







PROGRAMME

Part 1 – EU Research programs
Creating or improving new Blue

CIRCALGAE – Transforming the by-products from seaweed and microalgae processing into value added ingredients

CSIC - Toni Martinez Abad

FOODIMAR – From Bones to Bucks: Unlocking the Value of Marine side streams

SINTEF – Rachel Durand

IMPRESS – Advancing Zero-Waste Multi-Product Biorefineries Through Innovative Technologie *TEAGASC – Brijesh Tiwari*

Part 2 – Industry session Developing commercial biorefineries

CIRCALGAE – Seaweed Biorefinery – From the Shores to the Shelves *Alginor – Georg Kopplin*

FOODIMAR – From Fish Waste to Functional Value: Scaling Marine Biorefineries with Green Technology

TETIS - Emre Yemisken

IMPRESS – Microalgae biotechnology as a tool for Blue biorefineries NEOALGAE - Maria Alvarez Gil

Microalgae as a Source for Commercial Fucoxanthin Algalif - Oran Ayalon

Questions







Microalgae biotechnology as a tool for Blue biorefineries

Maria Alvarez Gil, NEOALGAE





Co-funded by

the European Union





Microalgae biotechnology as a tool for Blue biorefineries

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- BLUE CIRCULAR BIOECONOMY
- Microalgae: a brief introduction
- Microalgae BIOREFINERY
- Microalgae contribution to biorefinery schemes/circular economy
- Microalgae: wastewater recycling (success stories)
- IN SUMMARY: Microalgae contributes to circular economy













Microalgae biotechnology as a tool for Blue biorefineries

NEOALGAE: overview

- Biotech Company (INNOVATIVE SME) founded in 2012 and located in Gijón, Asturias (north of Spain).
- EU leader in microalgae biotech, focused on INGREDIENTS, MICROALGAE BIOMASS and INNOVATION
- Business units (B2B): Cosmetic / Dietary Supplements / Food / Feed / Agriculture / R&D



2.000 m² Industrial facility
FSSC 22.000 certification
Microlgae industrial cultures
Extraction / purification area
Laboratories: Cosmetic / DS / Food
Biostimulant production area
R&D area















Microalgae biotechnology as a tool for Blue biorefineries

NEOALGAE: overview

Contributing to **nutrition** and **health** and **care for the environment**, through the development of different products based on microalgae (through the **BLUE AND CIRCULAR ECONOMY**).



STRAIN

SCALIN UP

INDUSTRIAL VOLUMES



BIOMASS PROCESING

INGREDIENTS















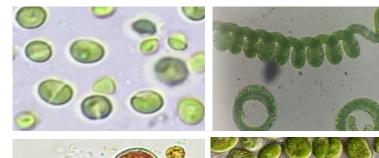


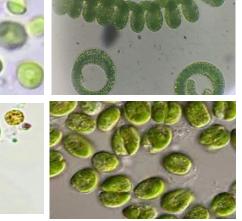
CIRCALGAE

MICROALGAE

BIOTECHNOLOGY

SUSTAINABLE AND HEALTHY SOLUTIONS















Microalgae biotechnology as a tool for Blue biorefineries

BLUE CIRCULAR BIOECONOMY



- ✓ BLUE ECONOMY: Sustainable use of ocean resources for economic growth, improved livelihoods, and jobs while preserving the health of ocean ecosystem.
- ✓ The Blue Economy's emerging and innovative sectors include Marine renewable energy, Blue biotechnology, Desalination, Maritime defence, security and surveillance, Research and Infrastructure.
- One of the most dynamic sub-sectors in the field of Blue biotechnology is the algae sector. Available socio-economic estimates show that algae production in Europe generated an annual turnover well above €10 million in the MSs with the largest number of production facilities (France, Spain and Portugal).
- ✓ The EU Algae Initiative and other EU policy positions recognise that marine bioresources can and should be very important contributors to healthy environments on land as well as in the oceans, carbon neutrality, innovative, healthy and sustainable food systems, and a sustainable and circular bioeconomy.
- There is a high potential for algae to bring benefits to the EU, in particular to alleviate environmental pressures from conventional agriculture, aquaculture, and fisheries, including mitigation of nutrient run-offs into surface and coastal waters, management of harmful algal blooms and the circularity of wastes as inputs.













Microalgae biotechnology as a tool for Blue biorefineries

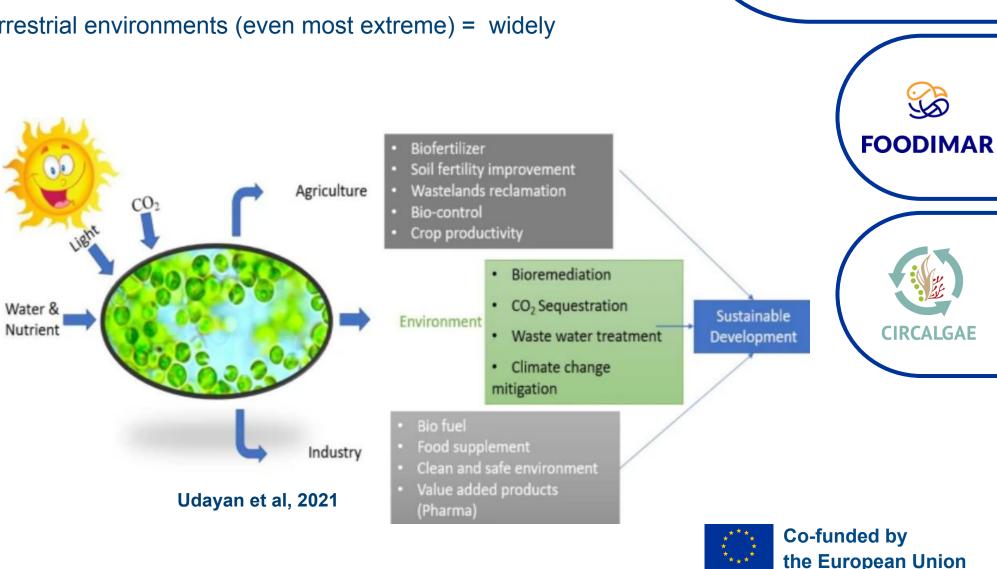
Microalgae: a brief introduction

Highlights

- Single-celled microorganisms / photosynthesis (generation of organic biomass from CO2 and light).
- Basis of food chain / large number of species / versatility / are used successfully in different industrial fields.
- All environments with water (lakes, seas and rivers) also in soil and in most terrestrial environments (even most extreme) = widely distributed in the biosphere adapted to a large number of conditions

Benefits

- Sustainable agriculture: their cultivation does not require agricultural land, so they do not compete with food crops.
- They grow in all types of water: brackish, wastewater, fresh or salt water, they do not require drinking water.
- High productivity: rapid growth cycle and daily harvesting.
- Inexhaustible source of nutrients: fatty acids, amino acids, proteins, antioxidants, pigments, etc...
- They capture CO2 and convert it into oxygen: they form the most efficient ecosystem on the planet







Microalgae biotechnology as a tool for Blue biorefineries

Microalgae: a brief introduction

SOME DATA

- Fixation CO₂ rate: 0.39 to 51.5 g L-1 d-1 (Magdalena et al, 2022)
- The growth potential can be up to 100 times faster than plants
- 20 times greater photosynthesis efficiency than plants
- Achieving productivities of 100 tn/ha·year (DM)
- Nutritional requirements for each tonne of biomass produced:
 - 2 tn CO₂
 - 100 kg N
 - 10 kg P

flue gases // wastewater !!

Controlling factors

Environment

- · Light intensity
- · Temperature)

Nutrients

- Carbon sources
- Nitrogen sources
- Phosphorous sources

Sunlight CO₂ Minerals

Microalgae

- Phaeodactylum
- Haematococcus
- Arthrospira
- PavlovaArthrospira
- Dunaliella
- Porphyridium
- Tetraselmis
- Porphyridium

Bioactive compounds

- Nitrogen compounds
- Phenolic compounds
- Sterolic compounds
- Polysaccharides
- Carotenoids
- LipidsLutein
- Peptides
- Vitamins:
- A, B1, B6, B12, C, E, biotin riboflavin, nicotinic acid,
- pantothenate, folic acid
 Eicosapentaenoic acid
- Astaxanthin
- y-linolenic acid
- Brassicasterol
- Phycocyanin
- β-carotene
- Superoxide dismutase
- α-tocopherol
- y-aminobutyric acid

Applications

 Pharmaceuticals Medicine

food/feed supplements
Drug delivery

Cosmetics

Whitening &
moisturizing products
Sun protection

Anti-aging products

- Animal feed
- BiofuelsAgricultural applications
- Chemicals production

Olaby et al, 2023





CIRCALGAE

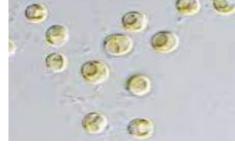
MAIN MICROALGAE SPECIES CULTIVATED AT NEOALGAE

Phaeodactylum tricornutum



FUCOXANTHIN and omega 3 (EPA) for nutraceutical uses. cosmetic applications

Isochrysis galbana



Extraction of omega 3 fatty acids (DHA)

Tetraselmis chuii



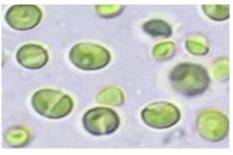
Use of biomass for food (approved in the EU)

Arthrospira platensis (Spirulina)



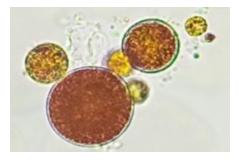
biomass for food (approved in the EU), biostimulants, Protein extraction, cosmetic applications

Chlorella vulgaris



Use of biomass for food (approved in the EU) and cosmetic applications

Haematococcus pluvialis



ASTAXANTHIN extraction for nutraceutical uses. cosmetic applications







Microalgae biotechnology as a tool for Blue biorefineries

Microalgae BIOREFINERY Microalgae-based zero-waste biorefinery Valuable products Treated Pigments Techno-economic analysis ▶ Protein ➤ Carbohydrate Microalgal biomass → Lipids Environmental Exopolysaccharides Wastewater analysis Sustainable production of microalgal biomass

Biodiesel Is cause of Oil fractions Is associated with **Food Healthcare Transesterification** Minerals Fertilizer Is cause of Protein Pretreatment, **ALGAE** Animal feed fractions extraction and product **BIOMASS** purification Is associated with Is cause of Antioxidants, Healthcare & Is associated with Carbohydrate Bioethanol fractions Value added Olaby et al, 2023 chemicals

FOODIMAR

CIRCALGAE

- Efficient process for producing various integrated products for vast industrial, agricultural, and household applications.

Benjamas et al, 2023

- Sustainable use of natural resources for a variety of commercial commodities and energy with the least amount of or no emissions and waste
- Wastes constitute a crucial element of biorefineries, where prospects for reuse, recycle, and reproduce, should be practical.
- Allows for the exploitation of microalgae to their full potential and minimizes biomass waste accumulation

- Microalgae are light-driven cell factories that synthesize bioactive compounds from:
- a) primary metabolites (lipids, proteins, and carbohydrates)
- b) secondary metabolites (pigments, carotenoids, vitamins, and sterols)





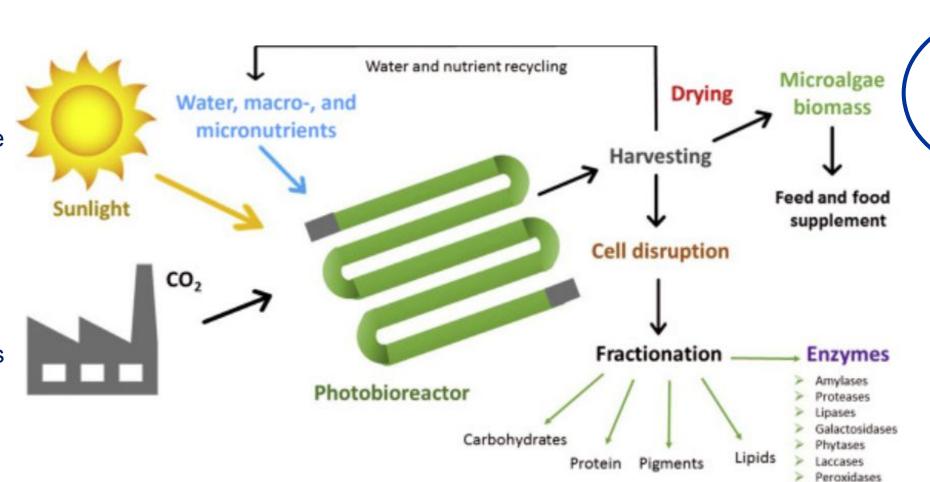




Microalgae biotechnology as a tool for Blue biorefineries

Microalgae contribution to biorefinery schemes/circular economy

- Microalgae can use effluent for different industries (liquid / gas)
- By utilizing microalgae in bioreactors, industries can achieve resource recovery, reduce wastes and environmental footprint.
- Microalgae effluents/wastes can be also reused. Ex:
- Water stream from microalgae centrifugation step
- Biomass wastes resulted from compound extraction process (can be use in other products such as biofertilizers)



How Microalgae Fit into a Circular Economy:

1. Wastewater Treatment and Resource Recovery	Microalgae consume nutrients (like N and P) and pollutants
2. Carbon Capture	Microalgae are highly efficient at fixing CO ₂
3. Microalgae are highly efficient at fixing CO2	microalgal biomass generated from wastewater treatment can be used as a
	feedstock in biorefineries to produce a diverse range of products



FOODIMAR

CIRCALGAE





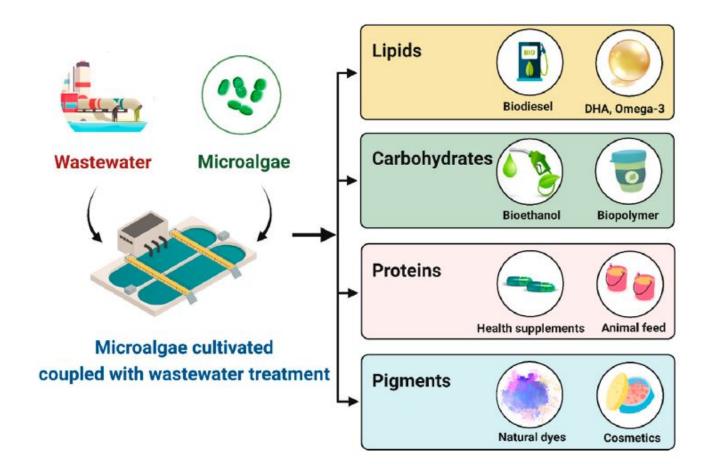
Microalgae biotechnology as a tool for Blue biorefineries

wastewater

Microalgae: wastewater recycling

- Many studies reveal that microalgae can completely remove N, P, and hazardous components from various types of wastewater.
- This cultivation strategy can reduce manufacturing costs by combining wastewater treatment with the cultivation of microalgae (this avoid the economic cost of artificial cultures medium)

<u>MAIN WASTEWATERS USED</u>: Industry effluents, piggery wastewater, municipal wastewater, aquaculture effluents, hydroponic crops, etc



	wastewater				
Microalgae consortium	85–90% carpet industry effluents with 10–15% municipal sewage	Cultured in Erlenmeyer flasks	63.9% biodiesel of algal oil	Chinnasamy et al. (2010)	
Chlorella zofingiensis	Piggery wastewater	Semi-continuous feeding operation in the tubular bubble column photobioreactors under outdoor conditions	9.19 g biodiesel/100 g dry weight		
Scenedesmus obliquus, Micractinium pusillum, Dictyosphaerium pulchellum and Coelastrum sp	Municipal wastewater	Cultivated in High-Rate Algal Pond (HRAP)	70.9% yield of biodiesel	IMPRESS	
Microalgae	Wastewater-grown microalgae	Fermentation by Clostridium saccharoperbutylacetonicum N1-4 using wastewater algae biomass pretreated with xylanase and cellulase enzymes	9.74 g L ⁻¹ of total acetone, butanol, and ethanol (ABE)		
Nannochloropsis gaditana	Municipal wastewater	Microalgae biomass production and fermentation	94.3 mg ethanol/g biomass	Onay, (2018)	⊘ ⊵
C. vulgaris	Wastewater treatment effluent from tilapia culture pond	Microalgae biomass production and fermentation	33.213 g ethanol L ⁻¹	Bhuyar et al. (2021)	₩ \ FOODIMAR
S. obliquus	Urban wastewater	Microalgae biomass production and dark fermentation using Enterobacter aerogenes	56.8 ml H ₂ g ⁻¹ VS.	Batista et al. (2015)	
S. obliquus	Artificial wastewater	Sulfur deprivation and two light quality priors to anaerobic condition	128 ml H_2 L^{-1} (productivity 204.8 ml H_2 L^{-1} d^{-1})	Ruiz-Marin et a (2020)	
C. vulgaris and mixed culture of native algae	Synthetic and wastewater media	Cultured in synthetic medium, wastewater (sterilized and non-sterilized) and digestate from anaerobic digestion of pulp and paper biosludge (sterilized and non-sterilized)	154-252 L CH ₄ kg ⁻¹ (depending on culture media)	Kinnunen and Rintala, (2016)	THE STATE OF THE S
Chlorella sp. and Scenedesmus sp.	Domestic sewage	High-rate algal ponds (HRAP) for post-treating Up flow anaerobic sludge blanket (UASB) reactors' effluent and anaerobic co-digestion with microalgae	156-211 NL CH ₄ kg _{vs} ⁻¹	Vassalle et al. (2020)	CIRCALGAE
H. pluvialis	Primary-treated sewage (PTS), Primary-treated piggery wastewater (PTP)	Cultured in wastewater with serial dilution	5.1 and 5.9% of the total biomass of the PTS and PTP	Kang et al. (2006)	
Nostoc sp., Arthrospira platensis and Porphyridium purpureum	Industrial wastewater	Cultured in Erlenmeyer flasks	179 mg phycobiliproteins/g dry weight	Arashiro et al. (2020)	
C. vulgaris,S. obliquus	Aquaculture effluents	Cultured in Erlenmeyer flasks sealed with	31% proteins, 6% lipids and 39%	Views et al.	

hydrophobic cotton and agitated by an air flow

carbohydrates of C. vulgaris bion

carbohydrates of S. obliquus biom

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Microalgae biotechnology as a tool for Blue biorefineries

Microalgae: wastewater recycling

SUCCESS STORIES: USING HIDROPONIC CULTIVATION EFFLUENT

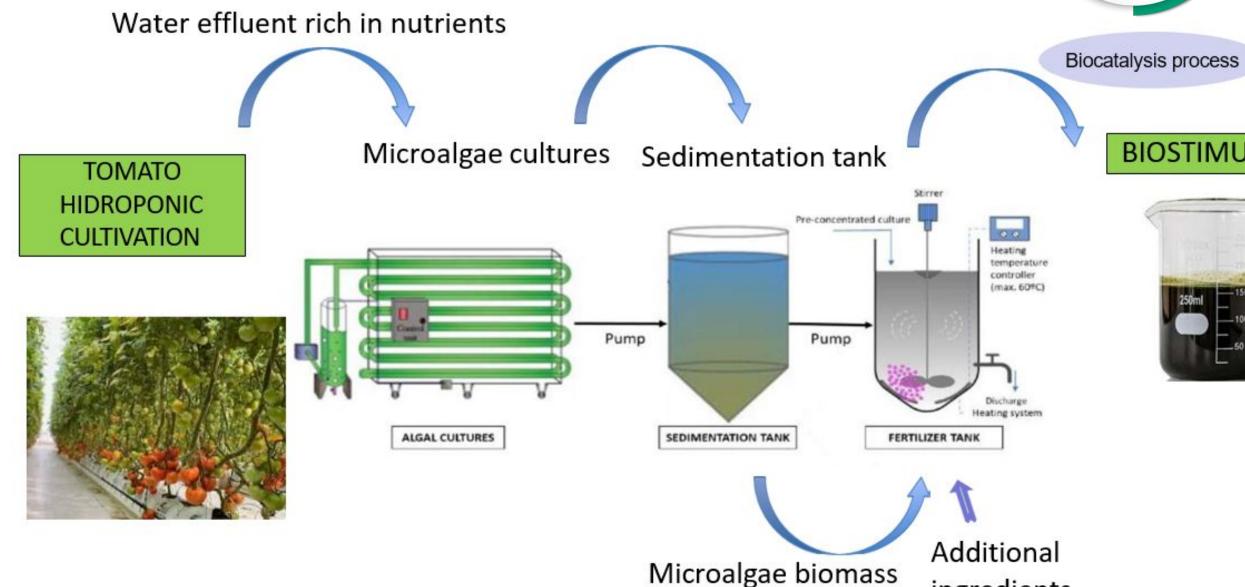


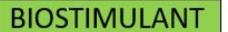
ingredients



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Microalgae biotechnology as a tool for Blue biorefineries

Microalgae: wastewater recycling

SUCCESS STORIES: WITH RAW LIQUID SLURRY

COLLECTION of raw liquid slurry of bovine origin by NEOALGAE



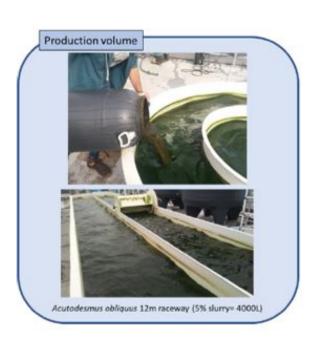




APLICATION IN MICROALGAE CULTURES















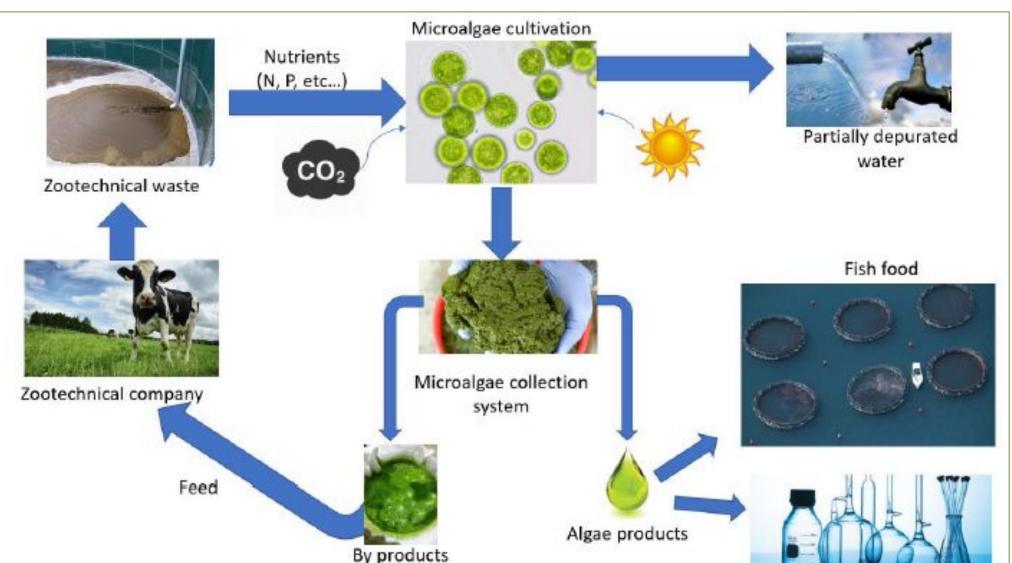




Microalgae biotechnology as a tool for Blue biorefineries

Microalgae: wastewater recycling

SUCCESS STORIES: WITH RAW LIQUID SLURRY







Chemicals















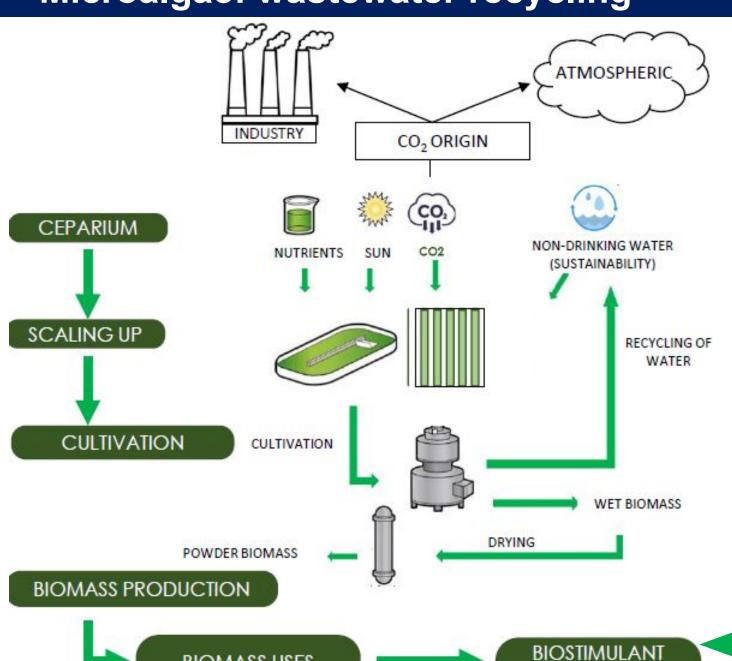
PRODUCTION





Microalgae biotechnology as a tool for Blue biorefineries

Microalgae: wastewater recycling



BIOMASS USES

COMPOUND

EXTRACTION

SUCCESS STORIES: REUSE OF DIFFERENT EFFLUENTS



- **♦** 60% reduction of water consumption
- **♦** 55% reduction of Nutrient intake
- average of 1.55 kg of CO2 captured/m3



OTHER SUPRODUCTS REUSED

ALPECHIN (Olive Industry waste)

Biomass waste after phycocyanin extraction from Spirulina



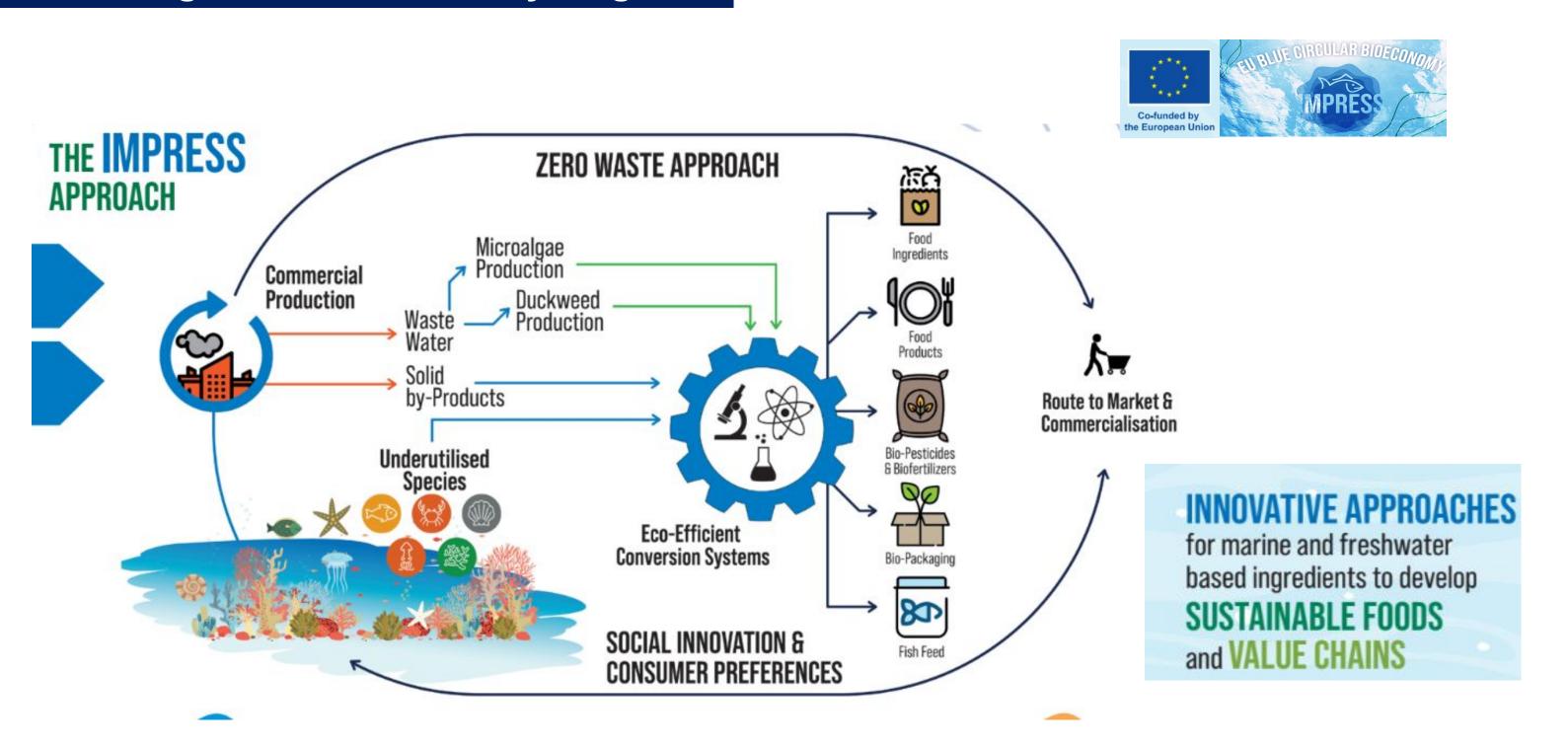




Microalgae biotechnology as a tool for Blue biorefineries

Microalgae: wastewater recycling

SUCCESS STORIES: WITH AQUATIC EFFLUENTS





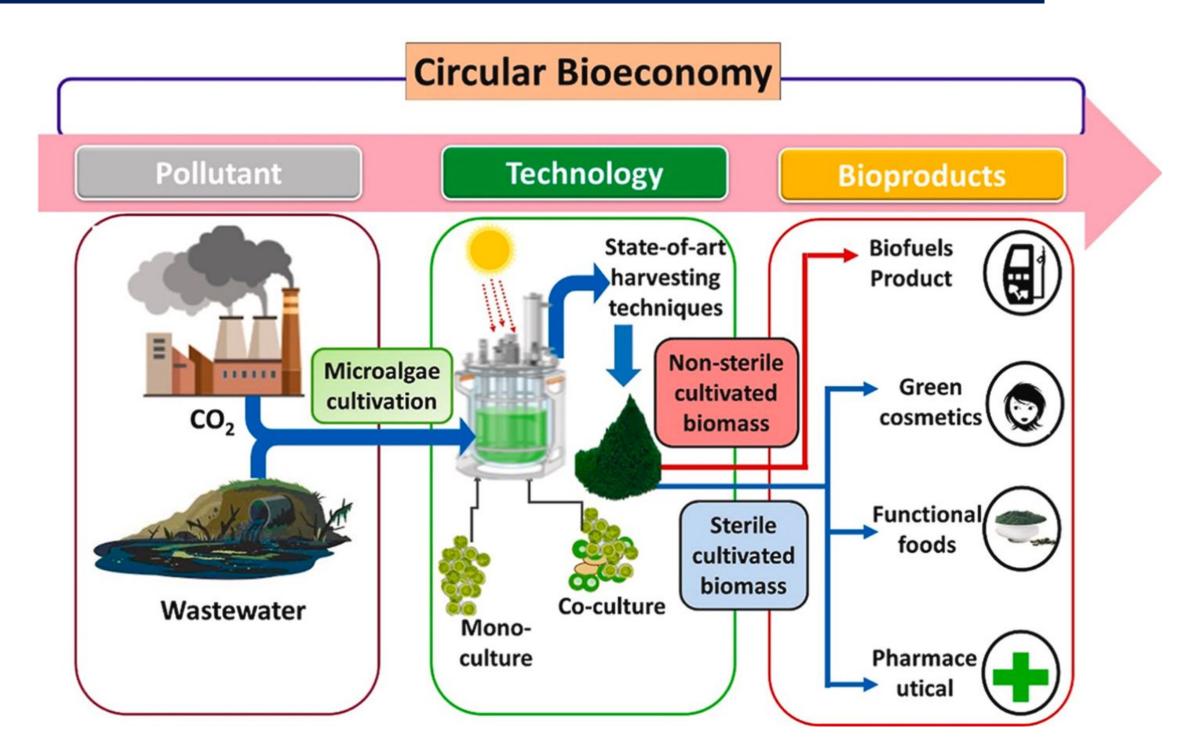






Microalgae biotechnology as a tool for Blue biorefineries

IN SUMMARY: Microalgae contributes to circular economy











Microalgae biotechnology as a tool for Blue biorefineries



THANKS FOR YOUR ATTENTION!!



