

Reusing urban and industrial effluents to unlock the potential of microalgae

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CIESOL



Phoenix



Introduction

What are microalgae?

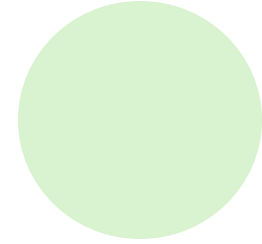
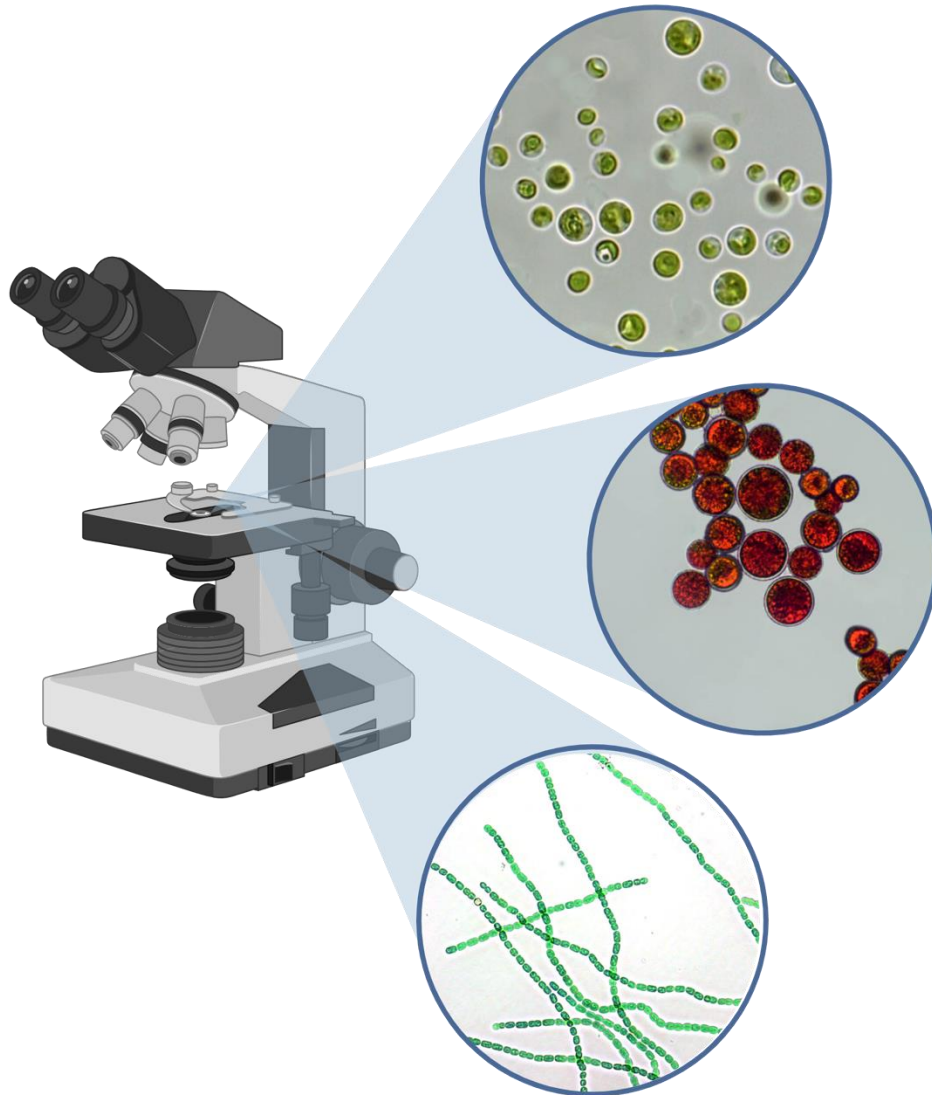
What have they done for us?

What are they doing now?



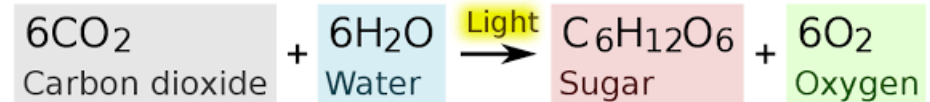
What are microalgae?

Much more than a single cell



- Microscopic (1-10 μm)
- High growth rate (10-36 h)
- Phototrophs (energy source: light)
- Autotrophs (carbon source: CO_2)

- Photosynthetic organisms:



What are microalgae?

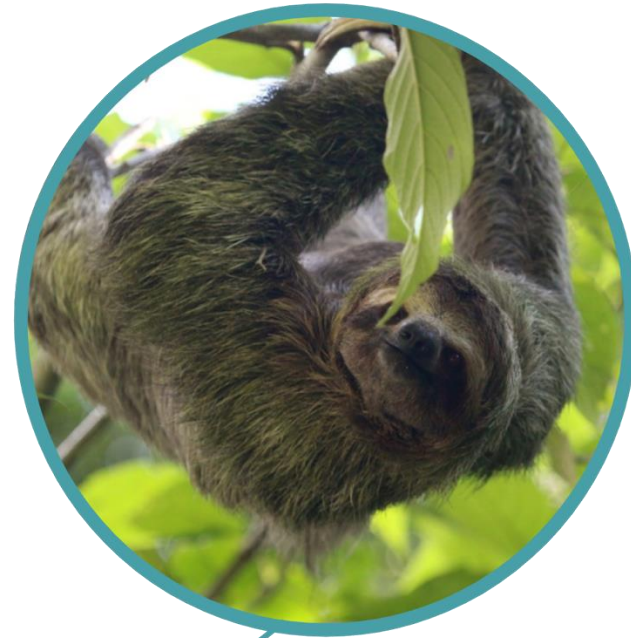
Much more than a single cell

Patagonia, Argentina



Pink lake, Australia

Sloth, Costa Rica

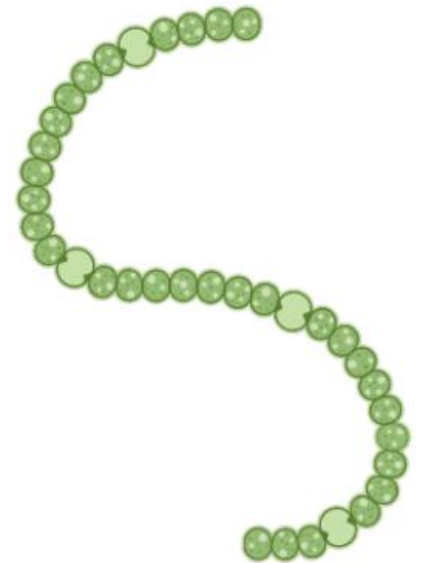




What are microalgae?

What have they done for us?

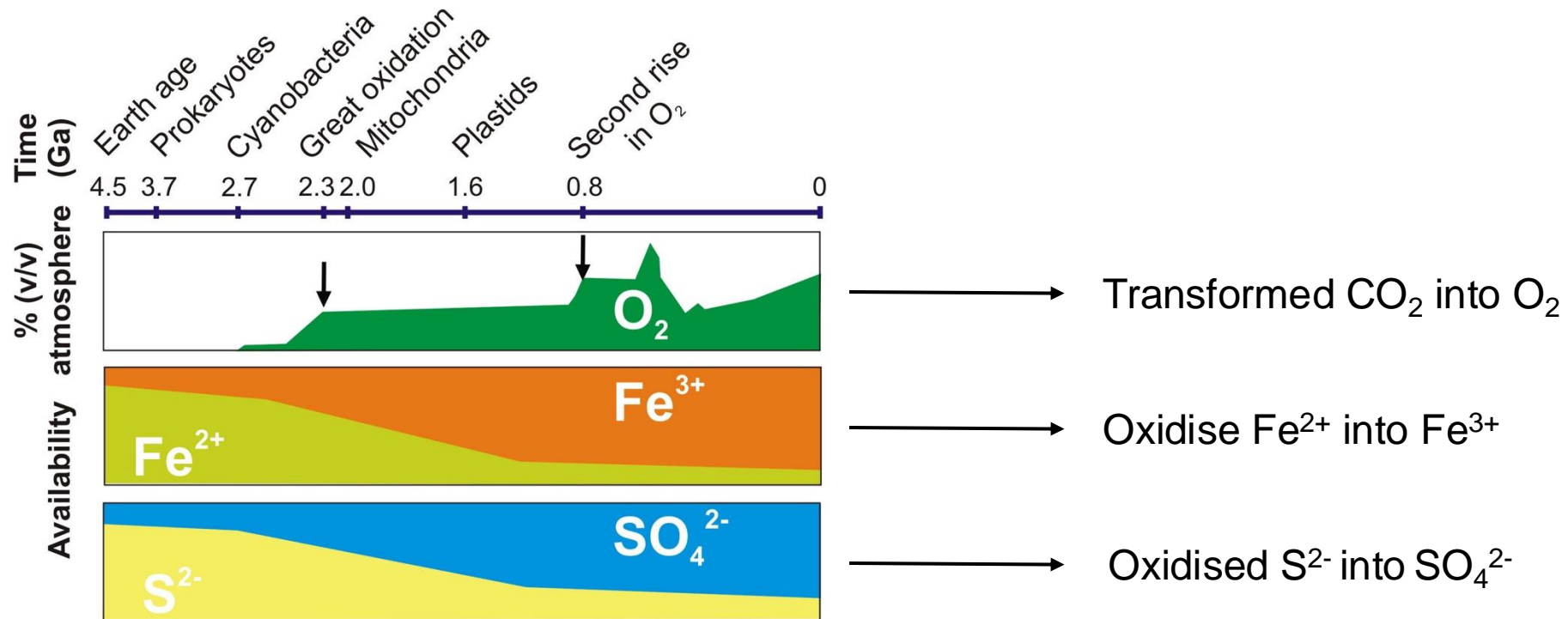
What are they doing now?



What have they done for us?

They transformed the atmosphere...

Life in Earth originated about 3.5 billion years ago in an **anaerobic environment** where oxygen was largely absent and **Fe²⁺ and sulphide plentiful**...

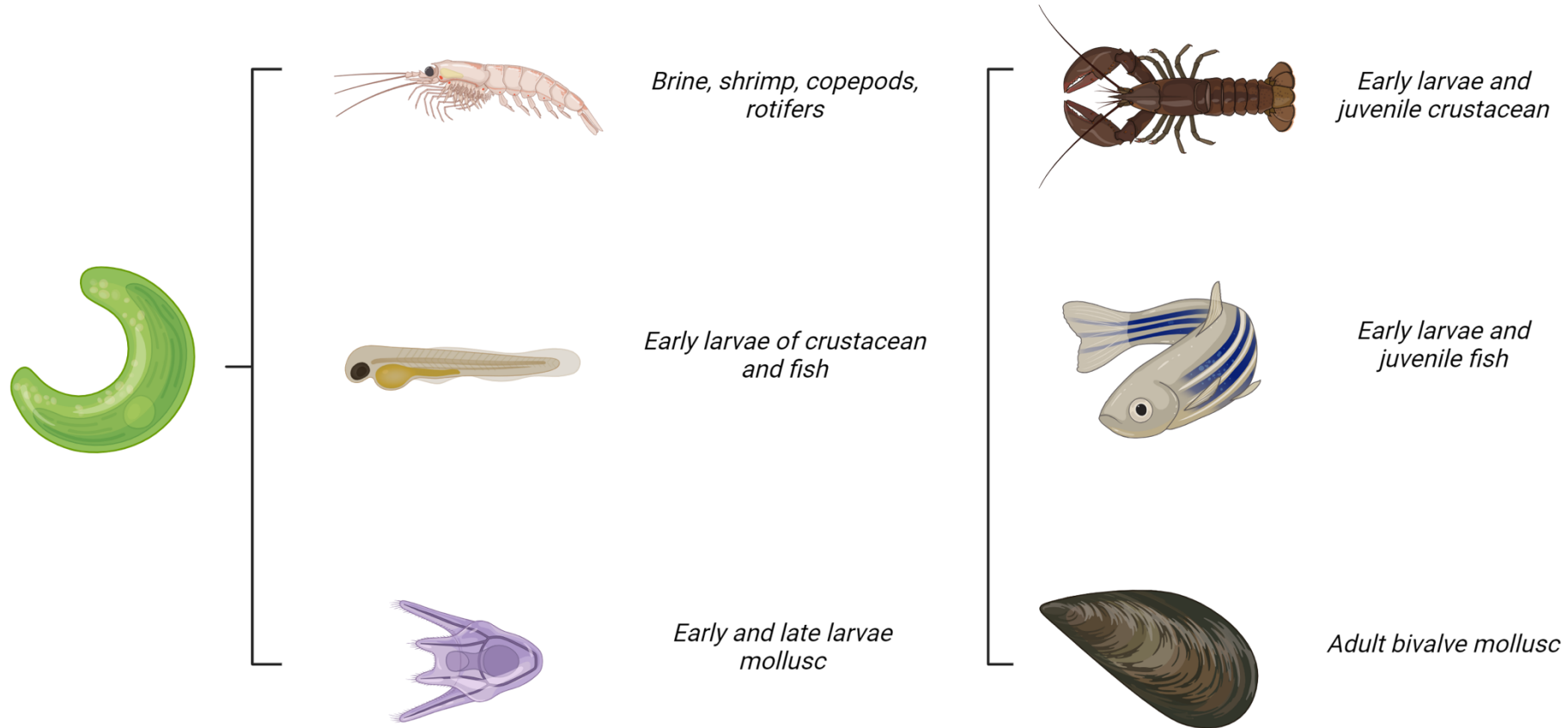


Lodeyro et al. (2012) FEBS Letters 586:2917-2924.

What have they done for us?

... and obviously water

Microalgae are at the base of the ocean food chain. They transform inorganic matter into biomass and permitted the appearance of thousands of aquatic and land animals.



What have they done for us?

They also transformed soil...



White cliffs of Dover,
UK



Seven sisters cliffs,
UK

Microalgae transformed huge amounts of CO₂ into limestone (calcareous stone), modifying not just air but also the Earth's surface.

What are microalgae?

What have they done for us?

What are they doing now?



What are they doing now?

They continue to do the same...



<50%



>50%

What are they doing now?

We can use them as feedstock for valuable products!



Does oil really come from microalgae?

That sounds like an opportunity



Does oil really come from microalgae?

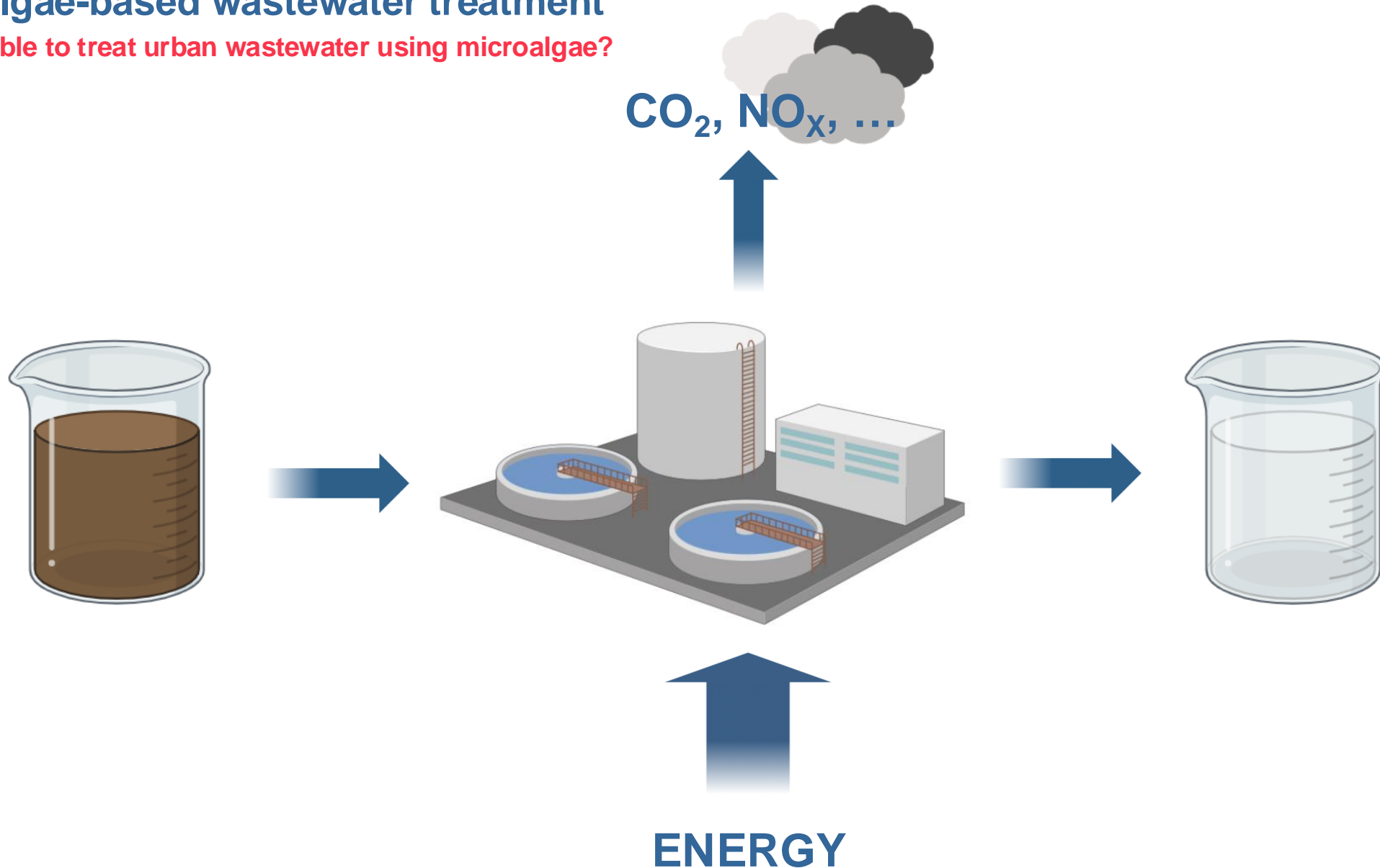
That sounds like an opportunity

The screenshot shows the European Commission website. At the top left is the European Commission logo. To its right is a language selector set to 'EN' and a search bar. Below the navigation bar, the breadcrumb trail reads: 'Home > Publications > Communication from the Commission: Towards a strong and sustainable EU algae sector'. The main heading is 'COMMUNICATION' followed by 'Communication from the Commission: Towards a strong and sustainable EU algae sector'. A link below the heading states: 'All language versions of the communication are available in EUR-Lex'. On the left side, there is a 'PAGE CONTENTS' menu with 'Details' selected. To the right of the menu, the 'Publication date' is listed as '15 November 2022' and the 'Author' is 'Directorate-General for Maritime Affairs and Fisheries'.



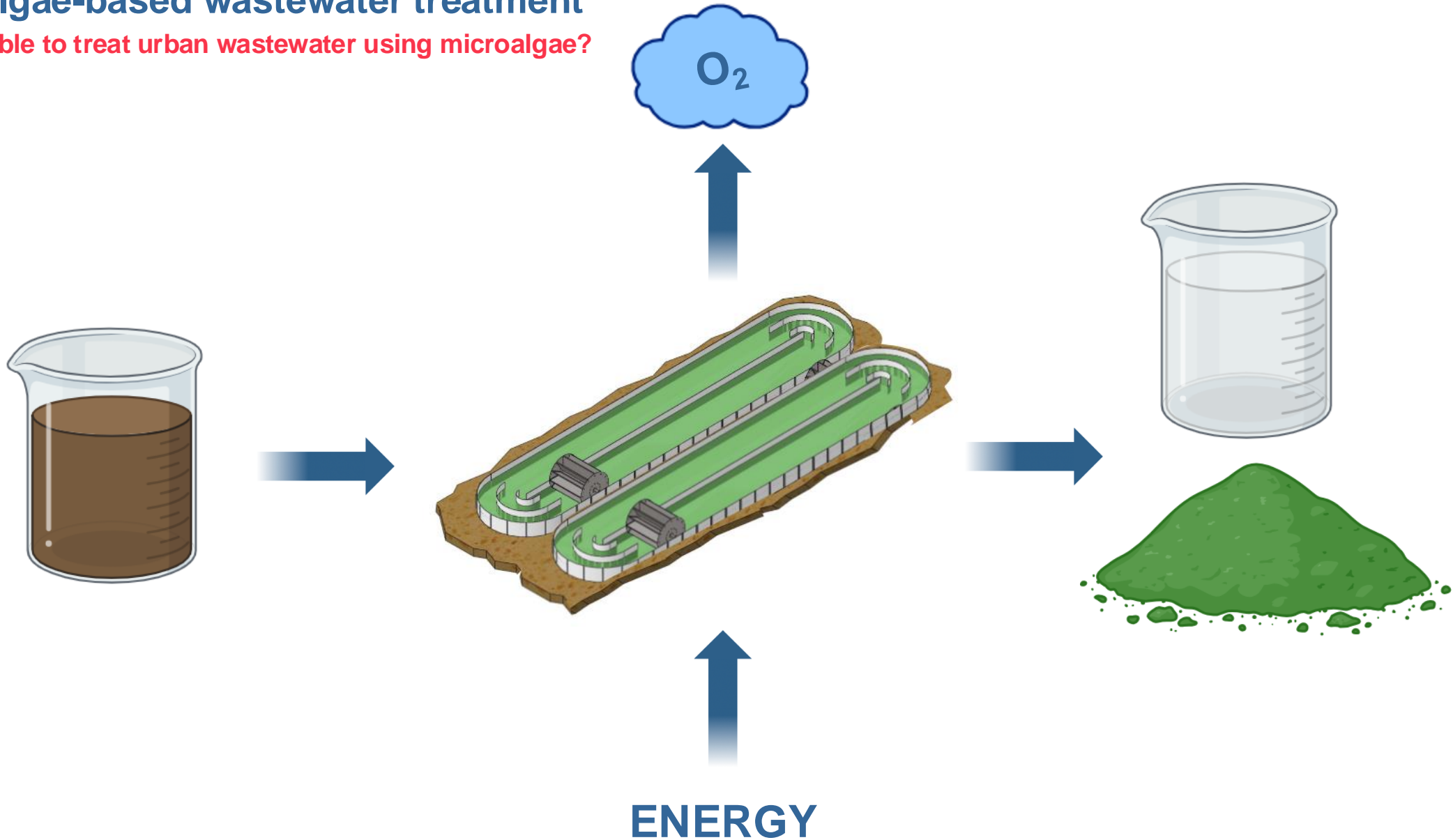
Microalgae-based wastewater treatment

Is it possible to treat urban wastewater using microalgae?



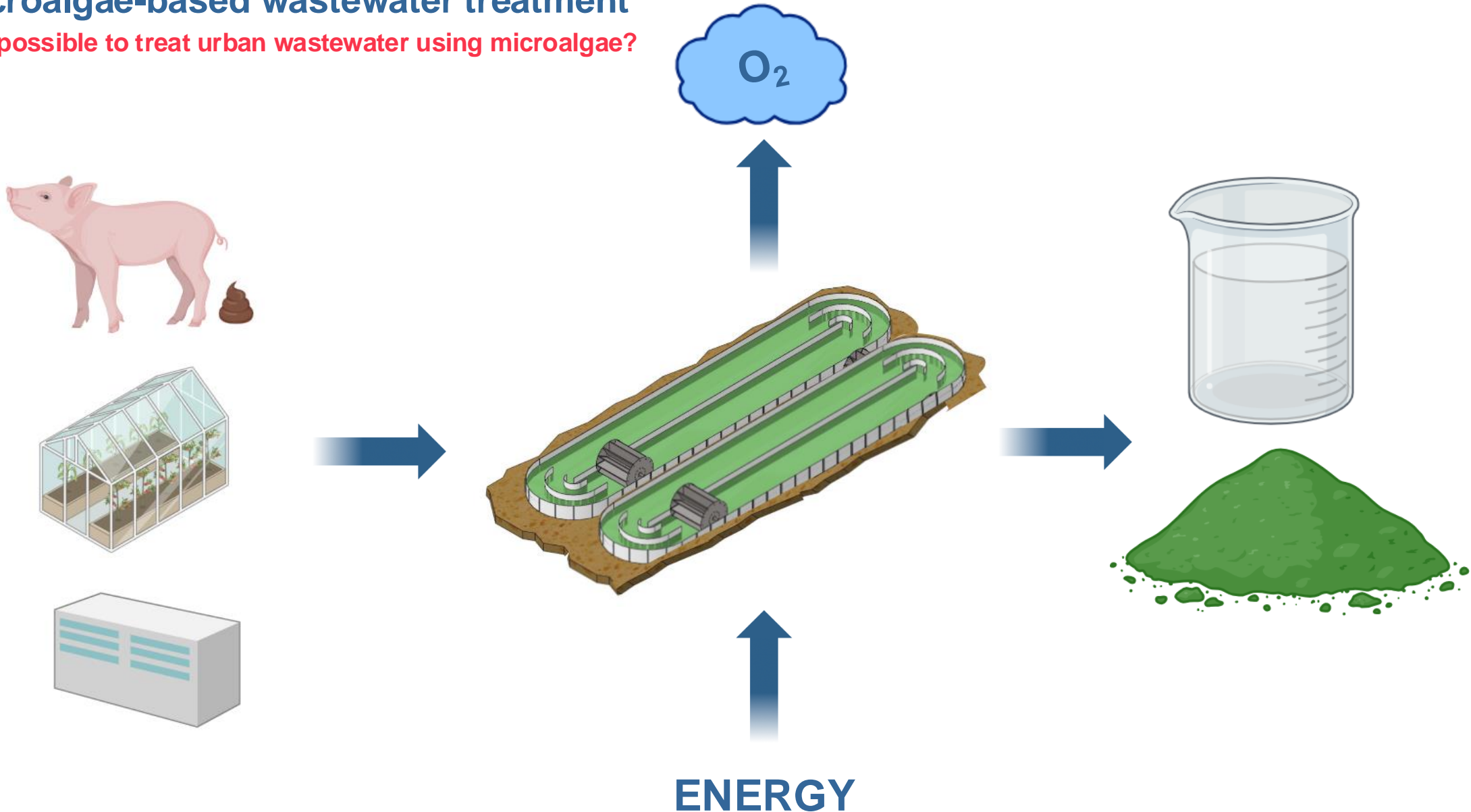
Microalgae-based wastewater treatment

Is it possible to treat urban wastewater using microalgae?



Microalgae-based wastewater treatment

Is it possible to treat urban wastewater using microalgae?

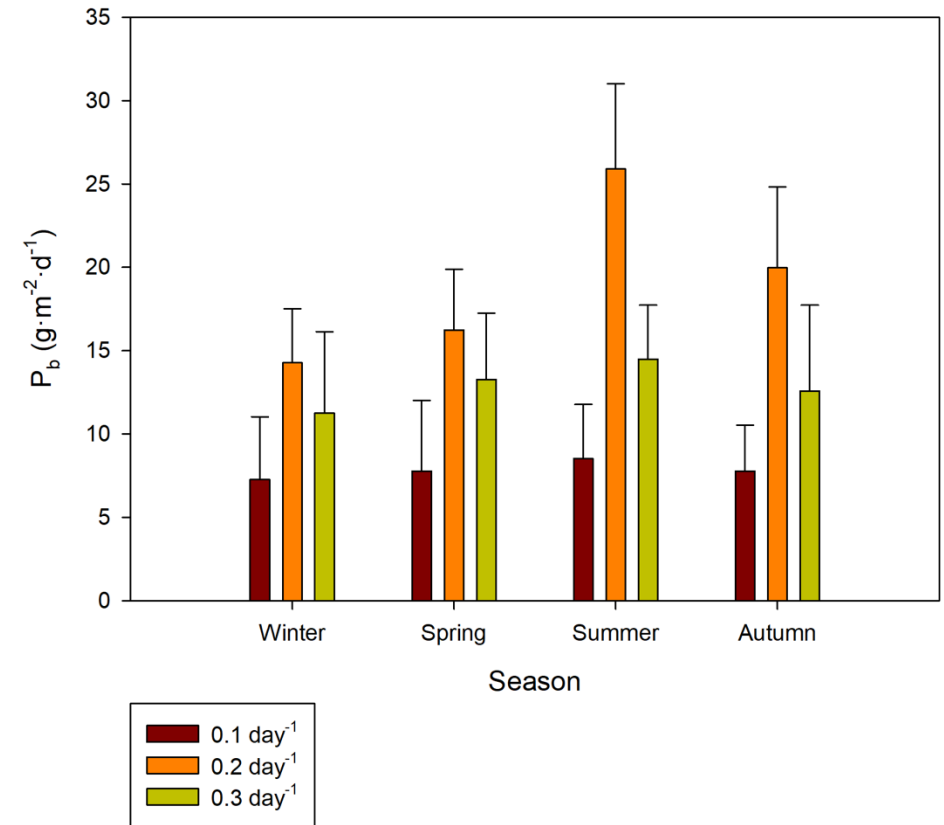




Does it really work?

Is it possible to produce microalgae using wastewater?

Yes, it is!

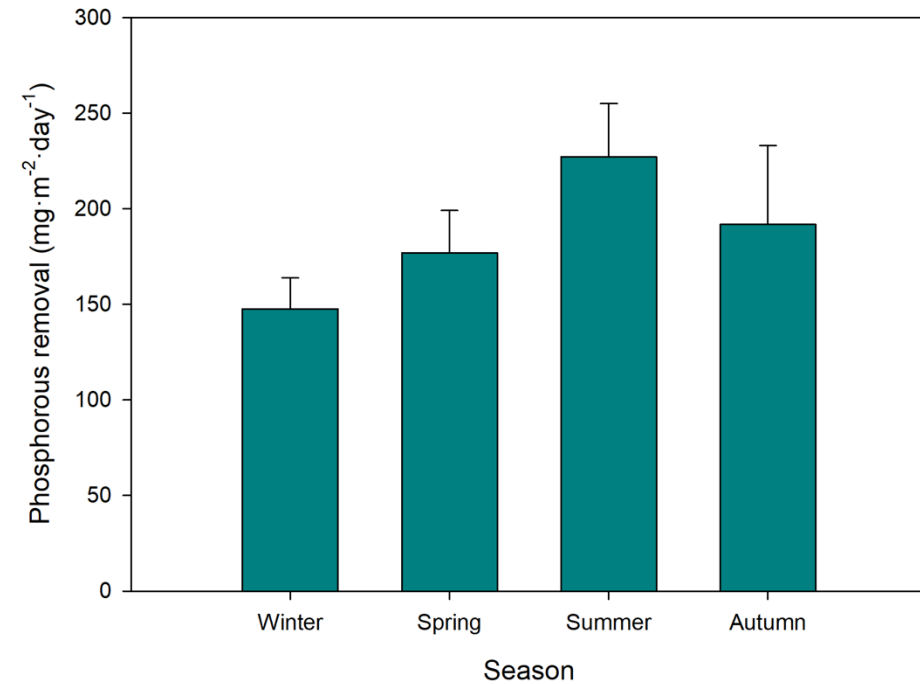
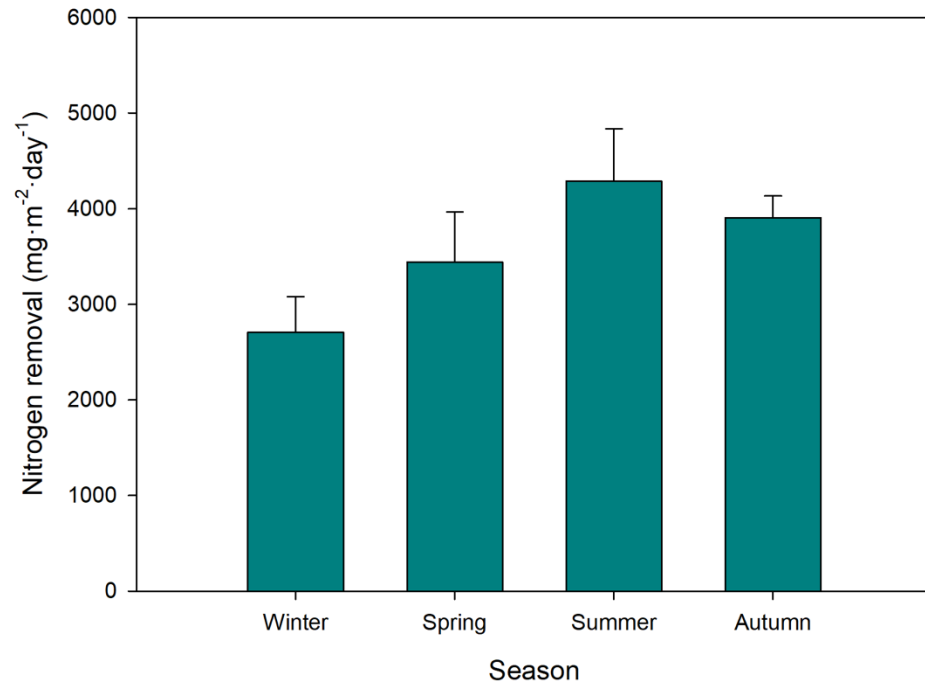


Biomass productivities in the range $10\text{-}25 \text{ g}\cdot\text{m}^{-2}\cdot\text{day}^{-1}$ ($50\text{-}60 \text{ tn}\cdot\text{ha}^{-1}\cdot\text{year}^{-1}$)

Morillas-España et al. (2021) Algal Research 60:102500.

Is it possible to produce microalgae using wastewater?

Nutrient removal: Primary-treated wastewater

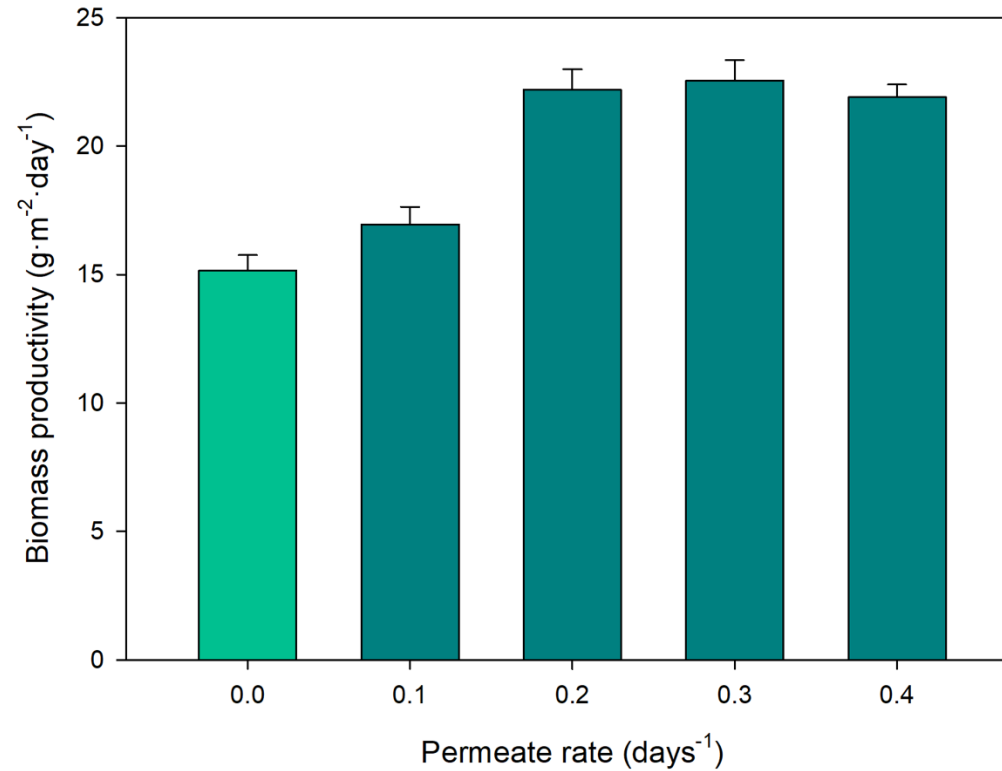
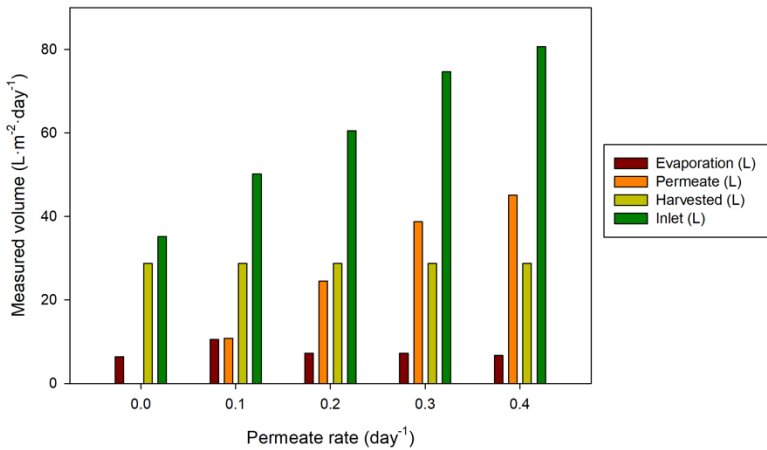
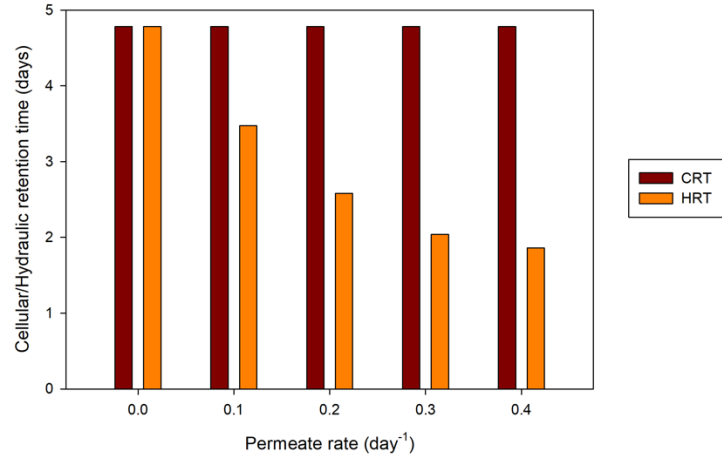


Nitrogen and phosphorus recoveries in the range 9-20 and 0.6-1.0 tn·ha⁻¹·year⁻¹, respectively.

Morillas-España et al. (2021) *Algal Research* 60:102500.

Is it possible to produce microalgae using wastewater?

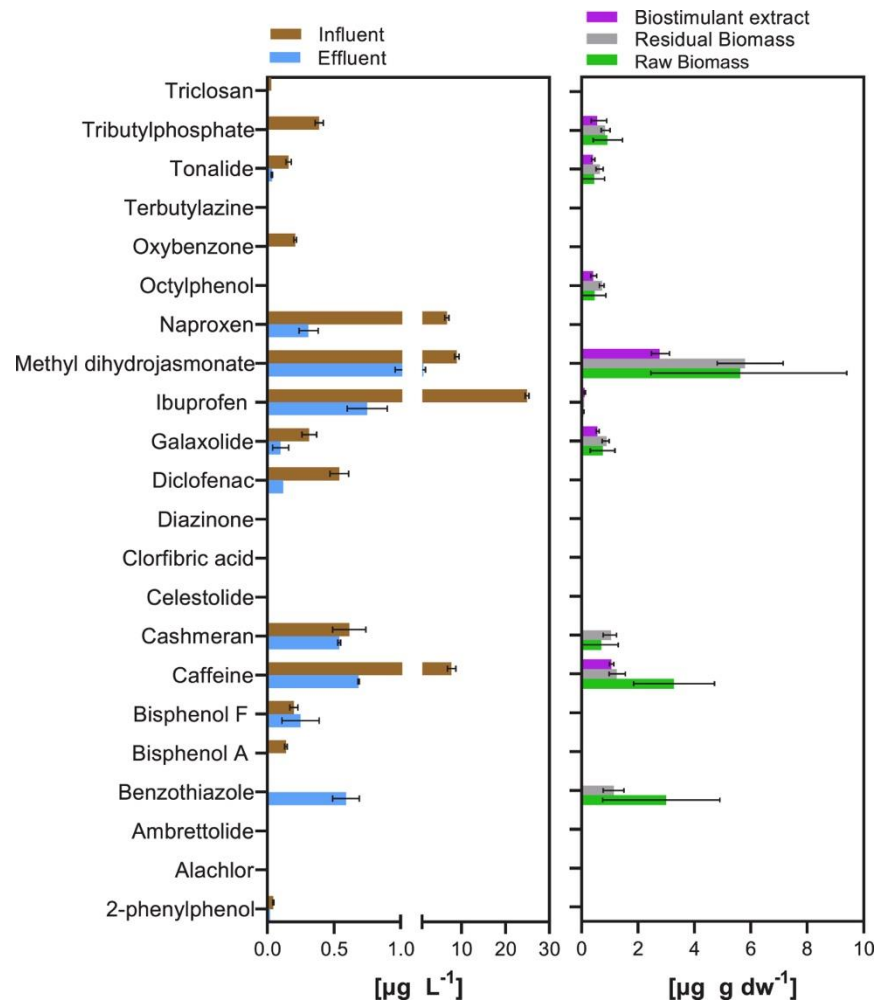
Nutrient removal: Secondary-treated wastewater



By using membranes, we were able to increase the amount of water processed per surface unit by 2-fold

Is it possible to produce microalgae using wastewater?

Emerging contaminants of concern

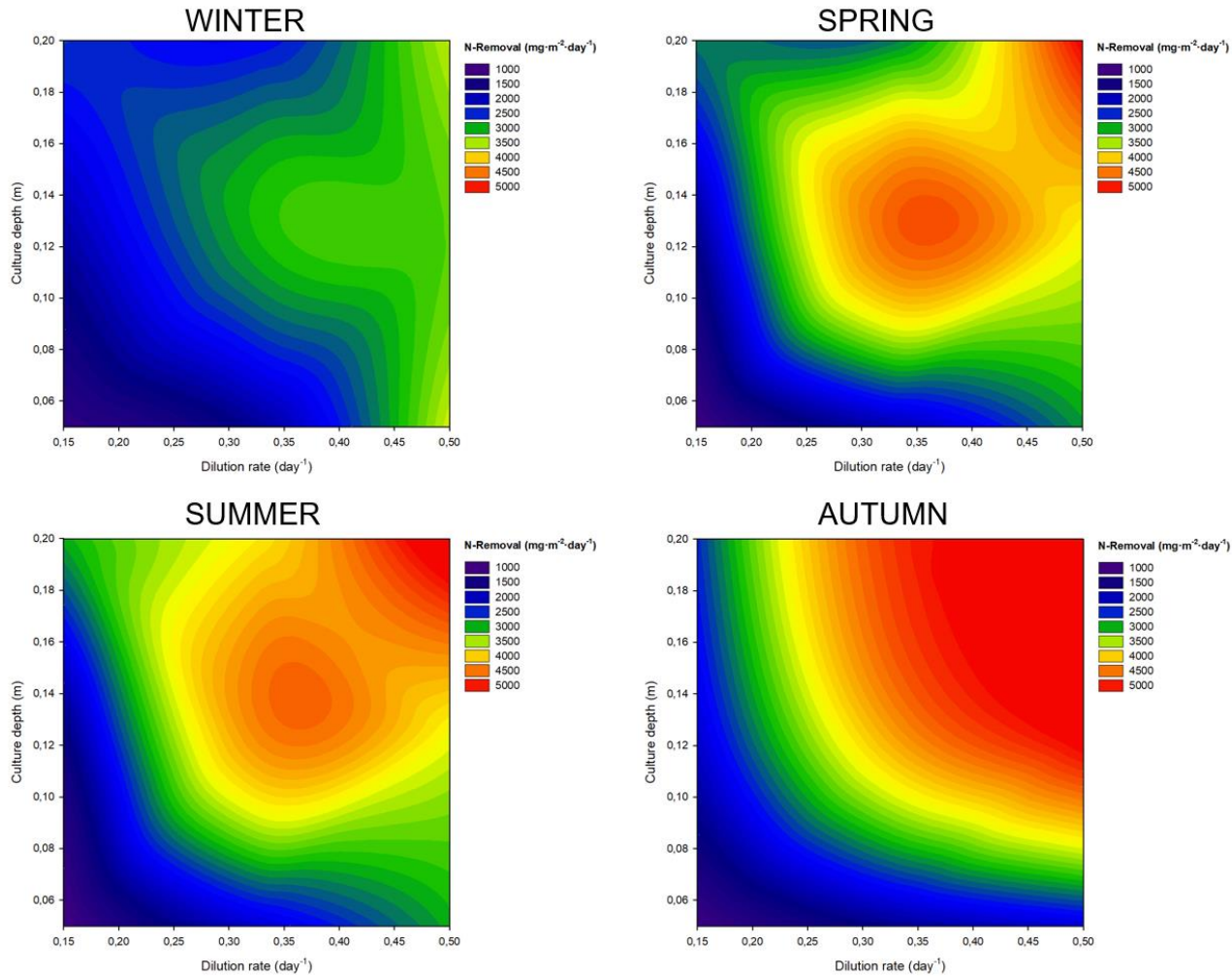


The removal of contaminants of emerging concern was higher than 80%

The biomass was processed into an agricultural product and only 6 out of 22 contaminants were present in the end product (at lower concentrations)

Is it possible to produce microalgae using wastewater?

Effect of operational parameters on nutrient recoveries

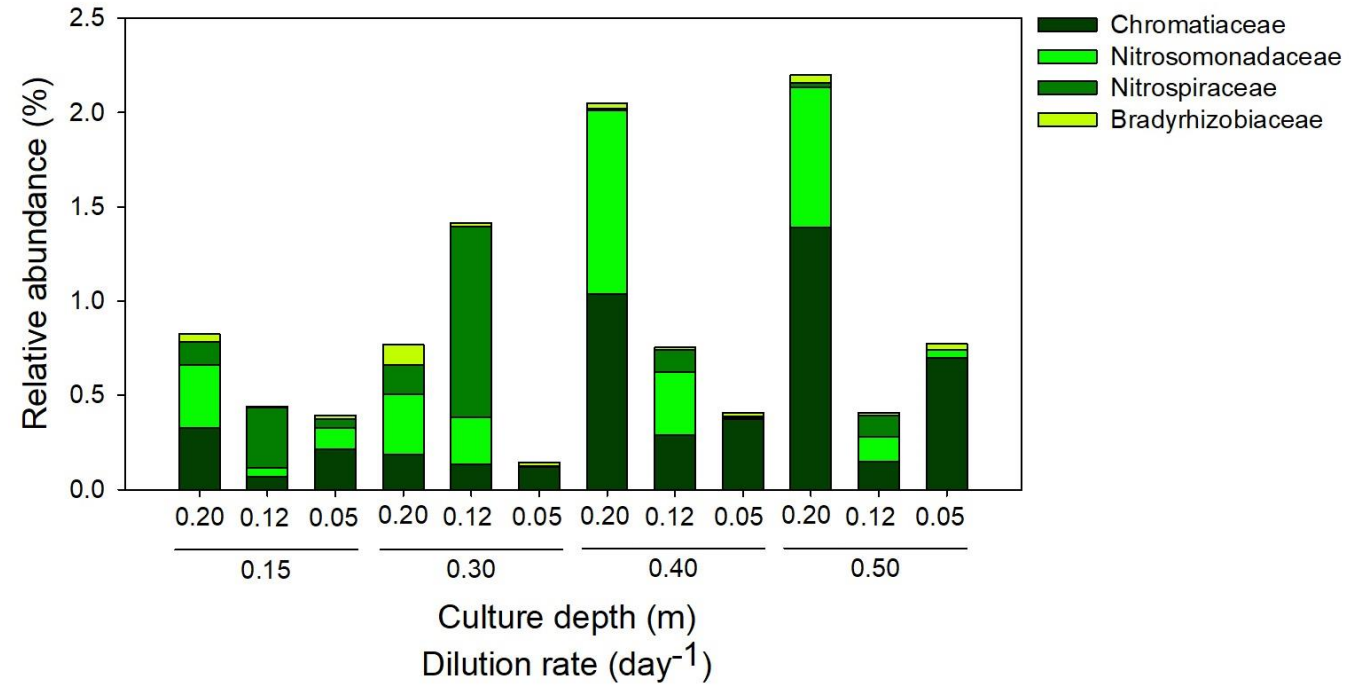
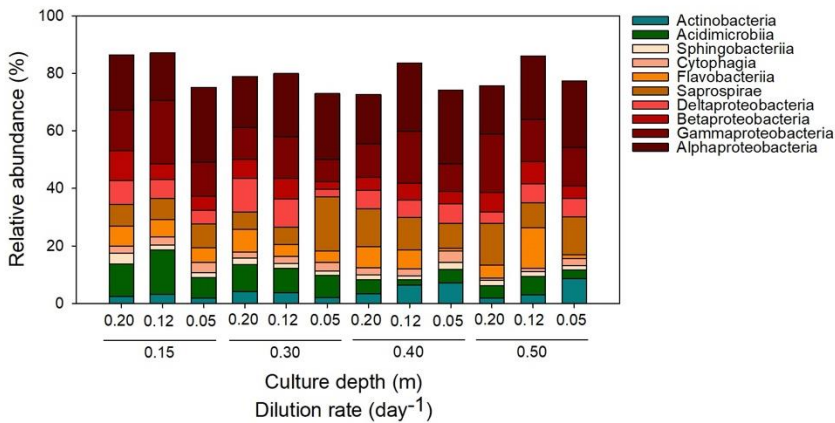
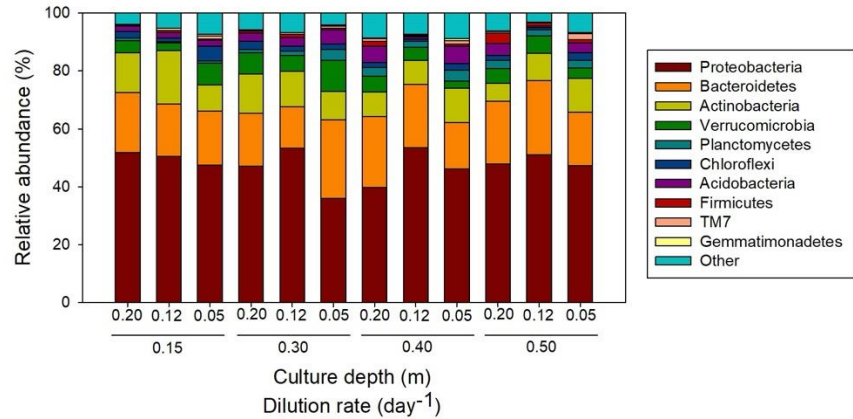


Strong effect of environmental and operational conditions

Overall, higher dilution rates and a depth of 0.2-0.3 m were the best performing conditions

Is it possible to produce microalgae using wastewater?

Effect of operational conditions on the microbial diversity



Operational conditions affect the microbial diversity

The abundance of nitrifying bacteria increased with culture depth

Sánchez Zurano et al. (2021) *Journal of Applied Phycology* 33:3885-3897

Is it possible to produce microalgae using wastewater?

Effect of operational conditions on the microbial diversity



Mérida

INFRAESTRUCTURAS

Mérida recibe un premio nacional por su planta de tratamiento de aguas residuales basada en microalgas

Se trata de la mayor instalación de este tipo en toda Europa, con una inversión de más de 12 millones de euros



Depuradora de Mérida Canal Extremadura

Hoy es noticia



Mérida recibe un premio nacional por su planta de tratamiento de aguas residuales basada en microalgas

Mérida

INFRAESTRUCTURAS



Mérida recibe un premio nacional por su planta de tratamiento de aguas residuales basada en microalgas

Lo más visto

1

Fallece un trabajador de 30 años en Don Benito tras quedar atrapado por maquinaria pesada

07 OCTUBRE 2024

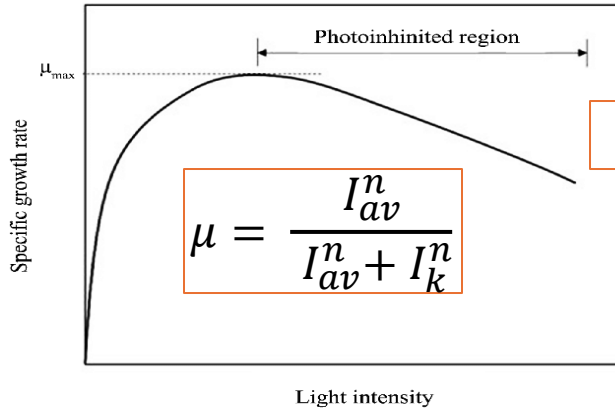
2

Una rejilla metálica provoca la rotura de neumáticos de

Can these numbers be improved?

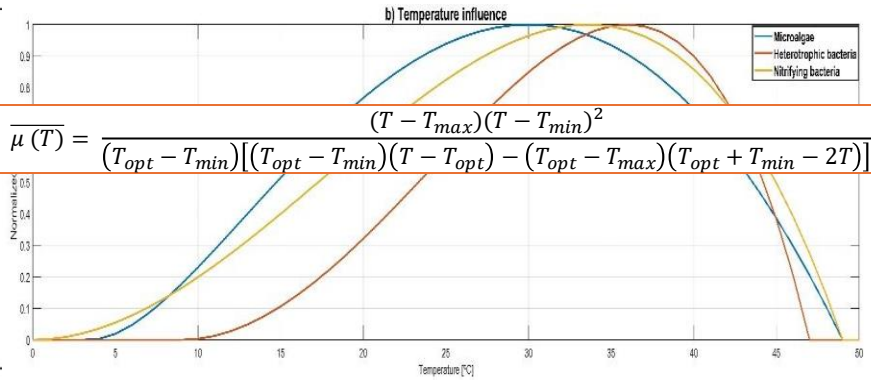
Let's see...

Light



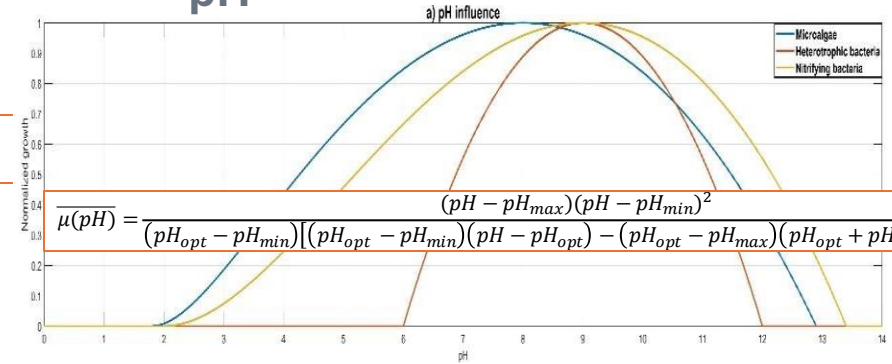
$$\mu = \frac{I_{av}^n}{I_{av}^n + I_k^n}$$

Temperature



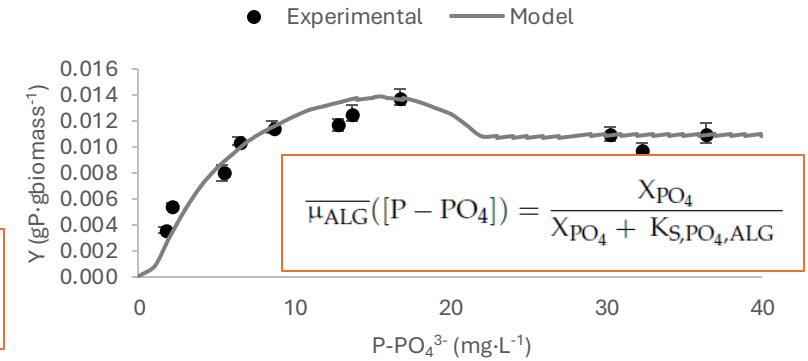
$$\overline{\mu(T)} = \frac{(T - T_{max})(T - T_{min})^2}{(T_{opt} - T_{min})[(T_{opt} - T_{min})(T - T_{opt}) - (T_{opt} - T_{max})(T_{opt} + T_{min} - 2T)]}$$

pH



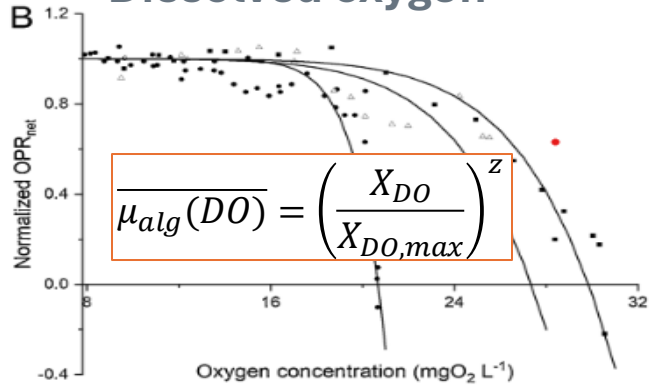
$$\overline{\mu(pH)} = \frac{(pH - pH_{max})(pH - pH_{min})^2}{(pH_{opt} - pH_{min})[(pH_{opt} - pH_{min})(pH - pH_{opt}) - (pH_{opt} - pH_{max})(pH_{opt} + pH_{min} - 2pH)]}$$

Phosphorous



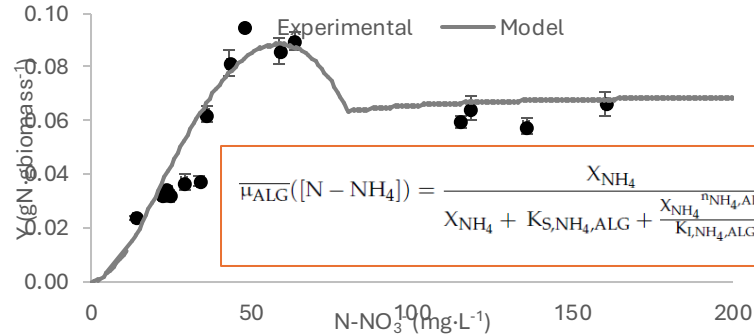
$$\overline{\mu_{ALG}}([P - PO_4]) = \frac{X_{PO_4}}{X_{PO_4} + K_{S,PO_4,ALG}}$$

Dissolved oxygen



$$\overline{\mu_{alg}(DO)} = \left(\frac{X_{DO}}{X_{DO,max}} \right)^z$$

Nitrogen



$$\overline{\mu_{ALG}}([N - NH_4]) = \frac{X_{NH_4}}{X_{NH_4} + K_{S,NH_4,ALG} + \frac{X_{NH_4}^{\theta_{NH_4,ALG}}}{K_{I,NH_4,ALG}}}$$

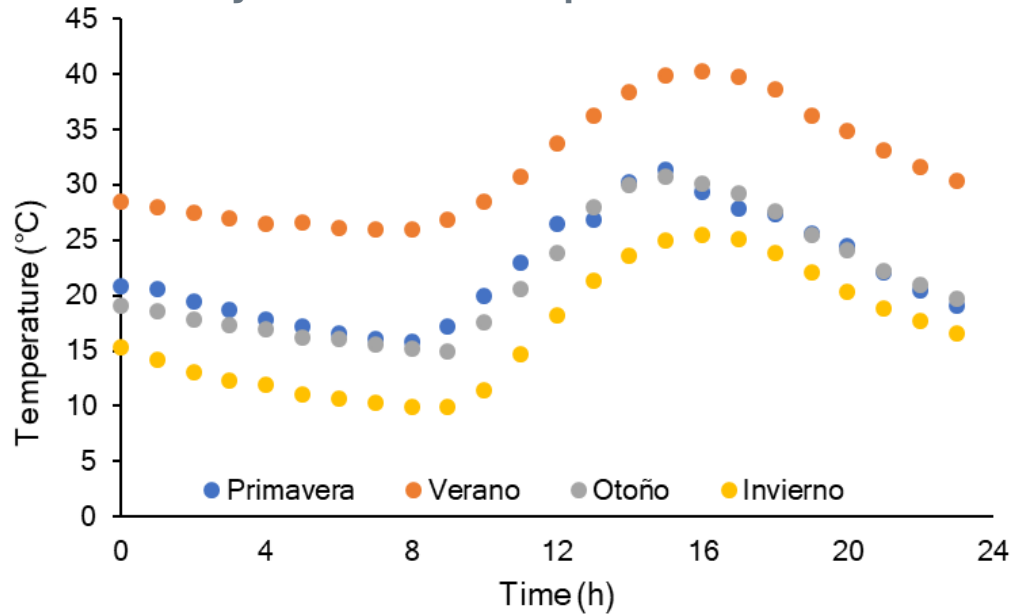
Using a photorespirometer we identified that it is a COMPLEX process, but it can be modelled (ABACO)

Sánchez Zurano et al. (2021) Applied Sciences 11:998

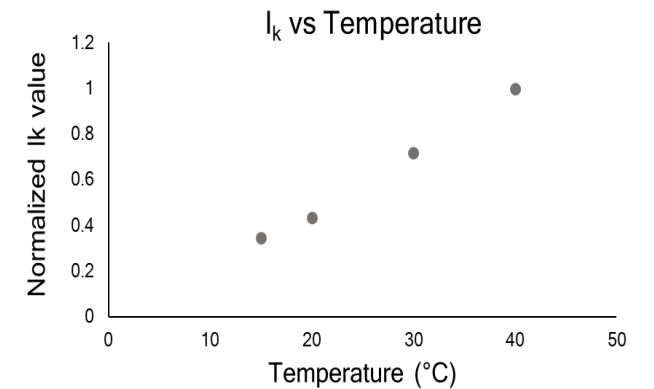
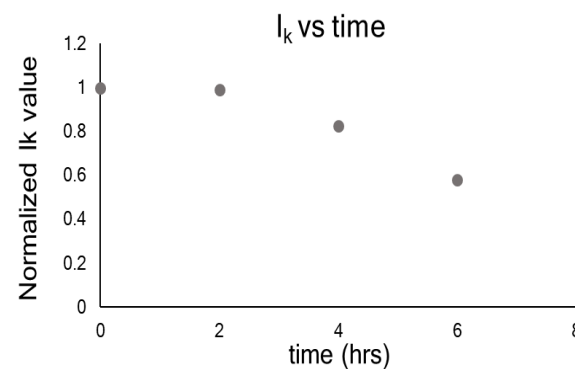
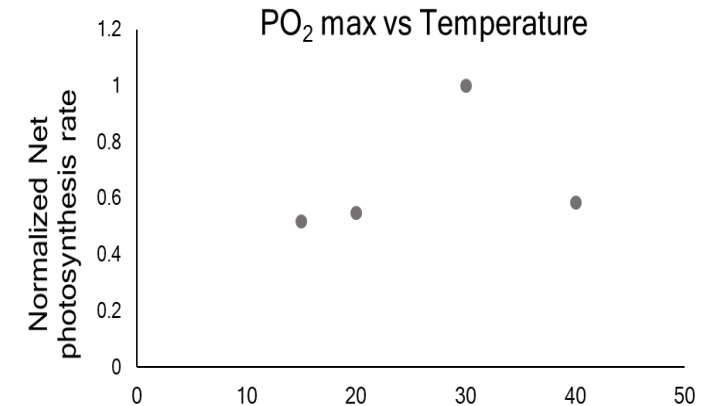
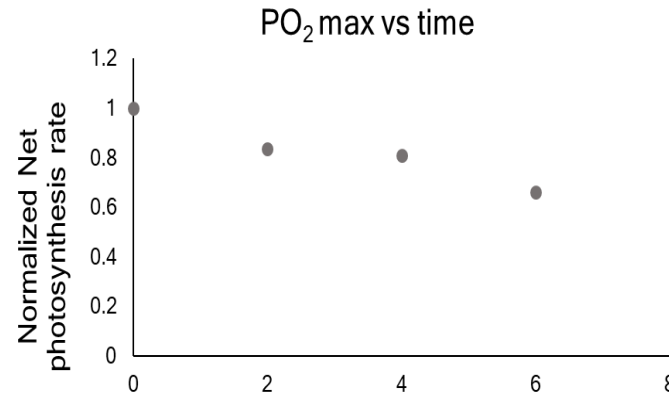
Can these numbers be improved?

Adaptation to the dynamic variation of culture conditions

Daily variation of temperature



Variation of characteristics parameters as a function of adaptation



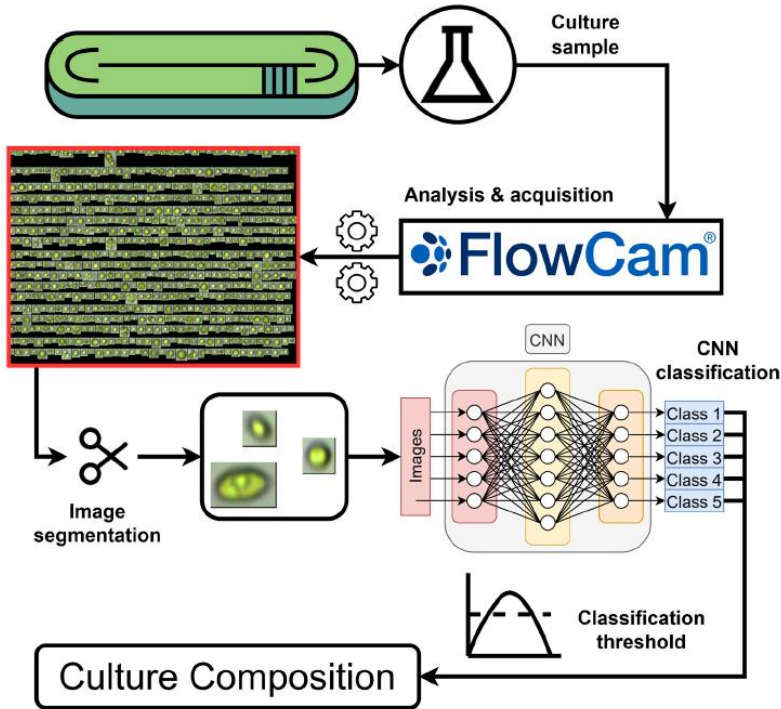
$$PO_2 = \frac{PO_2max \cdot I_{av}^n}{I_k^n + I_{av}^n}$$

Cells modify their response because of dynamic variations of the culture conditions. This means that methods for online monitoring are needed...

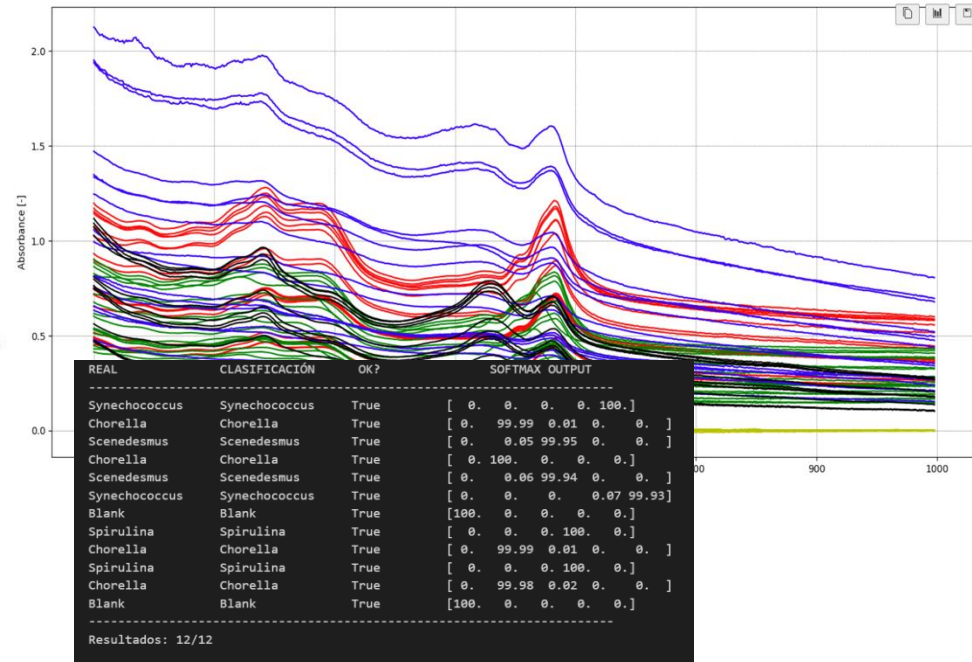
Can these numbers be improved?

Adaptation to the dynamic variation of culture conditions

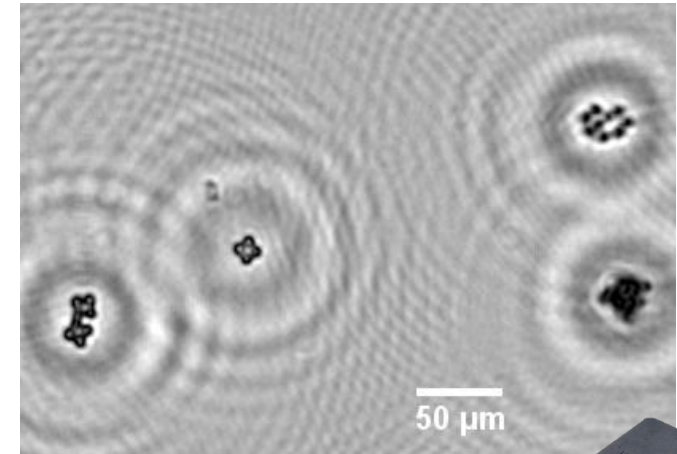
Digital images



Spectrophotometry



Lens Free Images



LFI setup and software for image reconstruction

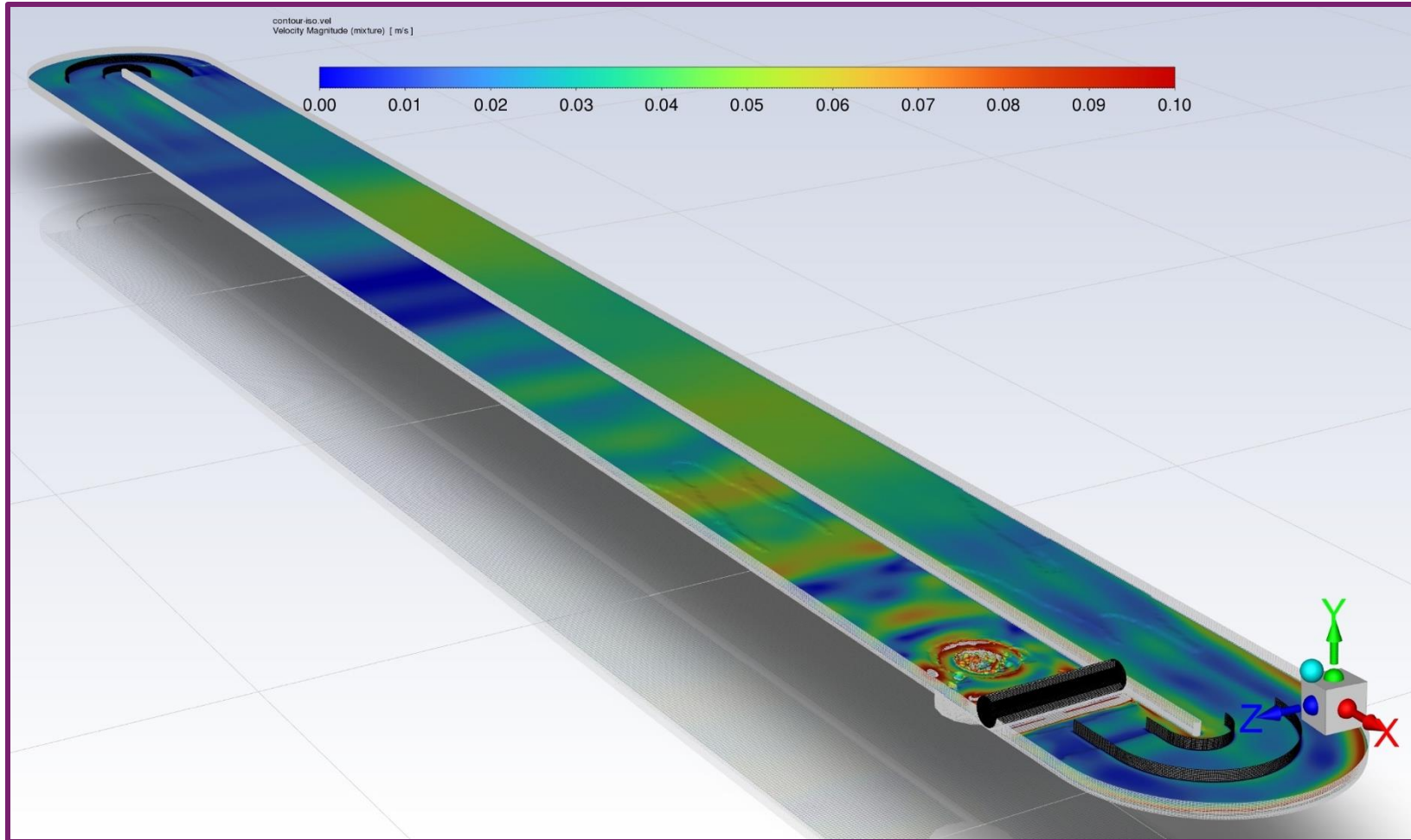


New methods are being developed for the evaluation of cultures, the identification of strains and the detection of parasites

Can these numbers be improved?

What about the photobioreactor?

Computed Fluid-Dynamic tools



The maximum size for a single photobioreactor is smaller than 1ha.

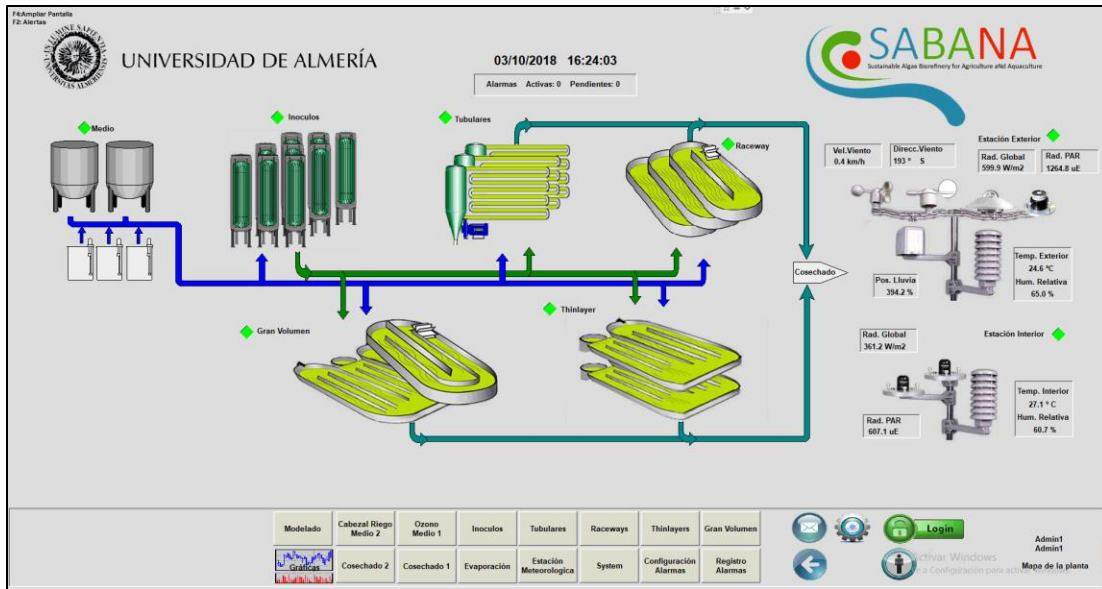
The optimisation of the sump and the turbulence in the channels might increase productivity and nutrient recoveries by approximately 20%

Can these numbers be improved?

What about the photobioreactor?

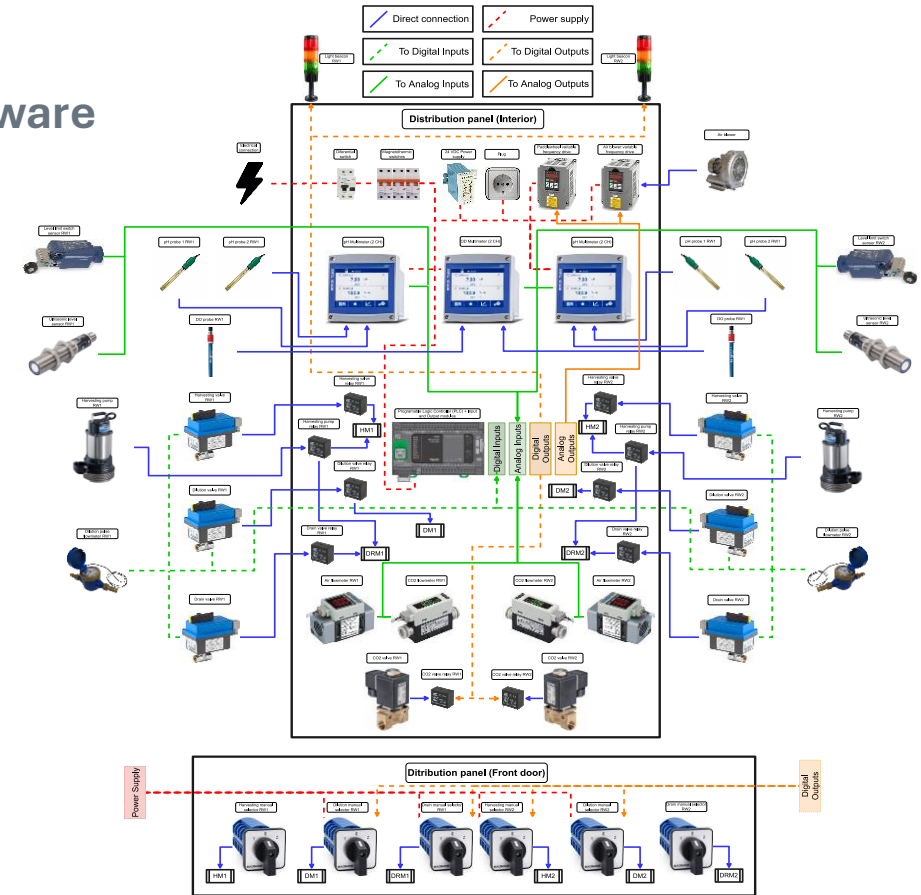
Monitoring, control and automatic operation

Software



- Fully automatic operation
- Optimal control of culture variables
- Minimize inputs/energy consumption

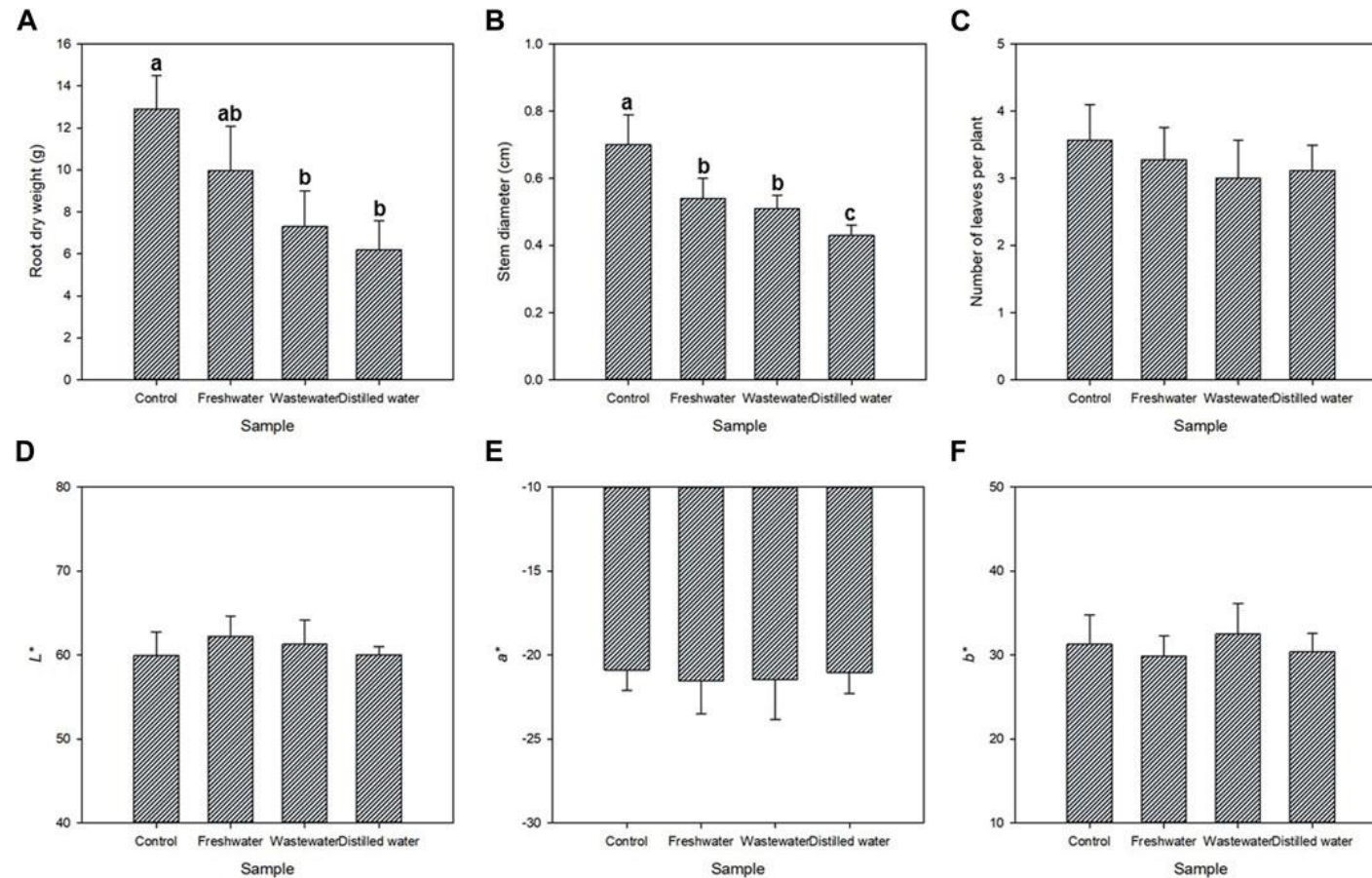
Hardware



Monitoring and control systems for microalgae production is mandatory for industrial development

What about the treated water?

Can it be reused?



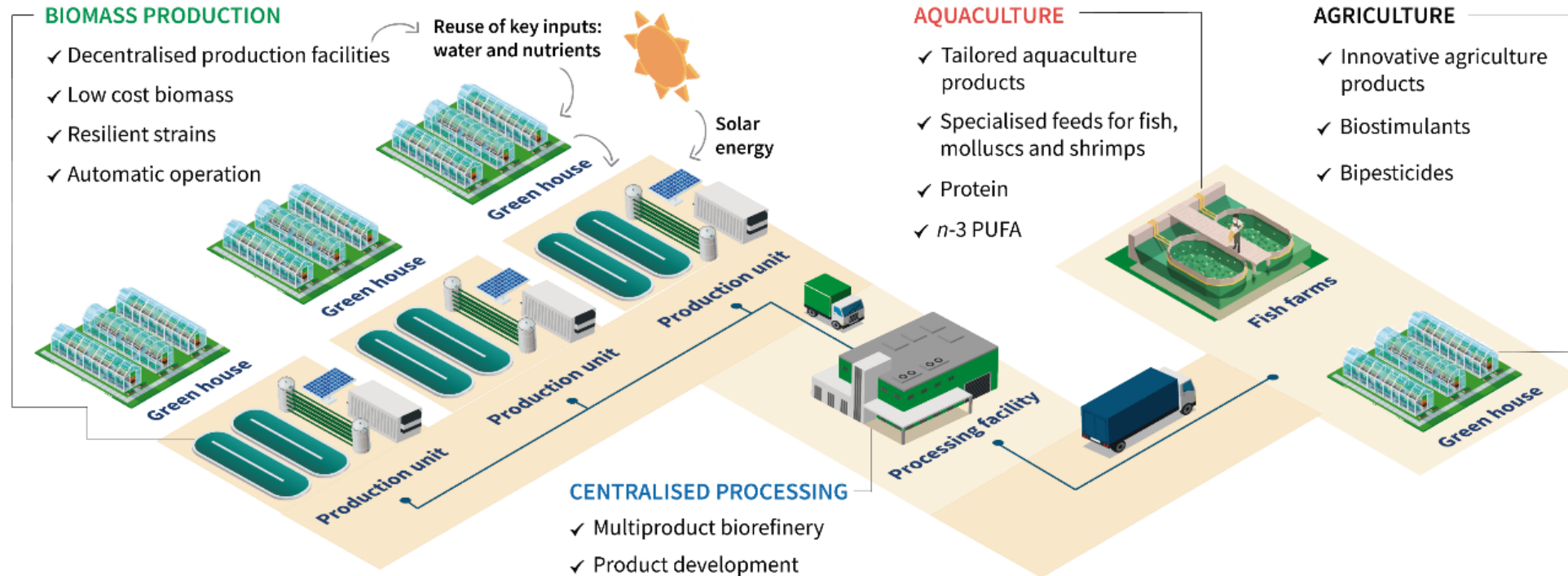
Morillas España et al. (2024) *Frontiers in Bioengineering and Biotechnology* 12:1364490

No negative effects on the hydroponic production of zucchini seedlings.

Ongoing research projects

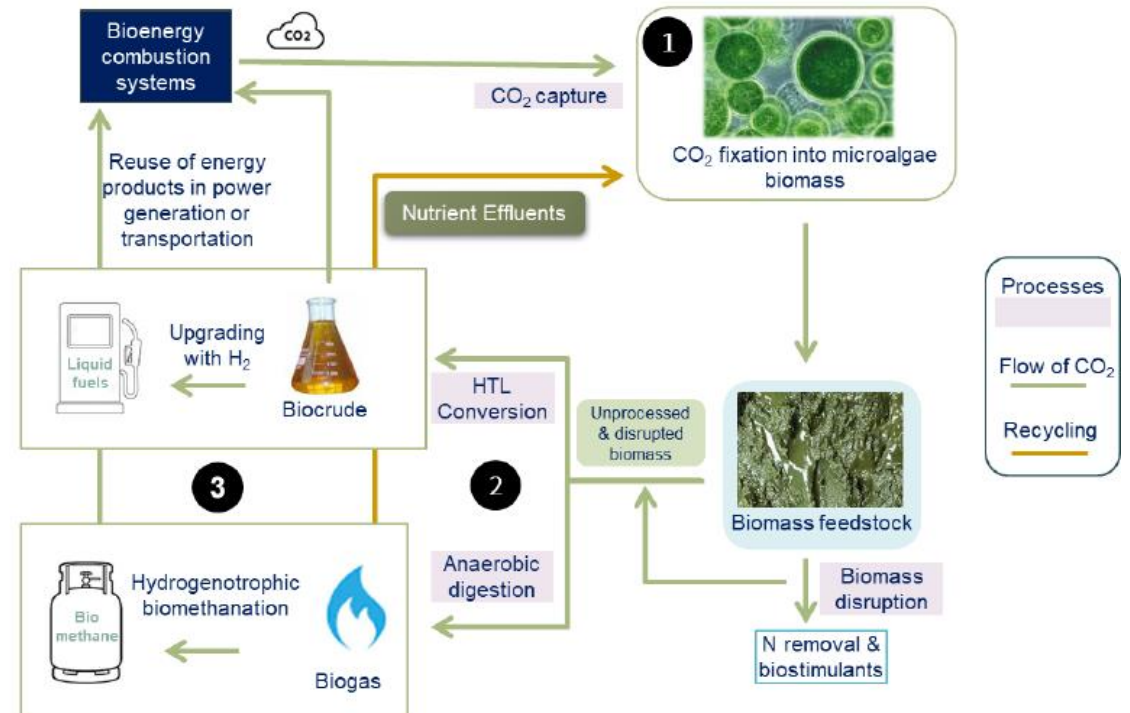
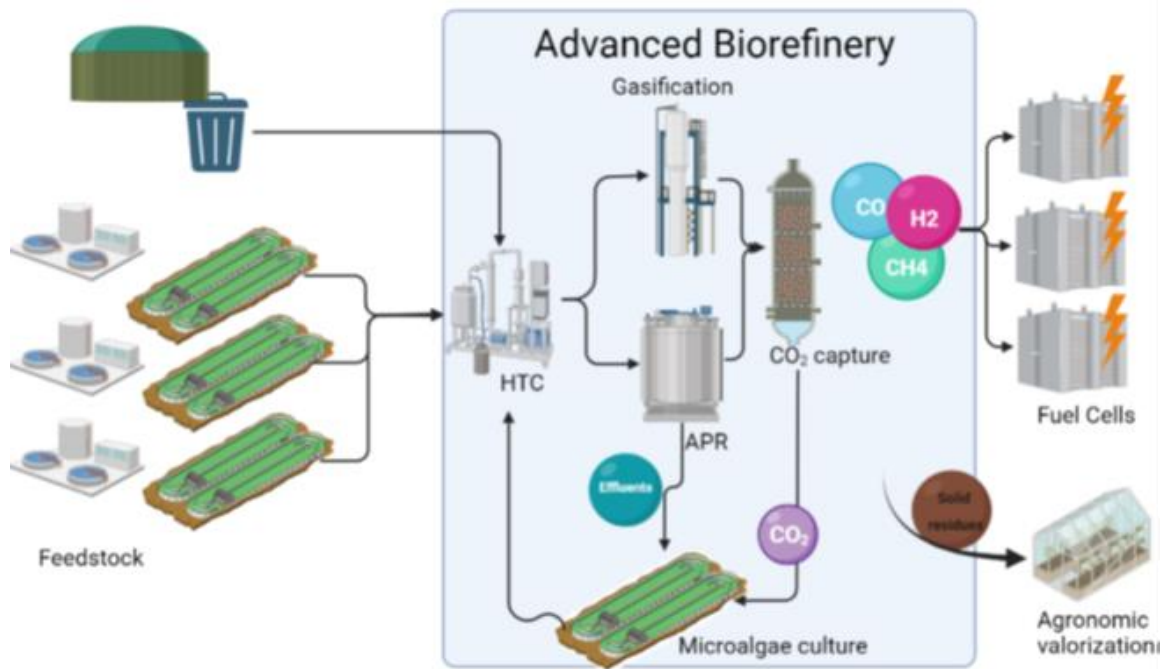
REALM

REALM VALUE CHAIN CONCEPT



Ongoing research projects

NIAGARA & COSEC



Take home message

- Microalgae can be used to **recover** (not remove) nutrients from urban and industrial wastewater
- The process is energy self-sufficient as a large part of the energy is fixed from sunlight
- They can be used as a secondary/tertiary treatment obtaining reusable water and **valuable microalgal biomass**
- The produced biomass has industrial value and can be used to produce energy or agricultural products
- Because of their **light requirement**, their use in populations larger than 20,000 inhabitants is challenging
- More work is needed to fully understand the biological and engineering aspects of microalgae photobioreactors

Thank you very much for your attention!

Tomás Lafarga

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@tomas.lafarga



Phoenix

