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The Microalgae hub project: how to use microalgae for agro-industrial wastewater bioremediation and valorisation of the algal biomass

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SaltGae
algae to treat saline wastewater

MICROALGAE AS A SUSTAINABLE ALTERNATIVE FOR WASTEWATER TREATMENT
SALTGAE FINAL EVENT
25 September 2019
Venue: Grand Hotel Union - Miklosiceva 1 (1000 Ljubljana)

The project – The microalgae hub

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Funding:

Fondazione CARIPLO

Regione Lombardia

Consortium

Partners:

istituto SPALLANZANI

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Provincia di Cremona

crea
Consiglio per la ricerca in agricoltura e l'analisi dell'economia agraria

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ERSAF ENTE REGIONALE PER I SERVIZI ALL'AGRICOLTURA E ALLE FORESTE
RegioneLombardia

Camera di Commercio Cremona
Ufficio Statistica e studi

Collaborations:

COLDIRETTI LOMBARDIA

GRUPPO RICICLA
DIPARTIMENTO DI SCIENZE AGRARIE E AMBIENTALI
PRODUZIONE, TERRITORIO, AGROENERGIA

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The motivation/context

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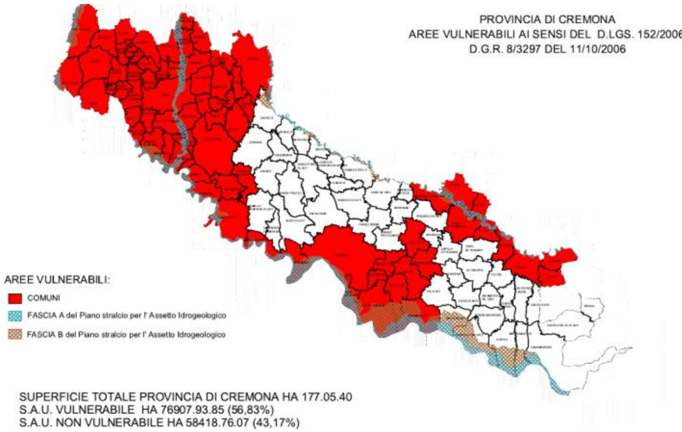
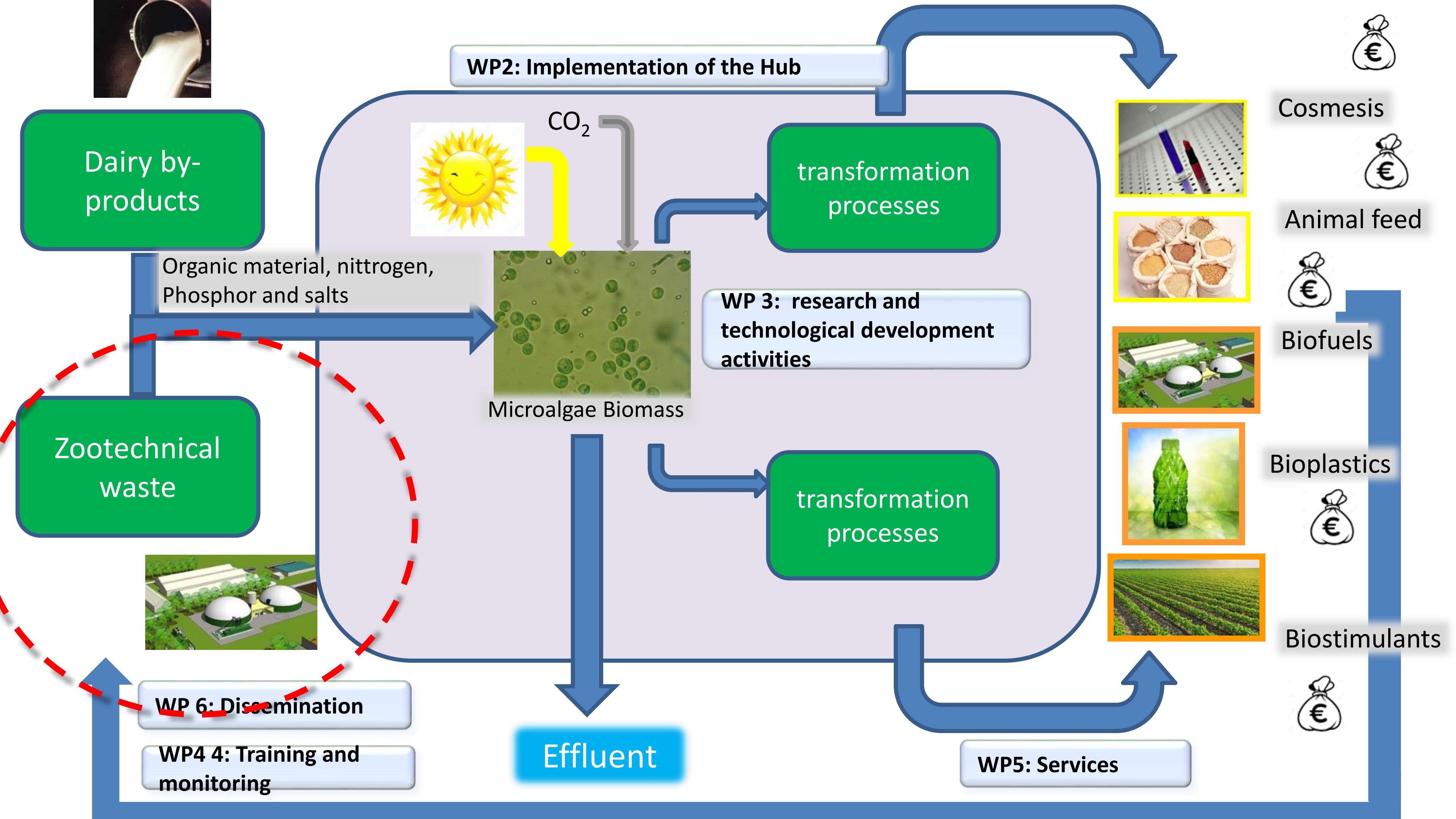
Cremona Province

- **Agriculture:** 15.5% of companies belong to the agricultural sector, breeding 887,000 pigs, 288,000 cows, e 1,800 buffalos → intensive breeding
- **Anaerobic digestion**: prompted by national incentive → more than 140 biogas plants



Nitrate directive (676/91/CE)

56% of the Cremona province is classified as vulnerable to nitrate

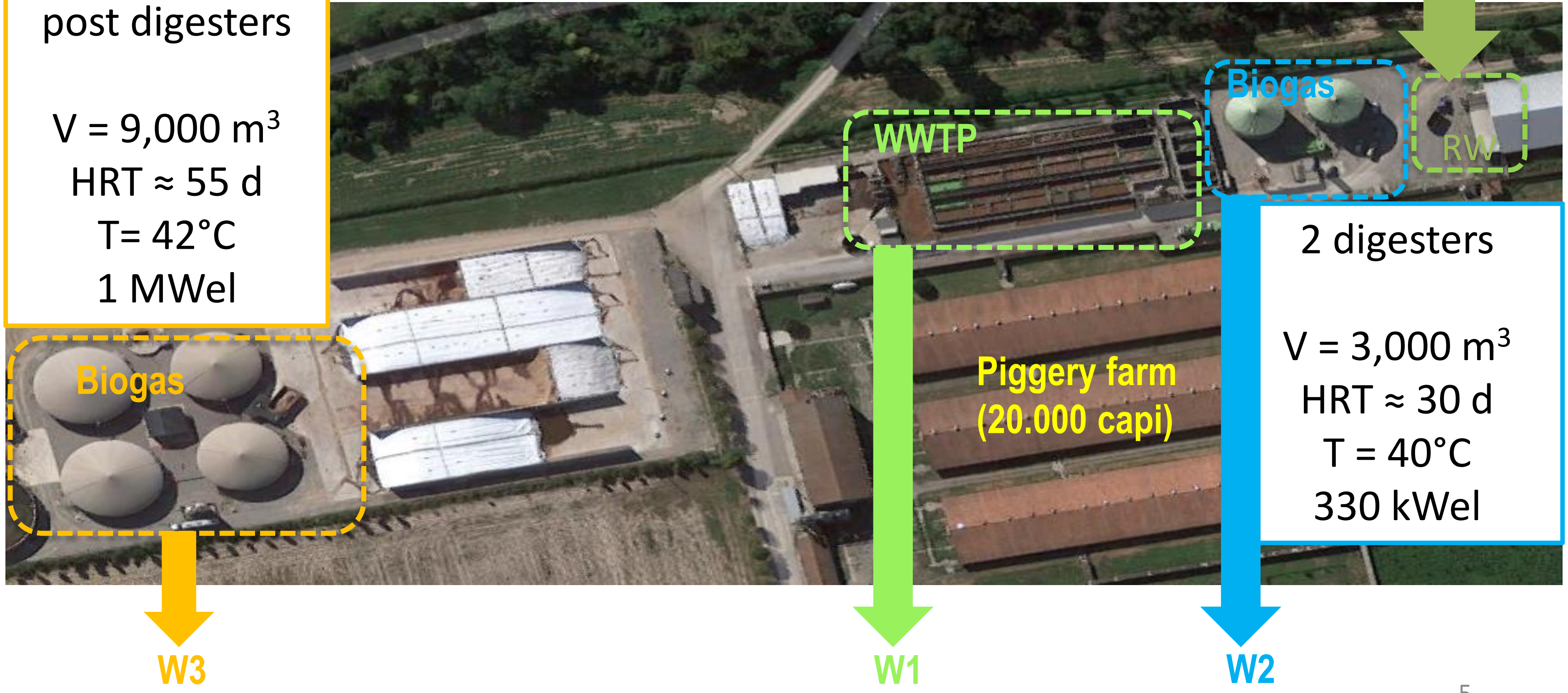


WP2: Implementation of the Hub
Dairy by-products
CO2
transformation processes
Organic material, nittrogen, Phosphor and salts
WP 3: research and technological development activities
Microalgae Biomass
Zootechnical waste
transformation processes
Cosmesis
Animal feed
Biofuels
Bioplastics
Biostimulants
WP 6: Dissemination
WP4 4: Training and monitoring
Effluent
WP5: Services

The case study

2 digesters + 2 post digesters

V = 9,000 m^3
HRT ≈ 55 d
T= 42°C
1 MWel



2 digesters

V = 3,000 m^3
HRT ≈ 30 d
T = 40°C
330 kWel

The case study

- Low optical density/turbidity
- Physiological pH
- Non –inhibiting N-NH_4
- N:P=10-30

Ideal

	W1 piggery		W2 digestate		W3 digestate	
	TQ	SL	TQ	SL	TQ	SL
TS g/L	5	2	[illegible]	[illegible]	[illegible]	[illegible]
VS (g/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
pH	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
N-NH_4 (mg/l)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
P (mg/l)	[illegible]	[illegible]	142	26	[illegible]	[illegible]
Turbidity (FAU)	148	191	4 280	70	3 660	4 460
COD sol (mg/l)	1 390	1 070	4 220	1 920	4 240	5 070
COD tot (mg/l)	4 550	1 000	72 440	3 400	5 560	50 000



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Pilot scale tests

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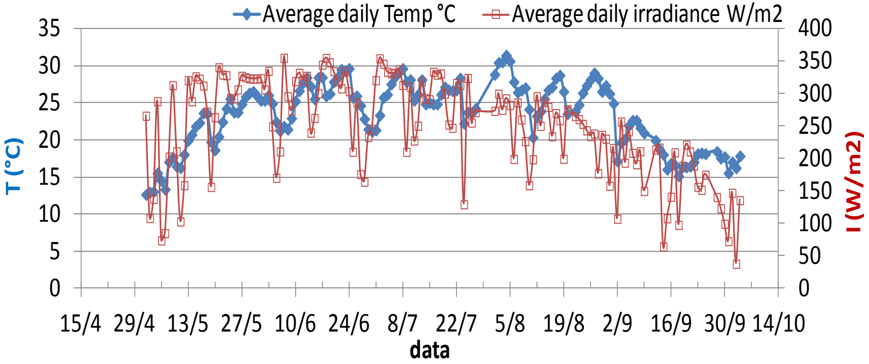

Raceway

A = 3.8 m^2 (V =0.9 m^3),

- paddlewheel
- pH control by bubbling CO_2
- CO_2 sump
- feeding pump

Experimental campaigns:

- **2016:** diluted digestate (1:5 → 1:3)
- **2017:** piggery wastewater
- **2018:** undiluted digestate

Assessment of:

- N and P forms
- Organic contamination (COD)
- Algae growth parameters (counts, TSS, OD680, turbidity)

Pilot scale tests - 2016: diluted digestate

- Microalgae could grow in the liquid fraction of agro-digestate and under sub-optimal climatic conditions for 200 d
- Average **productivity:** 8.2 g TSS m^{-2} d^{-1}
- **N apportioning**: 7±3% N was assimilated; 61 ± 24% was nitrified

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ELSEVIER
Contents lists available at ScienceDirect
Algal Research
journal homepage: www.elsevier.com/locate/algal

A novel option for reducing the optical density of liquid digestate to achieve a more productive microalgal culturing

CrossMark

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Bioresource Technology 274 (2019) 232–243
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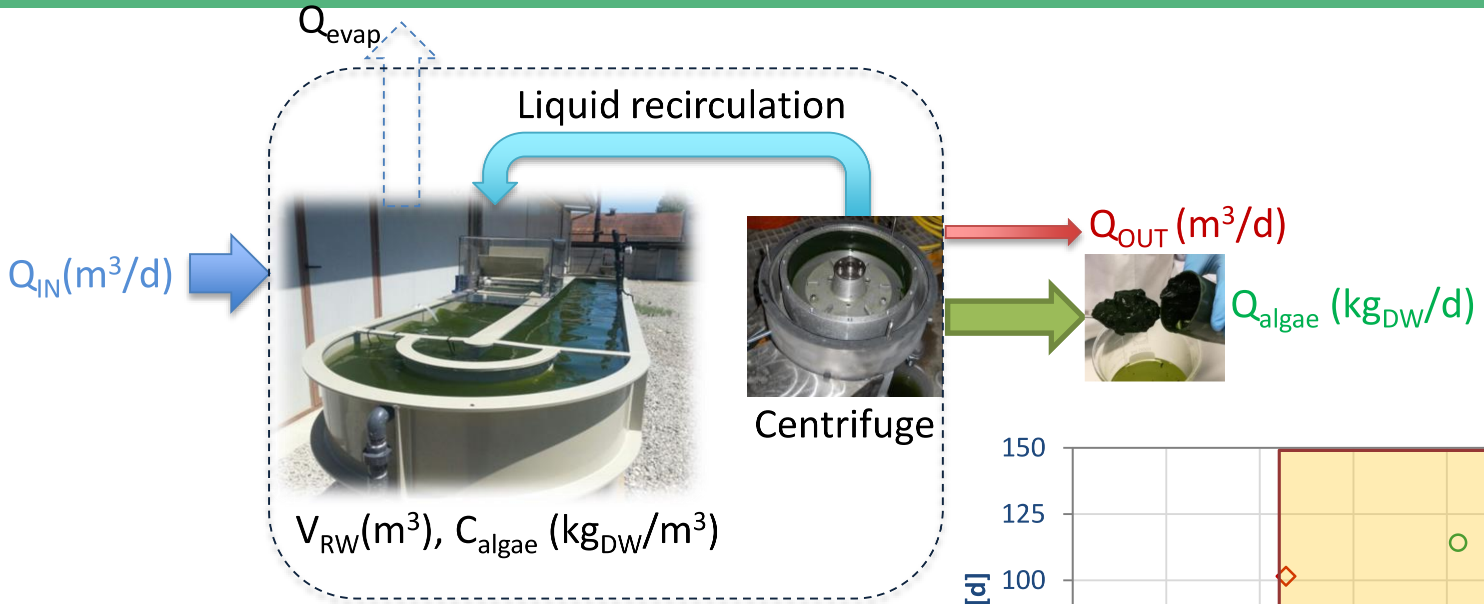
Digestate treatment with algae-bacteria consortia: A field pilot-scale experimentation in a sub-optimal climate area

Check for updates

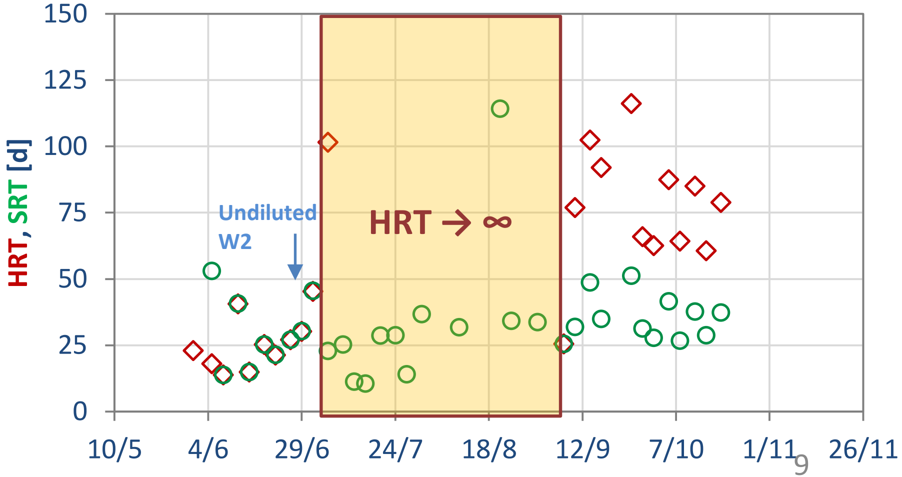
A. Pizzera[a], D. Scaglione[a], M. Bellucci[a], F. Marazzi[b], V. Mezzanotte[b], K. Parati[c], E. Ficara[a,*]

Pilot scale tests - 2018: undiluted digestate



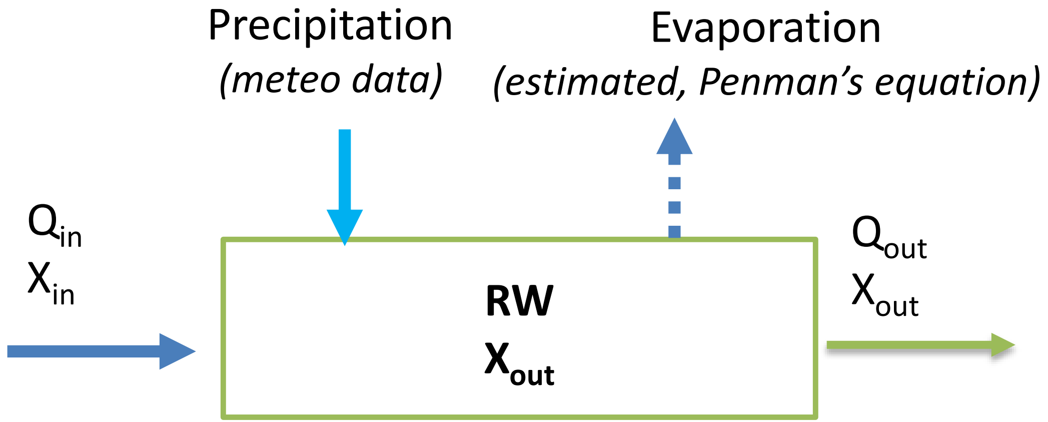
$$SRT = V_{RW} \times C_{algae} / Q_{algae}$$

$$HRT = V_{RW} / Q_{OUT}$$



Pilot scale tests - 2018: undiluted digestate

Raceway mass balances:



$$\Delta V = Q_{in}\,\Delta t - Q_{out}\,\Delta t - Q_{algae}\,\Delta t + \Sigma P - E$$

$$\frac{d(X * V)}{dt} = Qin * X_{in} \; - Qalgae * Xalgae - QoutXout \quad + r$$

Pilot scale tests - 2018: undiluted digestate

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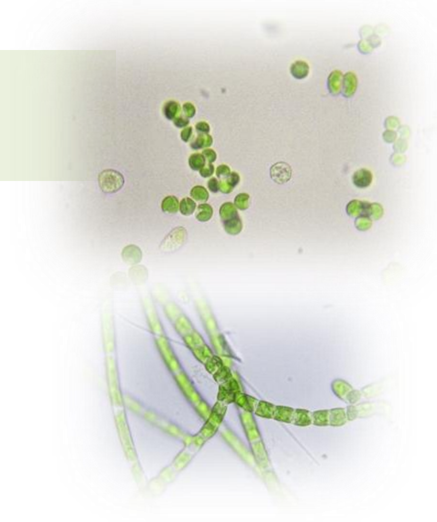
Productivity: 6.2 $g_{DM}/(m^2 \cdot d)$ (< 8.2 ± 8.5 $g_{DM}/(m^2 \cdot d)$ 2016)



Removal efficiencies:

- NH_4^+-N: 95 ± 12 [%]
- N: 52 ± 13 [%]

- PO_4^{3-}-P: 80 ± 21 [%]
- CODs: 45 ± 35 [%]

N-NH_4^+: 0 ± 1 % → high removal
N stripped: 35 ± 7 % → poor pH control → stripping (or denitrification)
N-NO_2^-: 8 ± 4 %
N-NO_3^-: 44 ± 12 % → nitrification
N-biomass: 13 ± 1 %

Pilot scale tests - 2017: piggery WW

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	TSS (g/L)	$N\text{-}NH_4$ (mg/L)	$N\text{-}NO_3$ (mg/L)	OD @680 (-)	sCOD (mg/L)	$P\text{-}PO_4$ (mg/L)	Cond. (mS/cm)
Mean	0.2	200	3.6	0.15	658	20	3.5
Standard dev.	0.28	60	3.6	0.08	314	14	0.3

Stable growth *but variable composition of algal community*

Average ***productivity:*** *= 10 gDM/m²/d → 9 months = 27 tDM/ha/year*

Pilot scale tests - 2017: piggery WW

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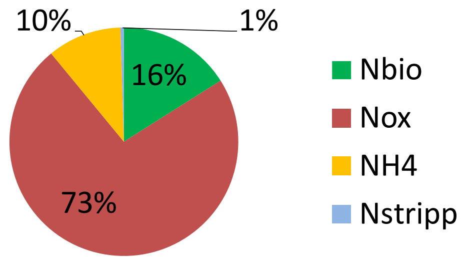
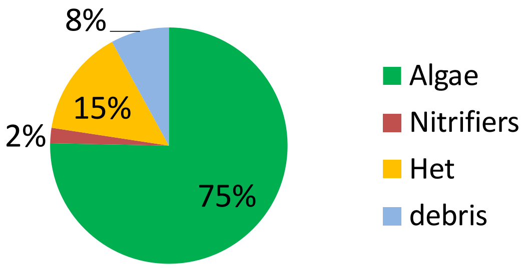
- **Ammonium removal** Mean: 90%
- **P removal:** More variable Mean: 46%
- **sCOD removal:** Mean: 67% (O_2 from algae)

N apportioning



Biomass apportioning



Conclusions/Perspectives

PROs

- Reduced N load to the fields *(→ reduced arable land demand for N disposal)*
- Lower energy request for aeration
- Production of valuable algal biomass *(CO_2 capture, organic C and nutrients to be returned to soils)*

CONs

- Large areal request for algae treatment
- Overall efficiency largely dependent on climatic conditions (*may imply discontinuous operation*)
- Long term stability still to be proven

→ Integrated schemes are to be tested for final applicability assessment
→ Biomass valorization
→ Optimization of culturing (respirometry+modelling)

Valorization

- Fertilisers, biostimulants
- Biofuels
- Feed in aquacultures
- Biomaterials

Valorization – CH4

Biogas

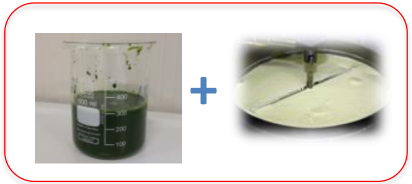
Simple/straightforward

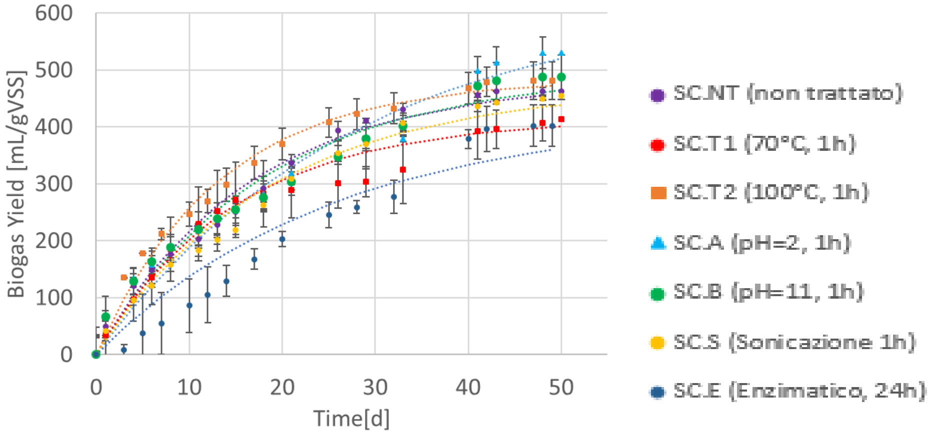
Reduces the overall N removal benefit

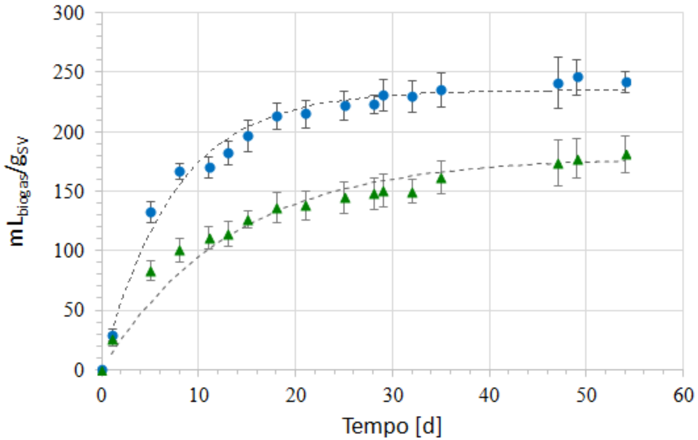
Low methane yield

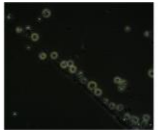
(100-200 Nm³_CH4/ton_DM)

- Pretreatments are required (cost/benefit balance)
- Co-digestion









Valorization - PHA

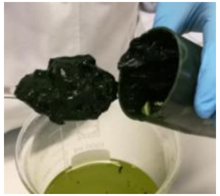
Bioplastics/VFAs

More complex

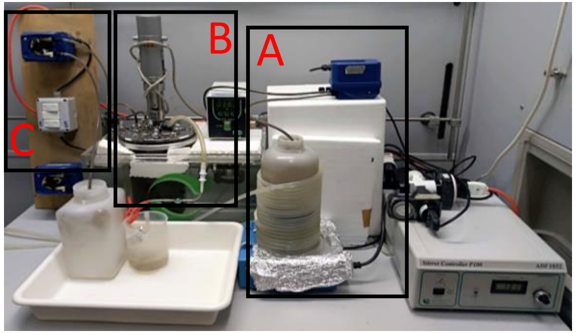
Allows for N, P recovery

Low yield (0,08 -0,2 g_PHA/g_DM)

- Optimization of process parameters
- Co-fermentation



Fermentation → VFA → Struvite Precipitation → PHA accumulation → PHA estraction



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Thanks to

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All of you for listening