INTRODUCTION TO ALGAL AND OTHER NUTRIENT REMOVAL TECHNOLOGIES

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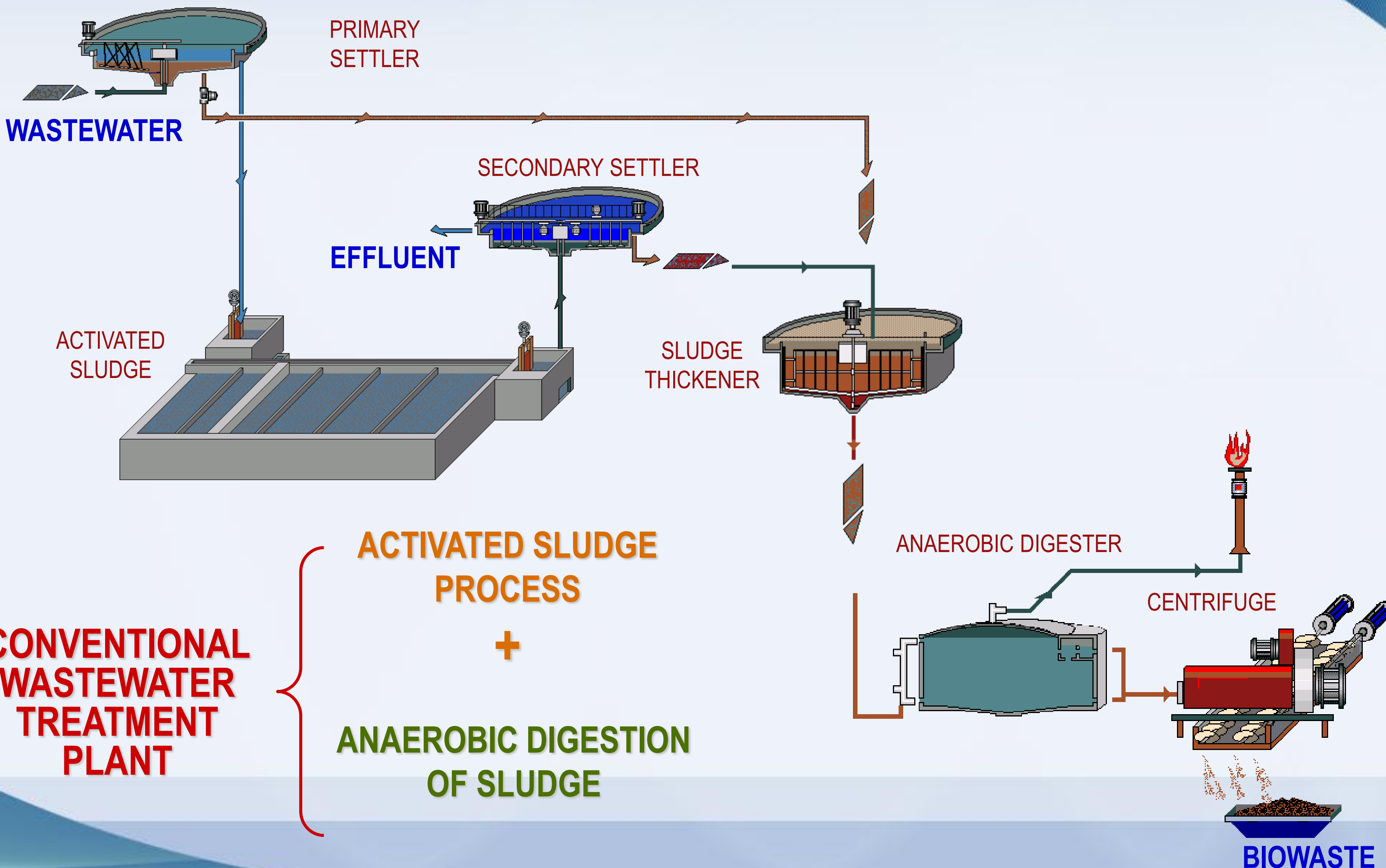
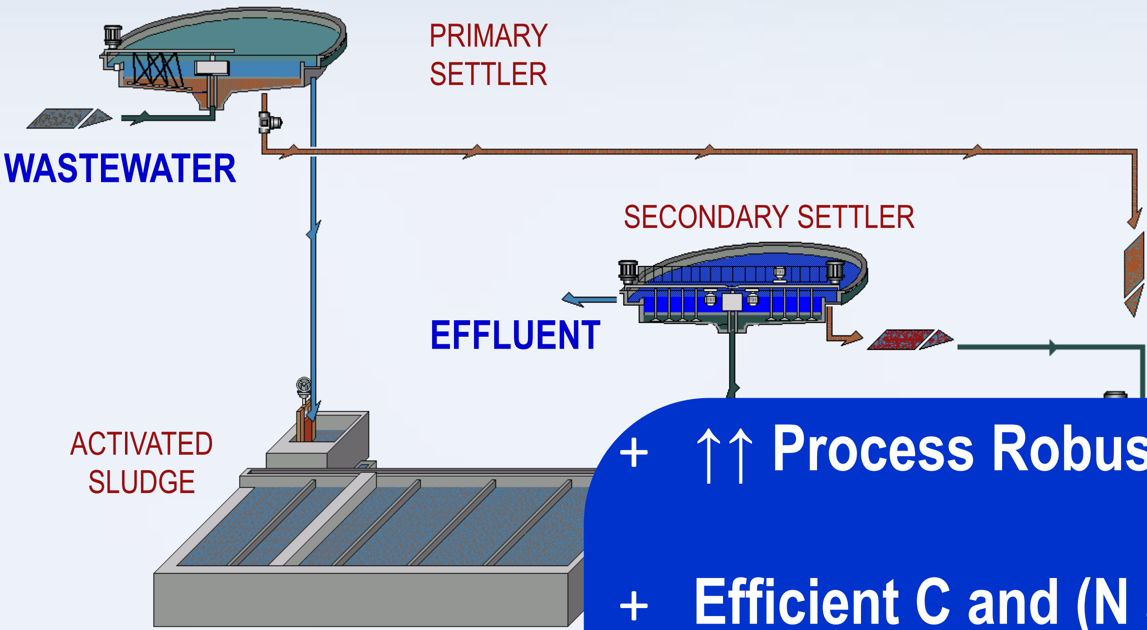
CONVENTIONAL WASTEWATER TREATMENT



CONVENTIONAL WASTEWATER TREATMENT PLANT

- **ACTIVATED SLUDGE PROCESS**
- **+**
- **ANAEROBIC DIGESTION OF SLUDGE**

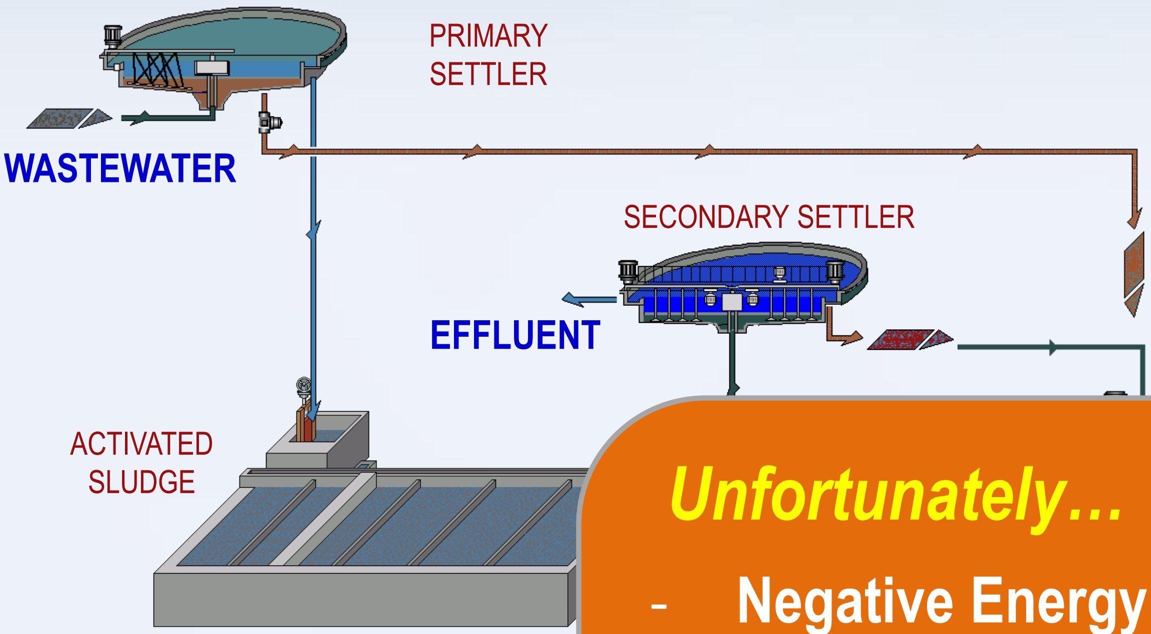
CONVENTIONAL WASTEWATER TREATMENT



CONVENTIONAL WASTEWATER TREATMENT PLANT

- ↑↑ Process Robustness at High SRT
- Efficient C and (N and P removal)
- Suitable at Low-Moderate Temperatures
- Extensive Design & Operation Experience
- Low Footprint

CONVENTIONAL WASTEWATER TREATMENT



CONVENTIONAL WASTEWATER TREATMENT PLANT

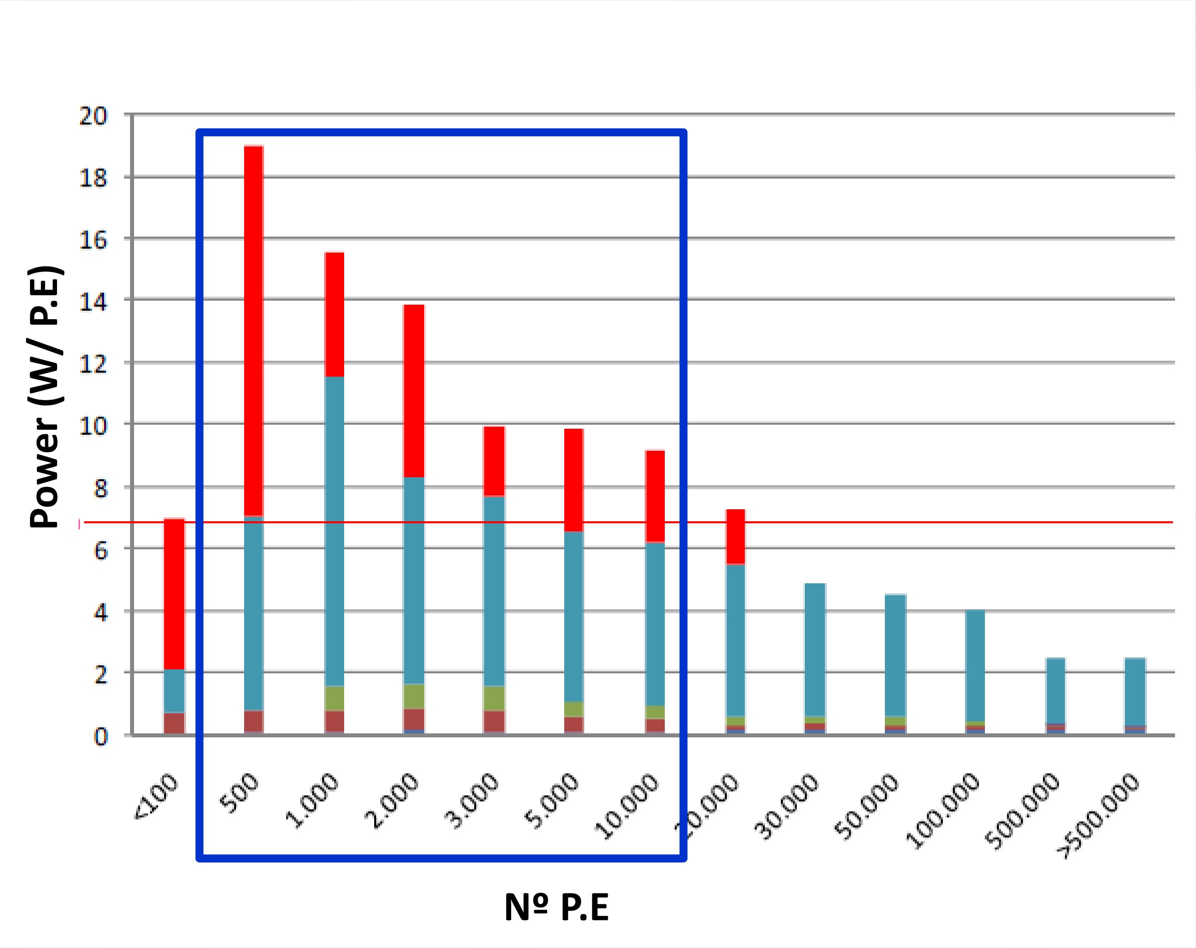
ACTIV

ANAER

Unfortunately…

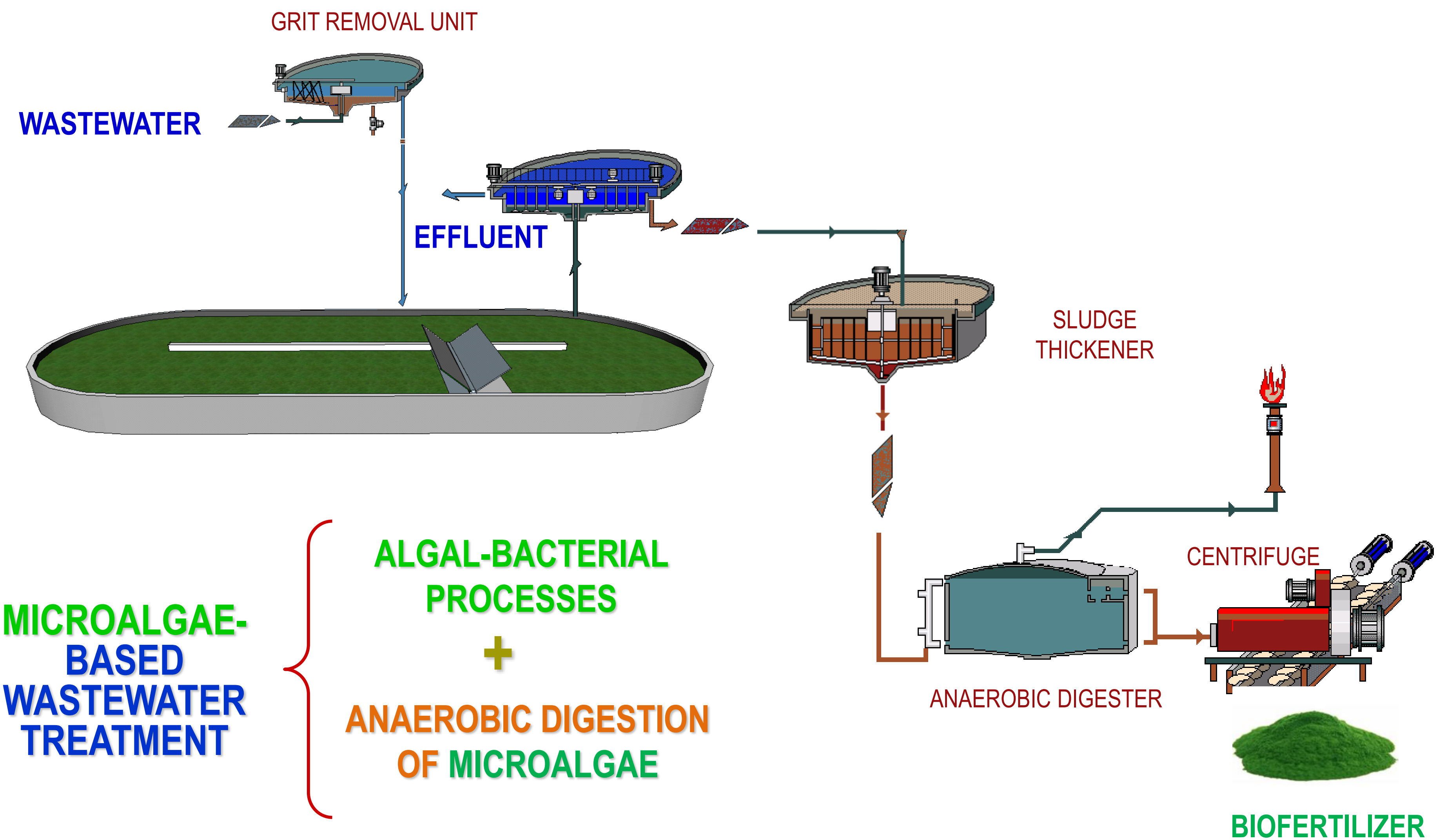
- Negative Energy Balance
- Low Nutrient Recovery
- High CO_2 Footprint (CO_2 + CH_4 + N_2O)
- Odour nuisance
- Poor emerging pollutant removal

CONVENTIONAL WASTEWATER TREATMENT



- Very inefficient process for low-medium size population

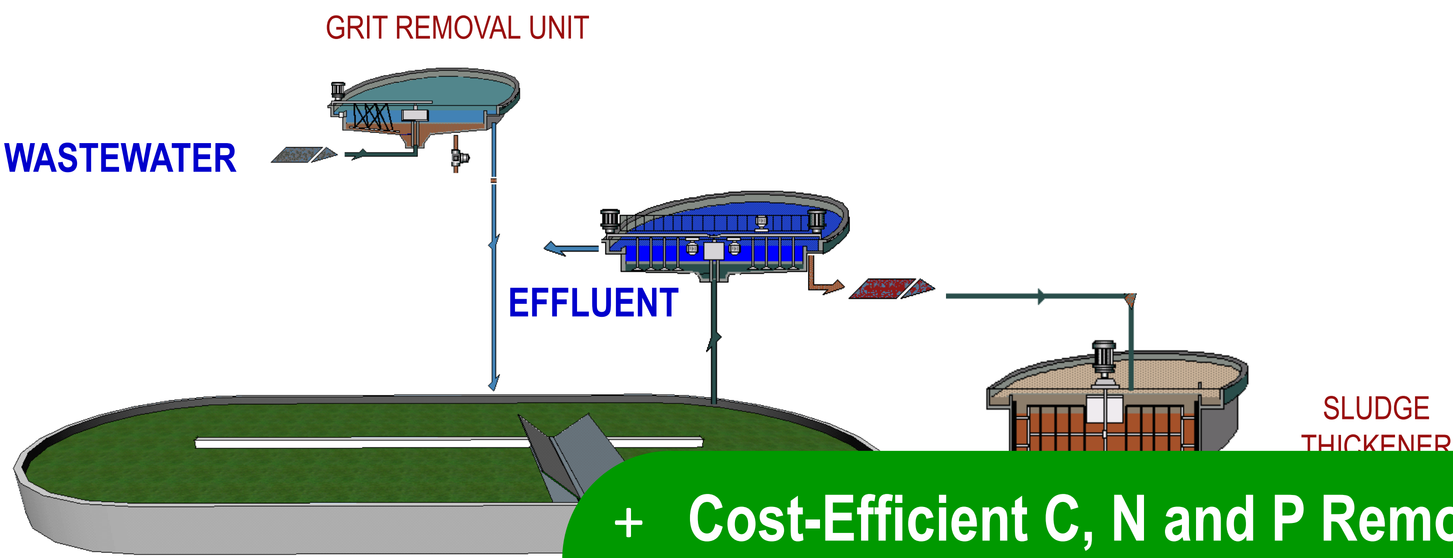
MICROALGAE-BASED WASTEWATER TREATMENT



MICROALGAE-BASED WASTEWATER TREATMENT

- **ALGAL-BACTERIAL PROCESSES**
- **+**
- **ANAEROBIC DIGESTION OF MICROALGAE**

MICROALGAE-BASED WASTEWATER TREATMENT



MICROALGAE-BASED WASTEWATER TREATMENT

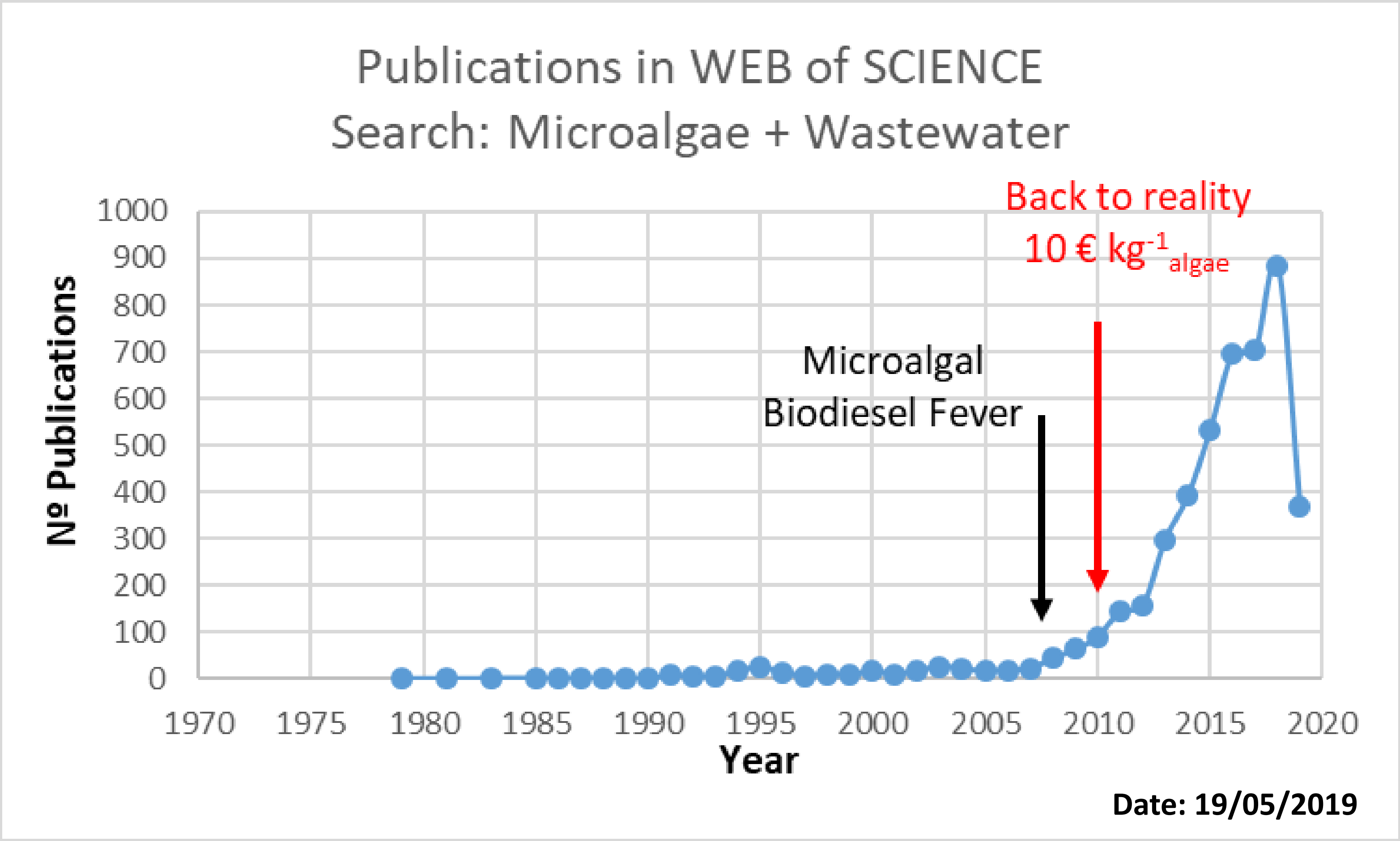
ALGA
PR

ANAER
OF M

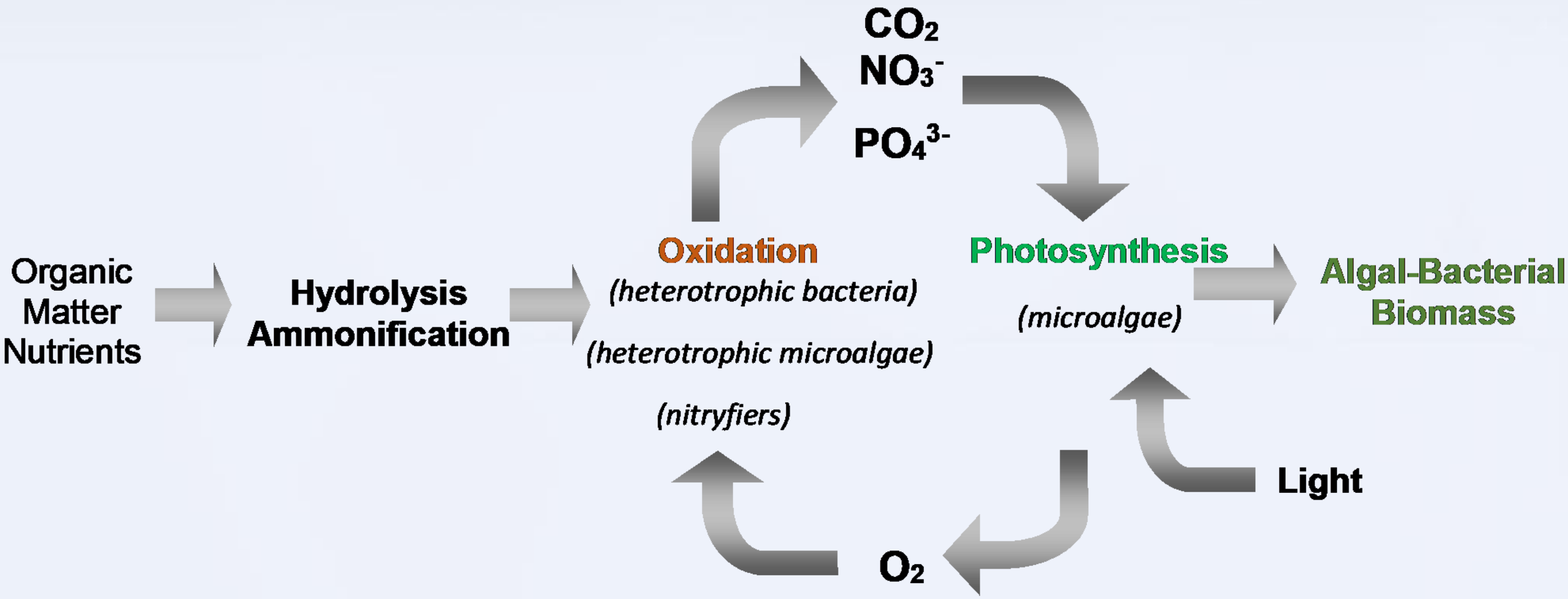
- Cost-Efficient C, N and P Removal
- Free Process Oxygenation
- Enhanced Nutrient Recovery
- Positive Energy Balance

(Muñoz and Guieysse 2006)

MICROALGAE-BASED WASTEWATER TREATMENT

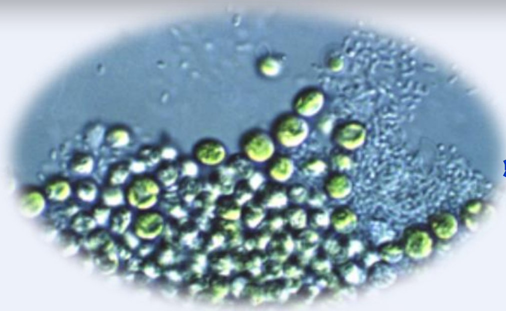


SYMBIOSIS MICROALGAE - BACTERIA



MICROALGAE-BASED WASTEWATER TREATMENT

In symbiosis with bacteria



Domestic

Livestock

- Cattle
- Swine

Industrial

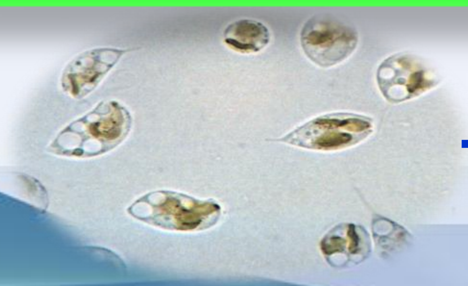
- Agro-industrial
- Pulp and Paper
- Textile
- Chemical

Photoautotrophic metabolism

Digestate

- N, P

Heterotrophic metabolism



- Acetate
- Glucose
- Cresol
- Phenol
- Naphtalene
- Phenanthrene
- Azo Dyes

MICROALGAE-BASED WASTEWATER TREATMENT

SaltGae algae to treat saline wastewater

Hydraulic Retention Time = 3-4 days

- ✓ **Organic Matter Removals ≈ 70-80 %**
- ✓ **Total Nitrogen Removals ≈ 60-70 %**
- ✓ **NH_4^+ Removals ≈ 98-100 %**
- ✓ **PO_4^{3-} Removals ≈ 40-60 %**

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Influence of pH and CO_2 source on the performance of microalgae-based secondary domestic wastewater treatment in outdoors pilot raceways

Esther Posadas[a,b,*], María del Mar Morales[a,1], Cintia Gomez[a,1], F. Gabriel Acién[a,1], Raúl Muñoz[b,2]
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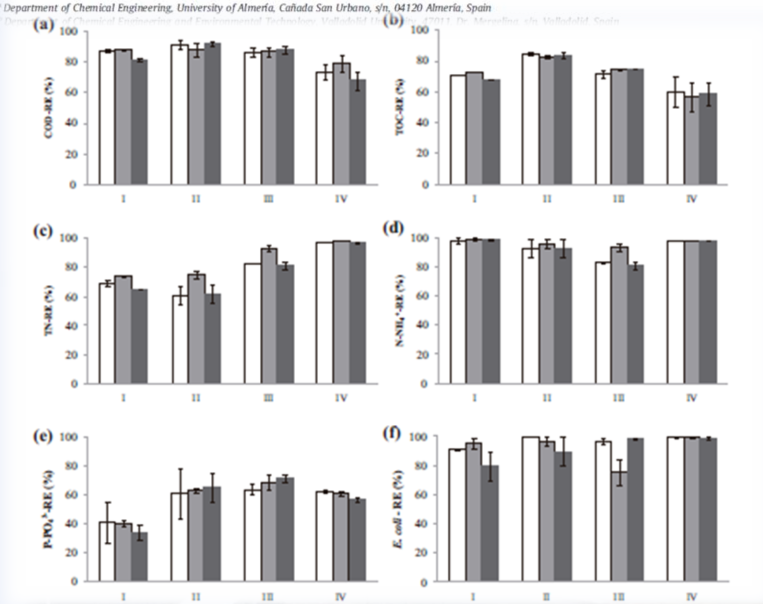
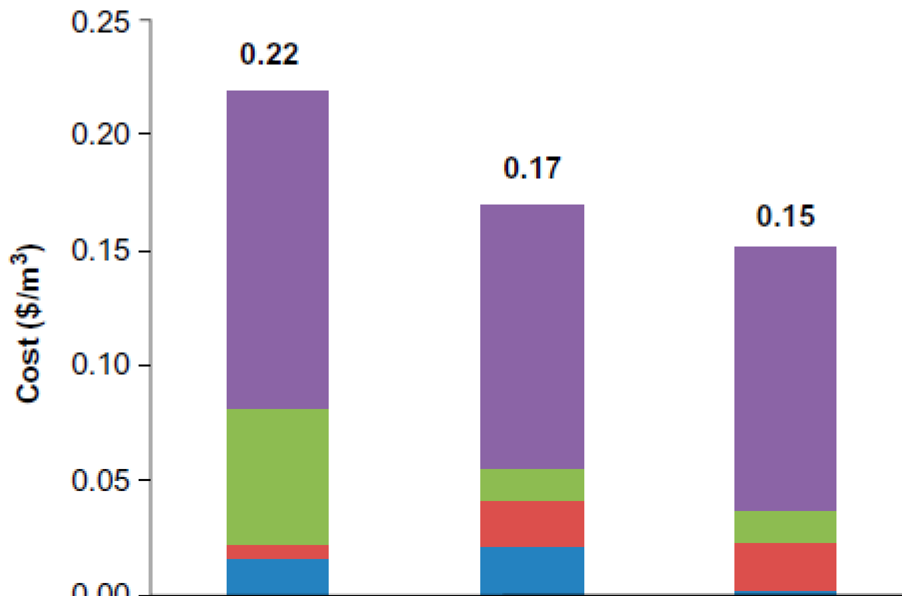
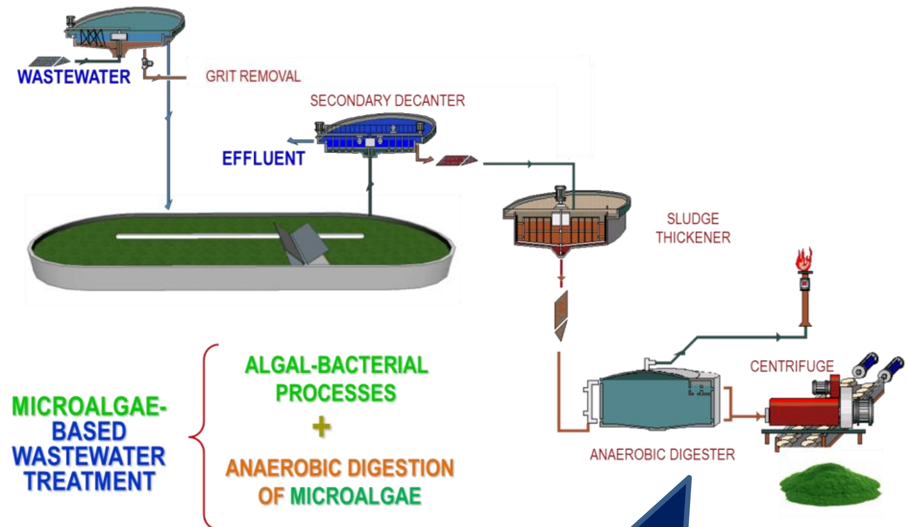


SaltGae
algae to treat saline wastewater

MICROALGAE-BASED WASTEWATER TREATMENT



	Activated sludge WWT	ALGAE WWT	ALGAE WWT + Biofertilizers
Fixed costs	0.138	0.115	0.115
Electricity	0.058	0.014	0.014
Chemicals	0.007	0.020	0.020
Residues disposal	0.015	0.020	0.002

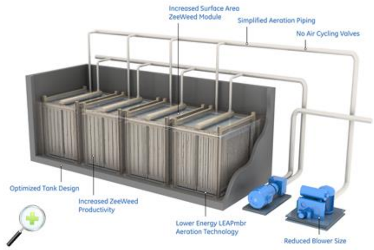


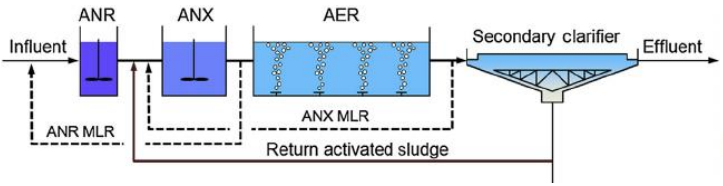
Energy consumption 4 times lower

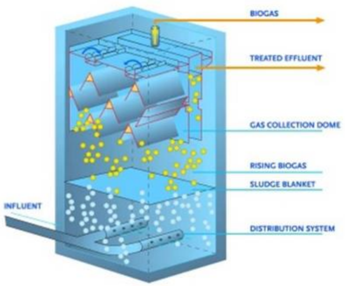
SaltGae algae to treat saline wastewater

MICROALGAE-BASED WASTEWATER TREATMENT

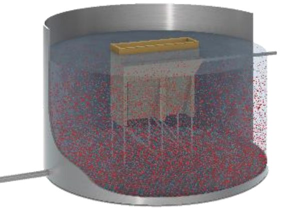
> 100 years of R&D *vs* < 10 years of R&D







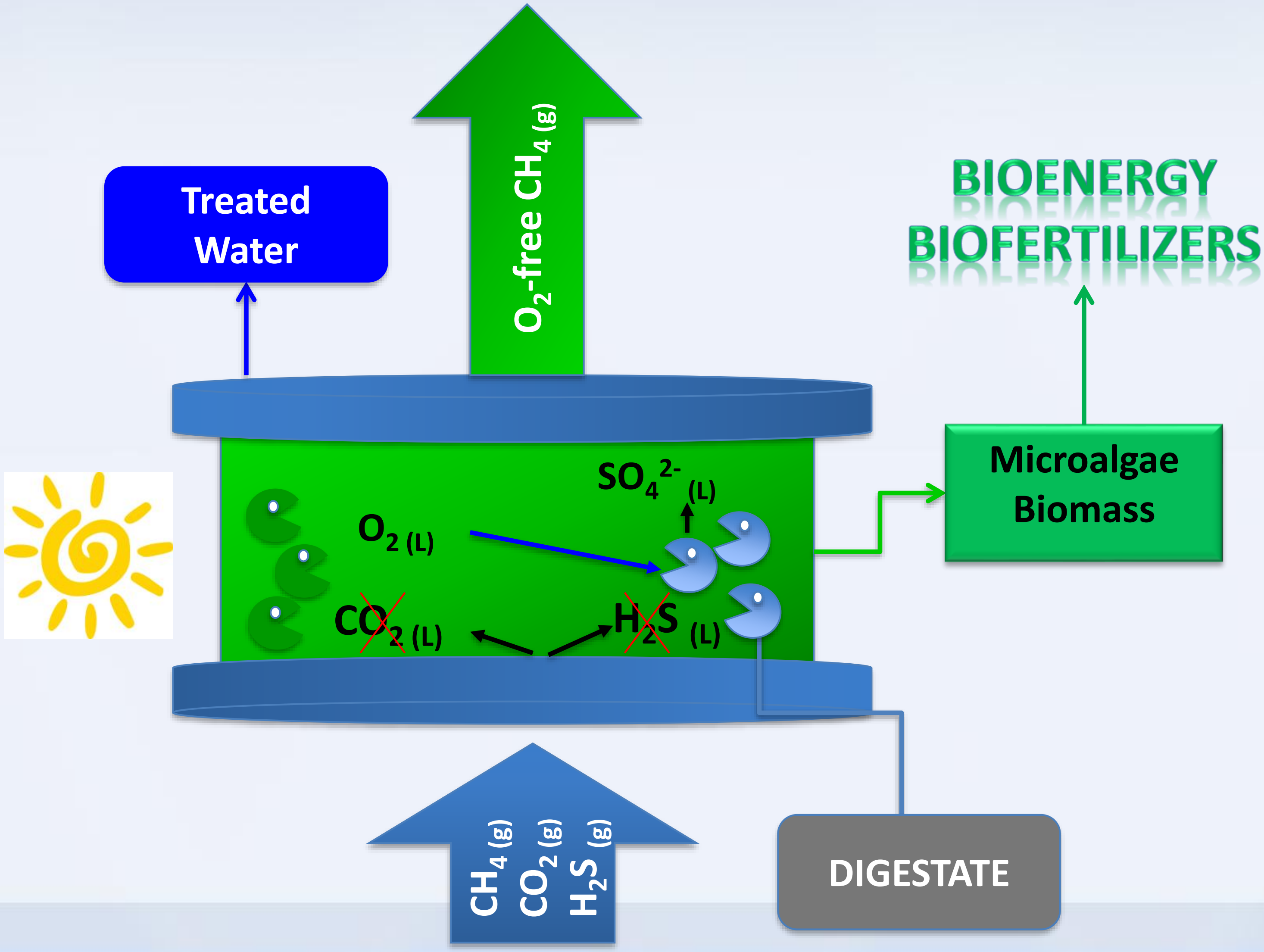
vs



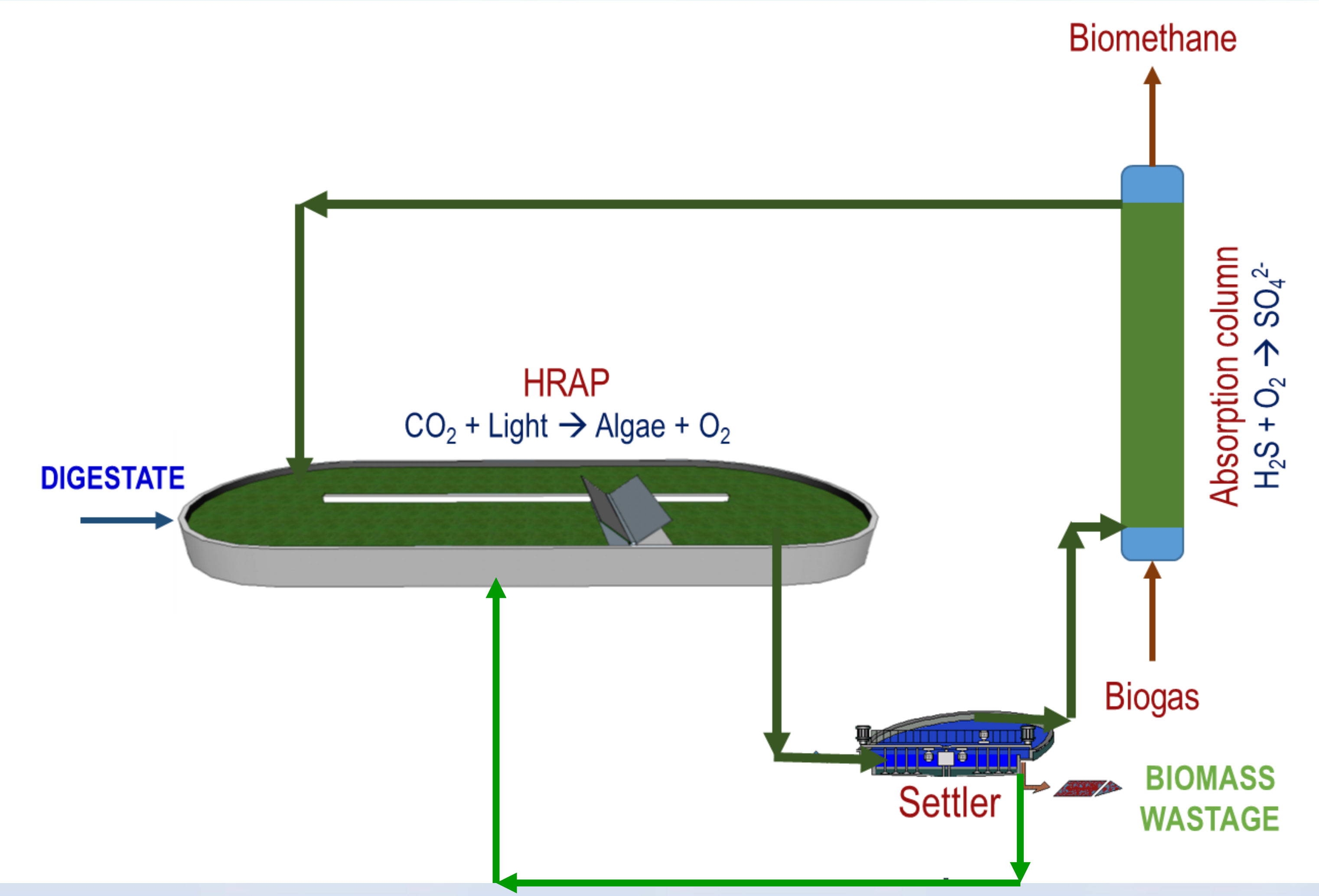
Limitations and on-going research to enhance nutrient recovery……

- ✓ Limited process performance in wastewaters with low C/N ratio
- ✓ Poor biomass sedimentation → operation costs ↑↑
- ✓ Limited biomass valorization → economic balance €€ ↓↓
- ✓ Limited experience at large scale → credibility ↓↓
- ✓ N_2O emissions?? → Environmental Sustainability ↓↓??
- ✓ Emerging Pollutants Removal??→ Biomass utilization??

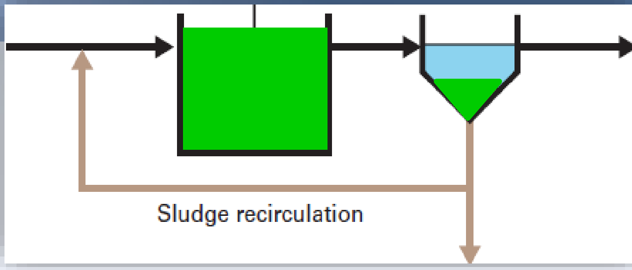
CO_2 supplementation from Biogas boosting microalgae-based nutrient recovery



CO_2 supplementation from Biogas boosting microalgae-based nutrient recovery

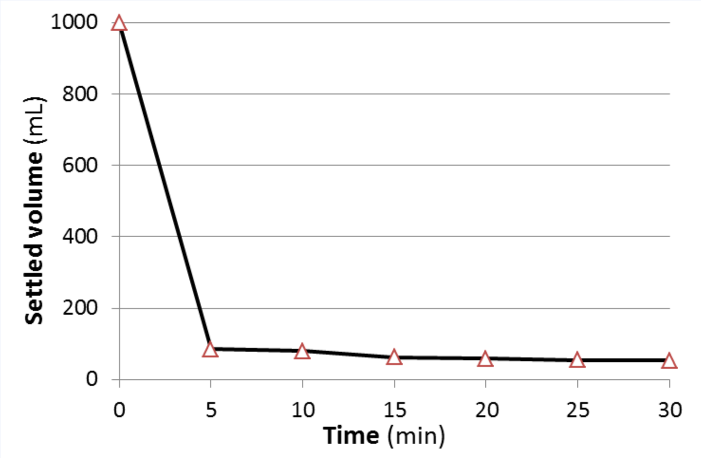


CO_2 supplementation from Biogas boosting microalgae-based nutrient recovery



Biomass settling and recycling allows for……

- ✓ **Process operation at 2000-3000 mg TSS/L and at low HRT**

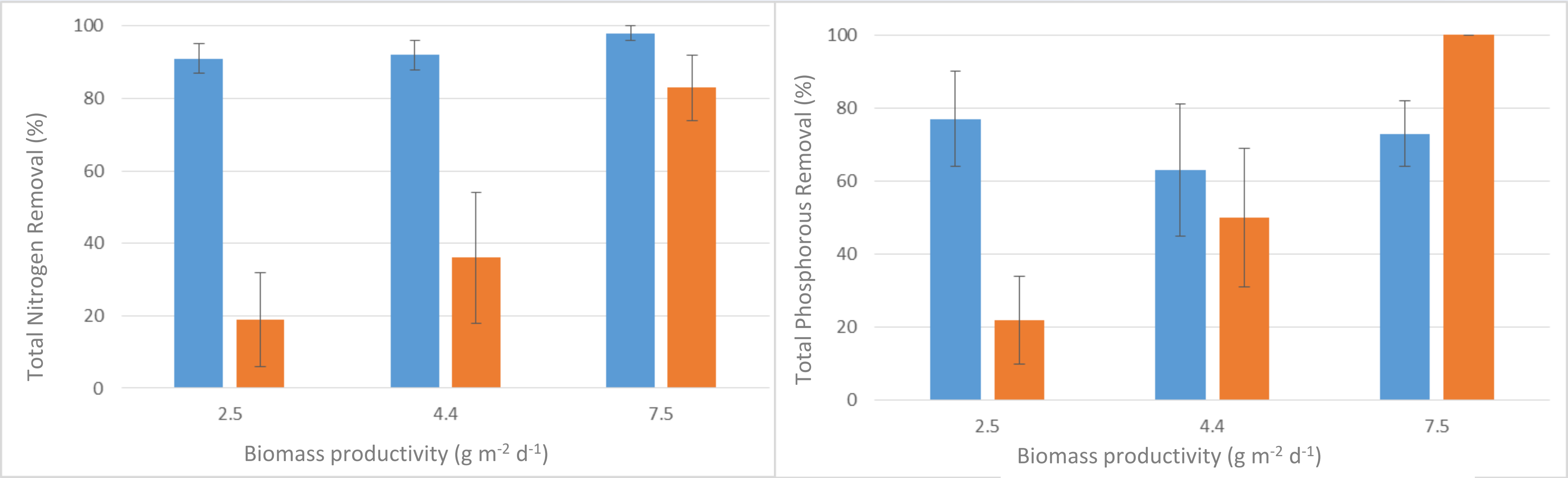


(Alcántara et al. 2015)

- ✓ **High biomass sedimentation rates**
  (1.5 – 2 m/h)

- ✓ **Low effluent TSS concentrations**
  (26±12 mg TSS/L)

CO_2 supplementation from Biogas boosting microalgae-based nutrient recovery



Removal

Recovery as Algal Biomass

Successful Demo scale microalgae-based WWT

Basic research

2010

Pilot plant 200m^2

2011

Prototype 1000m^2

2014

DEMO I 20000 m^2

2017

Successful Demo scale microalgae-based WWT

Impacts per hectare

1000 m3/d WWT
5000 PE
(0,2€/m3)

950 m3/d
reuse
(0,3€/m3)

0,3kWh/m3
energy saving in
WWT

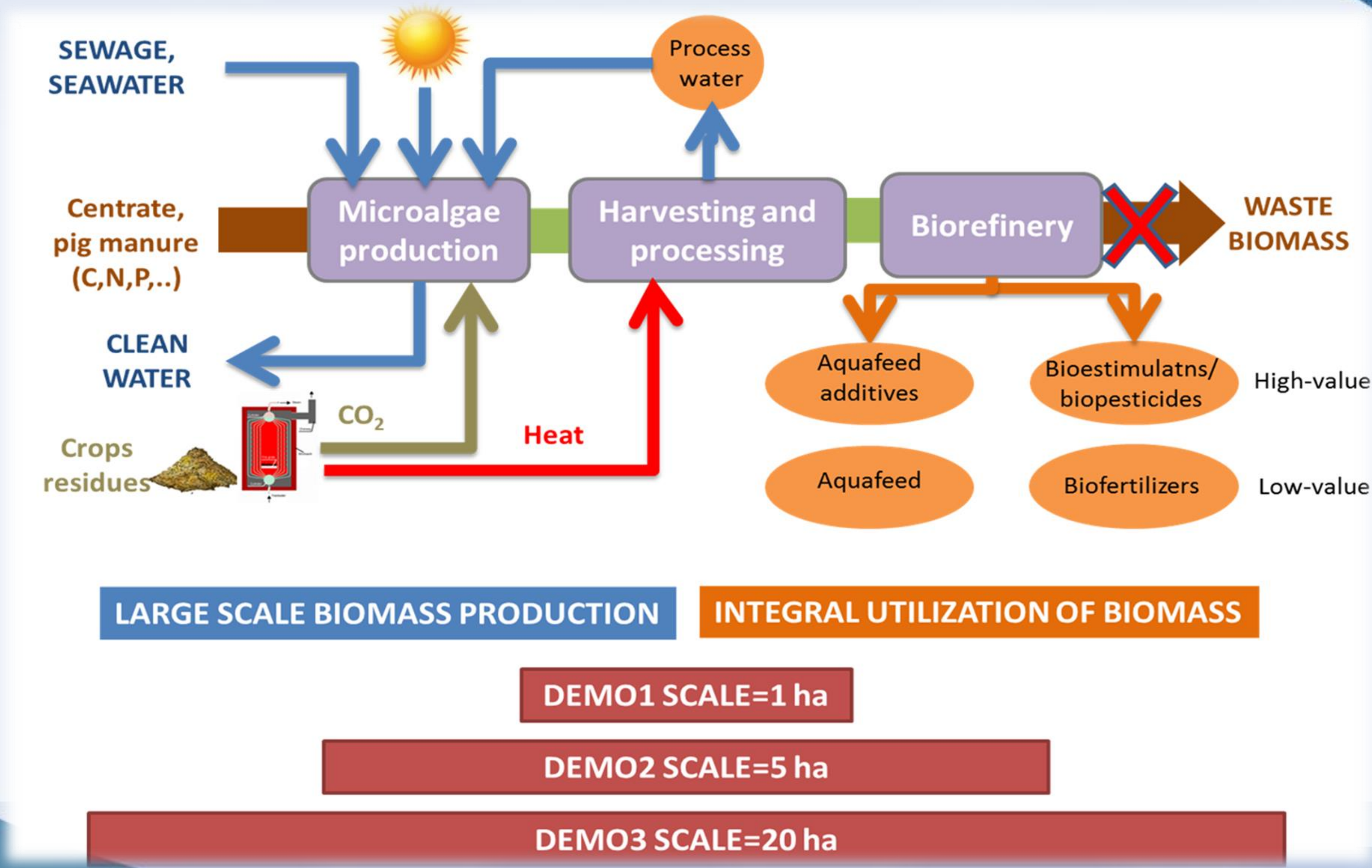
100 Ton/ year
Algal biomass

13,000 kg
CH4/year

10 cars
30.000 km/year/car

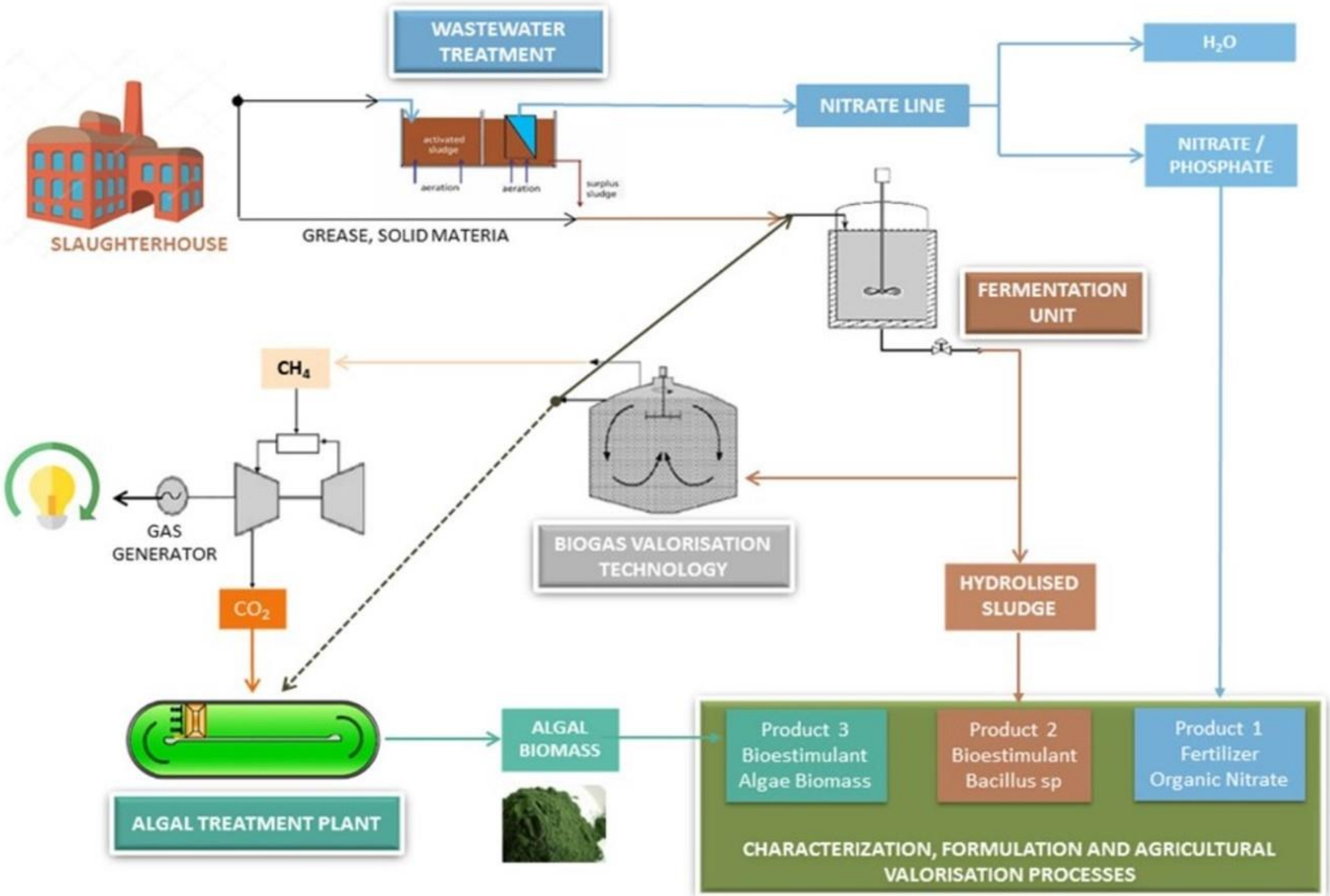
40-60 Ton/ year
biomass for
biofertilzers

Successful Demo scale microalgae-based WWT



Demo scale microalgae-based WWT

Successful Demo scale microalgae-based WWT



WATER LINE
SRM1: Nitrates concentrate
AP1: Organic fertiliser based on nitrates

SLUDGE LINE
SRM2: Hydrolysed sludge
AP2: Biostimulant based on *Bacillus sp*. biomass

ALGAE LINE
SRM3: Algal biomass
AP3: Biostimulant based on algal biomass

+

ENERGY RECOVERY MODULE
Biogas + CO_2 released

Successful Demo scale microalgae-based WWT

Camporosso Demo

Ljubljana demo

Arava Demo

Resins, adhesive, coatings, bio-composites

Biomass valorisation

Energy (biogas)

Brine

Saline waste water

Sludge valorisation

Algal pond

Effluent valorisation

Clean water

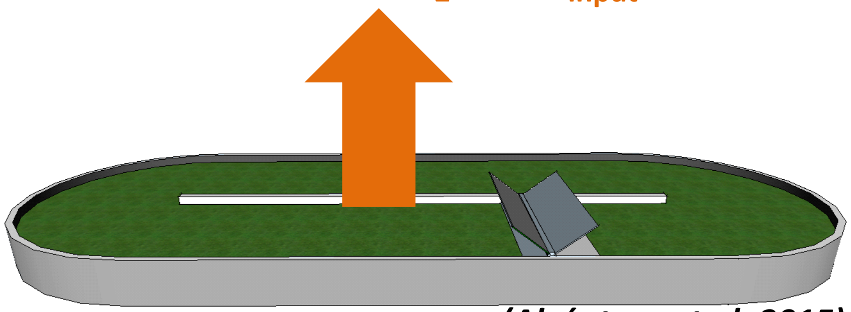
Pre-treatment COD removal

N & P removal

Salinity removal

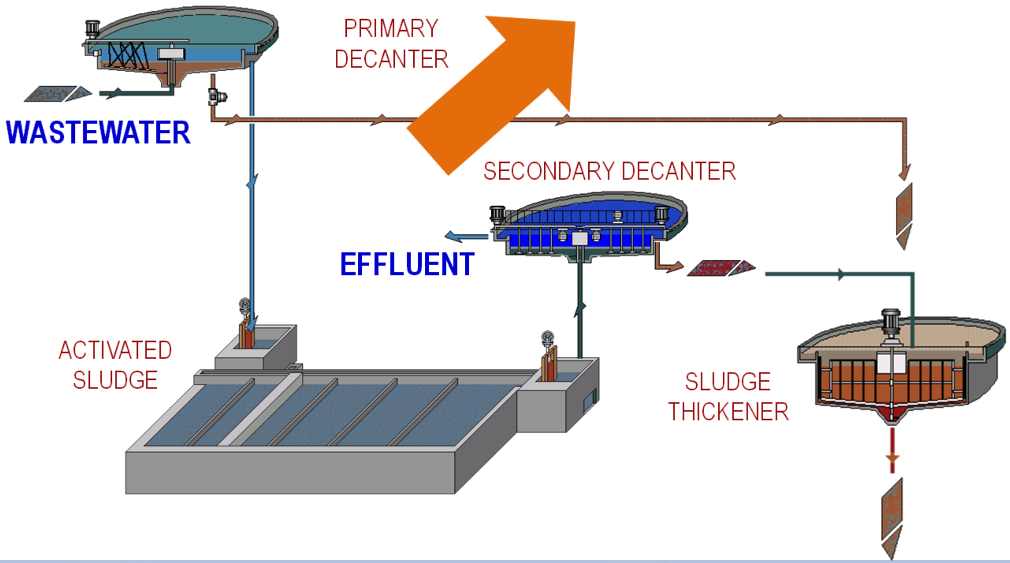
Assessing Environmental Sustainability: Quantifying N_2O emissions

~5×10^{-5} g $N\text{-}N_2O$/g N_{input}



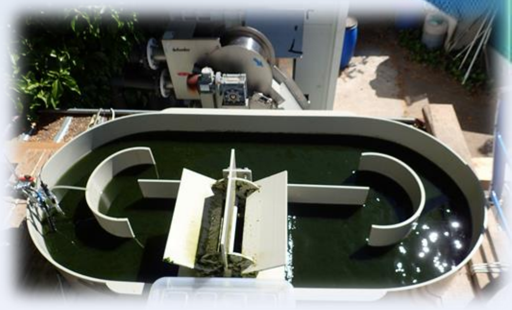
(Alcántara et al. 2015)

~ $\times 10^{-3}$ g $N\text{-}N_2O$/g N_{input}

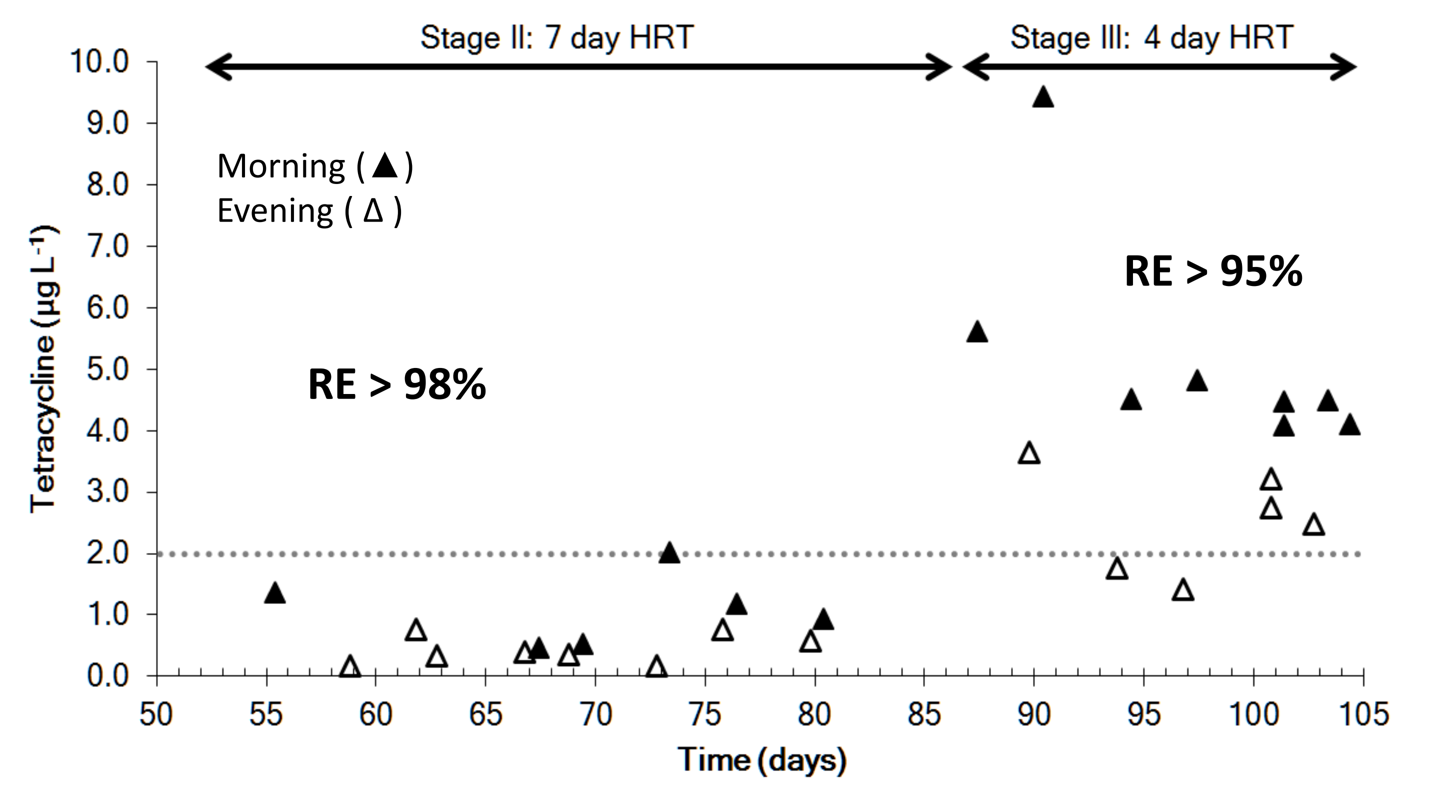


Emerging pollutant removal in algal-bacterial photobioreactors

- **Treatment of domestic WW doped with 100 µg l^{-1} of tetracycline at HRTs of 7 and 4 days.**



- **Photolysis as the main mechanisms of removal**



SaltGae
algae to treat saline wastewater

Take home messages

- ❑ CO_2 supplementation from biogas represents a cost-effective strategy to boost nutrient recovery during microalgae-based WWT while producing biomethane
- ❑ Biomass recycling promotes the enrichment of biomass with good settling capacity
- ❑ Innovative operational strategies decoupling the HRT from the SRT allows controlling biomass productivities and nutrient recovery
- ❑ Nutrient recovery using microalgae has been validated at large scale
- ❑ Valorization of residual biomass has been validated at large scale
- ❑ N_2O emissions in algal-bacterial systems are 100 times lower than in Activated Sludge processes
- ❑ Effective emerging pollutant removal by photolysis is not expected to jeopardize biomass valorization

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Take home messages

Thank you for your Attention

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