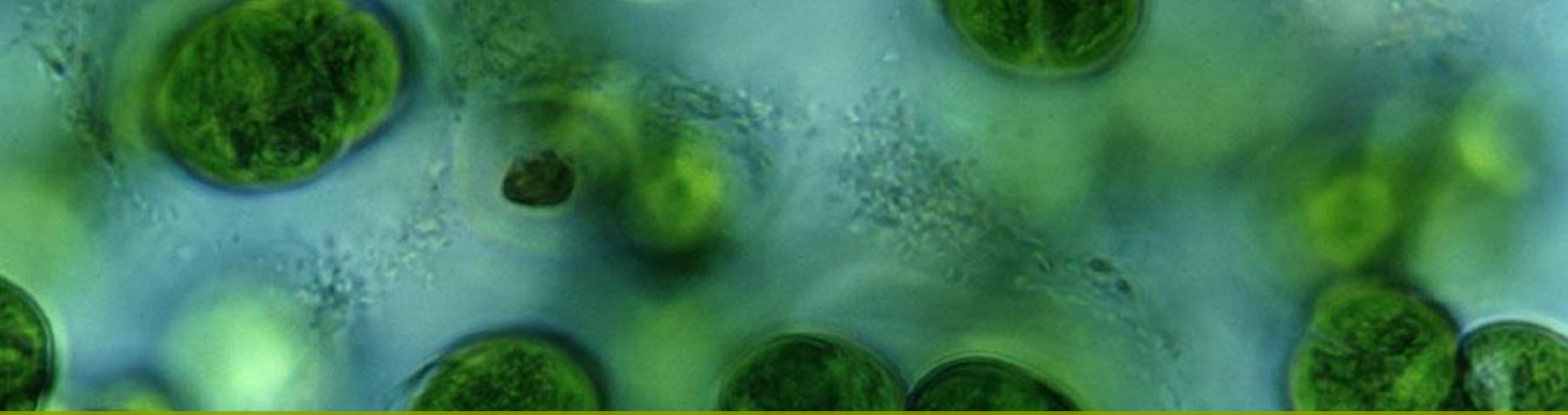
ENHANCE
MICROALGAE

EnhanceMicroAlgae Project

Multistr3am: the challenges of a microalgae biorefinery

Laura Monteiro | A4F – Algae 4 Future

La Rochelle, 20th October 2022



01 A4F

Who we are, What we do

ENHANCE MICROALGAE

Interreg Atlantic Area
European Regional Development Fund

EUROPEAN UNION

A4F is specialized in the process of design–build–operate–transfer (DBOT) of commercial scale algae production facilities

Biotechnology company, founded in 2008 in Portugal

People

- **50+** highly educated
  > 50 % PhD & MSc
- Highly trained people: **20 years of accumulated experience** in microalgae industrial production

Co-financed Projects

- **20+** R&D projects with
- **>95 M€** funding
- Involved in **9** projects:
  biorefining for added value products and energy

Units Operated

- **5 units**, from R&D to Commercial Scale
- **Currently** building
  4 units in Europe and Africa
- Currently involved in other projects abroad: South America, Africa, Europe and Middle East

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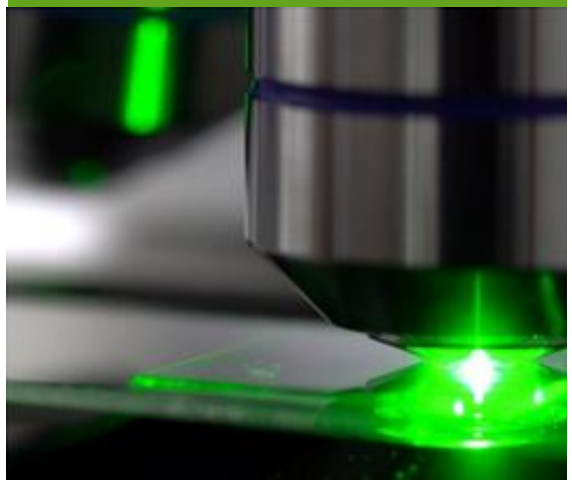
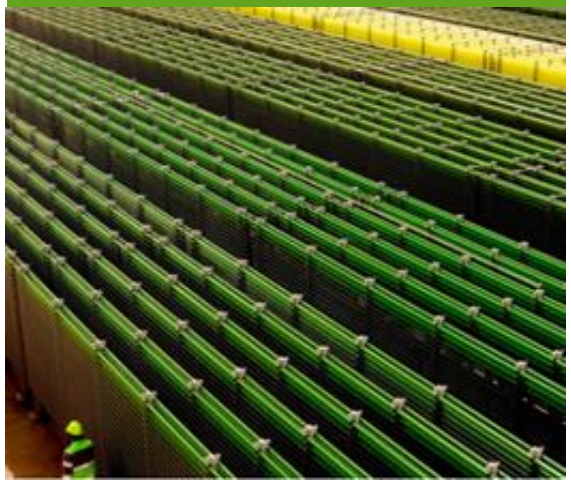
APPLIED R&D



CONTRACT R&D TECHNOLOGY SUPPLY

INDUSTRIAL PRODUCTION



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R&D projects

Jan 2011
GIAVAP (FP7)
36 months
7M€

Apr 2011
BIOFAT (FP7)
60 months
10M€

Oct 2012
PHOTO.COMM (FP7)
48 months

Dec 2012
DEMA (FP7)
54 months
6,4M€

Nov 2013
PUFACHAIN (FP7)
48 months
7M€

Dec 2013
D-FACTORY (FP7)
48 months
10M€

May 2019
EXTRATOTECA (P2020)
36 months
1,4M€

Nov 2017
ARA.FARM (P2020)
48 months
4,7M€

Nov 2017
ENHANCE (INTERREG)
54 months
3,45M€

Mar 2017
ABACUS (H2020)
48 months
5,1M€

Jul 2015
PHOTOFUEL (H2020)
48 months
6M€

Dec 2014
ALFF (H2020)
48 months
3,8M€

Apr 2020
ALGAREF (P2020)
24 months
2,8M€

May 2020
MULTI-STR3AM (EU-BBI-JU)
48 months
9,1M€

Dec 2020
Move2lowC (P2020)
36 months
11,2M€

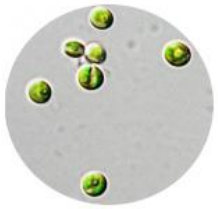
May 2021
RedWine (EU-BBI-JU)
48 months
5,7M€

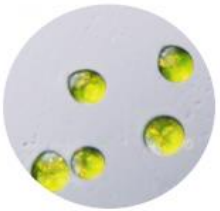
Oct 2022
CIRCALGAE (HORIZON)
48 months
10,3M€

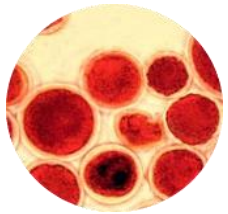
Microalgae production expertise at pilot and industrial scale

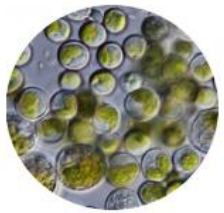

Arthrospira sp. (Spirulina)


Chlamydomonas sp.


Chlorella sp.


Dunaliella salina

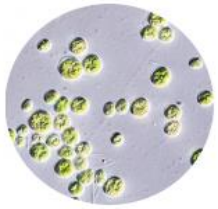

Haematococcus pluvialis


Lobosphaera incisa

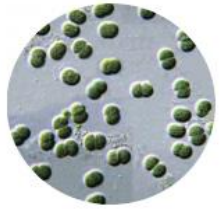

Nannochloropsis sp.


Phaeodactylum tricornutum

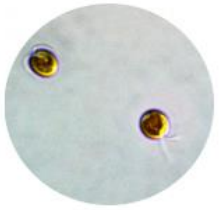

Raphidonema sp.

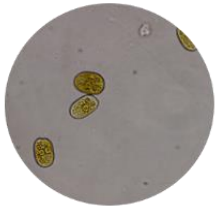

Scenedesmus sp.

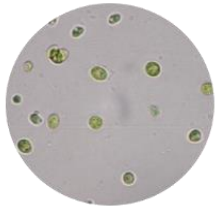

Synechococcus sp. PCC 7002


Synechocystis sp. PCC 6803


Thalassiosira weissflogii

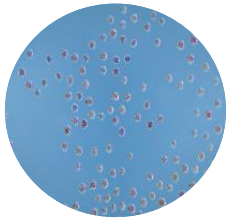

Tisochrysis lutea

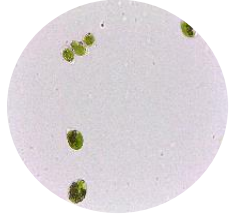

Prorocentrum Cassubicum

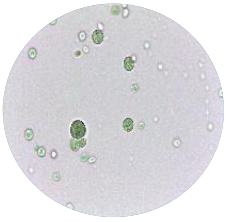

Scotiellopsis sp.


Tetraselmis sp.


Odontella sp.


Porphyridium cruentum


Euglena gracilis


Galdieria sulphuraria

BIOREF - Colaborative Laboratory for the Biorefineries

BIOREF
Laboratório Colaborativo para as Biorrefinarias

Enterprises

Renewable Gases

dourogás renovável

sysadvance

HYChem

Bio-based products

a4f algae for future

biotrend experts in bioprocessing

SILICOLIFE

Advanced biofuels

RAIZ

galp

TAP AIR PORTUGAL

BLC3 CAMPUS DE TECNOLOGIA E INOVAÇÃO

tratolixo gestão de resíduos urbanos

Universities

utad UNIVERSIDADE DE TRÁS-OS-MONTES E ALTO DOURO

universidade de aveiro

TÉCNICO LISBOA

Ciências ULisboa

Universidade do Minho

Instituto Politécnico Portalegre

U.PORTO

R&D Institutions – State laboratory

LNEG

Lisbon Innovation Laboratory (LIL)

Supports Client and R&D activities at pilot scale and industrial production

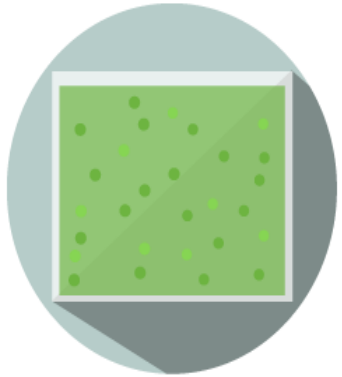
Services:

- Microalgae strain isolation and characterization
- Inoculum production up to 200+ litres scale
- Specialized analytical services
  - Pigments
  - Fatty acids
  - Elemental analysis
- Contamination diagnostic and control tools

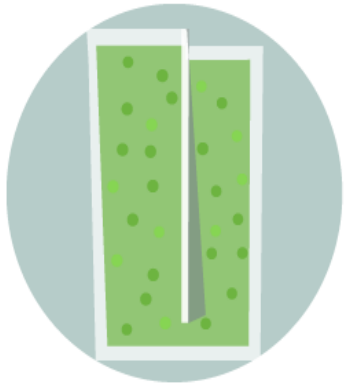
Lisbon Experimental Unit

Lisbon Experimental Unit

Tubular PBRs



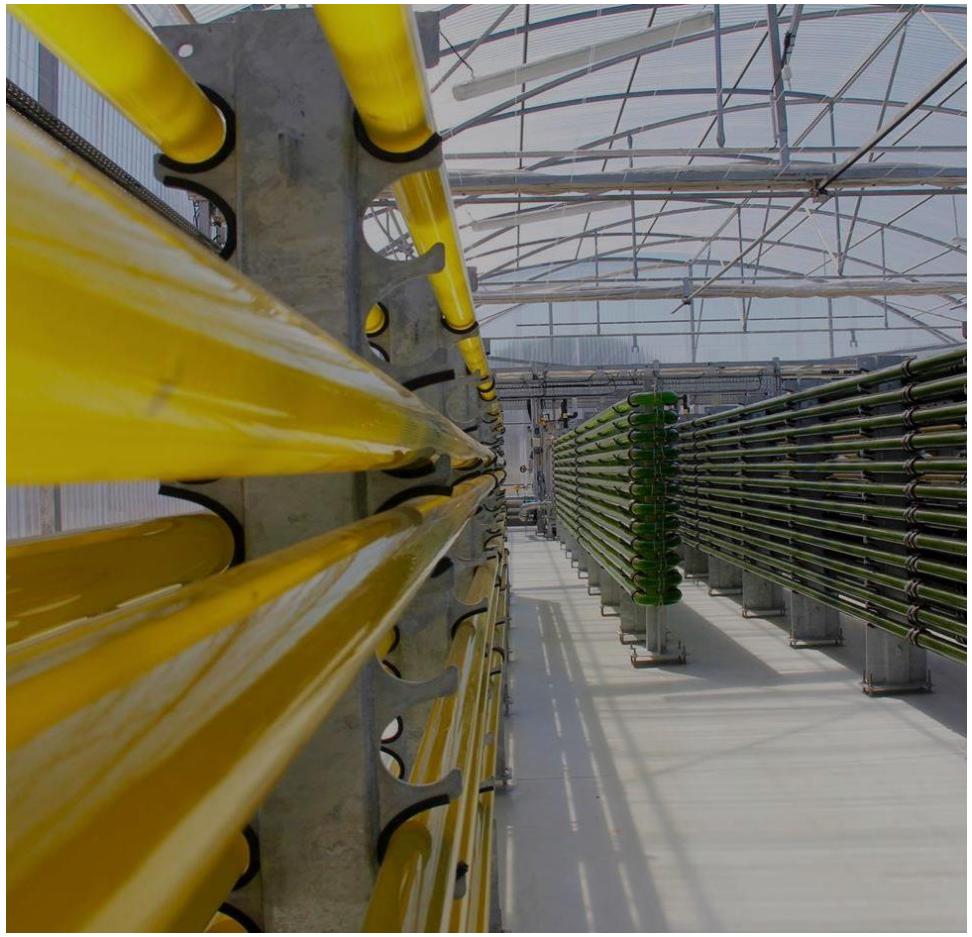
Flat panel PBRs



Cascade Raceways

Raceways

Lisbon Experimental Unit



Technological platform that mimics an industrial plant for microalgae production;
Supports A4F Clients and R&D projects at pilot scale production.

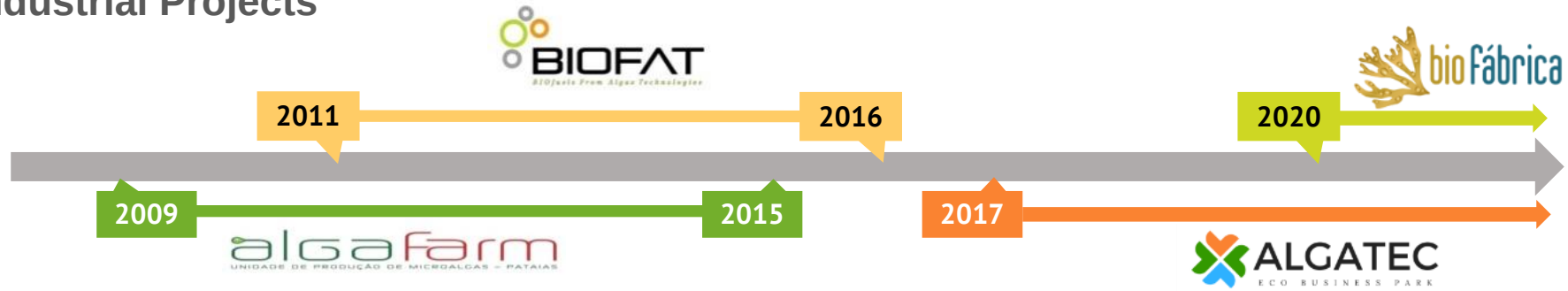
- Since 2013
- 2000 m2 / 10 m3
- GMO compliant
- From inoculum to product
- Scale-up to pilot scale
- Open and closed systems
- Harvesting technologies
- Processing technologies

Lisbon Experimental Unit

Services:

- Supply of kg-scale batches of microalgae
- Biomass enrichment and isotope labelling
- Growth medium design, supply and optimization for auto-, mixo- and heterotrophic growth
- Test-trials and performance evaluation for different production technologies and downstream equipment

Industrial Projects



ALGAFARM
SECIL/ALLMICROALGAE

- Tubular PBRs, 1.300 m^3
- Pataias, Portugal
- Designed, built, operated by A4F

BIOFAT
FP7 PROJECT

- Cascade raceways, 3.000 m^2
- Pataias, Portugal
- Designed, built, operated by A4F

ALGATEC
ECO BUSINESS PARK

- Multi-technology production, 14 ha
- Póvoa de Santa Iria, Portugal
- Implementation stage

BIOFÁBrica

- Ponds and Cascade raceways, 3,5 ha
- Aveiro, Portugal
- Design stage

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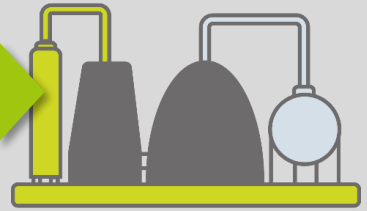
Large Industrial Projects

SITE	Macroalgae	BIOREFINERY	PRODUCT	APPLICATION
			Alginate Fucoidan Fucoxanthin Biopolymers	Feed Food Health Textiles
BIOFABrica	*Fucus vesiculosus*			

- Ponds and Cascade raceways
- 3,5 ha site
- Aveiro, Portugal
- 2020 – 2022
- Design stage

ALGAE CULTIVATION AND BIOREFINING

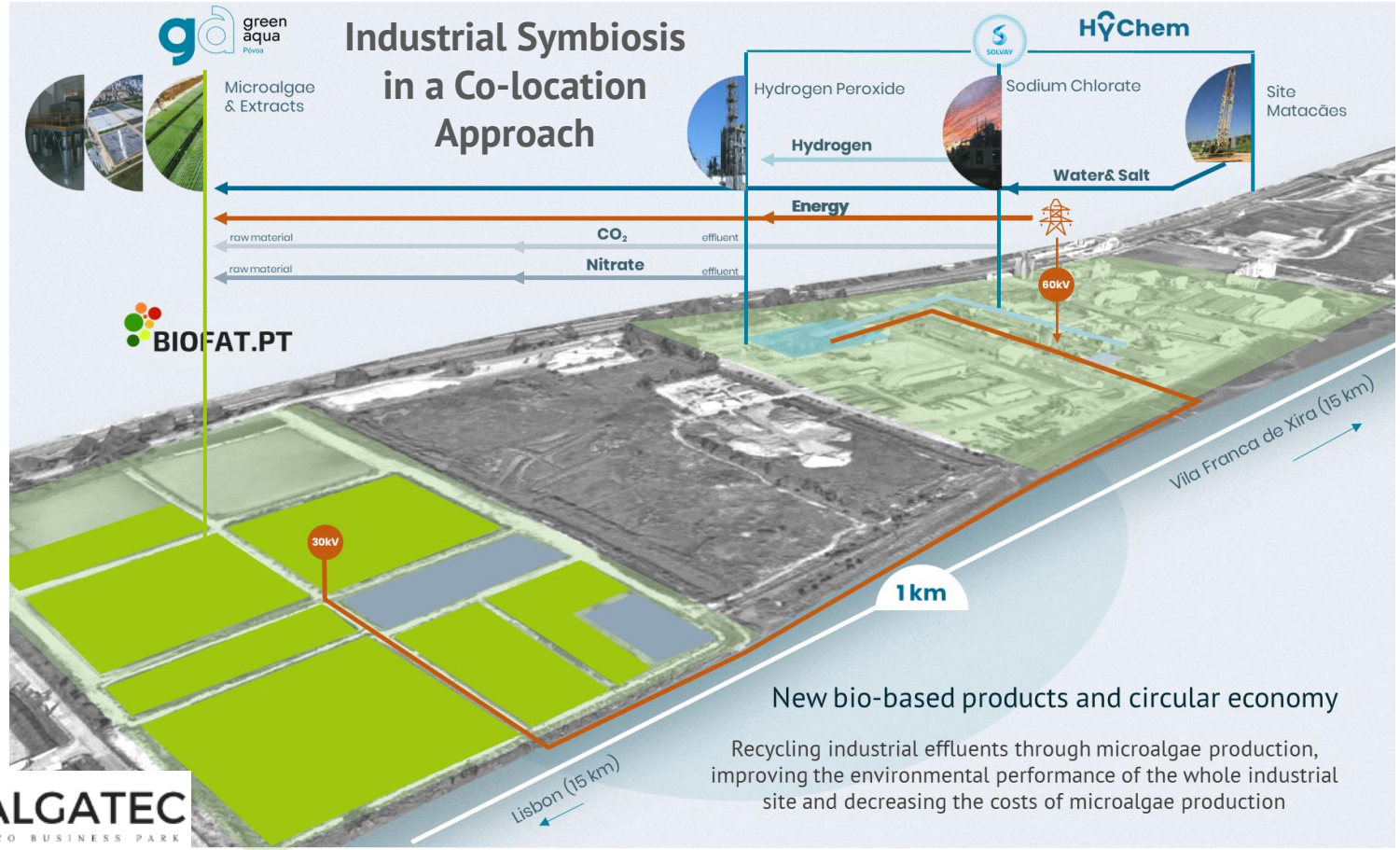
- Project design
- Technology provider
- Installation of the demonstration unit
- Operation of the unit and Training support

From a decomissioned site…

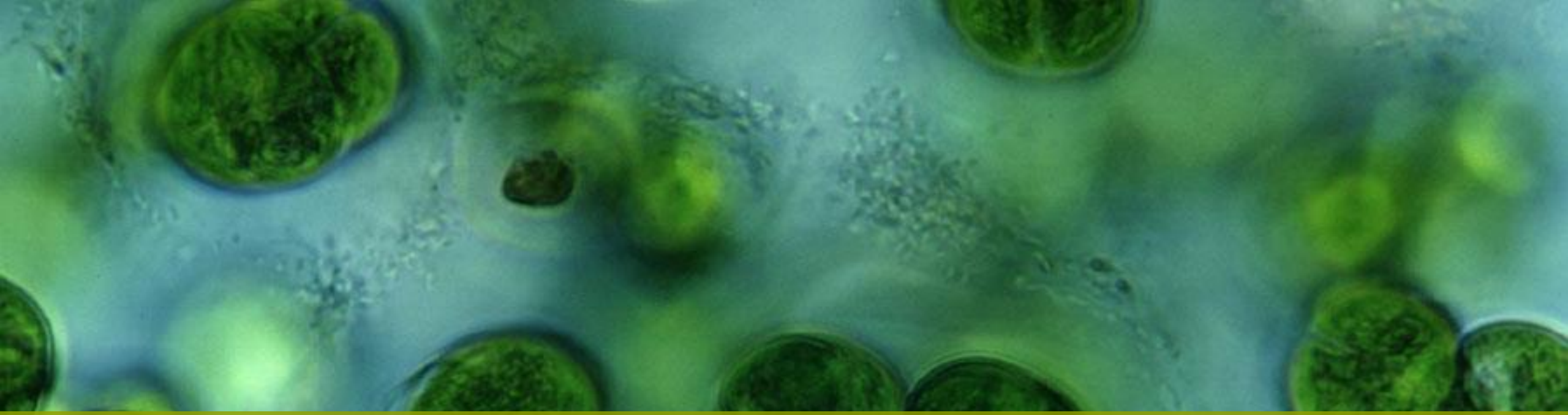
…to the largest microalgae production site in Europe!

- 10 ha of productive area
- Production of 270 ton/year
- Carbon feed source from a CO_2 emitting industry
- A combination of technological solutions

Industrial Symbiosis



ALGATEC
ECO BUSINESS PARK



02 Multi-str3am

A sustainable multi-strain, multi-method, multi-product microalgae biorefinery integrating industrial side streams to create high-value products for food, feed and fragrance.

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MULTI STR3AM

The Project

H2020 BBI - JU

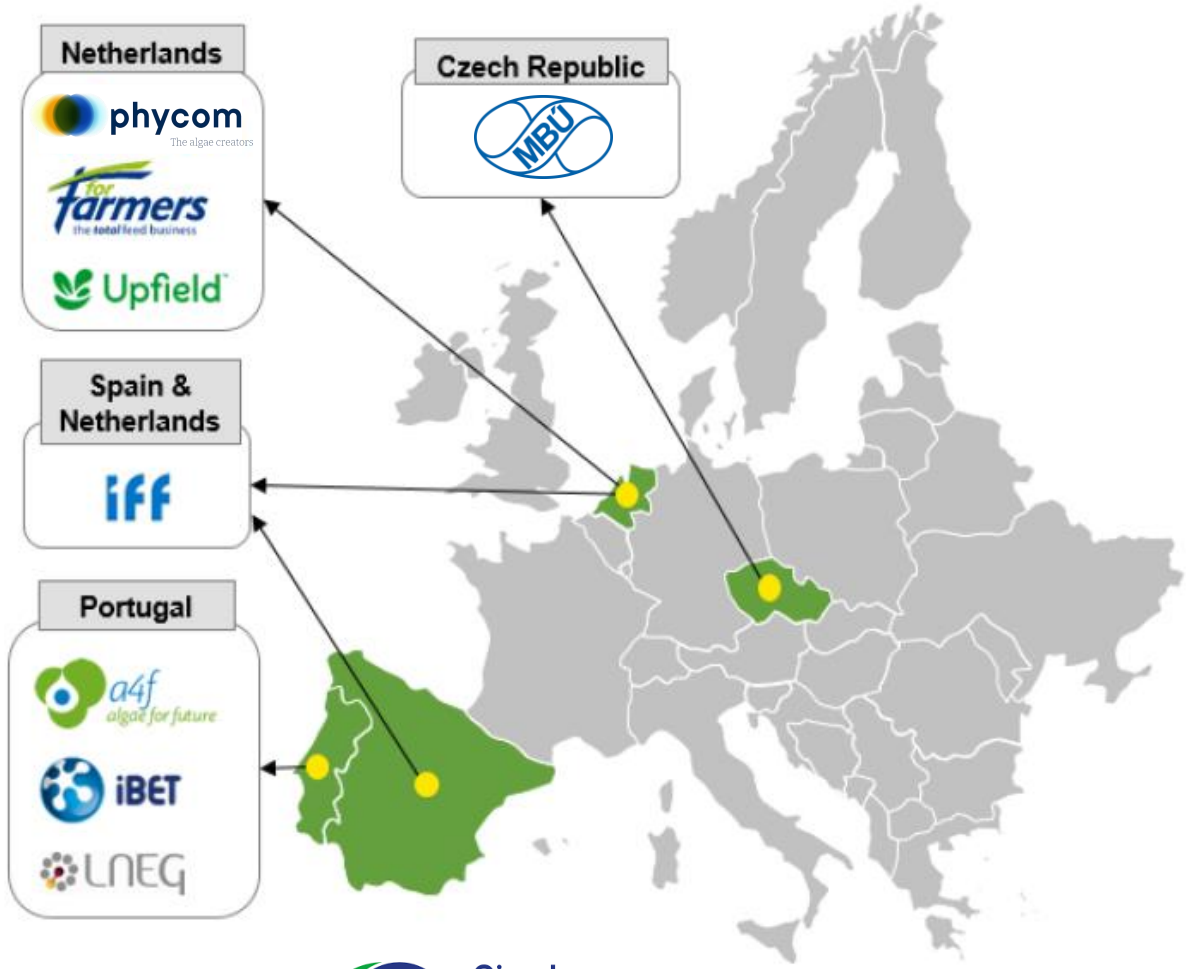
May 2020 – April 2025

Budget € 9,1M.

EU contribution € 6,6 Mi

8 partners (5 companies; 3 RTOs)

MULTI-STR3AM *solution will improve the use of microalgal resources with the valorization of all biomass fractions and boost the applications in food, feed and fragrance, contributing to a more bio-based, sustainable circular economy*



BBI JU

Bio-based Industries Consortium

Horizon 2020
European Union Funding
for Research & Innovation

Circular Bio-based Europe
Joint Undertaking

02 Multi-Str3am

The solution

1

- Constant **improvement of strains** through non-GM methods: to increase productivity & meet end user needs

2

- **Design and engineering improvements** to cultivation and harvesting technologies **to reduce CAPEX and OPEX**

3

- **Circular economy**: Exploitation of industrial and own side streams during cultivation

4

- **Synergistic integration of different technologies** in a multi-strain, multi-method, multi-product biorefinery

5

- **Valorisation of all fractions** of biomass in a **zero waste approach**

Market Drivers from Multi-Str3am end-users

1. Feed products with lower environmental impacts

2. Find alternatives to soy bean meal, fish meal or fish oil

1. Increase the renewability and biodegradability of its fragrance and encapsulation ingredients

2. Ingredients with lower environmental impact, non-animal and non-fossil based

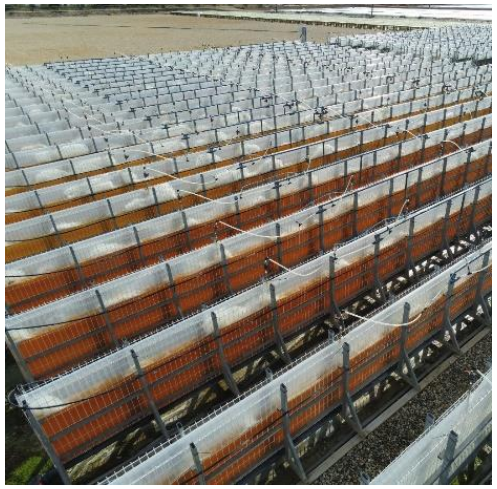
1. Production of healthier food ingredients and with lower environmental impacts

2. Find alternatives to palm oil as an ingredient and Omega-3 from fish and plant oils.

Phototrophic cultivation

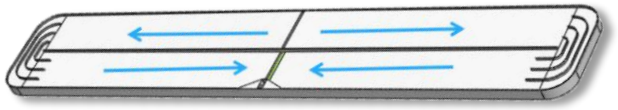
Cultivation at pilot (1-10 m^3) and demonstration scale (100 m^3)

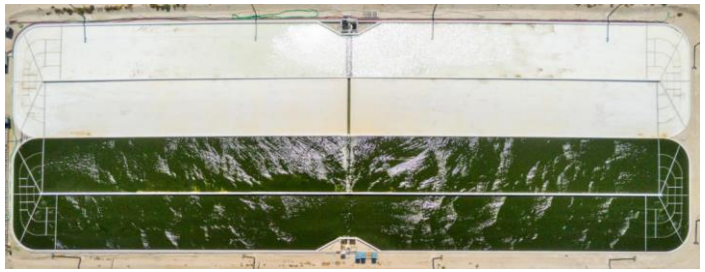
FP-PBR up to 45 m3
Production of all 3 species



UHT-PBR 1560 m2/ 35 m3
Production of all 3 species

CRW 2500 m2 / 80-1
Production of all 3 species.





Species:
Nannochloropsis,
Dunaliella and Spirulina

Heterotrophic cultivation

Reduce CAPEX and OPEX

- Production efficiency
- Reduction of raw materials, energy & water
- Economic improvements

phycom
The algae creators

Species: *Chlorella*

Single Product Biorefinery

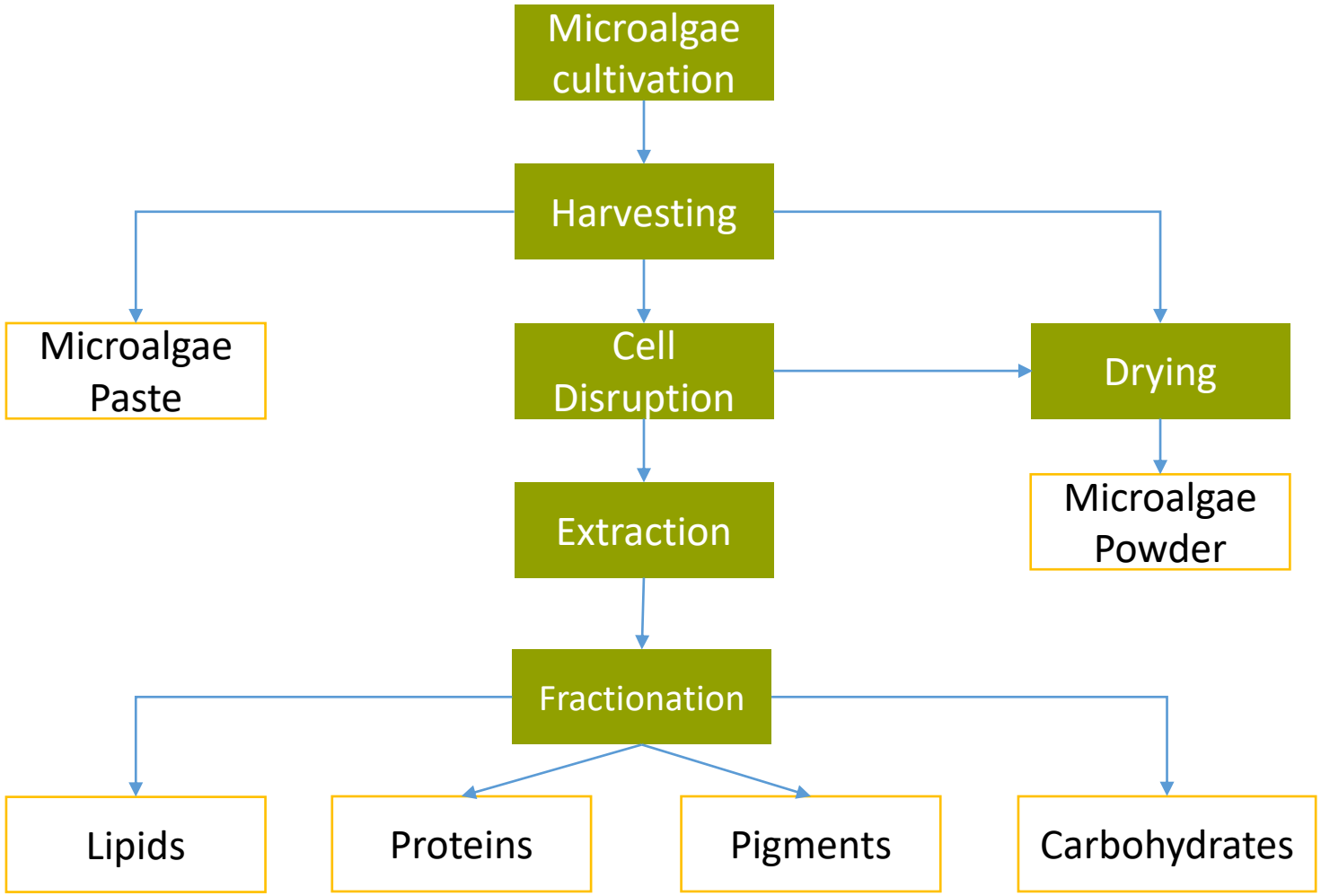
Business case viable for high-value products.
Not valid for bulk products: e.g. soluble protein.

Industrial production of specialty or niche products: Pigments, Phycocyanin, Omega3.

Multi-product Biorefinery

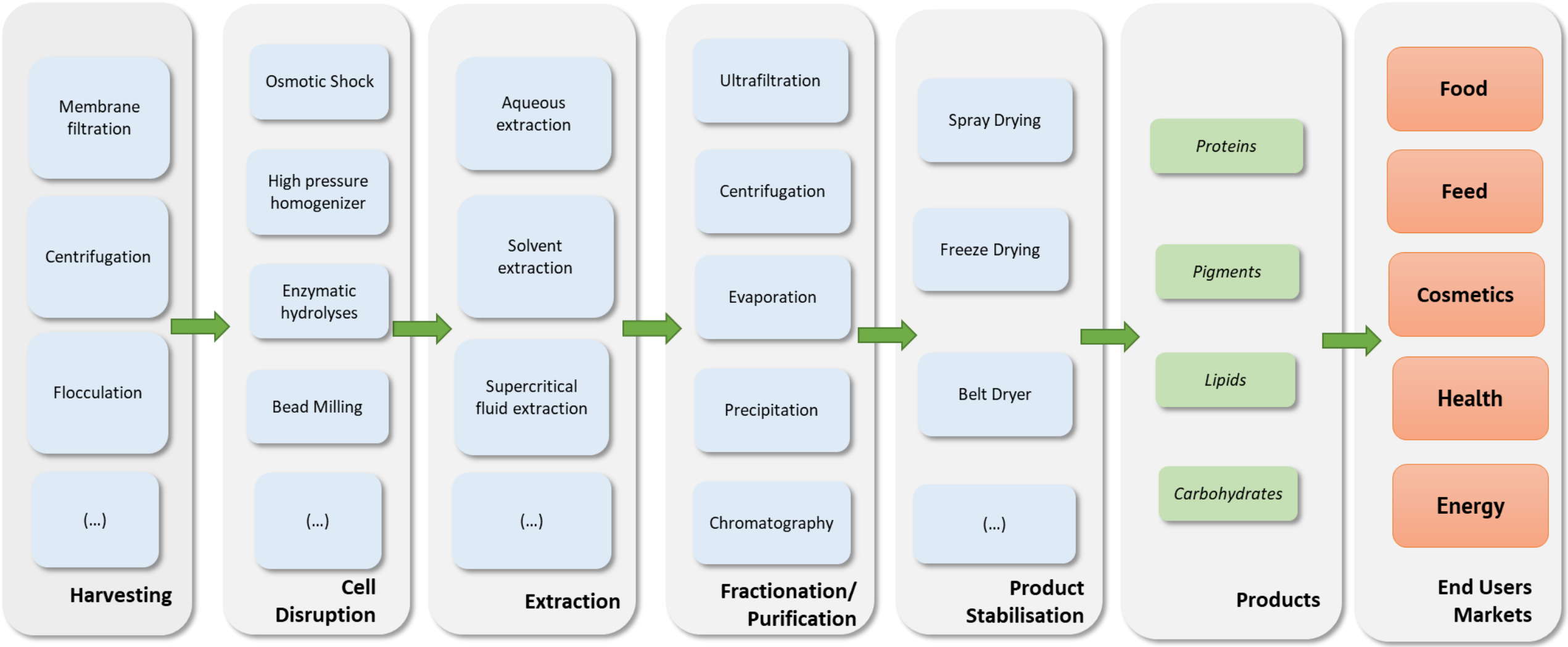
1. The production of bulk and high-value products may increase biomass exploitation up to 95% recovery[1].
2. The production of bulk products may become economical viable.

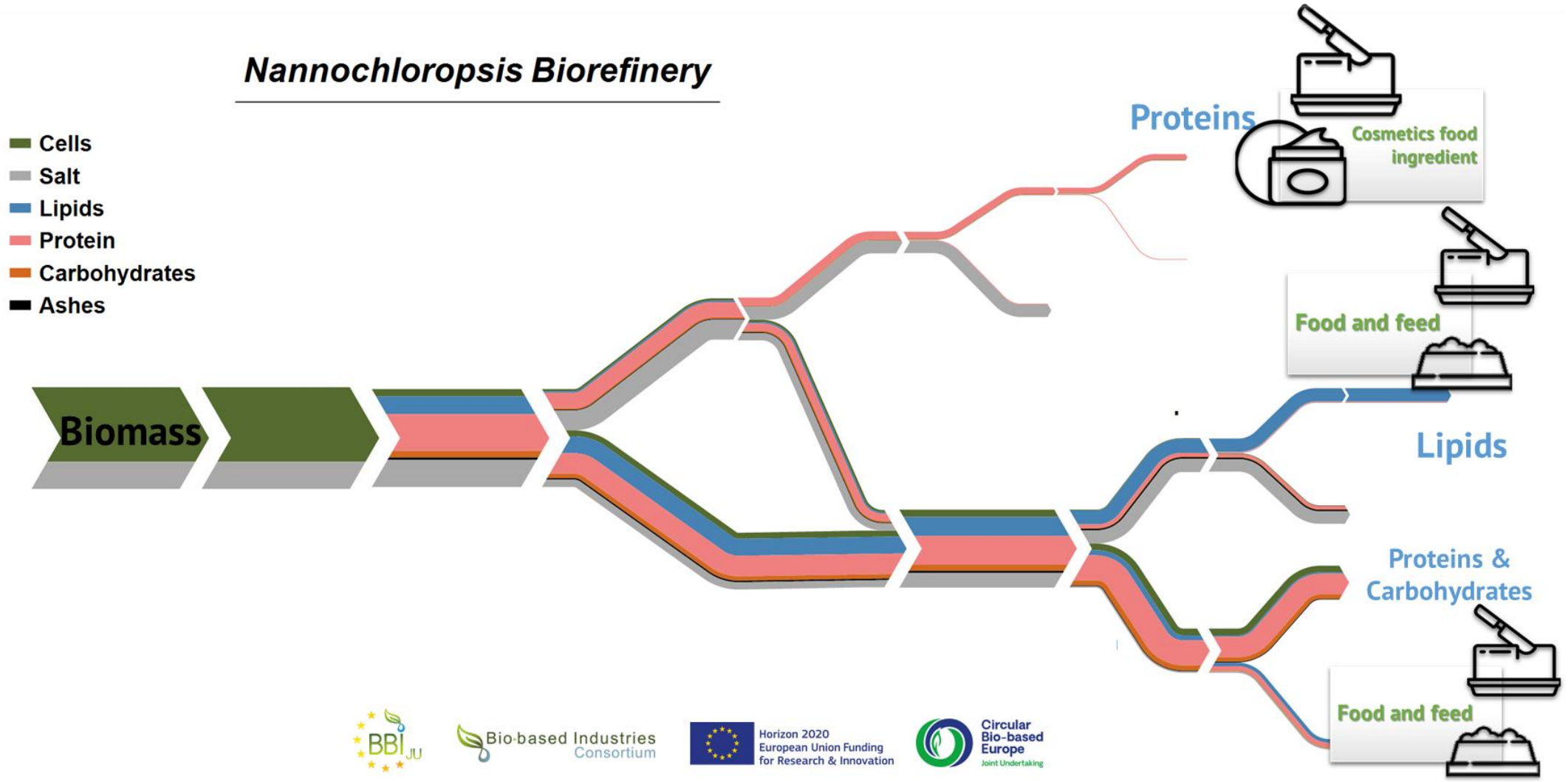
[1] Slegers PM, Olivieri G, Breitmayer E, Sijtsma L, Eppink MHM, Wijffels RH and Reith JH (2020) Design of Value Chains for Microalgal Biorefinery at Industrial Scale: Process Integration and Techno-Economic Analysis. Front. Bioeng. Biotechnol. 8:550758.


Microalgae cultivation
Harvesting
Microalgae Paste
Cell Disruption
Drying
Microalgae Powder
Extraction
Fractionation
Lipids
Proteins
Pigments
Carbohydrates

02 Multi-Str3am

Microalgae Biorefineries





BBI JU
Bio-based Industries Consortium
Horizon 2020 European Union Funding for Research & Innovation
Circular Bio-based Europe Joint Undertaking

Refurbishing of the industrial building for the biorefinery installation

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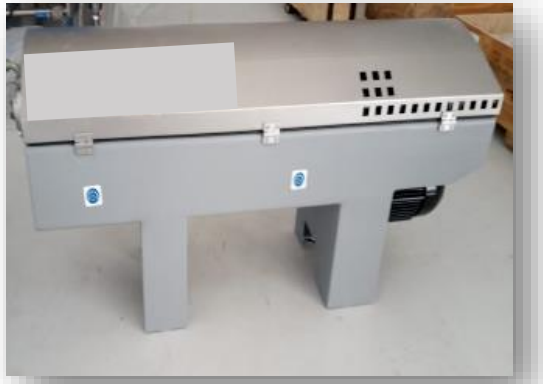
Installation of equipment: bead mill, UF and NF membrane systems, tricanter, spray dryer



First fractions

Carotenoid Extracts
3.8% Carotenoids

Omega 3 lipids
14% EPA

Bulk protein
Up to 80% protein

Bulk protein *44%* and carbohydrate *44%*

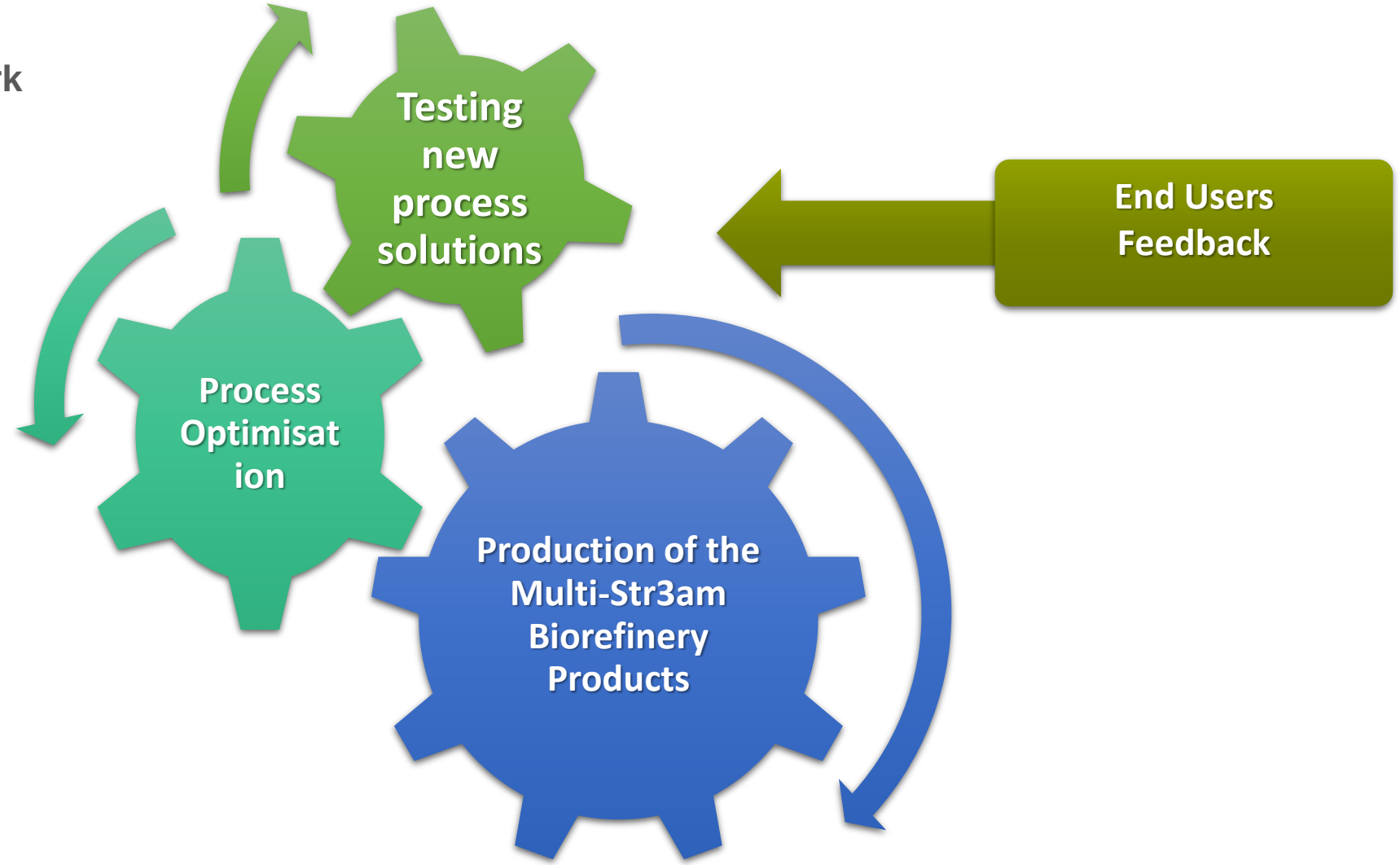
Phycocyanin *22 g/l*

Complete microalgae

On going work

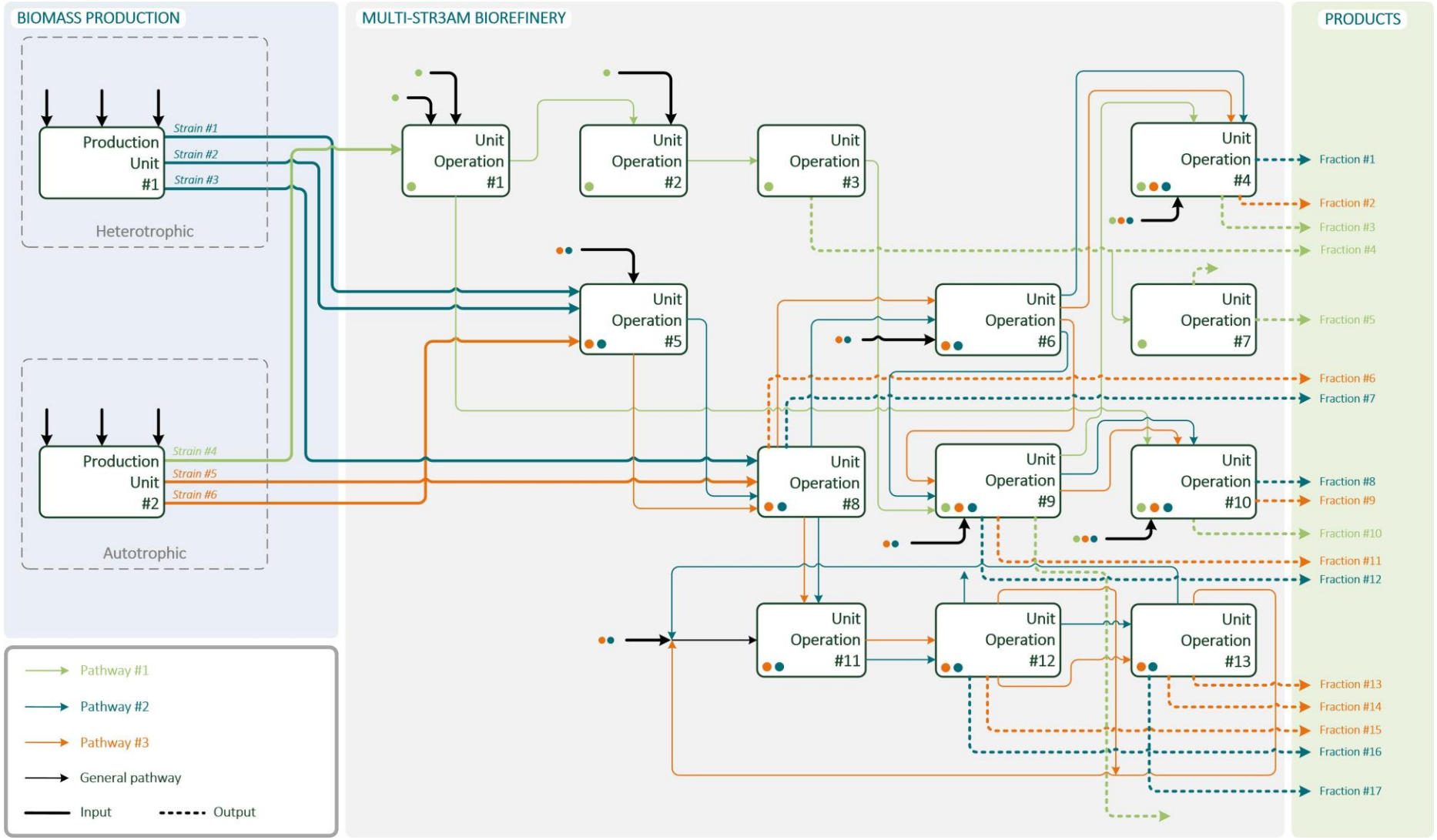
- Development of 6 **processing routes** and production of fractions/building blocks
- Development of the **analytical methods for fractions characterization**: proteins, carbohydrates, lipids, pigments, phycocyanin, EPA and complete fatty acid profile
- Development of **specification sheets** for each building block
- Testing alternative technologies for cell rupture, protein fractionation and carotenoid extraction

On going work



02 Multi-Str3am

Support from Process Simulation and Life Cycle Assessment



02 Multi-Str3am

Take-Home Messages

- Microalgae are a rich source of lipids, protein and high-value compounds (e.g. pigments)
- They can serve different markets
- Microalgae biorefineries start with the optimization of cultivation conditions
- Single product biorefineries are only viable for high value products, not for bulk products
- Multi-product biorefineries are need for full exploitation of the biomass
- We need projects such as Multi-Str3am to build economies of scale by increasing the scale of production and downstream processing of microalgae
- Synergy with large industries is a key advantage for algae production and supports circular economy


Thank you!
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Atlantic Area
European Regional Development Fund
EUROPEAN UNION