FCC Aqualia & Universitat de València AnMBRs

Mainstream Municipal Anaerobic Treatment

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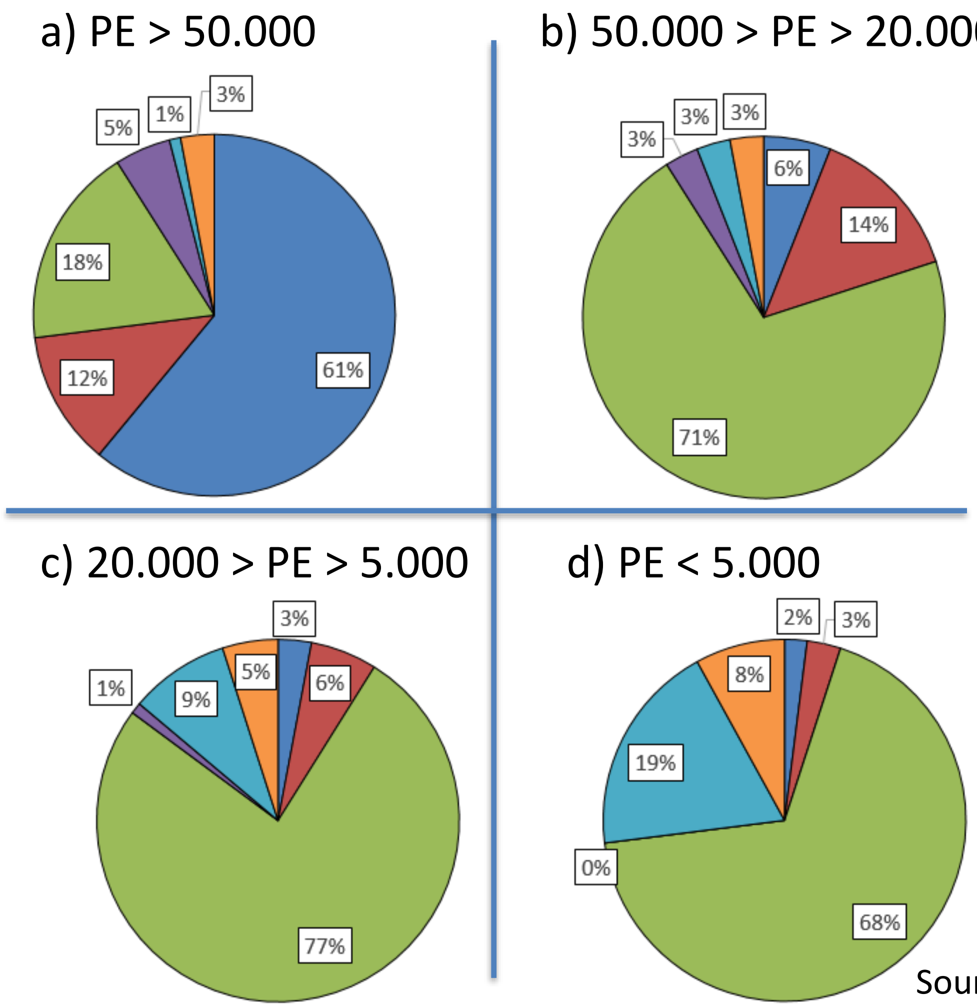
INTRODUCTION

Current WWTP facilities by plant size and type of process (Spain)



< 50.000 PE are mostly **aerobic based**

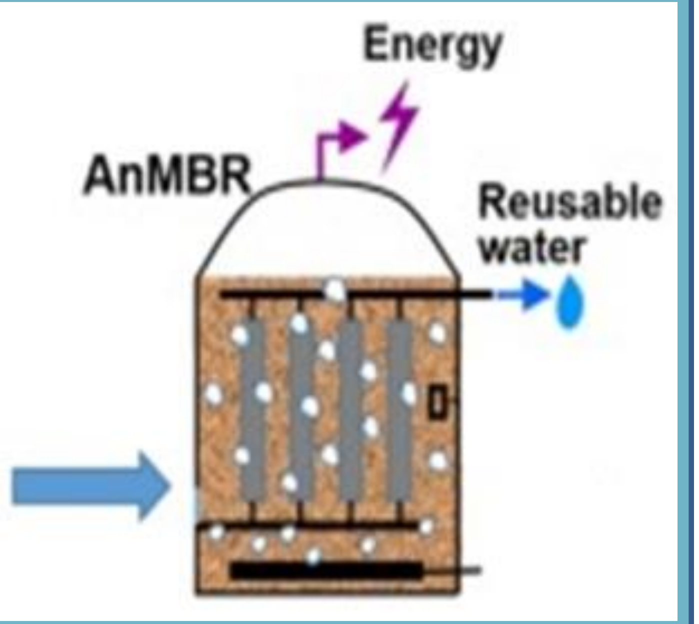
- Anaerobic digestion
- Aerobic digestion
- Extended aeration
  - Energy demand
  - GHG emissions
- Lime stabilization
- Lagooning
- Untreated sludge

Source: CEDEX, 2013

INTRODUCTION

We need a shift towards more sustainable technologies

Anaerobic Membrane BioReactor (AnMBR)



- **Anaerobic** treatment can be used in small WWTP (aerobic water treatment can be avoided)

BENEFITS:

IMPACT REDUCTION
- Low energy demand
- Low GHG emissions
- Low sludge production

RECYCLING & VALORIZATION
- High quality water (ultra-filtered, pathogen free, nutrient rich effluent)
- Organic matter → Biogas
- Nutrients & compostable sludge

AnMBRs allow **decentralisation**, which facilitates recycling of water and nutrients.

INTRODUCTION

- **CALAGUA: I+D+I on AnMBR technology**

Pilot plant

2009

Demo plant

2014

Semi-industrial plant

Present

Near future

AD19 Conference in València

the international water association

Torrent WRRF (València)

World's first full-scale AnMBR applied to sewage treatment
8,500 m^3 operating volume
14,500 m^2 filtration area
6,000 m^3/d of regenerated water for agricultural purposes

AnMBR for UWW treatment

Case study at prototype size

Anaerobic Reactor
40 m^3 (35 + 5)

3 Membrane tanks
0.8 m^3/tank (0.7 + 0.1)

PURON®, KMS
41 m^2 filtration area/module
Ultrafiltration (0.03 µm)

memory
http://www.life-memory.eu

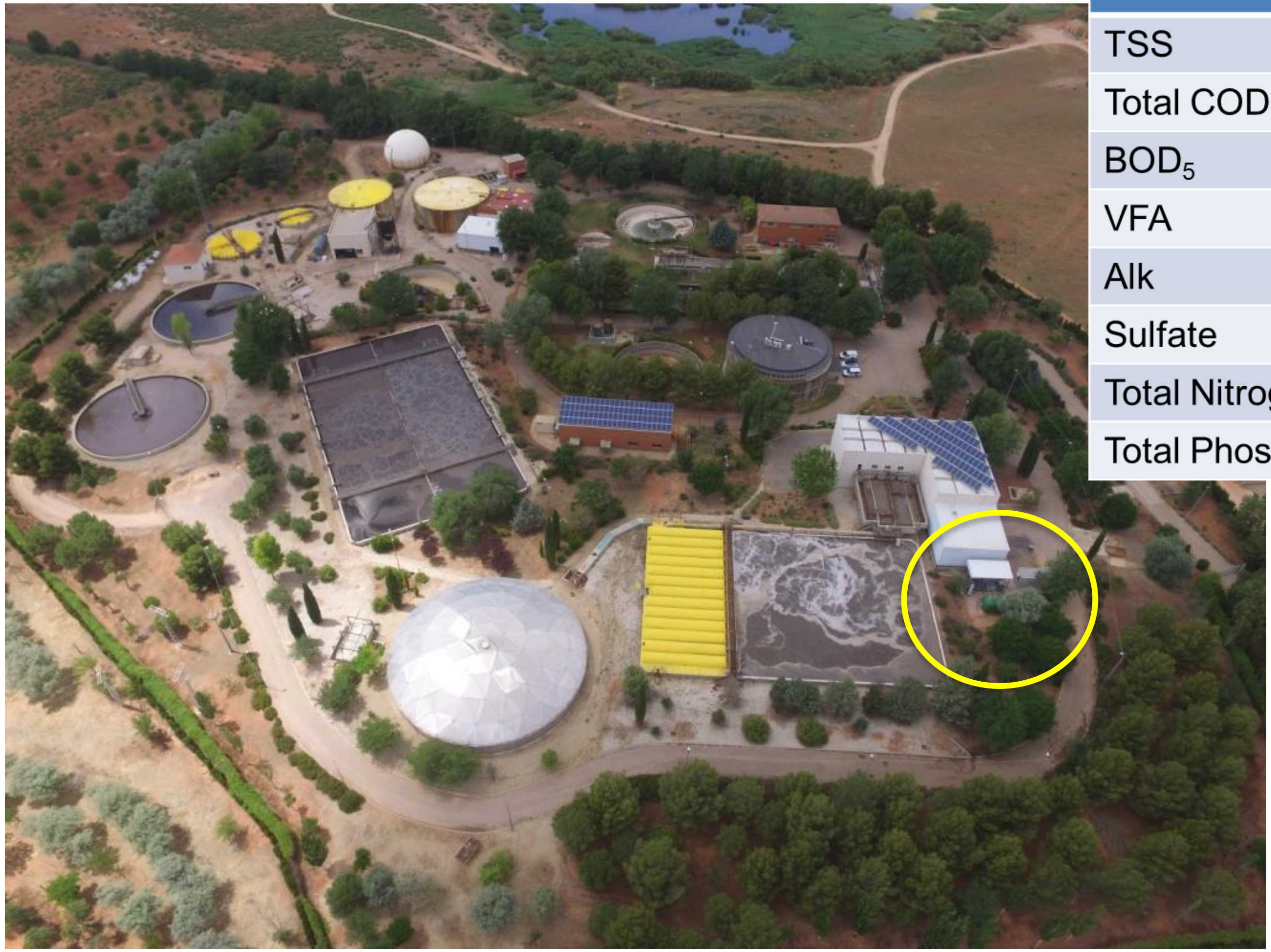
AnMBR for UWW treatment

Case study at prototype size

Parameter	Unit	Mean ± SD
TSS	mg TSS·L^{-1}	533 ± 246
Total COD	mg COD·L^{-1}	1227 ± 428
BOD_5	mg COD·L^{-1}	671 ± 257
VFA	mg COD·L^{-1}	113 ± 85
Alk	mg $CaCO_3$·L^{-1}	613 ± 125
Sulfate	mg SO_4-S·L^{-1}	165 ± 32
Total Nitrogen	mg N·L^{-1}	56 ± 14
Total Phosphorus	mg P·L^{-1}	10.2 ± 3.1

High BOD concentration

High sulfate concentration



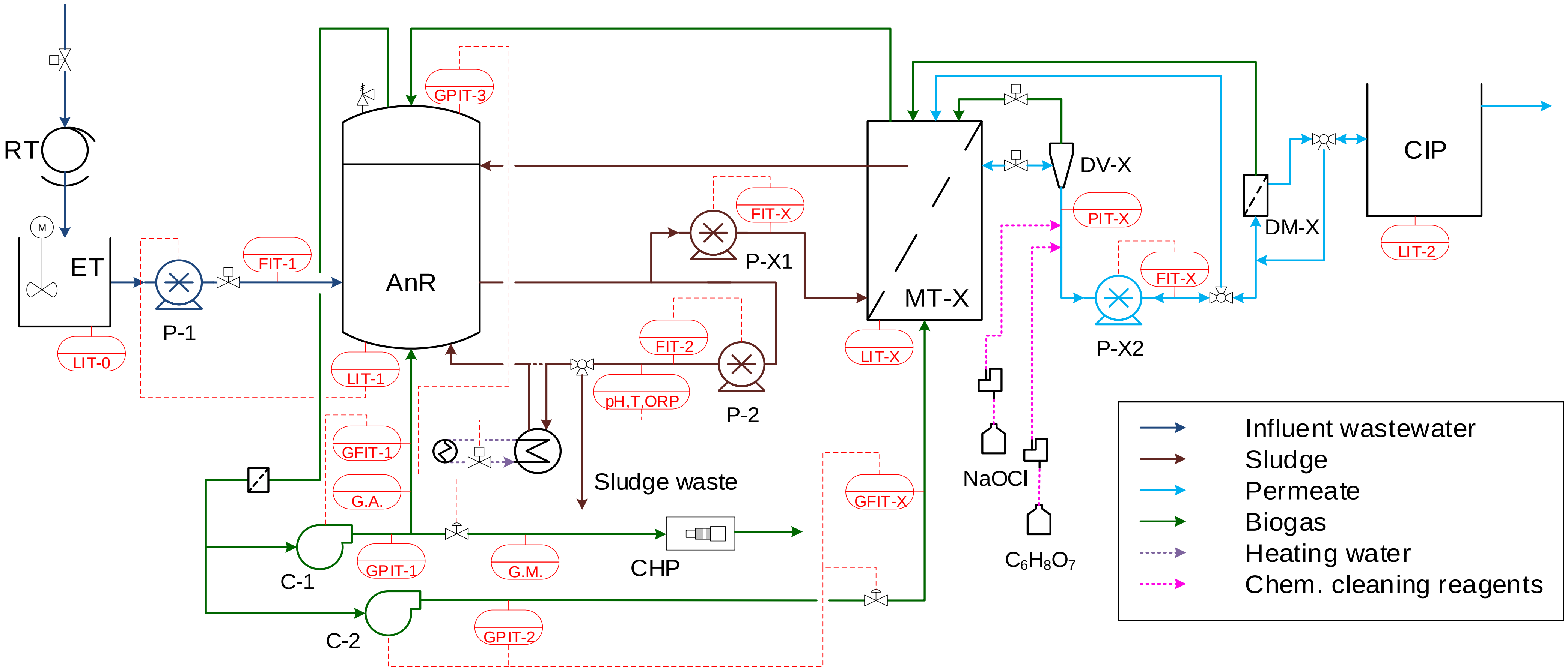
Location: Alcázar de San Juan WWTP (Ciudad Real, Spain)

Wine

Dairy

AnMBR for UWW treatment

Case study at prototype size



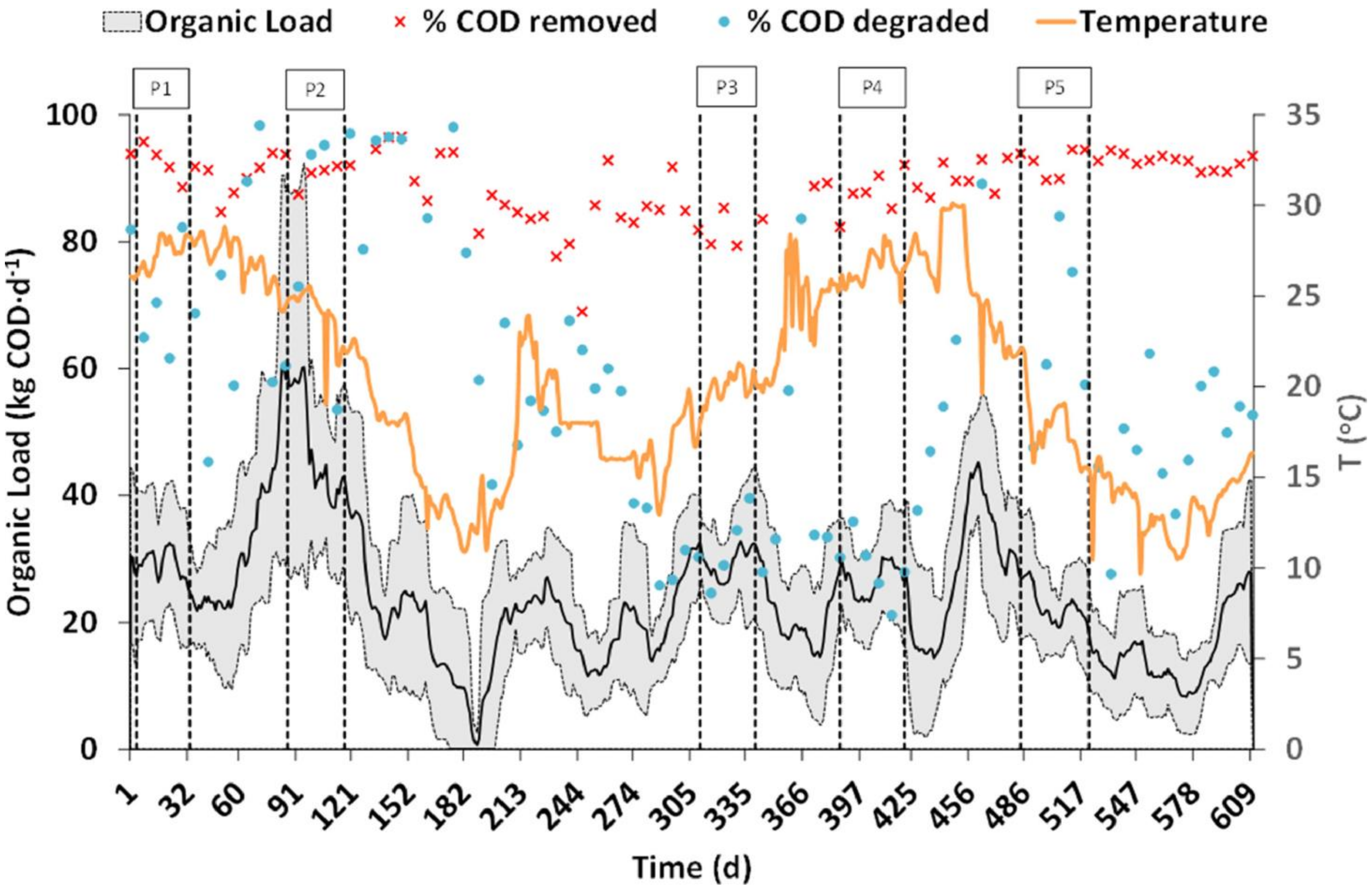
http://www.life-memory.eu

AnMBR for UWW treatment

Unidad Mixta UV-UPV

COD removal

http://www.life-memory.eu

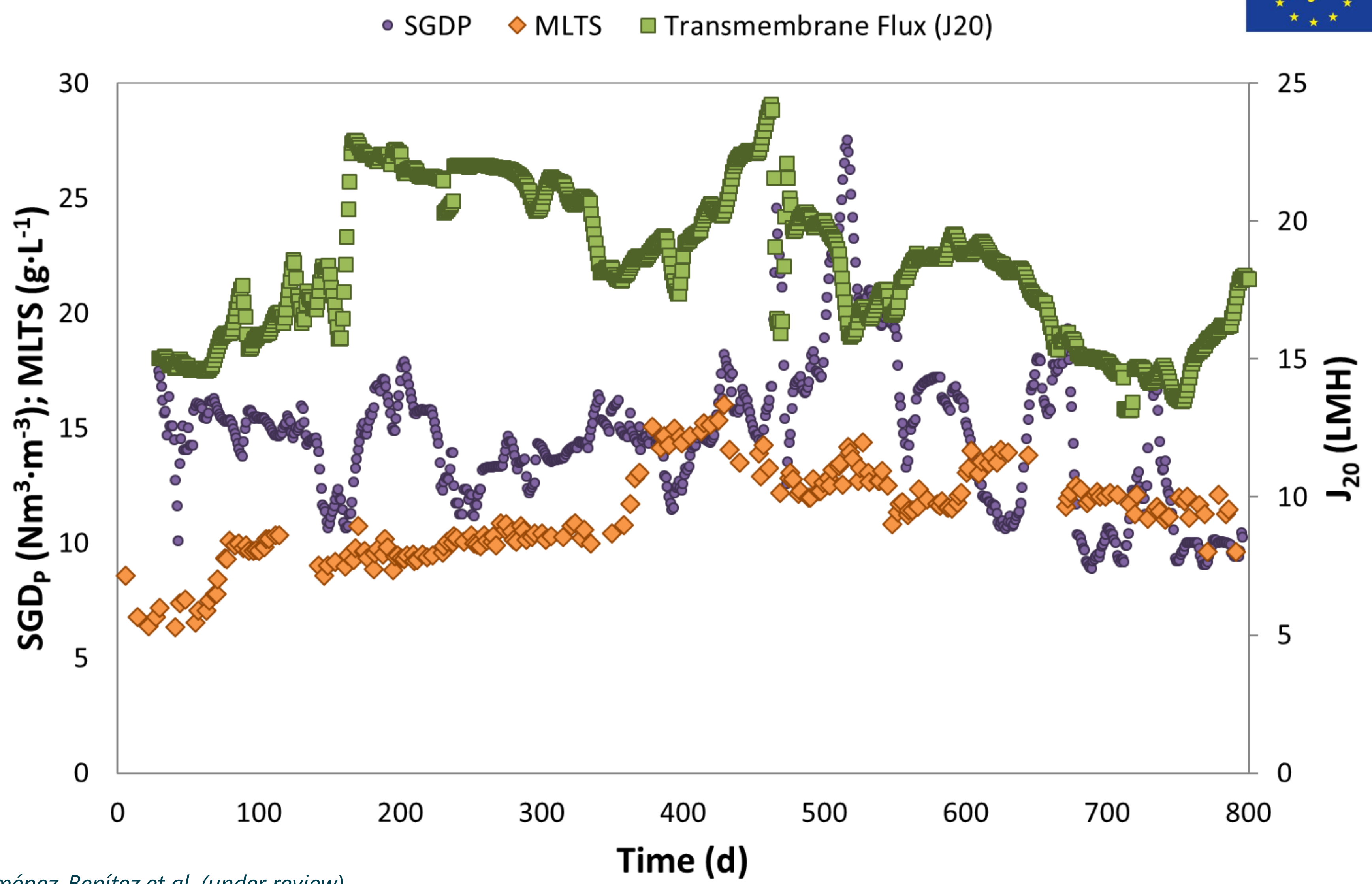


- **COD removal > 90%**
- **High quality rich-nutrient effluent**
  - COD < 125 mg/L
  - BOD < 25 mg/L

Robles et al. (2022) Water Research 215, 118249

AnMBR for UWW treatment

Permeate productivity capacity



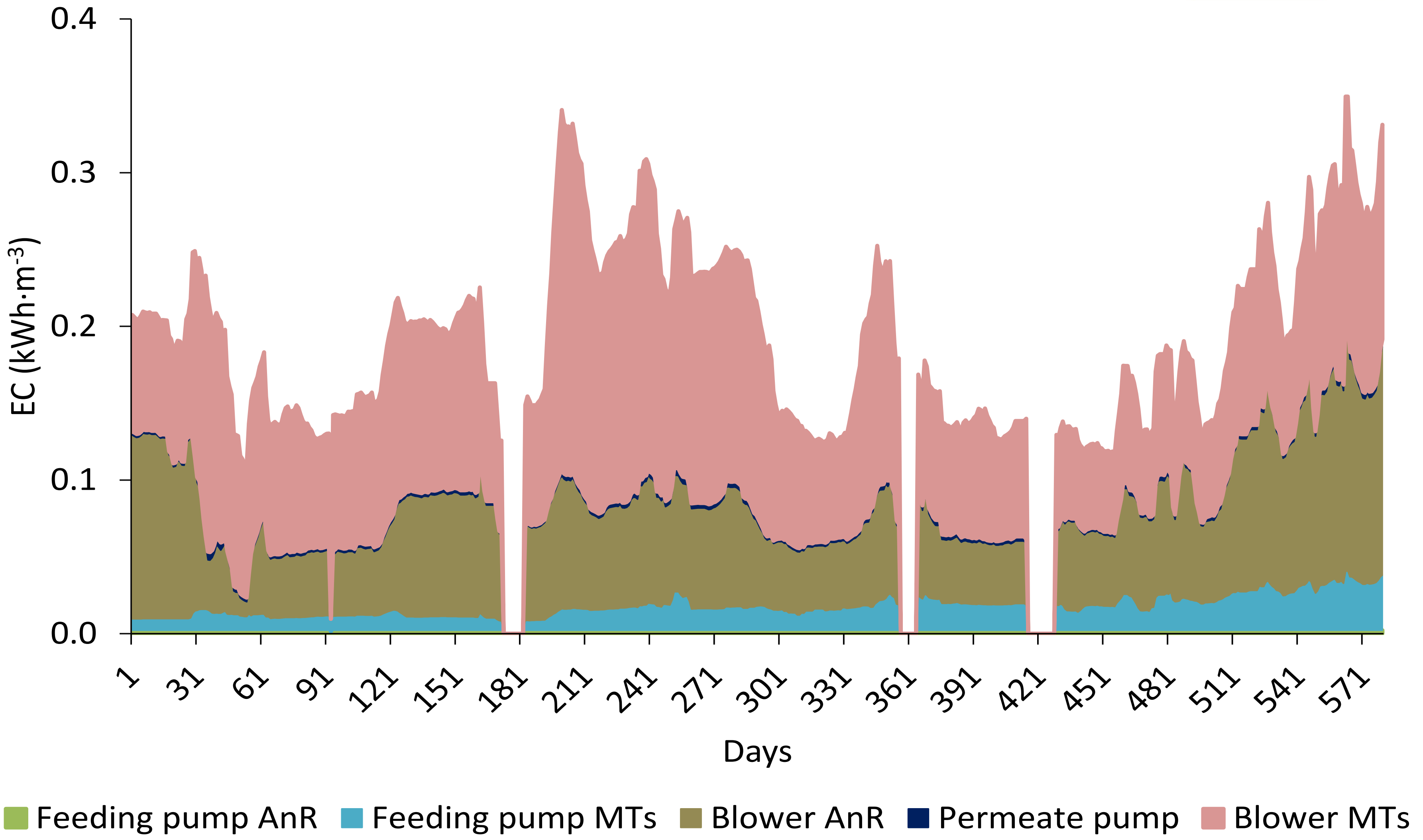
- **High energy efficiency**

Jiménez-Benítez et al. (under review)

AnMBR for UWW treatment

Energy requirements

http://www.life-memory.eu



CAS: 0.3 – 0.7 kWh/m^3

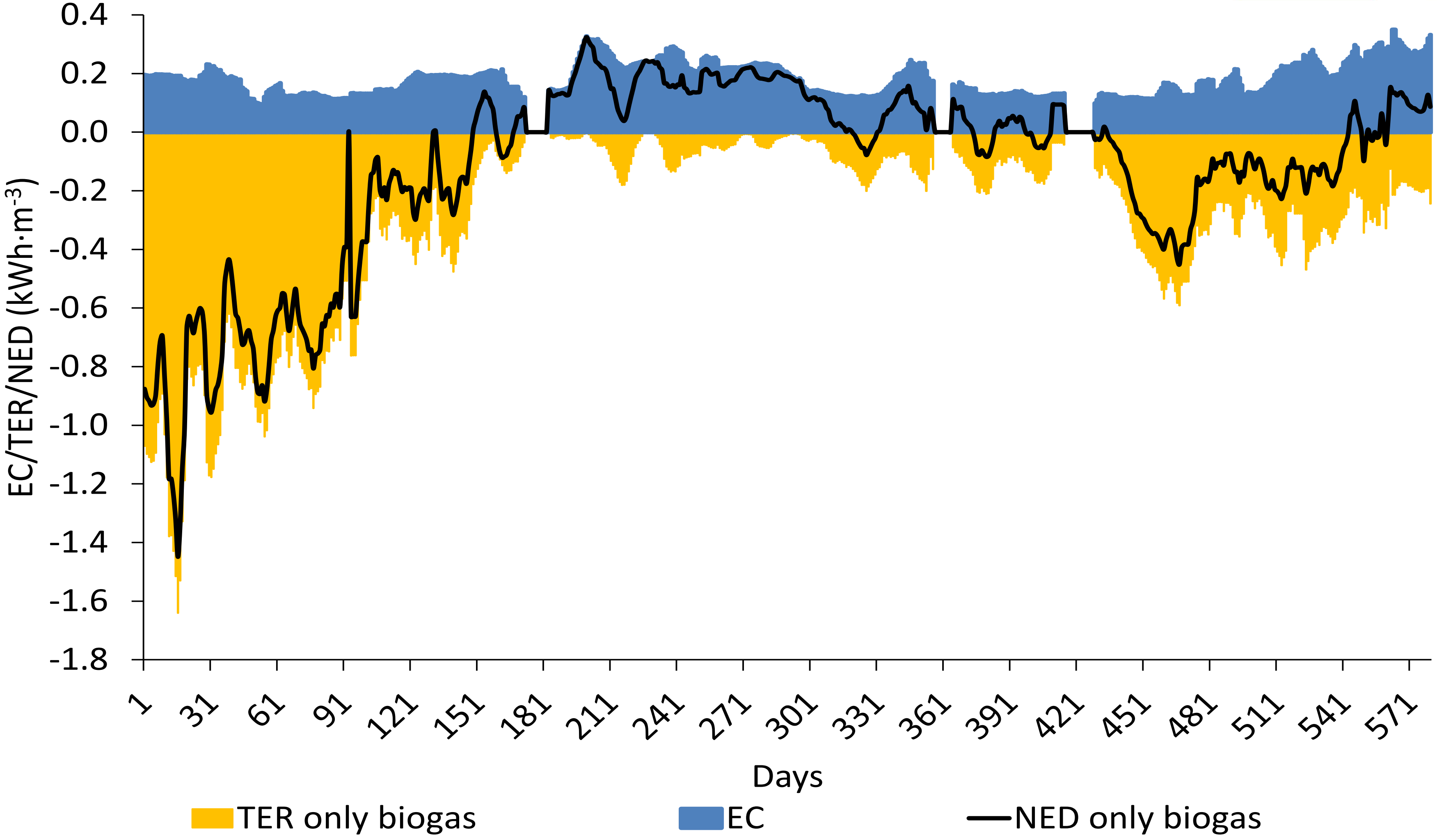
EA: 0.3 – 0.8 kWh/m^3

MBR: 0.5 – 1.0 kWh/m^3

Jiménez-Benítez et al. (under review)

AnMBR for UWW treatment

Energy balance



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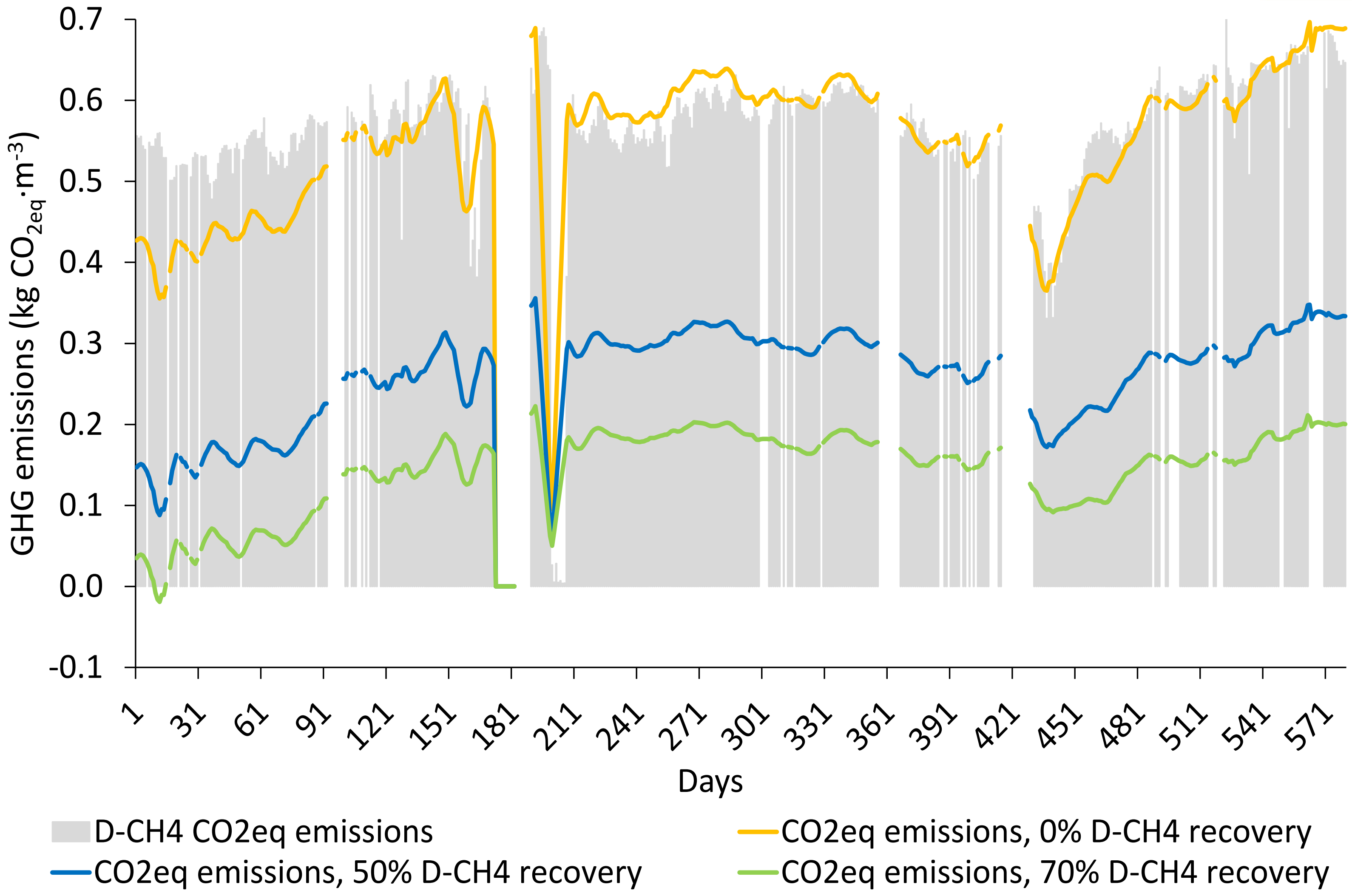
AnMBR for UWW treatment

CO_2 emissions



Related to energy demand:

CAS: 0.10 – 0.19 kg CO_2-eq per m^3

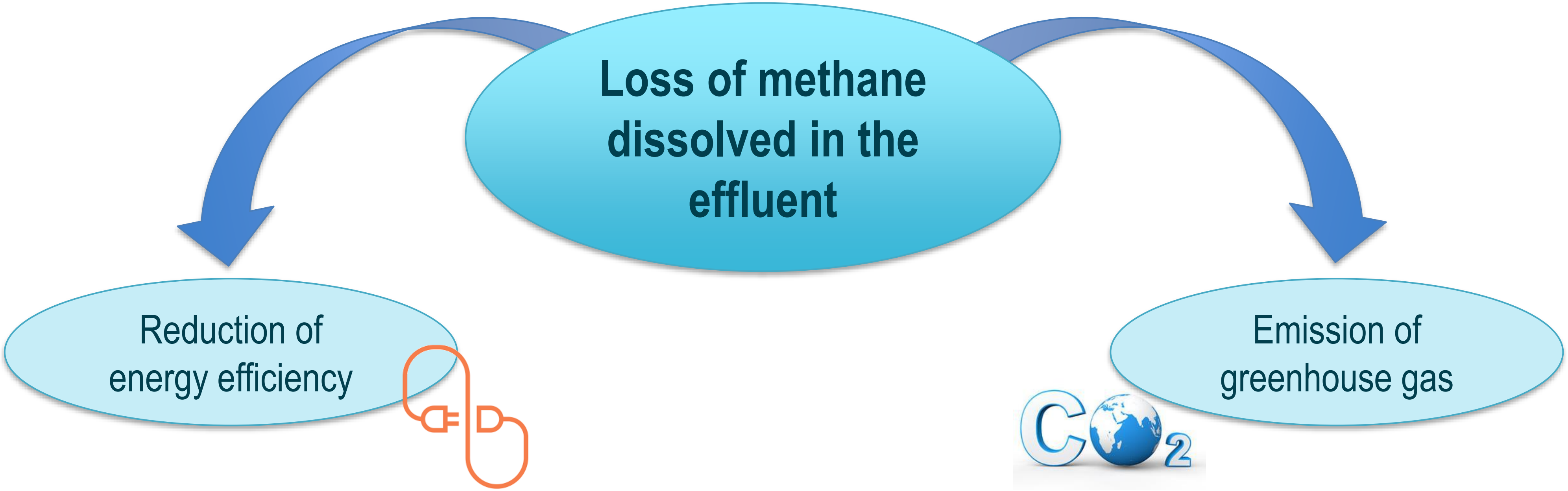
EA: 0.11 – 0.25 kg CO_2-eq per m^3

MBR: 0.16 – 0.31 kg CO_2-eq per m^3

Jiménez-Benítez et al. (under review)

AnMBR for UWW treatment

CH_4 emissions



Important in high-rate AnMBR systems operating at low temperatures

DISSOLVED METHANE CAPTURE

Dissolved methane recovery

AnMBR

+

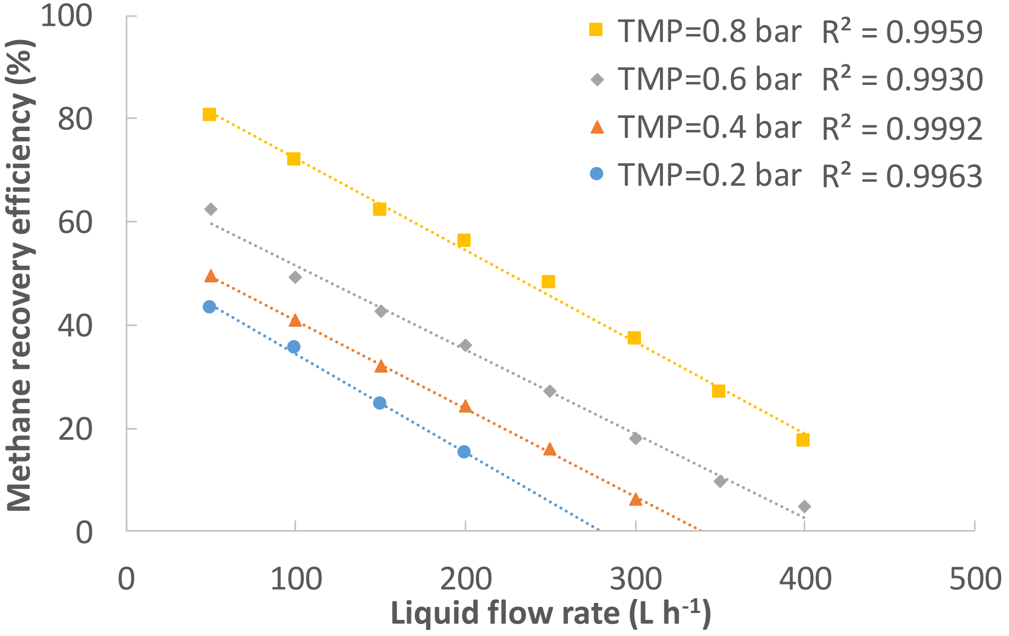
Degassing membrane

Anaerobic effluent

Treated Water

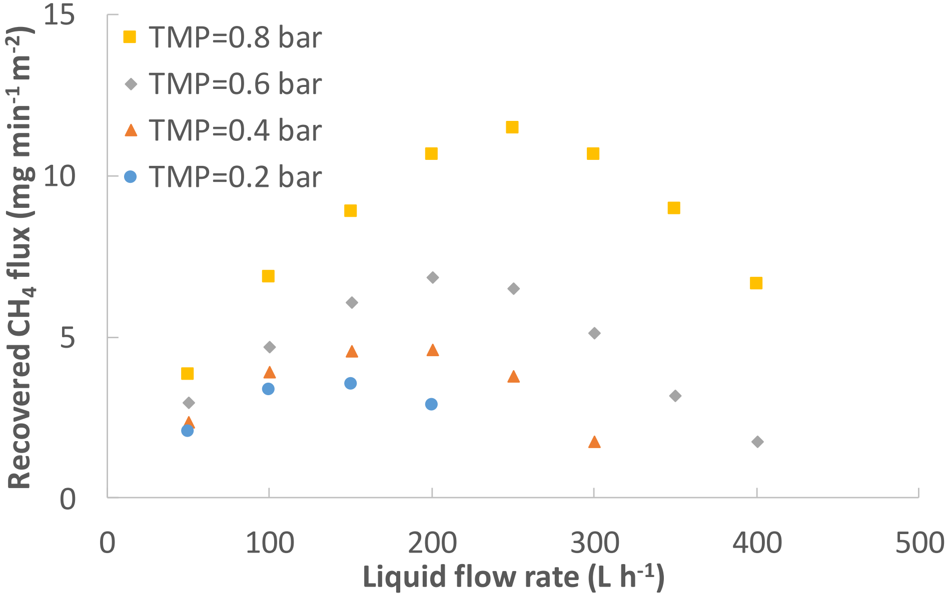
Recovered methane

METHANE RECOVERY



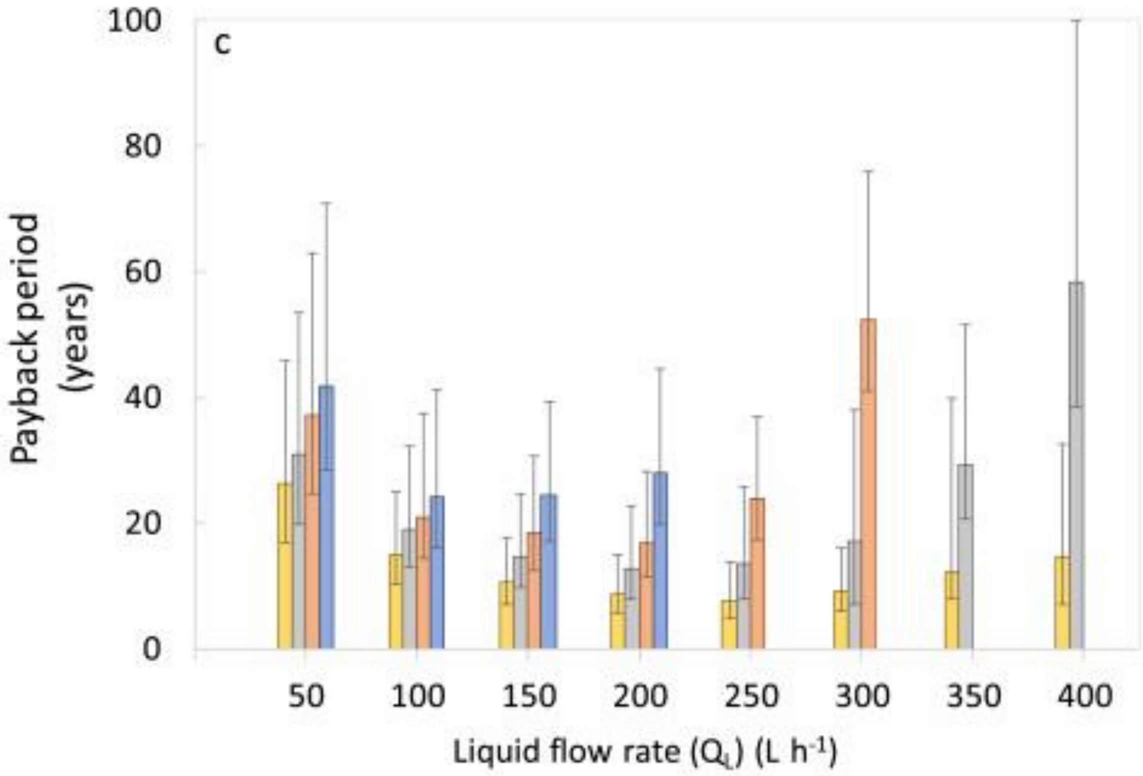
Methane recovery decreases as the HRT decreases

Reduction of contact time between liquid and membrane



Sanchis-Perucho et al. (2020) Journal of Membrane Science 604, 1 June 2020, 118070

PROCESS FEASIBILITY



TMP=0.8 bar
TMP=0.6 bar
TMP=0.4 bar
TMP=0.2 bar

Economic balance

Optimal operational conditions:

TMP = 0.8 bar
&
$Q_L/A = 101.4\ L\ h^{-1}m^{-2}$

Optimal operational conditions → Higher TMP & ~~Lower liquid flow rate~~ → Increased membrane area requirements → Economic balance

Sanchis-Perucho et al. (2020) Journal of Membrane Science 604, 1 June 2020, 118070

Energy balance: AnMBR + DM

Scenario	Dissolved methane recovered (%)	Membrane payback period (years)	Net Energy Consumption (kWh per m^3)
AnMBR	-	-	0.03
AnMBR+DM (Economic optimum)	48.1	5.2	- 0.03
AnMBR+DM (Maximum energy recovery)	80.4	16.9	- 0.06
AnMBR+DM (Economic and energy compromise)	71.8	9.5	- 0.05

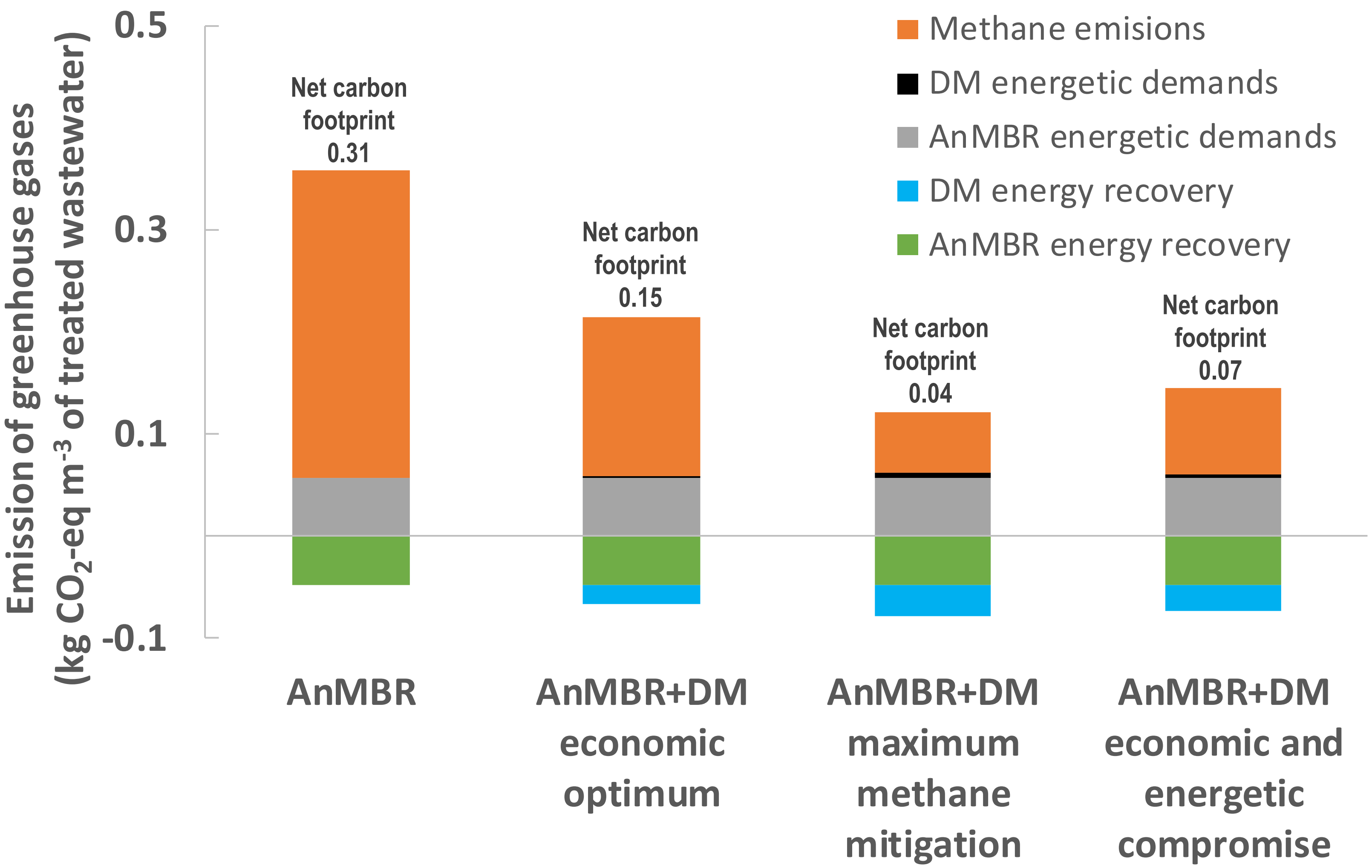
CAS: 0.3 – 0.7 kWh/m^3

EA: 0.3 – 0.8 kWh/m^3

MBR: 0.5 – 1.0 kWh/m^3

PROCESS FEASIBILITY

CO_2 emissions



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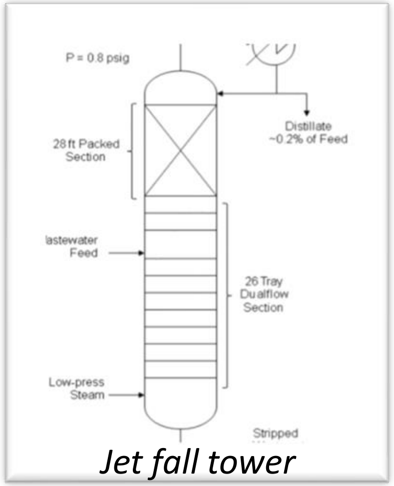
PROCESS FEASIBILITY

Combination with jet fall towers

Permeate

Recovered methane

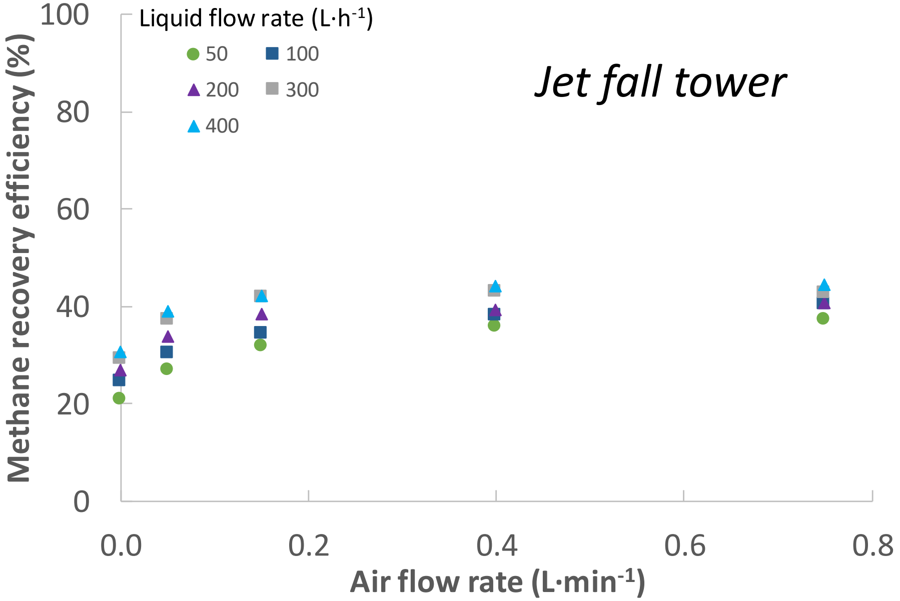
Effluent

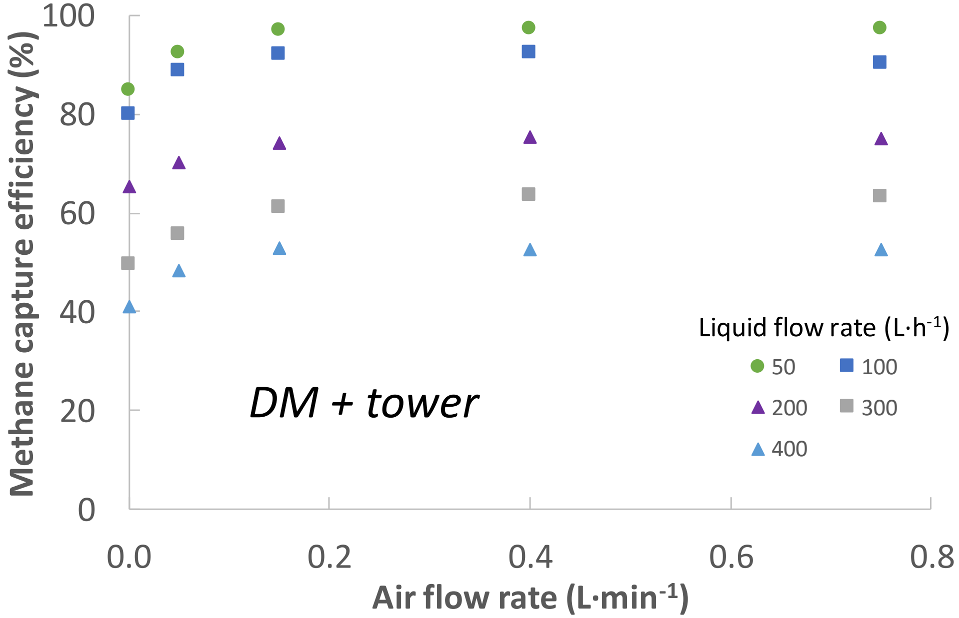


Enhance energy efficiency

Reclaimed water

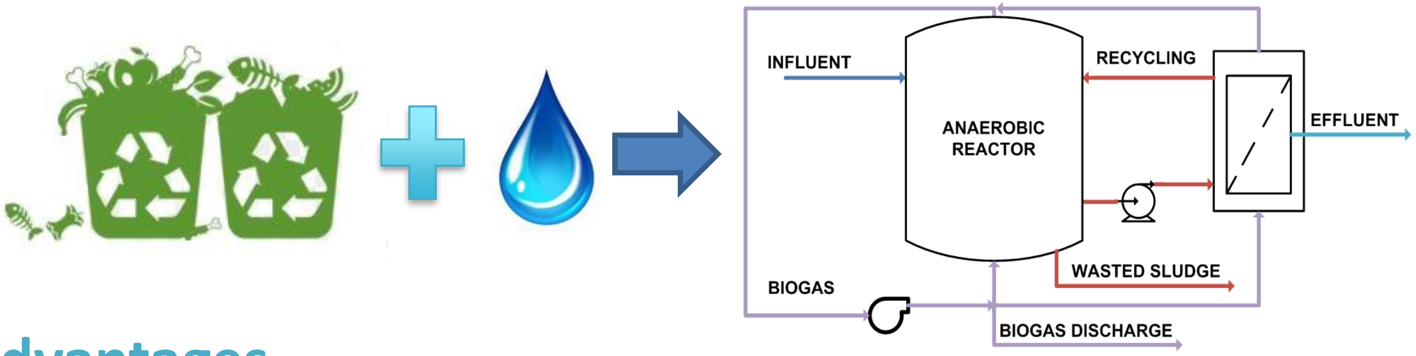
Reduce GHG emissions





Potentials of AnMBR for UWW treatment

Co-digestión of UWW and OFMSW



Process advantages

Higher biogas production

Blend synergy effects

Waste management advantages

Reduction of landfills volume

Savings on MSW transportation

Reduction in fossil fuel consumption

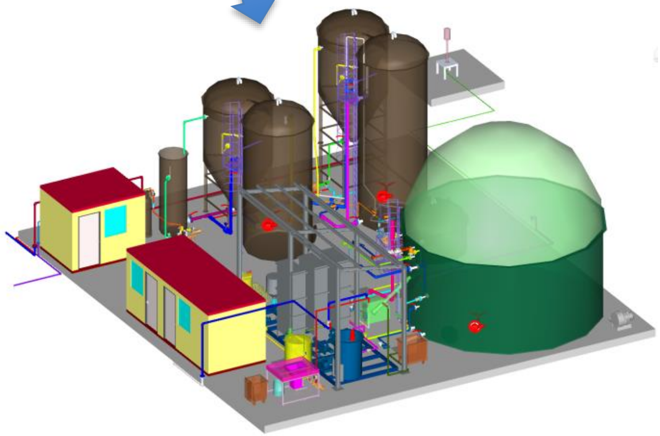
Pretel et al. (2014) Separation and Purification Technology 126, 30–38

LIFE ZERO WASTE WATER

Integrated management of Urban Wastewater (**UWW**) and the Organic Fraction of Municipal Solid Waste (**OFMSW**) for populations of **less than 50.000 inhabitants**

ZERO WASTE WATER

http://www.lifezerowastewater.com



PROJECT LOCATION: **Valdebebas WWTP, Madrid (Spain)**

BUDGET INFO:
- **Total amount: 2.464.520 €**
- **% EC Co-funding: 55%**

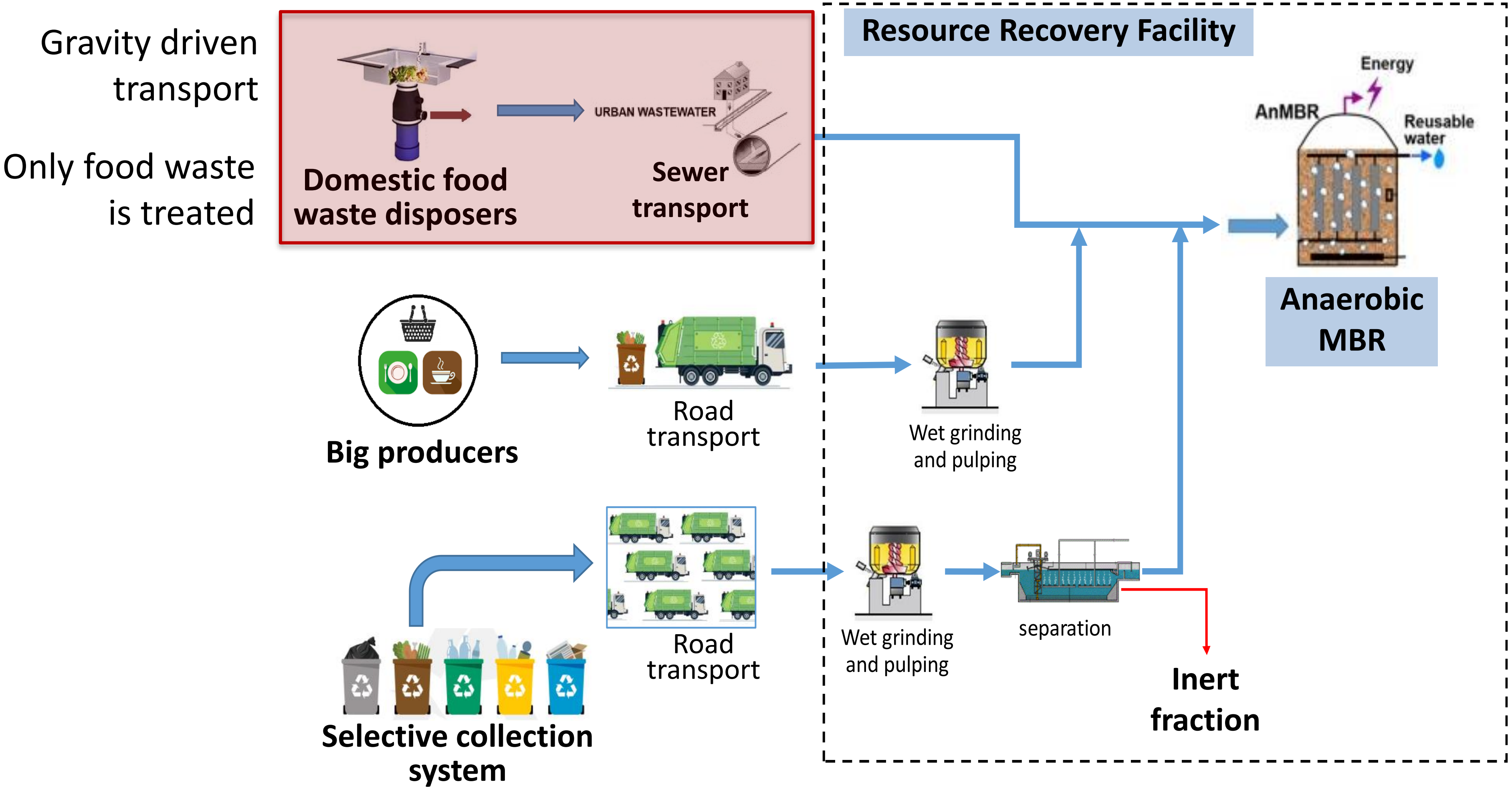
DURATION: 4 years + Extension

PROJECT'S IMPLEMENTORS:

aqualia · Canal de Isabel II · simbiente · USC Universidade de Santiago de Compostela · Vniversitat de València · VWM Solutions

LIFE ZERO WASTE WATER

Different integration options to be analysed in the project



The AnMBR Plant

Anaerobic digester and 3 types of membrane modules

3 membrane tanks 0.8 m^3/tank (0.7 + 0.1)

Tank A: PURON®, KMS, 41 m^2 filtration area (0.03 µm)

Tank B: ZENmbr2-S, LITREE, 40 m^2 filtration area (0.02 µm)

Tank C: IMMEM®, POLYMEM, 40 m^2 filtration area (0.03 µm)

Gasometer
60 m^3

Anaerobic reactor
100 m^3

Design flows:

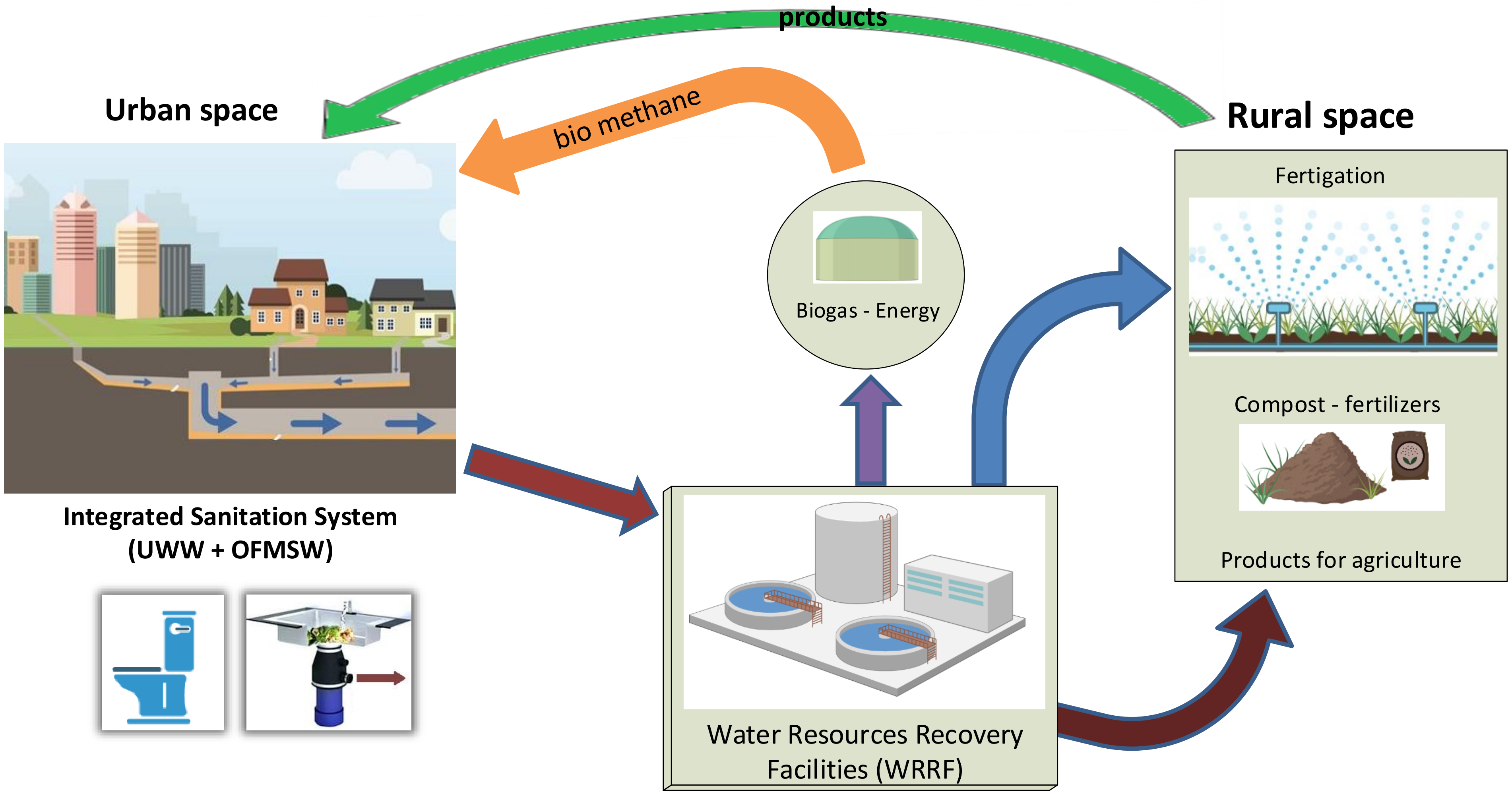
80 m^3/d UWW

125 kg/d OFMSW

(~ 300 PE with 70% PF)

The LIFE ZWW project concept

- **Circular economy in the urban sanitation sector**



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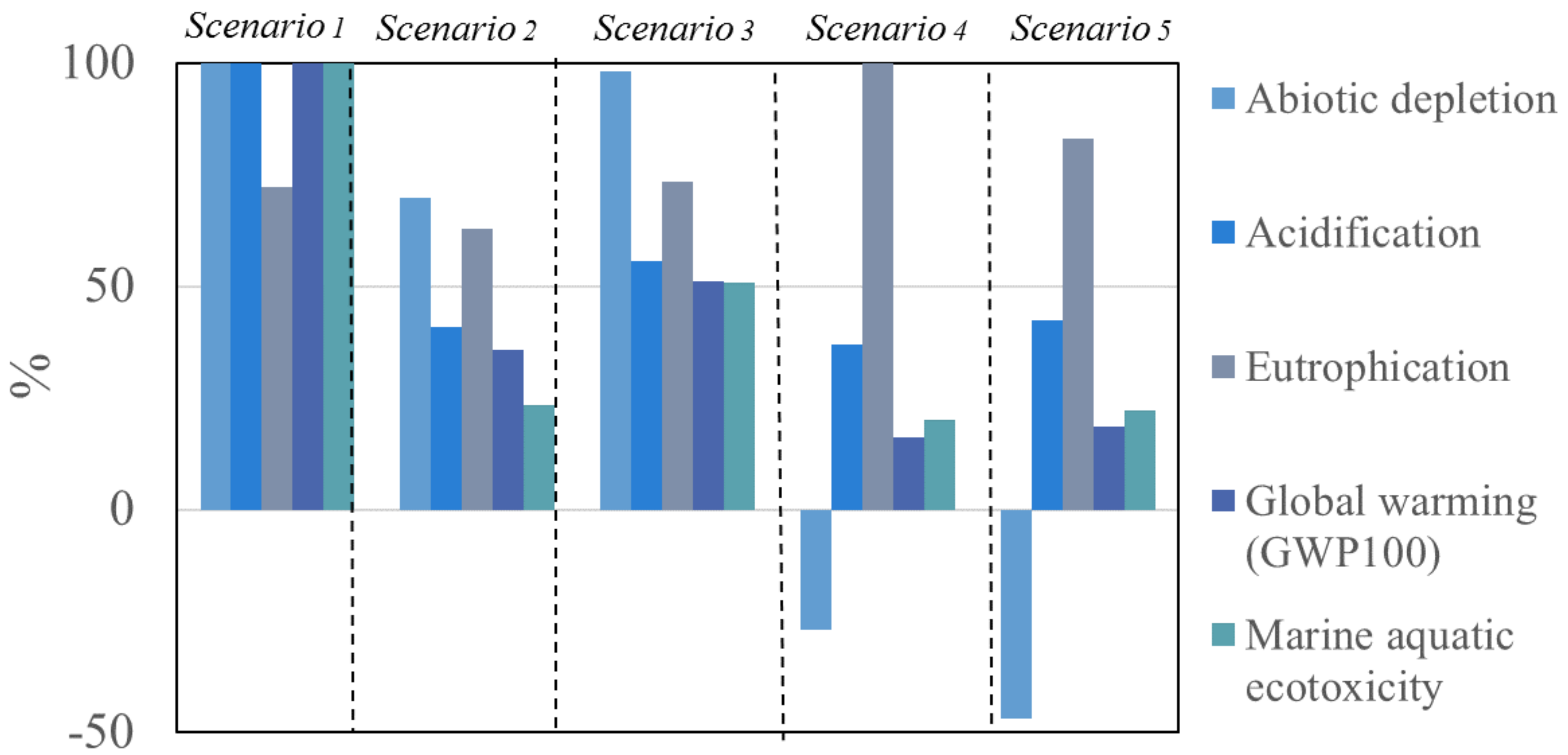
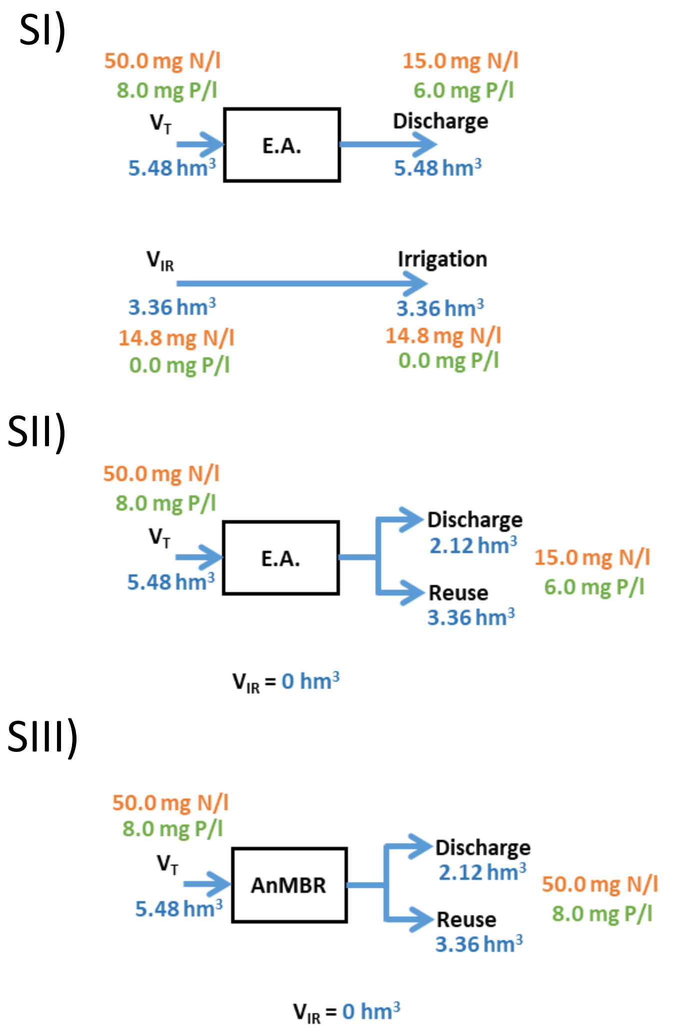


	SRT (days)	HRT (hours)	T (ºC)	PF (%)	OLR (kg COD·m^{-3}·d^{-1})
Scenario 1	40			0	0.537
Scenario 2	70			0	0.717
Scenario 3	40	≈20	≈25	40	0.871
Scenario 4	70			40	1.045
Scenario 5	70			80	1.014

Pretel et al. (2014) Separation and Purification Technology 126, 30–38

Combination with fertirrigation

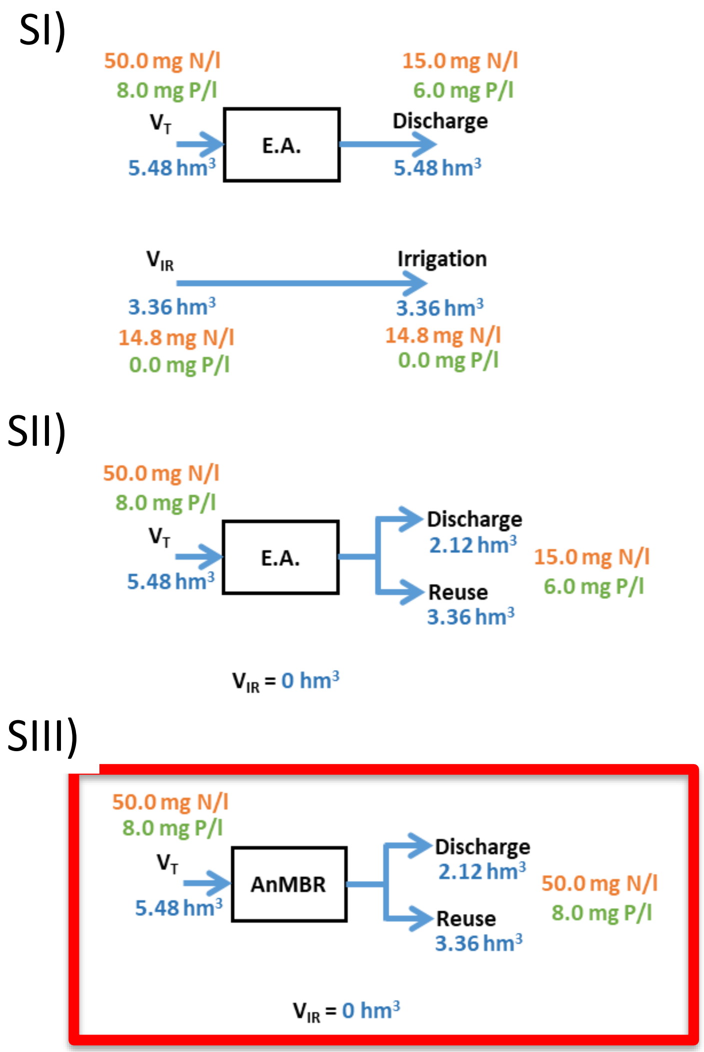


- Non sensitive area according to WWTD.
- Discharge to coastal water body.
- Vulnerable zone according to NiD.
- Water demand for agriculture: 3.36 hm^3/year currently supplied by groundwater abstraction (Scenario I).
- Irrigated Surface: 582 ha
- Crop type: Citrus.

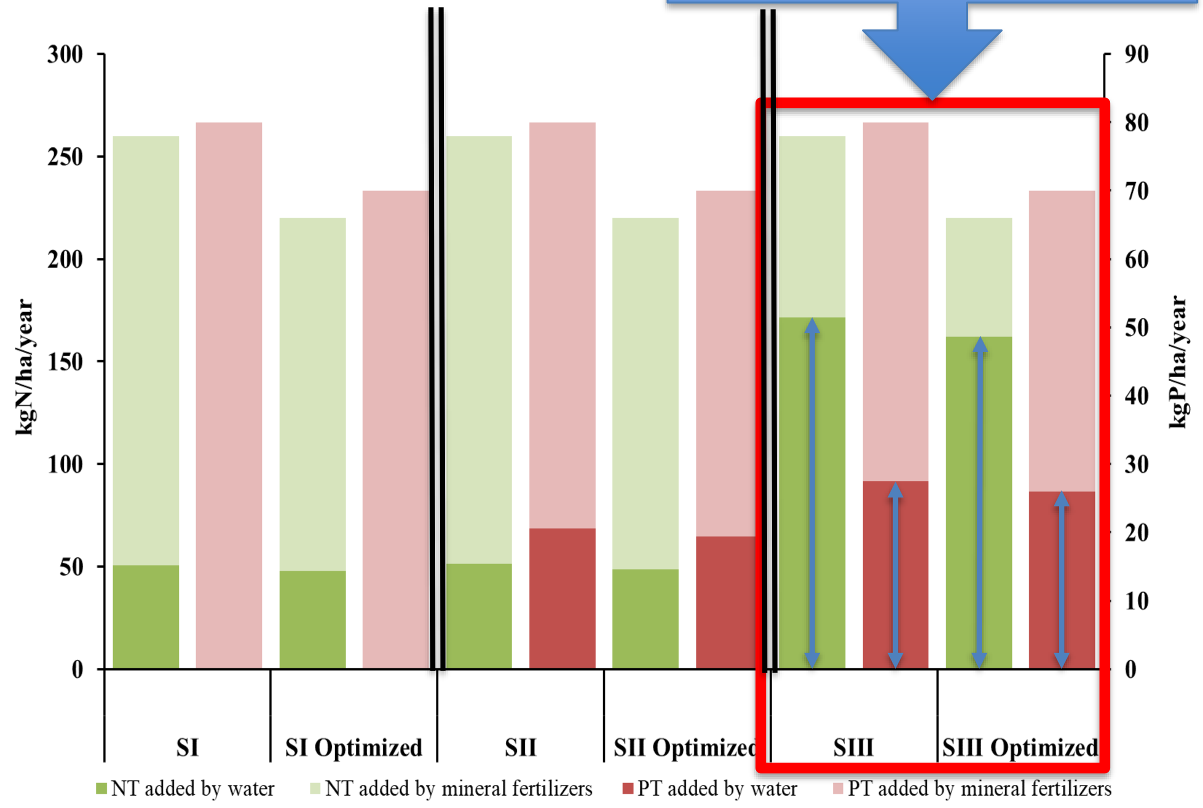
Jiménez-Benítez et al. (2020) Journal of Cleaner Production 27010, Article number 122398

Potentials of AnMBR for UWW treatment

Combination with fertirrigation



Nutrients recovery from wastewater increased



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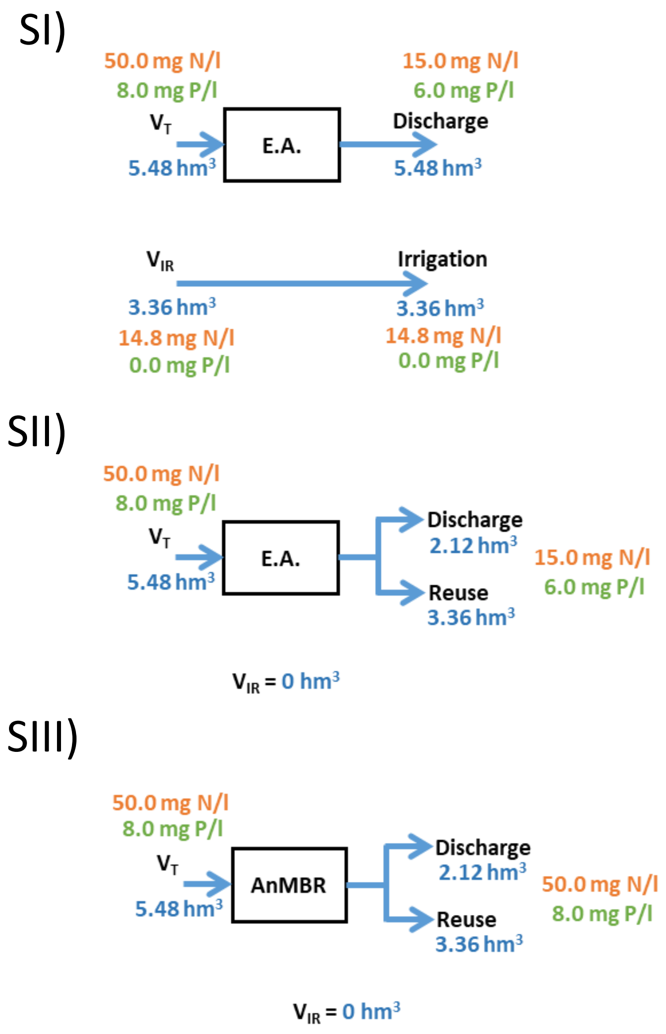
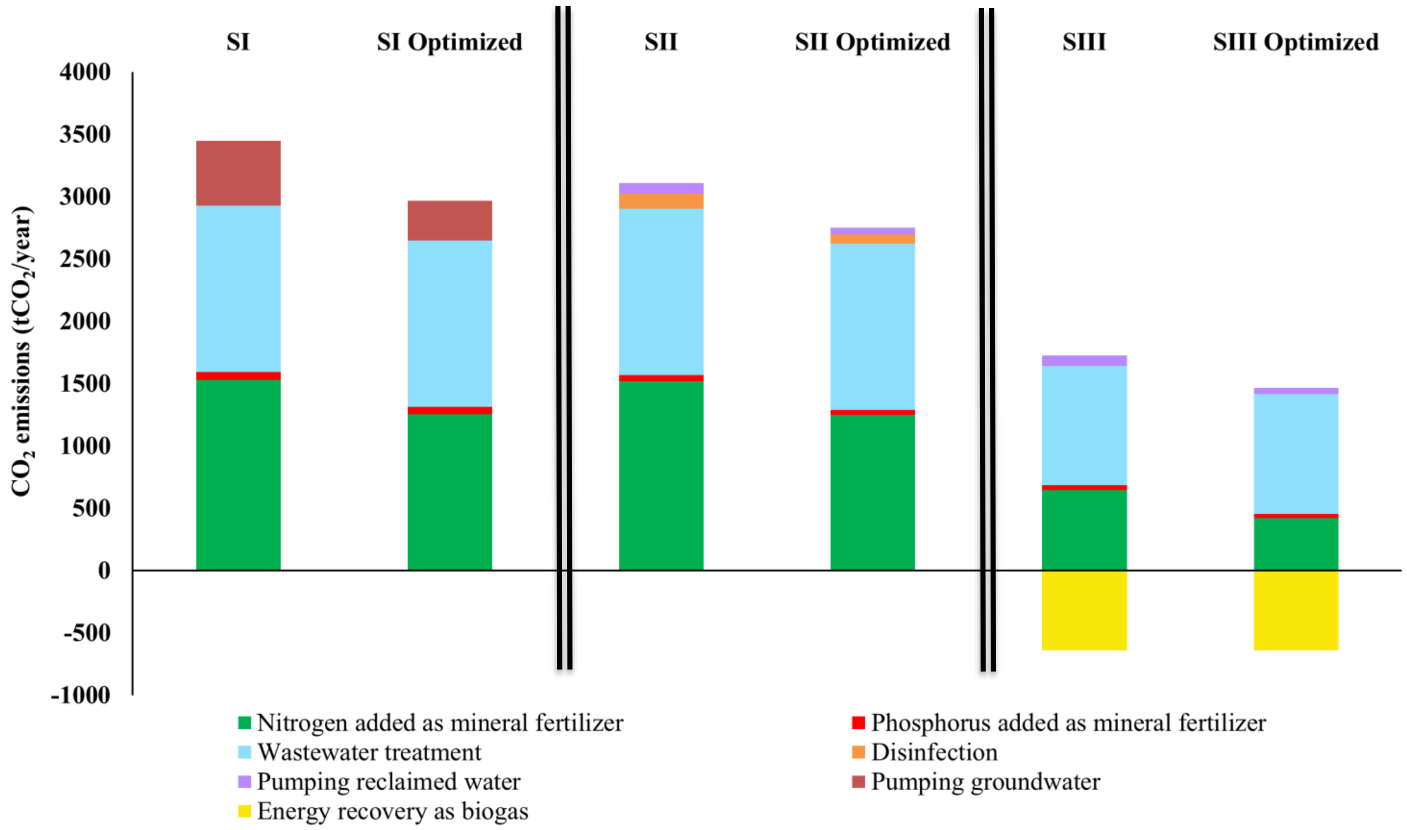




Jiménez-Benítez et al. (2020) Journal of Cleaner Production 27010, Article number 122398

Unidad Mixta UV-UPV

Characterization of regenerated water using AnMBR

Parameters Regulation 2020/741	
E. coli (CFU/100 ml)	0
Legionella ssp. (CFU/L)	0
Intestinal nematodes (eggs/1L)	0
DBO_5 (mg/L)	29.3±4.4
SS (mg/L)	0
Turbidity (NTU)	3.03±2.18
Parameters Real Decreto 1620/2007	
Sodium(mg/L)	20.9±2.0
Potassium (mg/L)	44.1±0.8
Calcium (mg/L)	161.8±0.4
SAR (meq/L)	3.71±0.47
Nt (mg/L)	64.4±7.5
Pt (mg/L)	10.9±0.1
pH	6.7
COD (mg/L)	64.44±7.52

Metals, transition metals and metalloids					
Parameter	Unit	Effluent **Mean±SD**			Spanish royal decree 1620/2007
B	$mg \cdot L^{-1}$	1.41E-01	±	4.08E-02	≤ 0.5
As	$mg \cdot L^{-1}$	8.26E-04	±	1.14E-04	≤ 0.1
Be	$mg \cdot L^{-1}$	2.90E-05	±	4.25E-05	≤ 0.1
Cd	$mg \cdot L^{-1}$	7.66E-05	±	5.97E-05	≤ 0.01
Co	$mg \cdot L^{-1}$	2.96E-04	±	1.16E-04	≤ 0.05
Cr	$mg \cdot L^{-1}$	2.70E-03	±	3.87E-03	≤ 0.1
Cu	$mg \cdot L^{-1}$	3.03E-02	±	2.90E-02	≤ 0.2
Mn	$mg \cdot L^{-1}$	1.61E-02	±	8.78E-03	≤ 0.2
Mo	$mg \cdot L^{-1}$	2.43E-03	±	9.87E-04	≤ 0.01
Ni	$mg \cdot L^{-1}$	3.70E-02	±	3.90E-02	≤ 0.2
Se	$mg \cdot L^{-1}$	9.64E-04	±	4.74E-04	≤ 0.02
V	$mg \cdot L^{-1}$	7.07E-04	±	3.75E-04	≤ 0.1

Micropollutants

Substance	Influent	AnMBR Efluent	%Removed
Diclofenac (ppb)	0.3616	0.1012	72
Acetamiprid (ppb)	0.0434	0.0200	54
Carbamazepine (ppb)	0.0408	n.a.	
Imidacloprid (ppb)	0.0865	n.a.	
Azithromycin (ppb)	0.5807	n.a.	
Octylphenol	n.d.	n.d.	
t-nonylphenol (branched)	n.d.	n.d.	
2,6-di-terc-Butil-4- methylphenol (BHT)	n.d.	n.d.	
Di(2-ethylhexyl) phthalate (DEHP)	n.d.	n.d.	

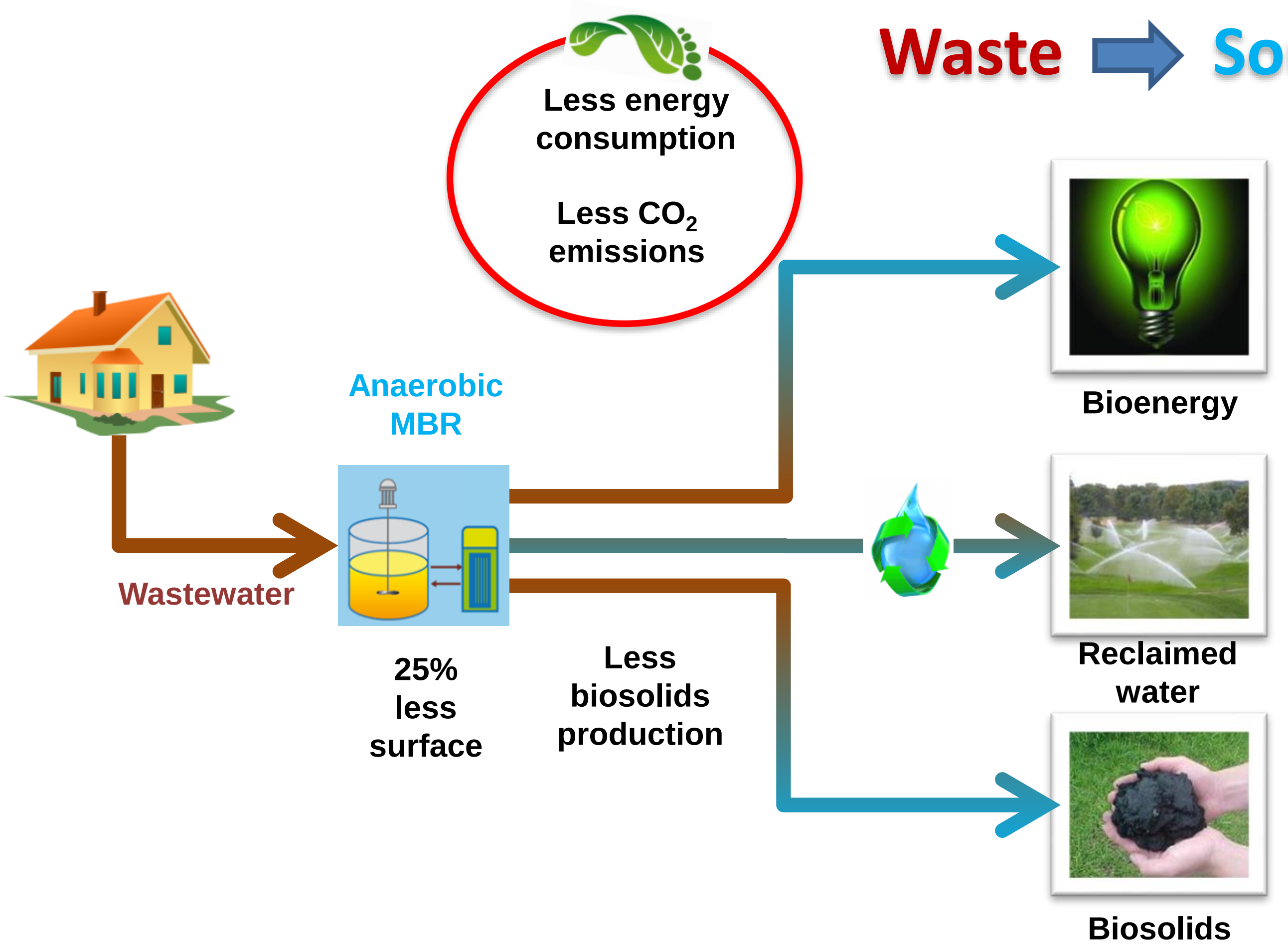
n.d. - not detected

n.a. – not available

TAKE HOME MESSAGES

Current WWTPs vs. AnMBR

Waste ➡ Source of Resources



Energy demand 0.2-0.5 kWh/m^3

Average net energy SURPLUS of up to 0.2-0.3 kWh/m^3

Reduction of up to 80% CO_2 and 100% N_2O emissions

Limited nutrient recovery potential

Energy savings by avoiding fertilizers production:

- N: 0,77 kWh/m^3 reused water (N typical concentration 40 mg/L; N_{org}: 15 mg/L and N_{amm}: 25 mg/L).
- P: 0,02 kWh/m^3 reused water (P typical concentration 8 mg/L).

Biosolids prod. of approx. 0.5 kg VSS/kg COD_{Rem}

Biosolids prod. of 0.05-0.10 kg VSS/kg COD_{Rem}

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