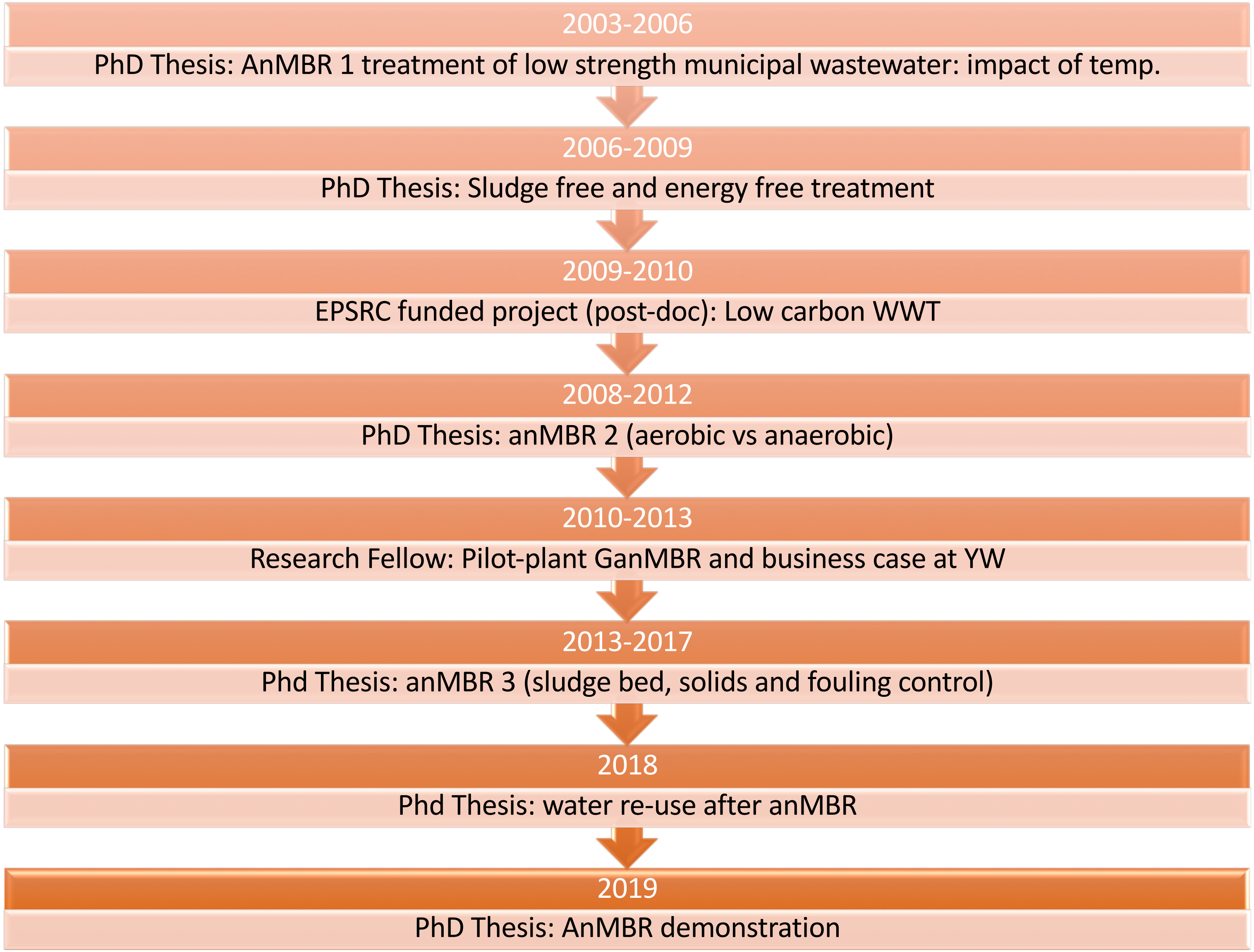
10-30 day SRT= HRT

Wastewater:
Low BOD + COD
Low suspended solids (0.1-0.6%)

↓

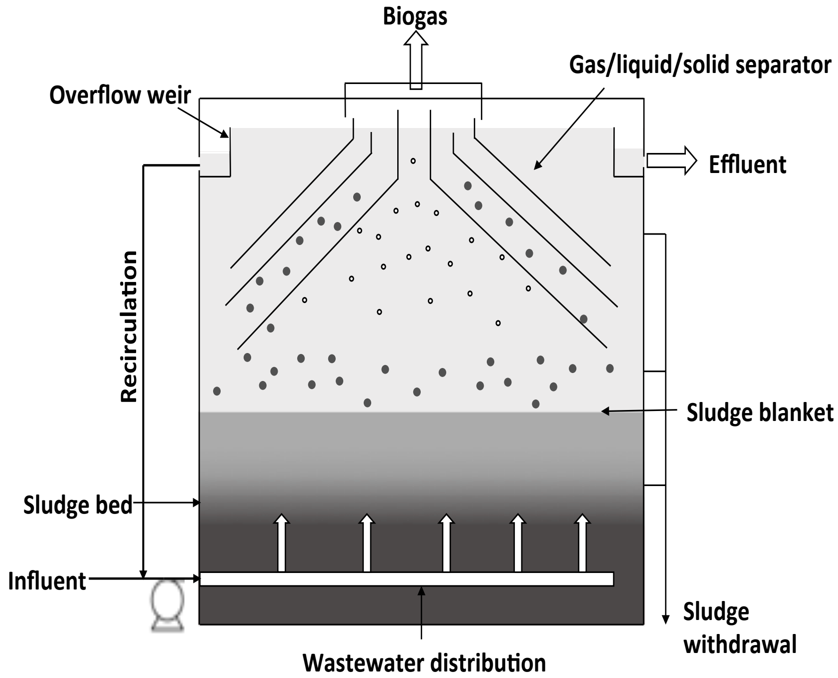
Anaerobic wastewater treatment

6-12 h HRT and 40-100 day SRT


2003-2006
PhD Thesis: AnMBR 1 treatment of low strength municipal wastewater: impact of temp.
2006-2009
PhD Thesis: Sludge free and energy free treatment
2009-2010
EPSRC funded project (post-doc): Low carbon WWT
2008-2012
PhD Thesis: anMBR 2 (aerobic vs anaerobic)
2010-2013
Research Fellow: Pilot-plant GanMBR and business case at YW
2013-2017
Phd Thesis: anMBR 3 (sludge bed, solids and fouling control)
2018
Phd Thesis: water re-use after anMBR
2019
PhD Thesis: AnMBR demonstration

Upflow anaerobic sludge blanket reactor (UASB)

- Maintains a high concentration of biomass through formation of highly settleable microbial aggregates
- The sewage flows upwards through a layer of sludge
- Separation between gas-solid-liquid takes place at the top of the reactor phase
- Recirculation enables solids to be recirculated to the sludge zone
- Widely used for treatment of municipal sewage in warm climates
- Number of studies at pilot-scale in temperate climates



Standard UASB performance in temperate climates

Number of studies (temperatures: 8-22°C)

Raw wastewater -14

Settled wastewater - 4

Settled WW (eff. averages):

$TSS_{eff.}$: 37 mg/L (71% removal)

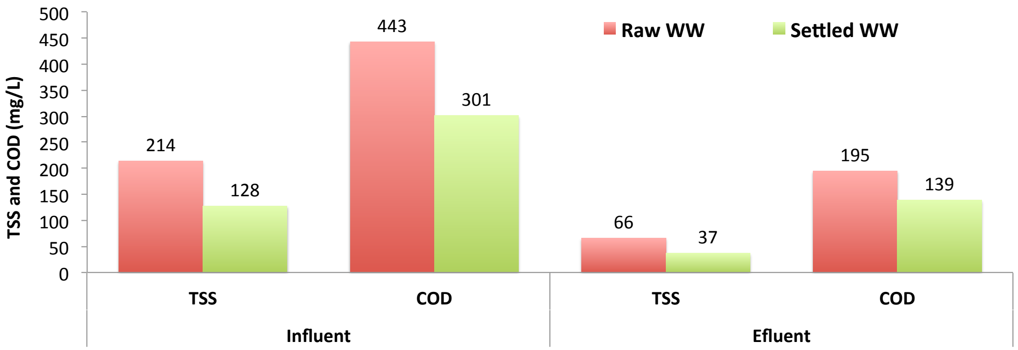
COD_{eff}: 139 mg/L (54% removal)

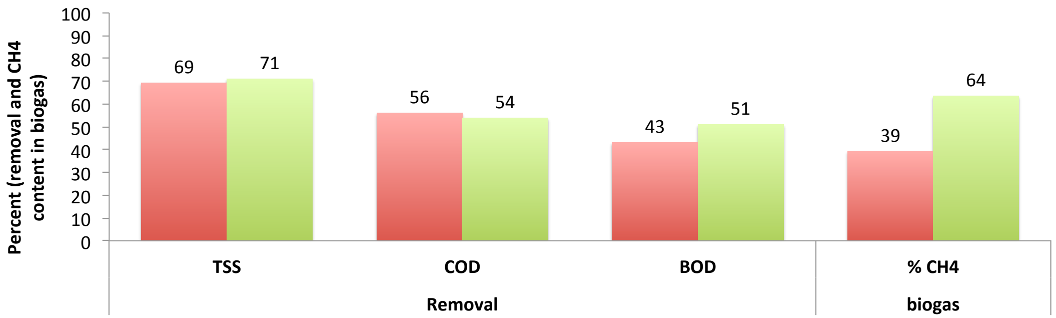
Desired performance:

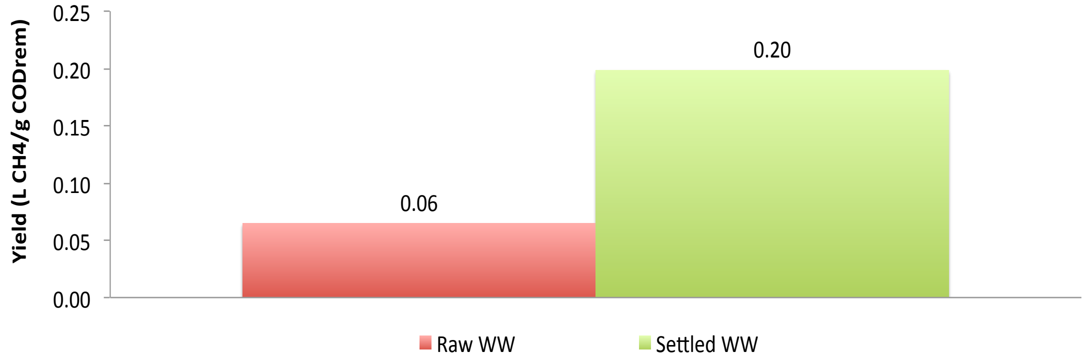
BOD_{eff}: 25 mg/L

COD_{eff}: 125 mg/L (>80% removal)

TSS_{eff}: 35 mg/L (>70% removal)



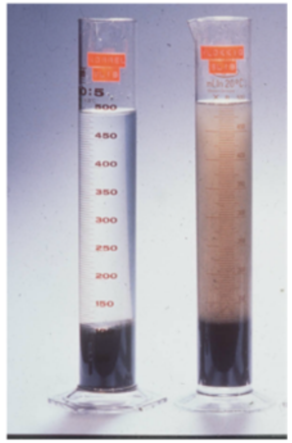


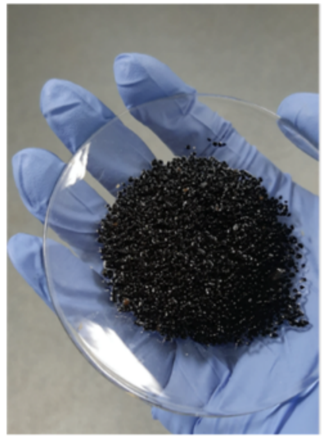


		Granular-UASB	Flocculent-UASB
Hydrolysis rate	%	23.0 ± 5.6	23.1 ± 7.4
Acidigenisis rate	%	37.9 ± 4.9	54.1 ± 5.5
Methanogenesis rate	%	43.1 ± 4.0	48.8±5.5

Comparison granular and flocculent UASB reactors for wastewater treatment in temperate climates (10C)

			Granular-UASB	Flocculent -UASB
	Temperature	°C	10.2 ± 1.5	10.2 ± 1.5
TSS	Influent	mg L^{-1}	113 ± 23	113 ± 23
	UASB effluent	mg L^{-1}	69 ± 11	75 ± 9*
	Removal	%	42 ± 13	39 ± 14*
COD_t	Influent	mg L^{-1}	213 ± 62	213 ± 62
	UASB effluent	mg L^{-1}	129 ± 19	140 ± 25*
	Removal	%	41 ± 14	36 ± 16*
SCOD	Influent	mg L^{-1}	72 ± 16	72 ± 16
	UASB effluent	mg L^{-1}	64 ± 13	60 ± 13
	Removal	%	18 ± 12	24 ± 14
BOD_5	Influent	mg L^{-1}	107 ± 22	107 ± 22
	UASB effluent	mg L^{-1}	84 ± 8	88 ± 10
	Removal	%	26 ± 17	19 ± 11

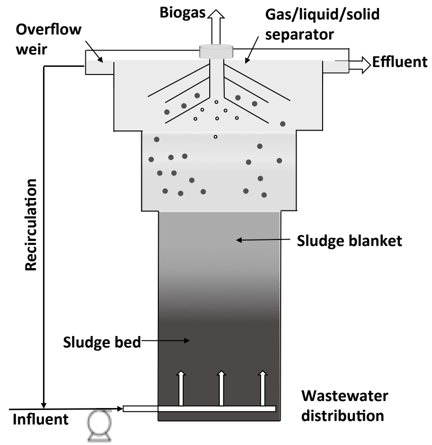

Granular Flocculent

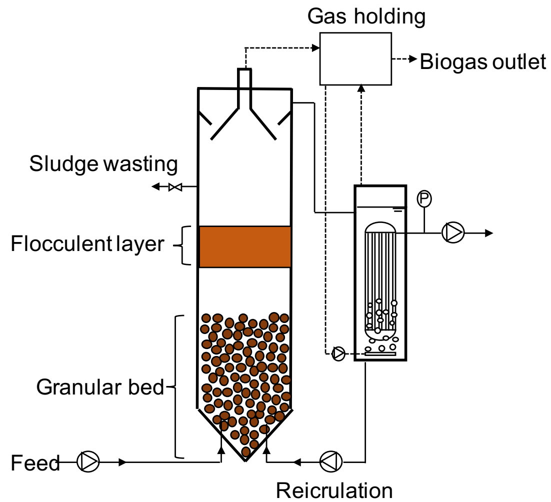


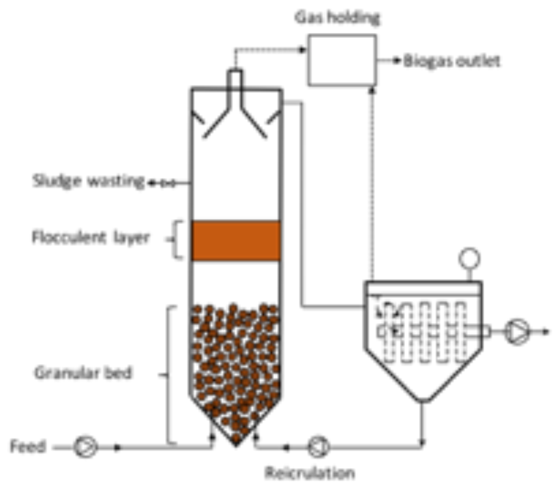
Wang KW, Soares A, Jefferson B, McAdam E. 2019. Comparable membrane permeability can be achieved in granular and flocculent anaerobic membrane bioreactor for sewage treatment through better sludge blanket control. Journal of Water Process. 28:181-189.

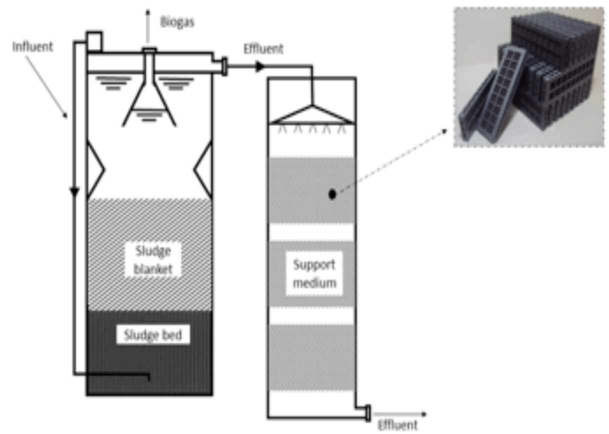
UASB configurations that can enhance solids retention

1. UASB with (2-3) three solid phase separators
2. UASB with increased diameter
3. UASB with support media (expanded bed biofilm reactor)
4. Package UASB coupled with lamella settler
5. Two stage UASB
6. Y shaped UASB
7. UASB combined with membrane filtration
8. UASB combined with microscreens/microstrainers
9. UASB combined with granular media filter
10. UASB combined with rapid filter/slow sand filter
11. UASB coupled with sponge media on top of the digester compartment
12. UASB coupled with sponge media filtration

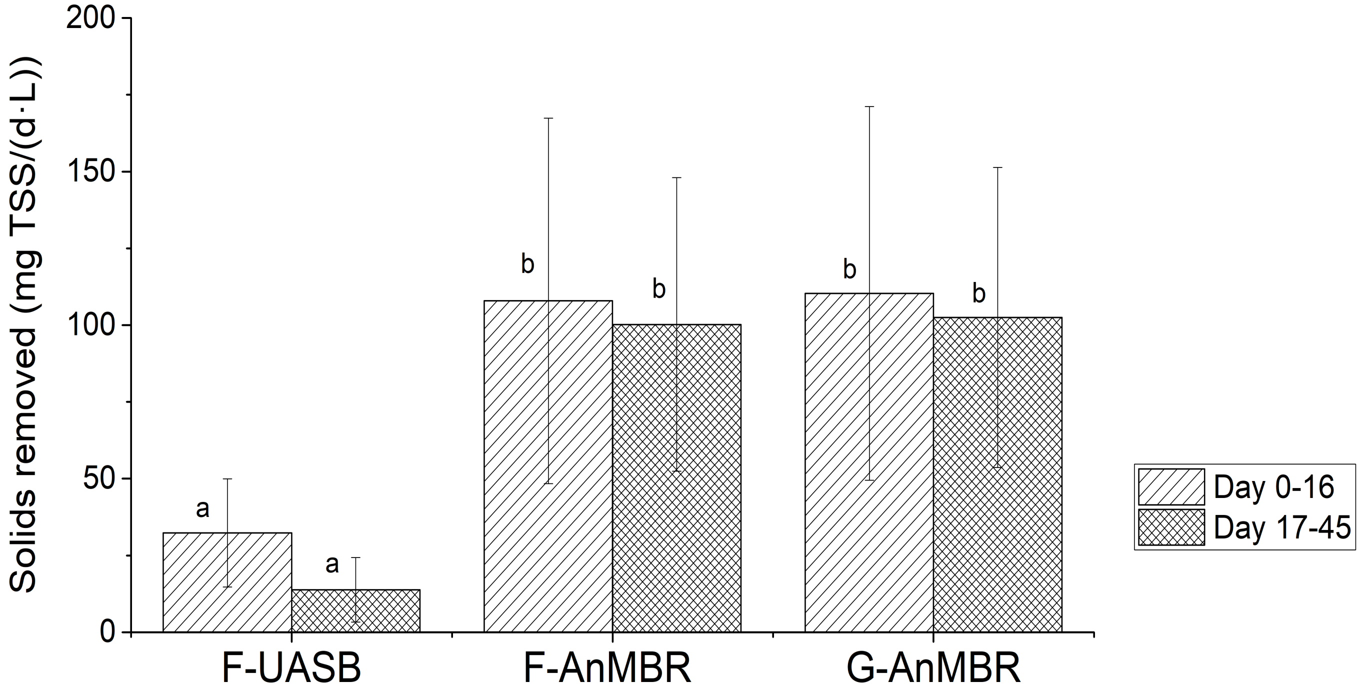






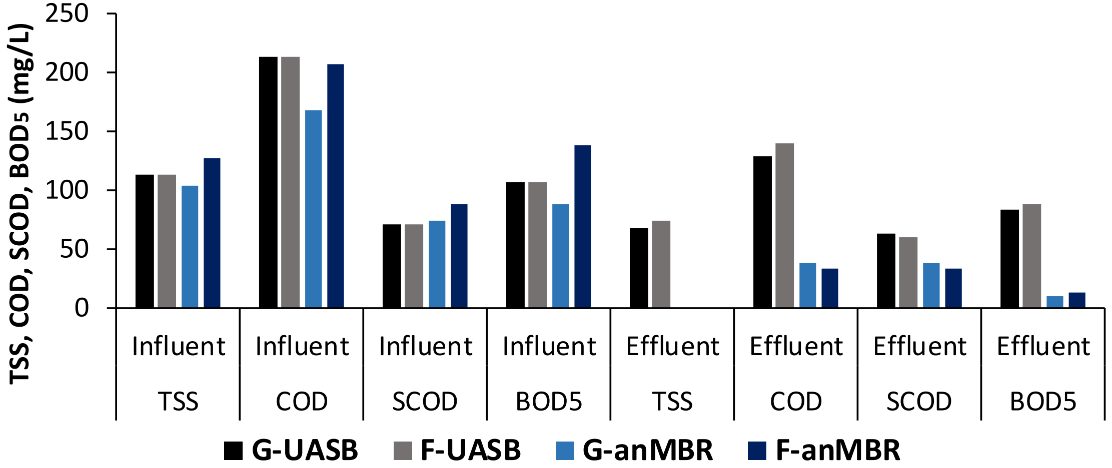


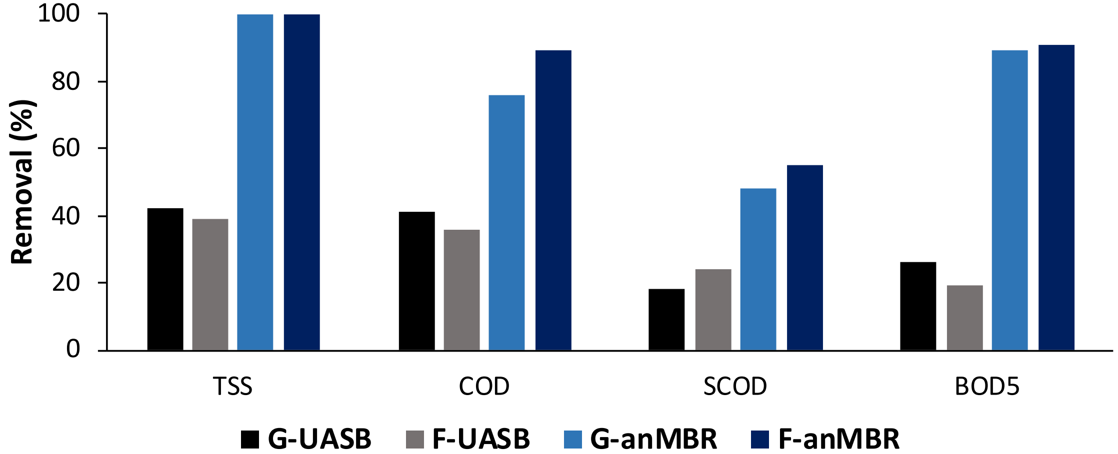
Solids capture in UASB



Ribera-Pi J, Campitelli A, Badia-Fabregat M, Jubany I, Martínez-Lladó X, McAdam E, Jefferson B, Soares A. 2020. Hydrolysis in upflow anaerobic sludge blanket reactors treating municipal wastewater under psychrophilic conditions: the importance of reactor configuration. Frontiers in Bioengineering and Biotechnology

UASB + MBR (anMBR) performance





UASB	Methane yield (m^3 CH_4/ kg $COD_{removed}$)
7°C	0.13
20°C	0.19
anMBR	
7°C	0.19
20°C	0.28

Municipal wastewater
8-12°C
HRT 8 h
upflow velocity: 0.4 m/h

Wang KW, Soares A, Jefferson B, McAdam E. 2019. Comparable membrane permeability can be achieved in granular and flocculent anaerobic membrane bioreactor for sewage treatment through better sludge blanket control. Journal of Water Process. 28:181-189.

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H2020 NEXT-GEN

- NextGen demonstrates innovative technological, business and governance solutions for water in the circular economy in ten high-profile, large-scale, demonstration cases across Europe, and we will develop the necessary approaches, tools and partnerships, to transfer and upscale.
- The resources include:

The consortium has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No. 776541.

#5.

Sperna l (UK)

Waste Water Treatment Plant

Circular solutions for

Water Materials Energy

Relevant data

Waste water plant serving the town of Redditch (Birmingham, UK): 92.000 PE

Relevant sectors

Agriculture

Domestic sector

Energy sector

Lead partners

Cranfield University

Resource recovery and innovation centre

WONDERFUL ON TAP SEVERN TRENT

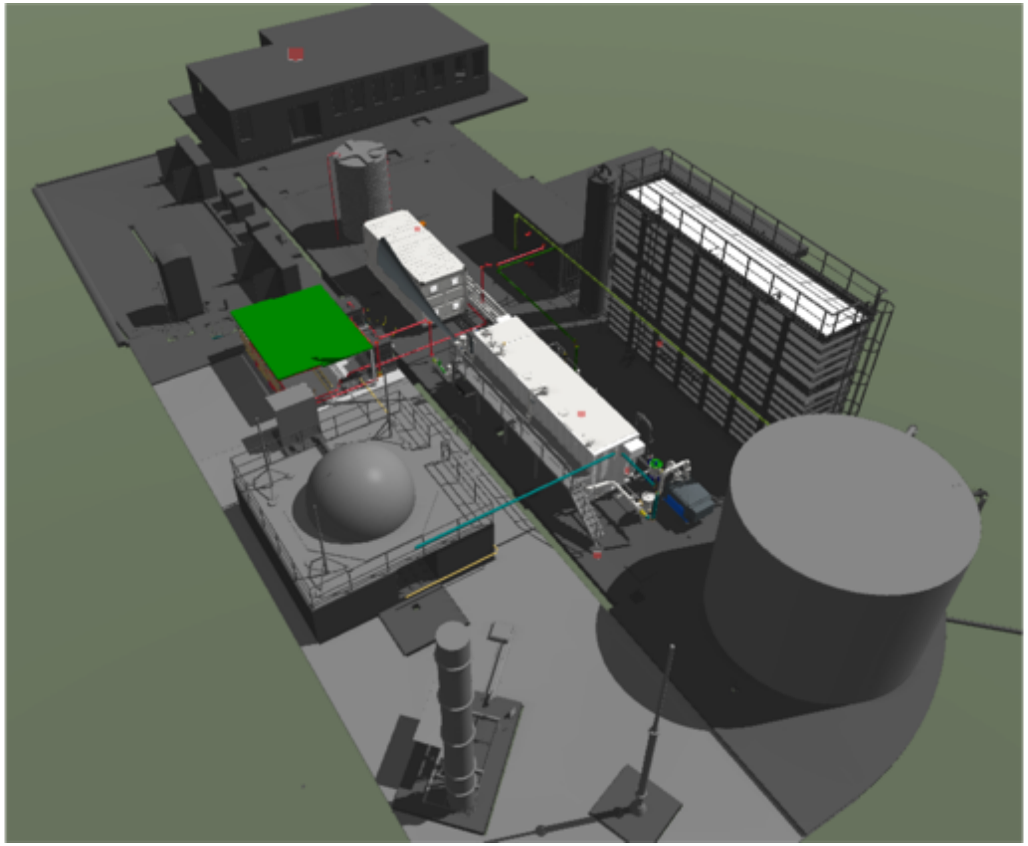
Spernal WWTP serves as Severn Trent Water's "Resource Recovery and Innovation Centre" where emerging technologies compatible with a low energy, circular economy approach will be evaluated.

A multi-stream test bed facility was constructed in 2019 and this will incorporate **an anaerobic membrane bioreactor (AnMBR) to be commissioned in Summer 2020. The AnMBR will also comprise a membrane degassing unit to recover dissolved methane and ion exchange processes to recover nitrogen and phosphorus from the effluent.**

AnMBR combines several benefits such as:

- no aeration energy for removal of Chemical and Biological Oxygen Demand (COD/BOD)
- low sludge production and hence reduced downstream sludge treatment costs
- biogas production (production of electricity/heat
- pathogen and solids free effluent which can be re-used in a number of applications (e.g.: farming and industrial use).

Building in Spernal



- Construction and commissioning of resource recovery innovation center completed in October 2019 – drone footage on right

- AnMBR to be commissioned in Summer 2020 – fabrication of the UASB reactors (Waterleau) shown on left

Video of R2IC in file sent via

https://youtu.be/BeETnMSnjss

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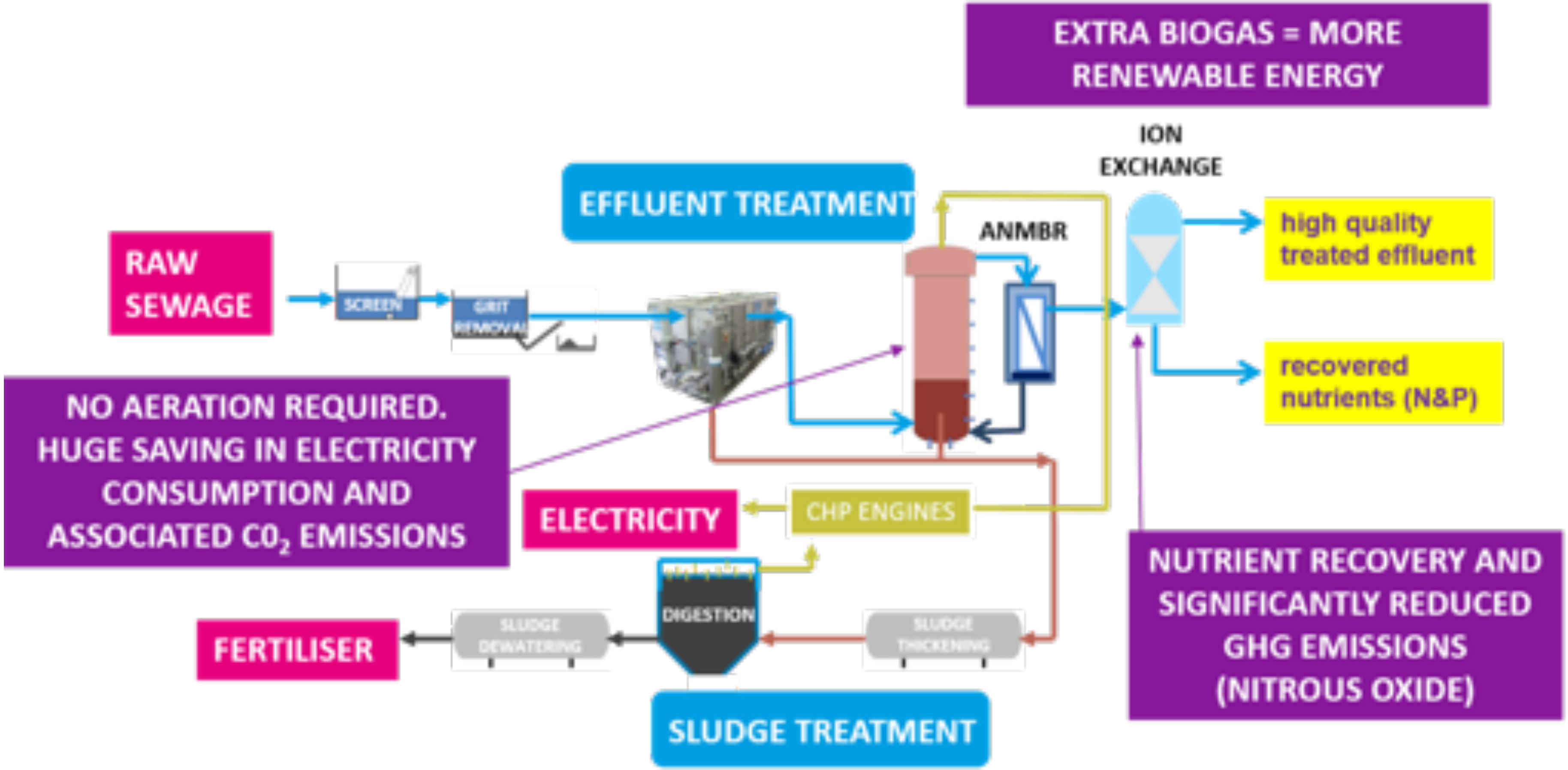
NEXT-GEN Demonstration case Spernal WWTP



Pilot data on the UASB with the same

JUL-SEPT 2020 (T=18°C)		Pilot hall sewage characterisation		Removal rates (%)
		Influent	R1 UASB effluent	R1 UASB
COD	mg L^{-1}	153	56	63
sCOD	mg L^{-1}	36	29	19
BOD_5	mg L^{-1}	65	38	42
TSS	mg L^{-1}	117	37	68
VSS	mg L^{-1}	108	31	71
SO_4	mg L^{-1}	62	40	35

OCT 2020 – ongoing (T=13°C)		Pilot hall sewage characterisation		Removal rates (%)
		Influent	R1 UASB effluent	R1 UASB
COD	mg L^{-1}	181	100	45
sCOD	mg L^{-1}	44	39	11
BOD_5	mg L^{-1}	71	44	38
TSS	mg L^{-1}	111	41	63
VSS	mg L^{-1}	96	37	61
SO_4	mg L^{-1}	68	43	37

Gas sensors and dissolved methane probe to assist on the measurement of energy production in the AnMBR

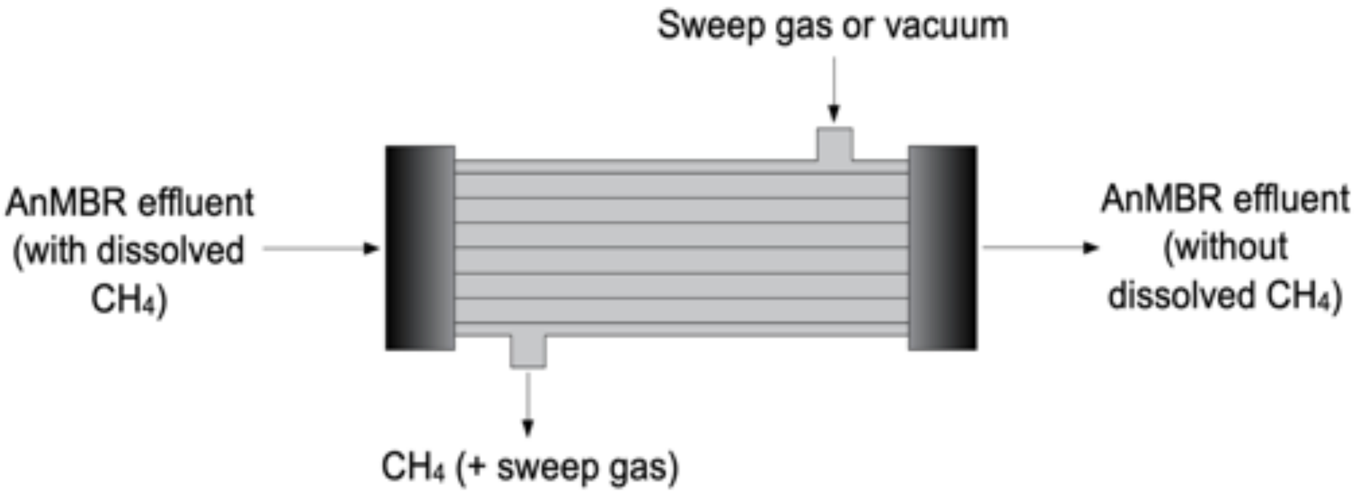
OCT 2020 – ongoing (T=13°C)		R1 UASB
Biogas production	L d^{-1}	0.6
Dissolved CH_4/total CH_4	%	93.6
Methane yield	L CH_4/g COD	0.13

Degassing Unit

In the process, water passes through the outside (shell side) of the hollow fibres while a sweep gas (or vacuum) is applied to the inside (lumen side) of the fibres. Because the membrane is hydrophobic it allows direct contact between gas and water without dispersion

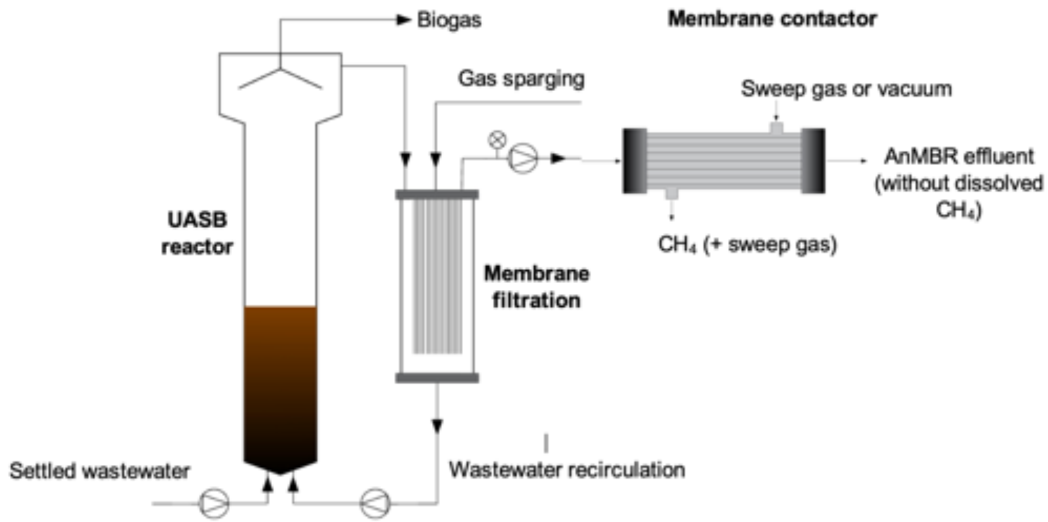
Applying a higher pressure to the water stream relative to the gas stream creates the driving force for dissolved gas in the water to pass through the membrane pores.

Membrane contactor

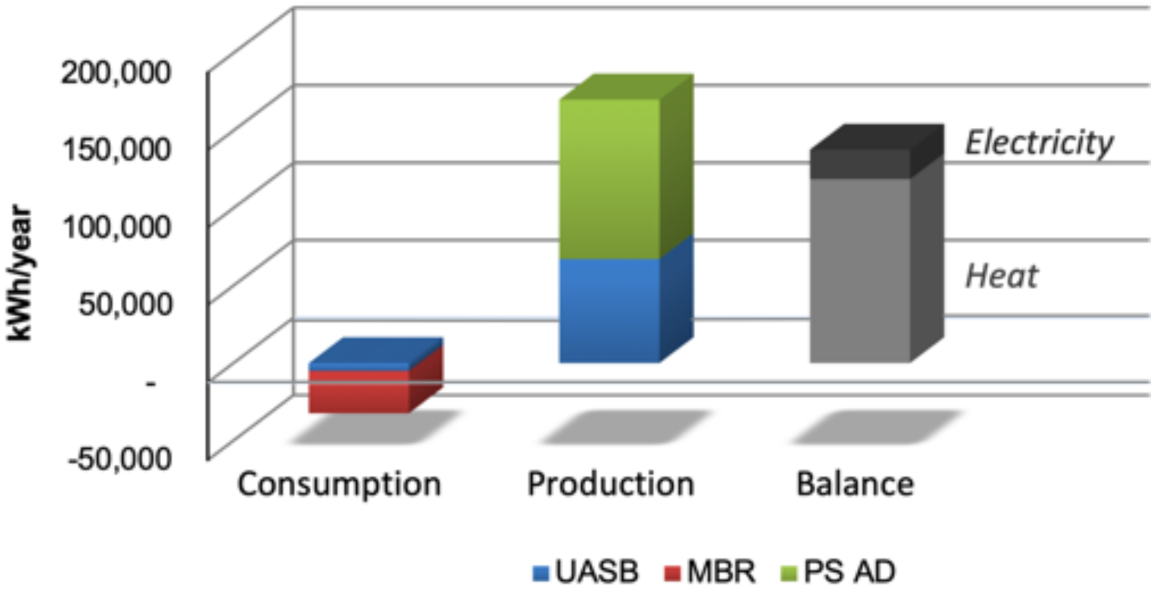


- **Technology provider – 3M (Membrana)**
- **The methane will be sent to the gas bag**

Energy balance in Spernal



- 360 m3/day WWTP
- anMBR energy consumption 0.25 kWh/m^3, production 0.2-0.5 kWh/m^3
- Heat recovery is of high relevance
- The anaerobic digestion of primary sludge balances energy and ensures solids management in the anMBR



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Water
Thank You