Ukraine biomethane sector development

RESULTS OF ANALYTICAL NOTE № 3

“ADVANCED BIOMETHANE PRODUCTION FROM MICRO-ALGAE HARVESTED ON DIGESTATE OF BIOGAS PLANTS”

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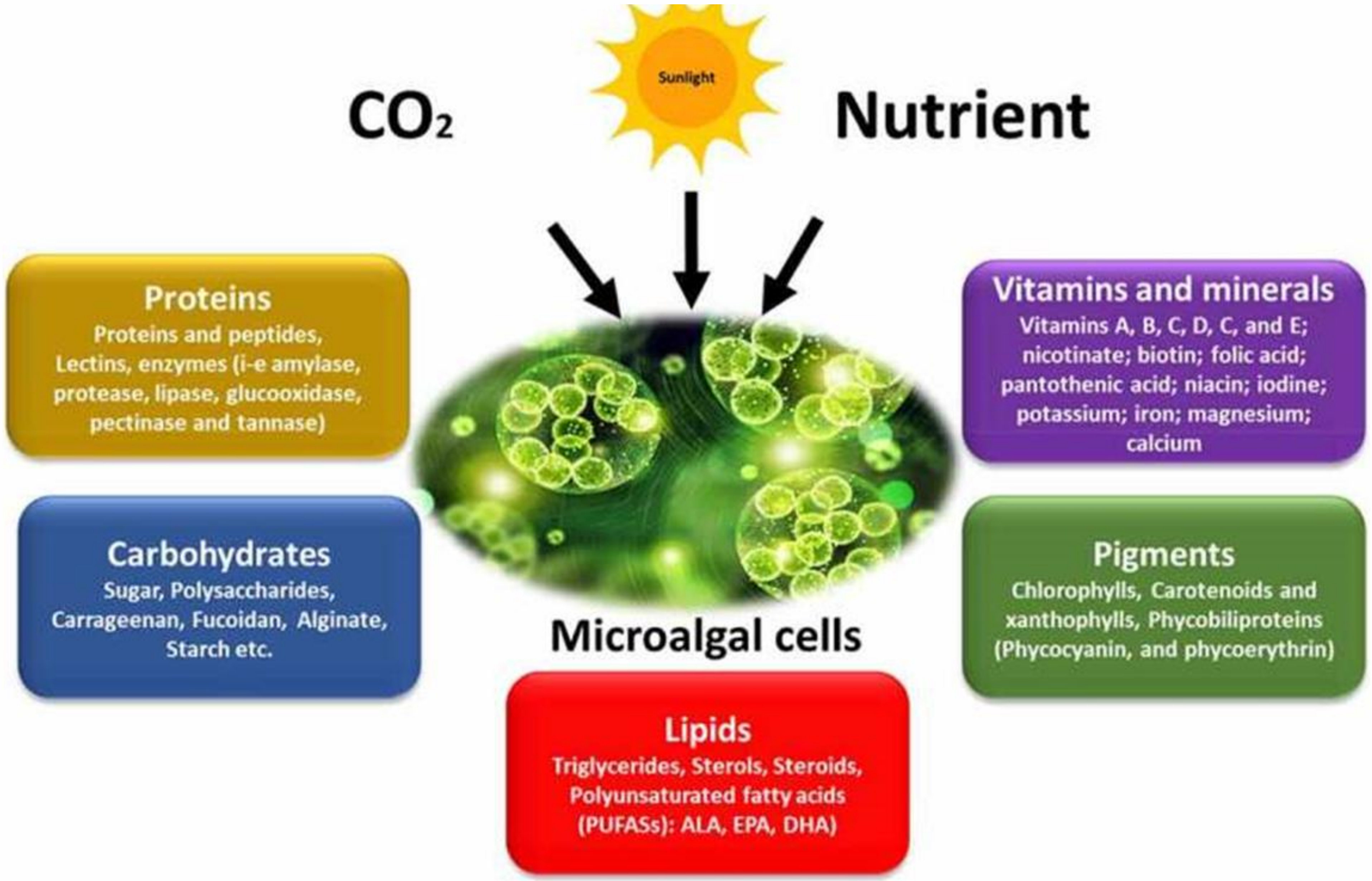
INTRODUCTIONS

$$6CO_2 + 6H_2O + light\ energy \rightarrow C_6H_{12}O_6\ (sugars) + 6O_2$$



https://pmc.ncbi.nlm.nih.gov/articles/PMC9161971/

The photosynthetic conversion of CO_2 into metabolic energy (which is stored in the carbohydrates and lipids form) is fundamental for algae productivity. **Microalgae, like land plants, grow and reproduce via photosynthesis, can fix 1.83 tons of CO_2 per 1 ton of dry mass.**

Microalgae can convert sunlight into chemical energy with high **photosynthetic efficiency (6%–8%**) in comparison with **land biomass (1.8%–2.2%).**

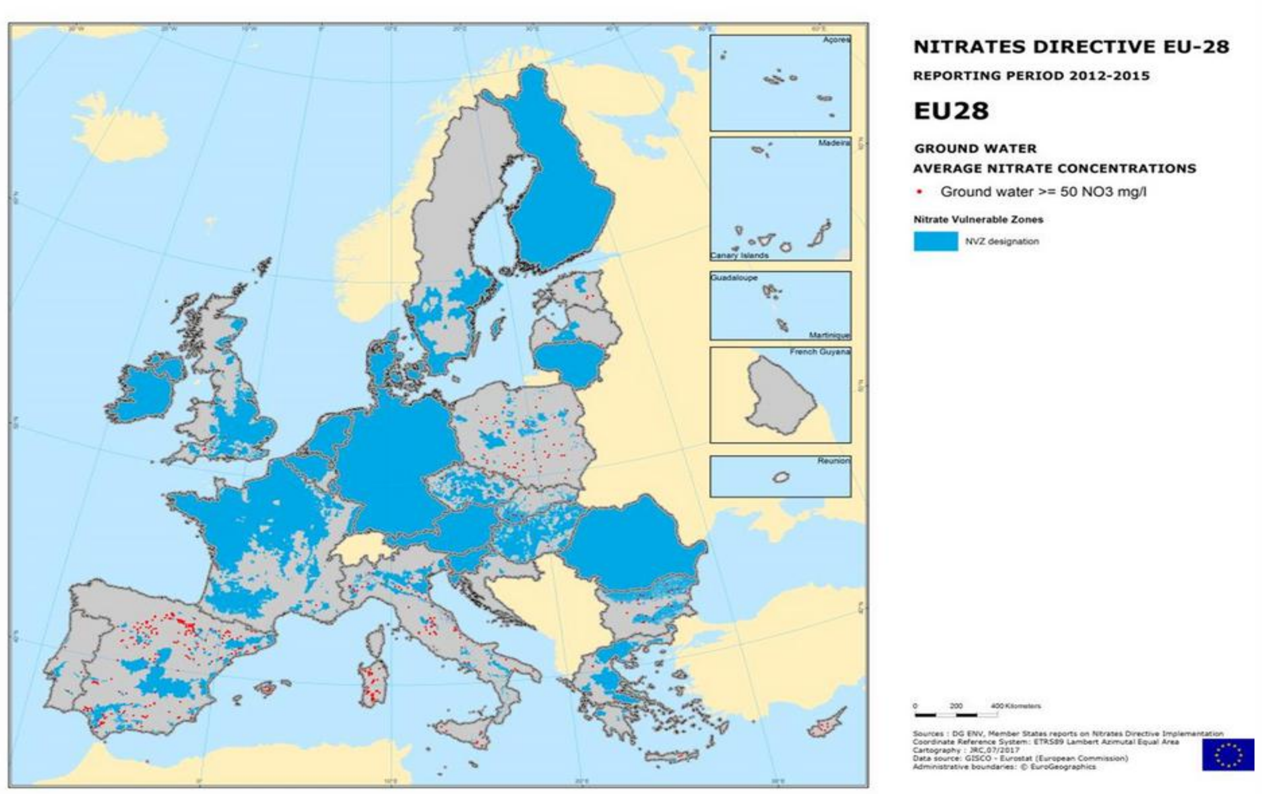
MOTIVATION AND RELEVANCE

- **Directive RED II, Annex 9, Part A**. Feedstocks to produce biogas for transport and advanced biofuels, the contribution of which towards the minimum shares referred to in the first and fourth subparagraphs of Article 25(1) maybe considered to be twice their energy content: **Algae if cultivated on land in ponds or photobioreactors;**

  https://lexparency.org/eu/32018L2001/ANX_IX/

Renewable Energy Directive EU

- **Microalgae** offer an innovative solution by **converting excess nitrogen and phosphorus from digestate** into valuable biomass, which is especially relevant in areas with **land-use restrictions and EU nitrate directive limits**. This approach reduces eutrophication, captures CO_2, and recycles nutrients sustainably.

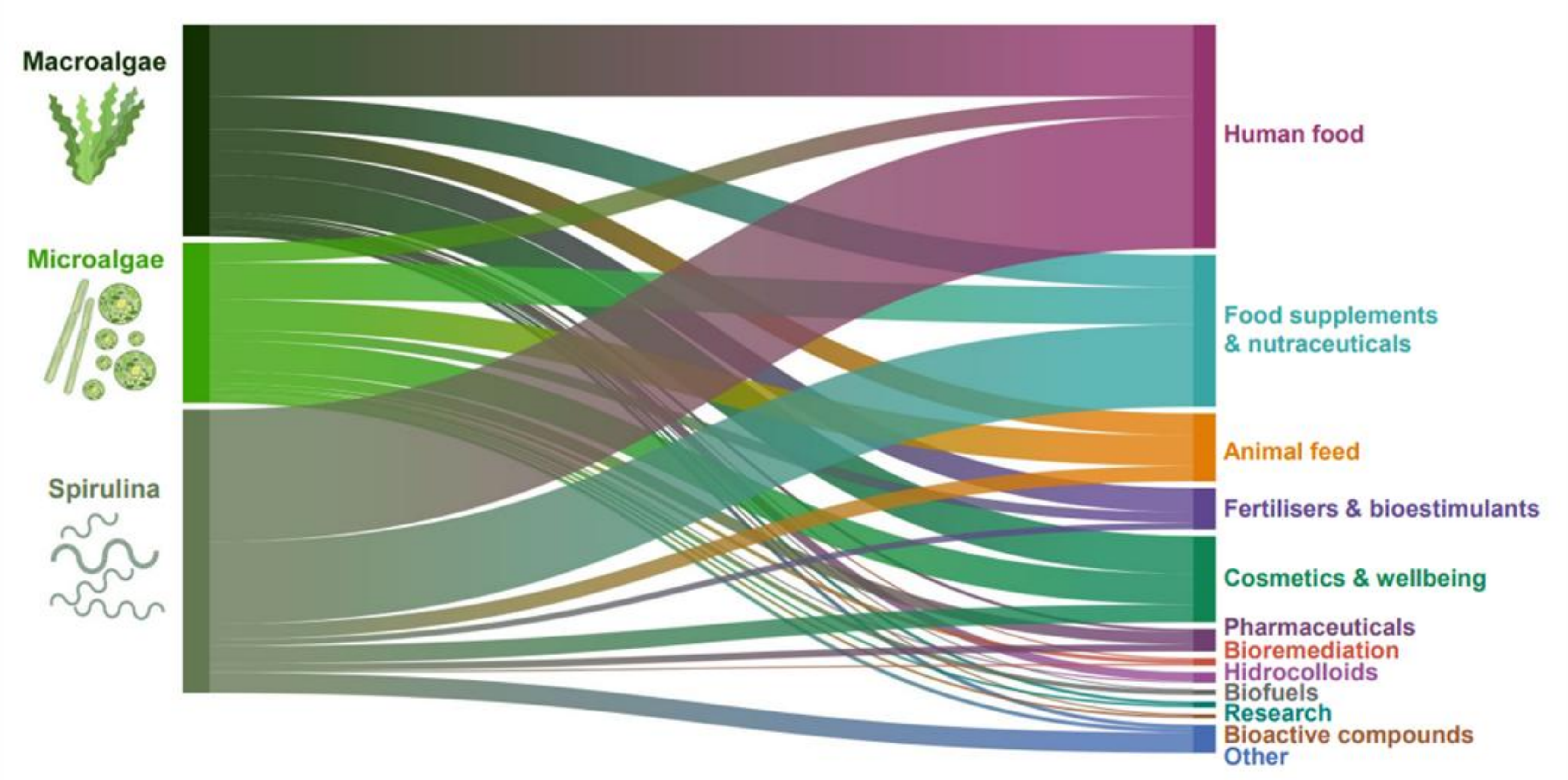


https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:52018DC0257

MICROALGAE TRENDS

The main areas of application of microalgae in 2022 are the production of food products and additives (23%), feed (19%), cosmetics (19%), pharmaceuticals (8%), fertilizers and bio stimulants (7%), which together account for 76% of total production in the EU.

The **limited use of microalgae for energy** production is mainly due to **high costs, energy-intensive processing, scalability challenges, and lack of policy support.** However, cultivating algae on digestate at biomethane plants in Ukraine can significantly reduce production costs and improve efficiency. Moreover, the market value of high-end algae products (e.g., nutraceuticals, animal feed, biomaterials) far exceeds that of biofuels, making energy applications less commercially attractive.



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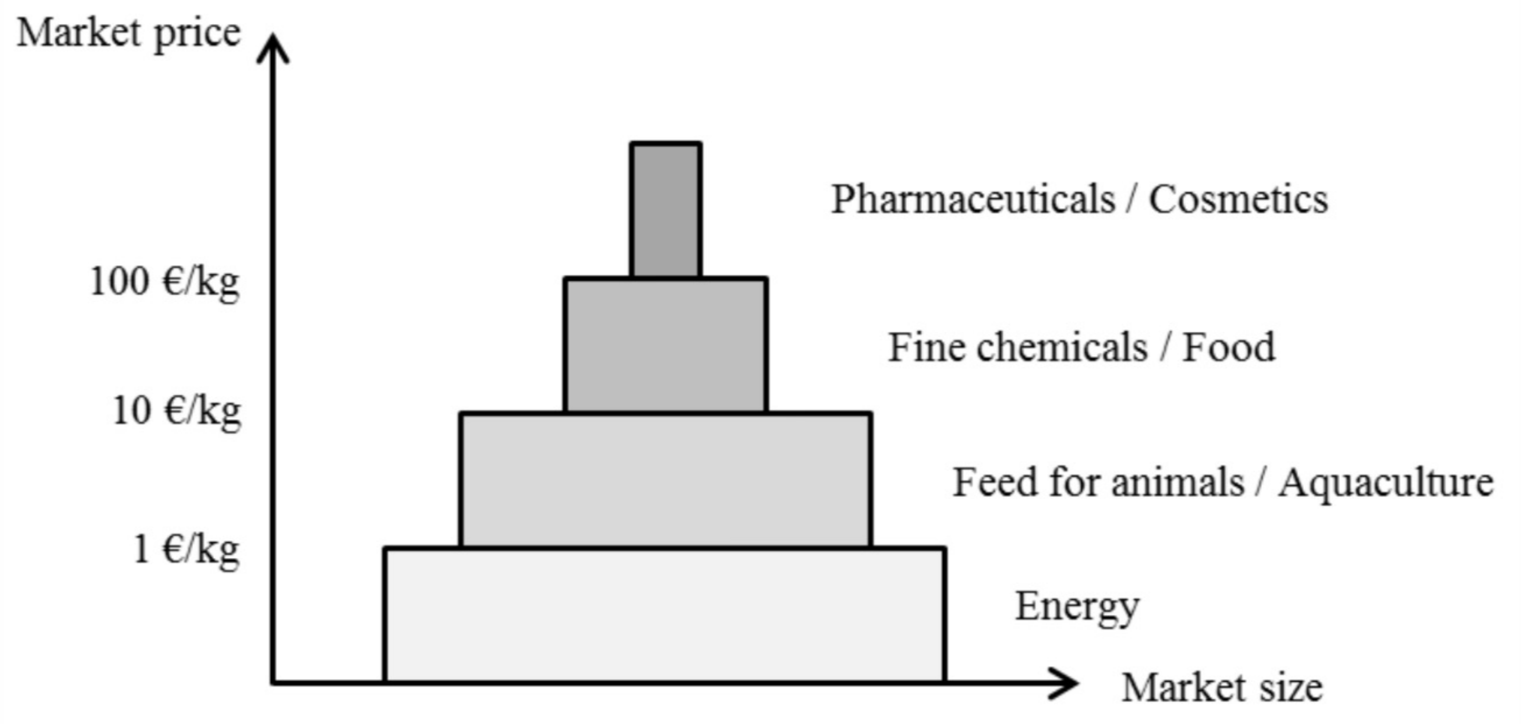


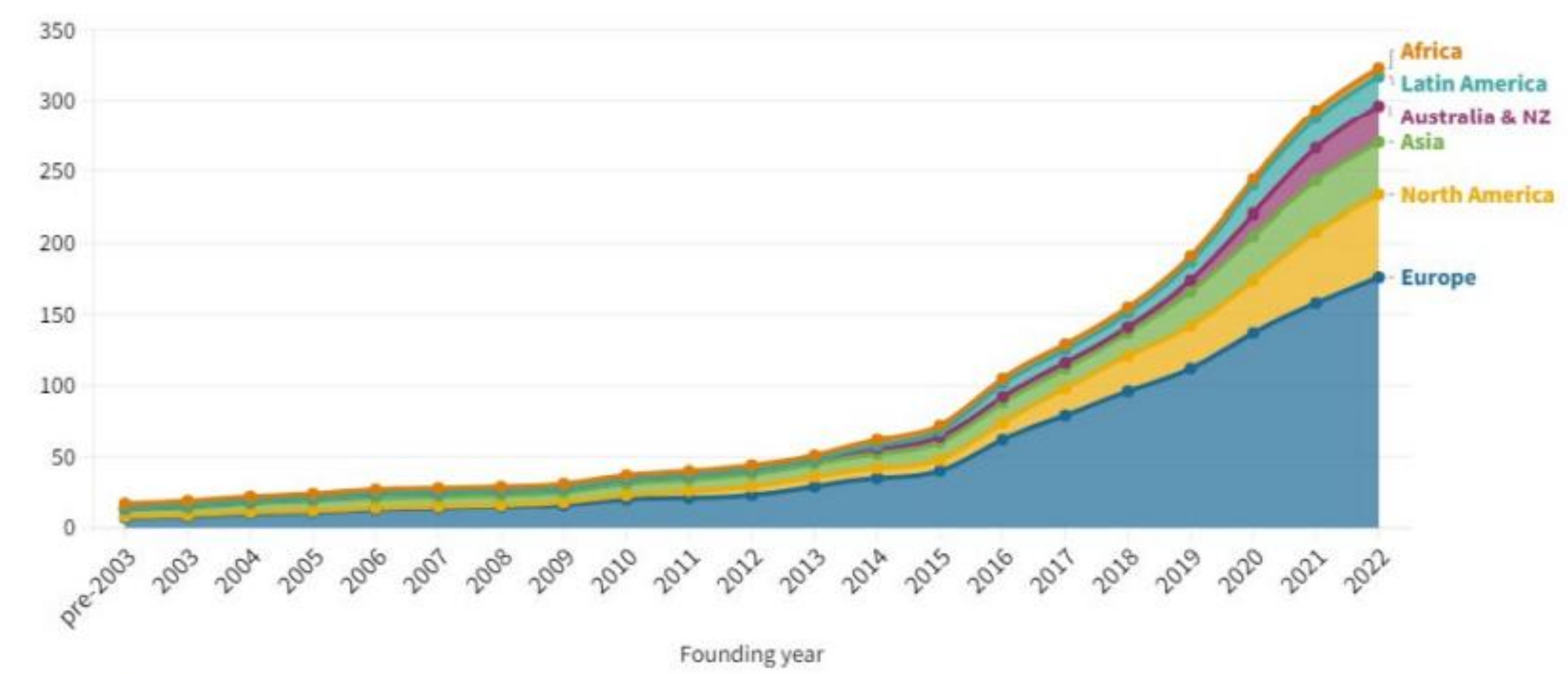
Figure 1: Markets and prices of microalgae as feedstock

https://www.diva-portal.org/smash/get/diva2:1092254/FULLTEXT01.pdf

MICROALGAE WORLD & UKRAINE

https://www.maximizemarketresearch.com/market-report/global-microalgae-based-products-market/63970/

Figure 16: Global development of algae start-ups by founding year, 2003 - 2022



Ukraine

Early-stage, applications include food supplements. Key Industrial Producers (spirulina in powder, tablets, and functional formats)

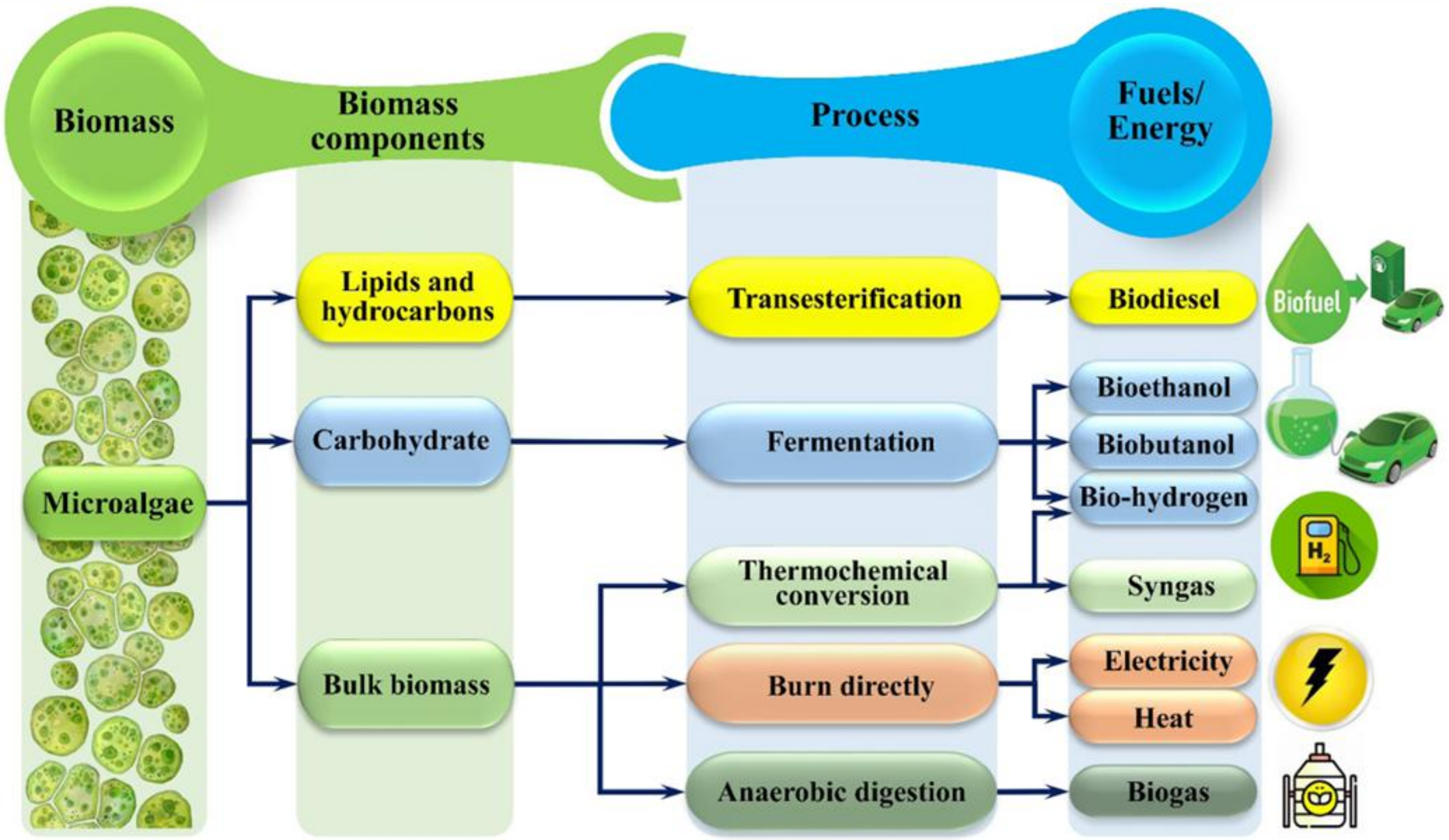
- Food Factory LLC (Spirulinka brand): 12 tons/month of edible spirulina.
- Aqvatic Farm (Dnipropetrovsk region): 1 ton/month, open pond system.

Other Market Players SME: Offers spirulina and chlorella products.

World

The North American region led the global microalgae-based products market with the highest market share of 32% in 2023. The region is expected to grow at a compound annual growth rate (CAGR) of 8.6% during the forecast period and maintain its dominance till 2030. **Growing demand for natural food colors, rising popularity of nutraceuticals and dietary supplements**, and technological investments are expected to be the major factors driving the regional growth.

ADVANTAGES OF MICROALGAE BIOFUEL PRODUCTION



https://link.springer.com/article/10.1007/s11101-022-09819-y

- No conflict with human or animal food chains.
- High carbohydrate (10-50%) , protein (30-60%), and lipids (10- 40%) content .
- Ability to grow in aqueous media such as wastewater, freshwater, and saline water.
- Create a long-term O2 generating method and employ it in photosynthetic respiration to reduce CO2 emissions.
- Microalgae contain a higher lipid content on a dry-weight basis compared to oilseeds such as soybeans.
- Additionally, the growth and cultivation cycle of microalgae is 15 days, in comparison to land biomass, for which the cycle occurs once or twice annually.

PHOTOBIOREACTORS AND OPEN PONDS

PBR	Advantages	Disadvantages	Biomass productivity g/l*day
Open ponds	• Economy • Easy to clean • Low energy consumption • Easily scalable • Low maintenance costsя	• Difficult to control parameters • Low productivity of biomass • Ability to contamination • Requires a large area • Inefficient mixing	0,03–0,2
Vertical photobioreactors (Airlift and bubble column)	•Excellent biomass productivity •High efficiency of photosynthesis • Limitation of photo-inhibition and photooxidation •Small land required for construction •Appropriate for outdoor cultivation •Low contamination risk •Low energy required •Low cost, relatively small size and easily maintain	•Possibility of cell shear stress •Low light exposure and low •Illumination area •Susceptibility of biofouling on walls of reactor	0,5-10
Horizontal tubular	• Large lighting surface • Suitable for outdoor placement • Good performance • Relatively inexpensive • Scalable • Easy control • Uniform mixing • Good temperature control	• pH gradient • Losses • Fouling on the walls • Requires significant areas • Hydrodynamic stress • Possibility of low gas exchange	0,35-1,5
Flat plate	•Maximum exposure to sunlight •High ratio of surface to volume •Well-appropriate for outdoor farming •High productivity of biomass • Well-distributed of total light for cultivation • Relatively cheap cost •Easy to construct, clean and handle •High photosynthesis efficacy Low concentration of dissolved oxygen	•Difficulty of Scalability •Difficulty of cultivation •Temperature regulating •Possibility biofouling •Possibility of hydrodynamic stress in algae cells	1,5 -28

Microalgae production method by company in Europe:
Photobioreactors 71%, Open Ponds 19%, Fermenters 10%.

*Raul Muñoz & Cristina Gonzalez-Fernandez.*Microalgae-Based Biofuels and Bioproducts (Enhanced Edition) From Feedstock Cultivation to End-Products. United Kingdom:Elsevier Science, 2017.P. 540
(PDF) Combined effects of Light Intensity, Light-Path and Culture Density on Output Rate of Spirulina platensis (Cyanobacteria)

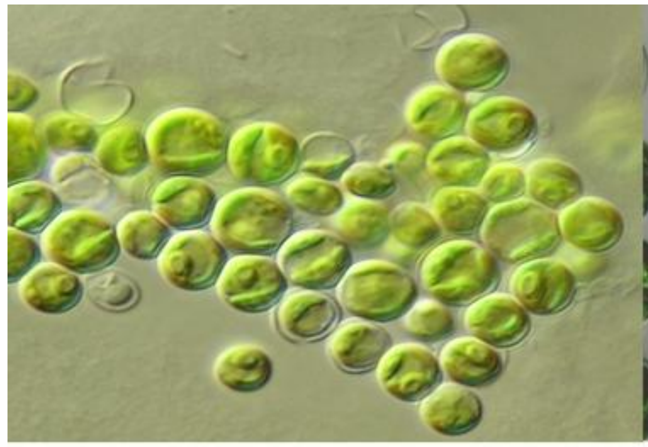
BIOMETHANE PRODUCTION FROM DIFFERENT TYPES OF MICROALGAE

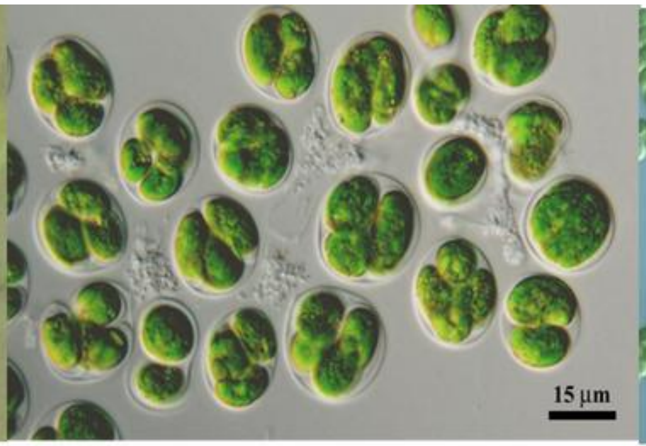
Species	Biogas prod. [L/kg VS]	CH4 prod. [L/kg VS]	CH4 content [%]
Chlorella kessleri	335 ± 8	**218**	65
Chlorella vulgaris	-	**310 – 350**	68 – 75
Spirulina (Anthrospira)	500- 556	**320 – 424**	76.3
Euglena gracilis	485 ± 3	**325**	67
Scenedesmus obliquuus	287 ± 10	**178**	62
Chlamydomonas rein.	587 ± 9	**387**	66

https://www.ieabioenergy.com/wp-content/uploads/2017/02/IEA-Bioenergy-Algae-report-update-Final-template-20170131.pdf

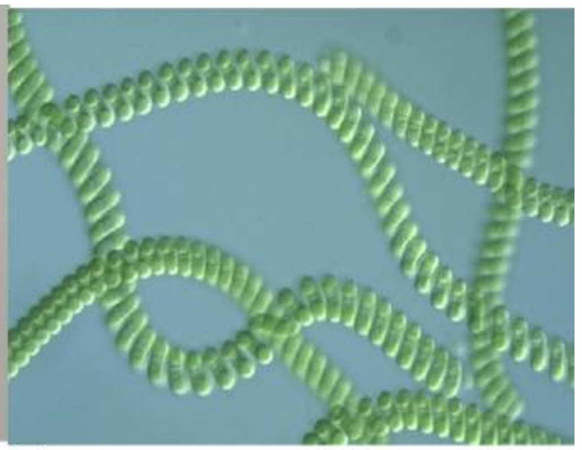
The most suitable microalgae strains for high biogas yields should possess:

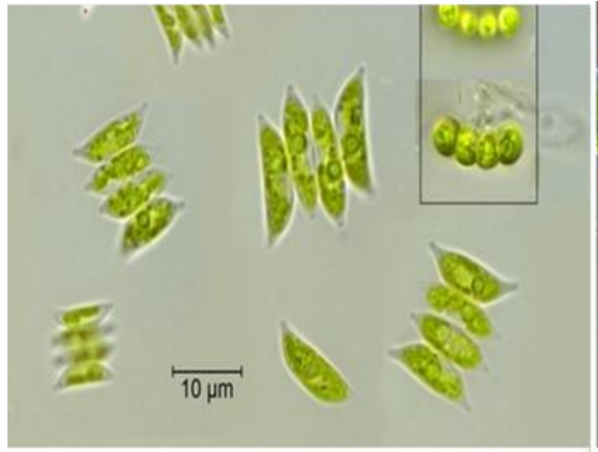
- Thin or absent cell walls – enabling easier anaerobic digestion;
- Large cell size – increasing volumetric biogas output;
- High growth rates in non-sterile environments;
- Strong resistance to natural contaminants;
- Tolerance to ammonia and ammonium concentrations
- Optimal chemical composition and high specific methane yield


Chlorella v.
5-10 µm



Chlamydomonas reinhardtii
14-22 µm


Spirulina
< 100 µm



Scenedesmus
3-78 x 2-10 µm


Euglena sp.
length 70 µm

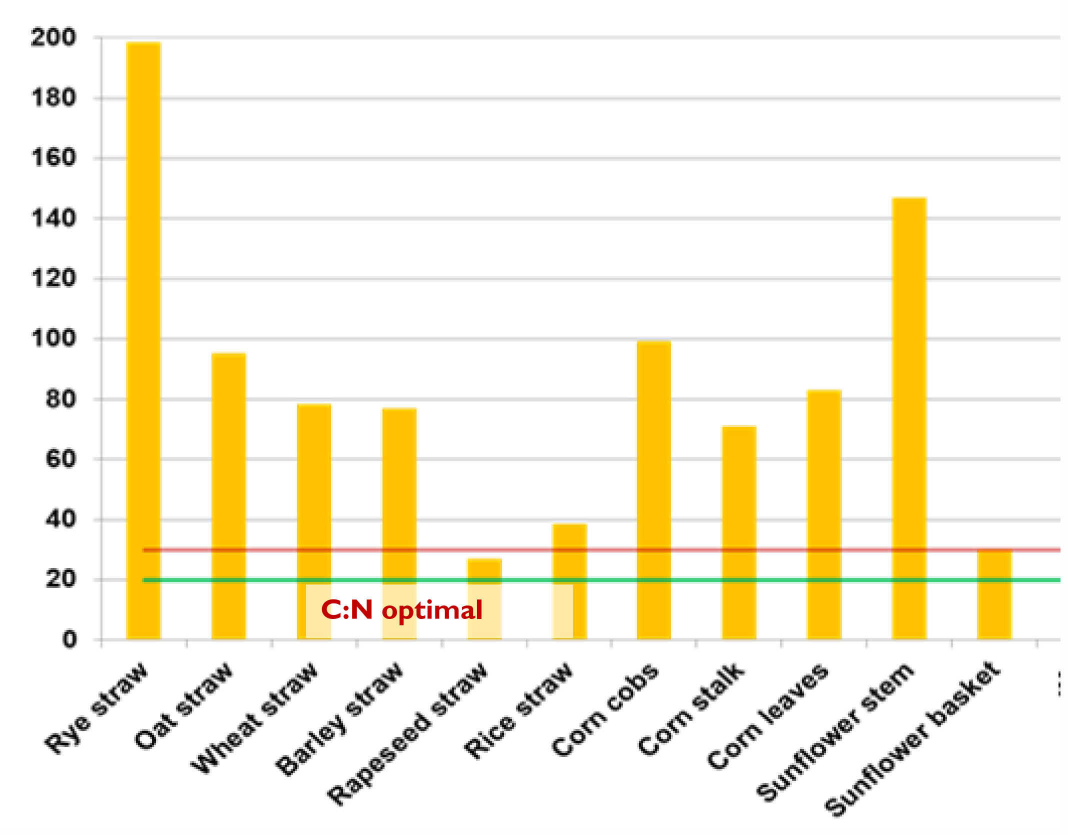
MICROALGAE SUBSTRATE FOR ANAEROBIC DIGESTION

PARAMETERS OF THE MIXTURE : SUSPENSION OF MICROALGAE GROWN IN DIGESTATE + STRAW

Inducator	Straw	Liquid digestate with microalgae	Mix (1:8)
TS	80	1	**9,8**
C/N	**70**	**3-9**	**19,8**

C:N – complementarity of Agro feedstock

The majority of **Ukraine's biomethane potential — 69%** — comes from **cover crops** and **agricultural residues**, which have a **high C/N ratio**.



Co-fermentation of microalgae (C/N <10) with crop residues (for straw C/N >70) allows obtaining an optimal substrate for fermentation (C/N = 15-30). It also reduces the need to concentrate the microalgae.

We can achieve optimal fermentation TS = 10-12% by mixing straw (TS = 80%) and microalgae (TS = 1-5 %)

Preliminary assessment of the biomethane potential from microalgae

14.53 billion m³ CO_2
(Ukraine potential - 21.8 billion m³ CH_4)

20 % CO_2
(2,9 billion m³)
for **microalgae cultivation –**
2,9 billion m³

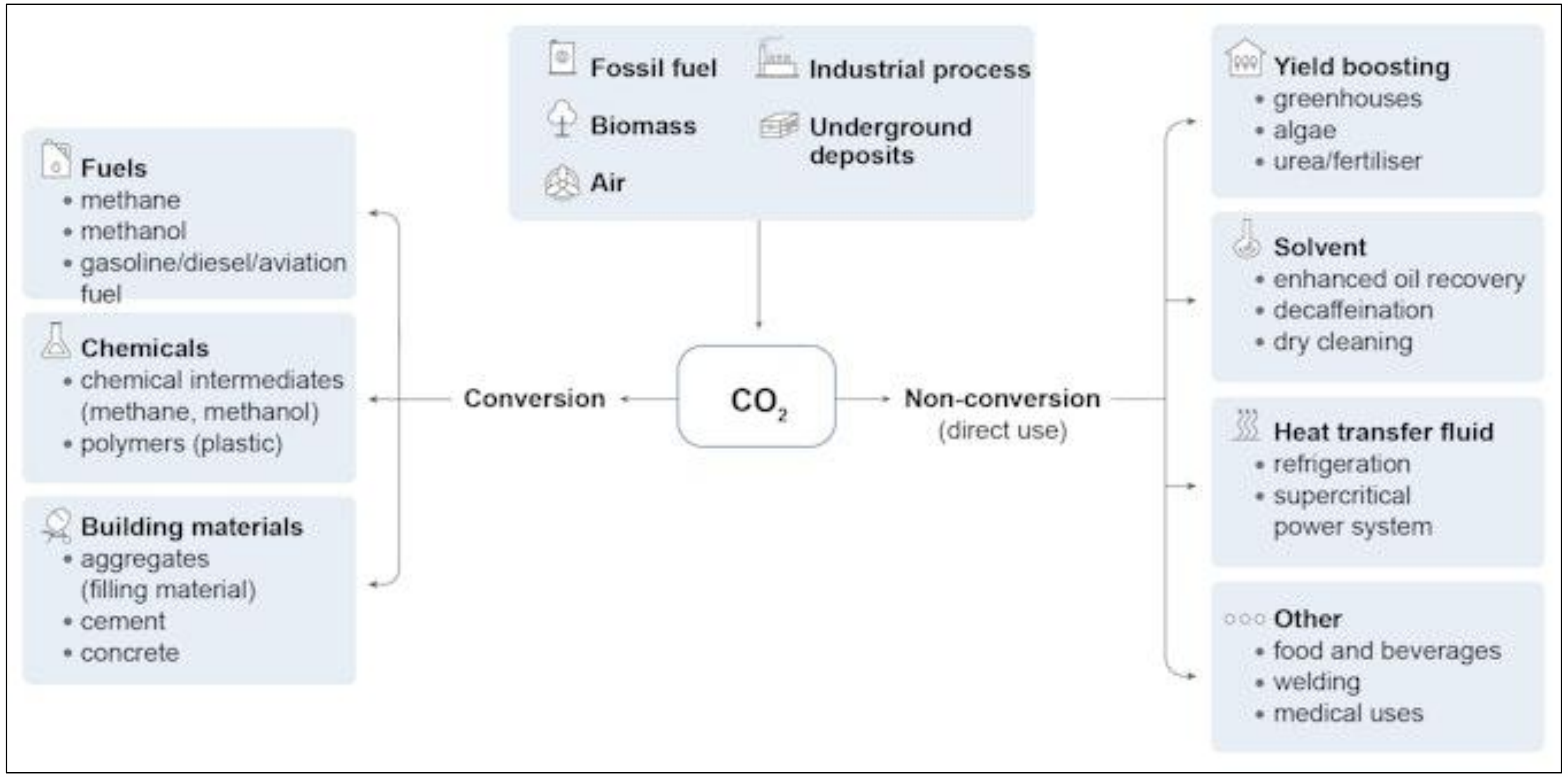
80 % CO_2
(11,6 billion m³)

Biomethane
0,83 billion m³
biomethane
(3.8% of potential)

Other pathways for CO_2 use

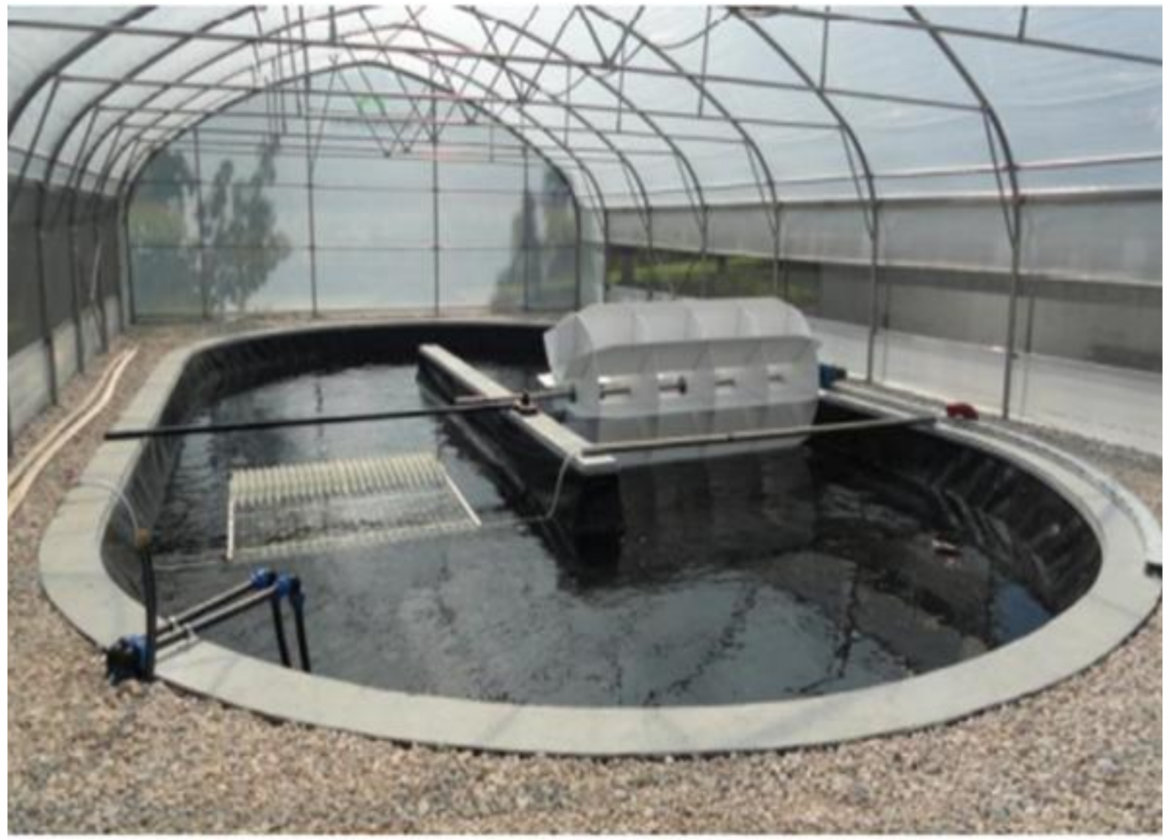
- Using 20% of CO_2 emissions from biomethane plants for microalgae cultivation yields an additional 0.8 billion m³ of biomethane per year.
- This corresponds to approximately 3.8 % of the total biomethane potential (21.8 billion m³).

Simple classification of pathways for CO2 use



https://www.iea.org/reports/putting-co2-to-use

CASE STUDY : SLOVENIA ALGAEBIOGAS DEMONSTRATION CENTER



Main pond with paddlewheel

The demonstration center consists of two algae ponds (a 100 m2 main pond and a 10 m^2 inoculation pond) located in a greenhouse to ensure optimal operating conditions and limit seasonal fluctuations. Digestate from the biogas plant is fed into the main pond.

The AlgaeBioGas project demonstrates a high integration of biogas plant technology and bioremediation with microalgae, ensuring:

- **deep purification of digestate,**
- **generation of additional biomass,**
- **significant reduction of CO_2 emissions (1,100 t CO_2/year)**
- **saving land for growing fodder crops, 9–27 hectares (instead of 335 hectares of general needs for silos)**

https://algaebiogas.eu

ALG-AD – INTEGRATING ANAEROBIC DIGESTION AND MICROALGAE CULTIVATION

- The ALG-AD project was implemented within the framework of the **Interreg North-West Europe program** with the aim of integrating anaerobic digestion (AD) systems with microalgae cultivation.

- **The main objective** was to find an efficient solution for the processing of surplus nutrient-rich digestate that cannot be applied to fields as fertilizer due to environmental restrictions in the EU.

- **The project was implemented at three pilot sites: the UK (Swansea), France (Brittany), Belgium (Flanders)**. **These sites covered different types of substrates for anaerobic digestion,** including food and agricultural waste, and used different photobioreactor configurations to evaluate the performance of algae cultivation on pre-treated digestate.

https://vb.nweurope.eu/projects/project-search/alg-ad-creating-value-from-waste-nutrients-by-integrating-algal-and-anaerobic-digestion-technology/

ALL-GAS LARGE-SCALE PRODUCTION OF BIOFUEL FROM MICROALGAE (Spain)

The project was implemented in the **municipality of Chiclana de la Frontera (Spain), on the territory of an existing wastewater treatment plant.**

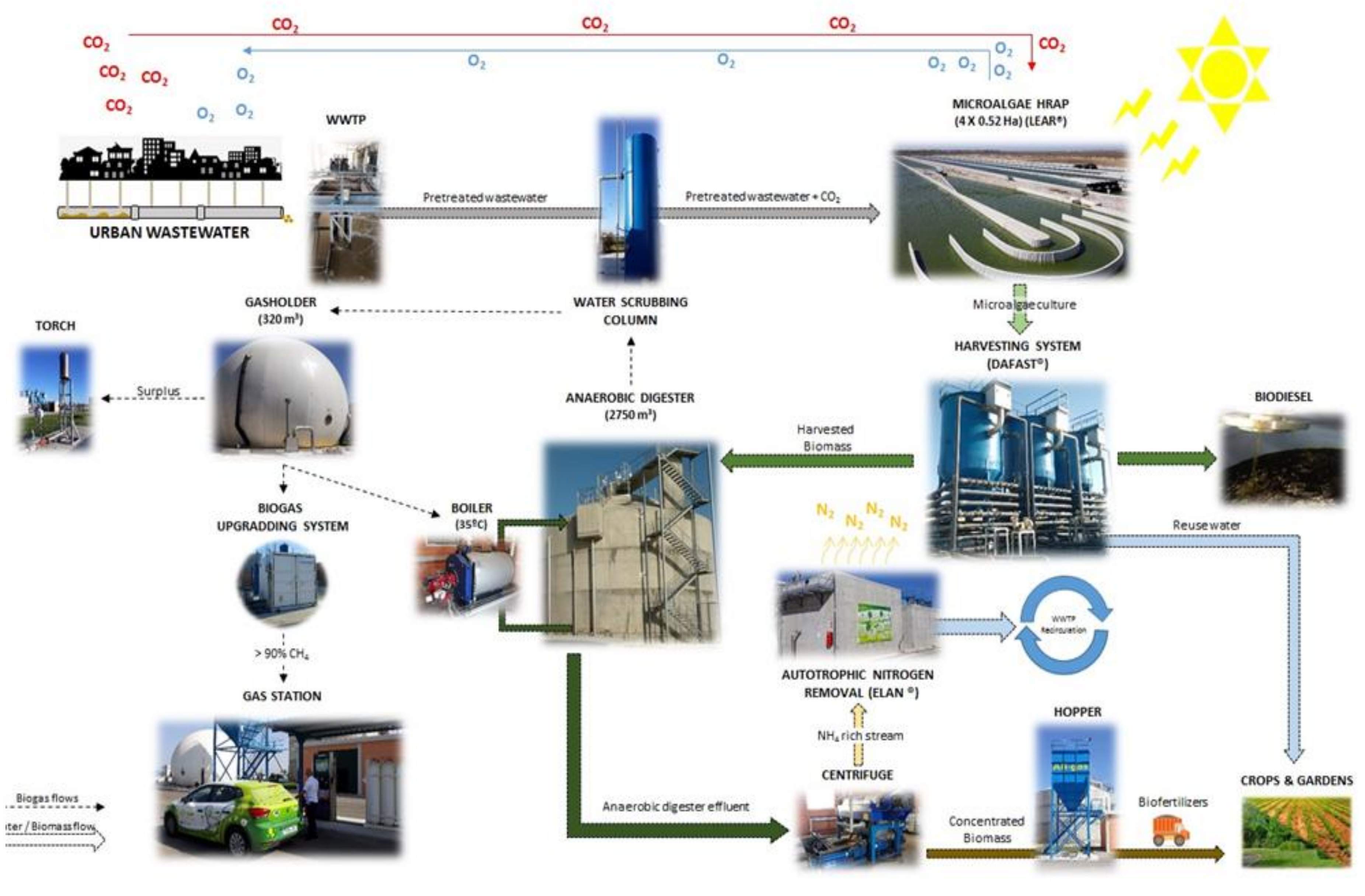
ALL-GAS (Spain) - the world's first example of full-scale application of microalgae for biofuel production based on wastewater treatment.

The ALL-GAS cycle includes:

- Wastewater discharge from the treatment plant into open ponds/channels (up to 4 ha).
- Cultivation of microalgae in water rich in organic matter, nitrogen and phosphorus.

Biomass processing:

- **Lipid fraction → transesterification → biodiesel.**
- **Residues and activated sludge → anaerobic digestion → biomethane + CO_2.**
- **Biogas purification and compression → fuel for transport.**



[Home - All-Gas](#)

Innovate Ukraine project : Advanced biomethane production from microalgae grown in digestate from biogas plants 2024-2026

The project will be implemented for 2 years by a consortium of Ukrainian and UK partners.
Project goals:

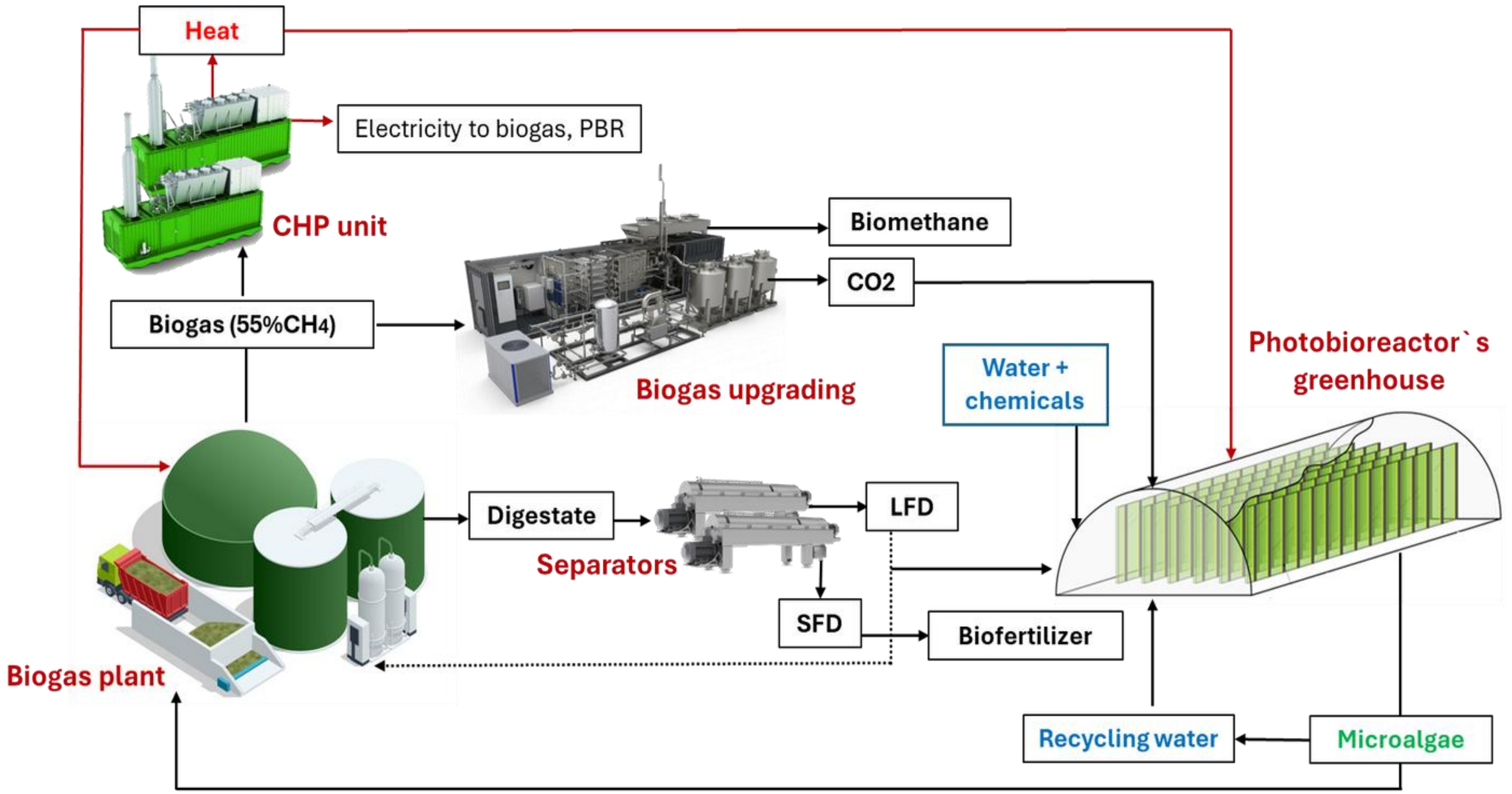
- A novel cost- and energy-efficient microalgae cultivation process in biogas digestate.
- A novel cost- and energy-efficient biomethane production process through the anaerobic digestion (AD) of the harvested microalgae.

The project will combine experiments from the laboratory to the pilot scale – including microalgae cultivation in flat panel and tubular photobioreactors with new computational models for microalgae cultivation and anaerobic digestion, for process optimization and techno-economic analysis.

Innovate UK

Project Partners:

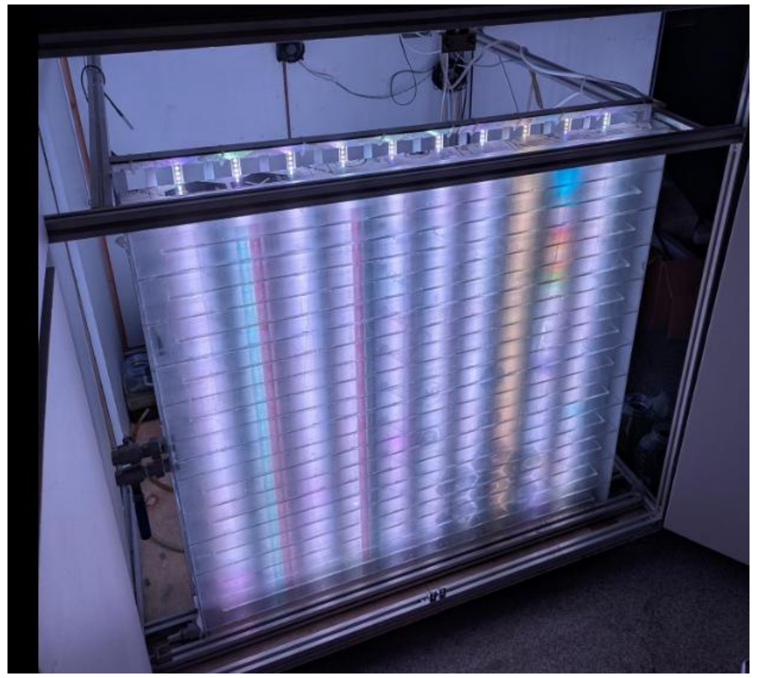
UABIO MHP algaecytes MANCHESTER 1824 The University of Manchester



Innovate Ukraine project: LABORATORY STAGE

UABIO

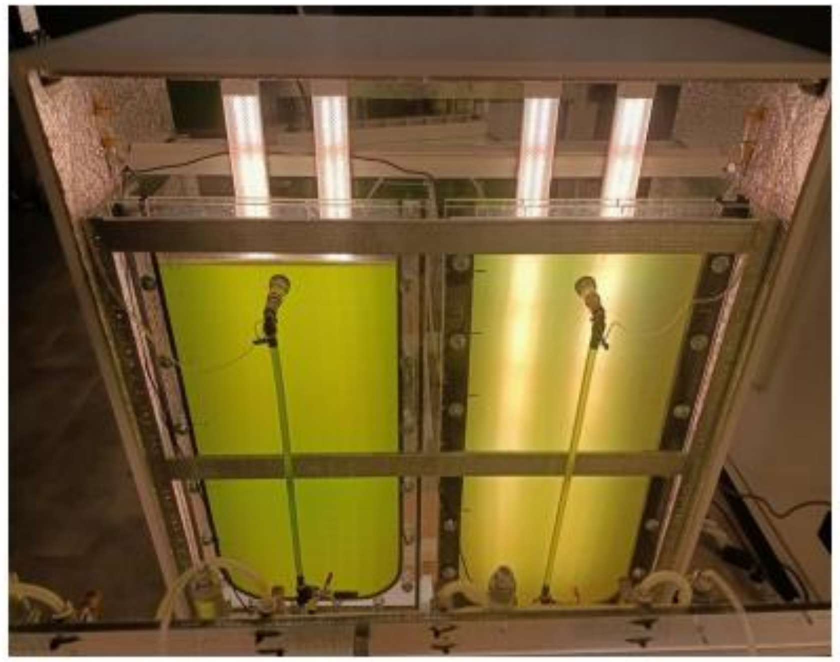
Flat-plate PBR made of polycarbonate sheet



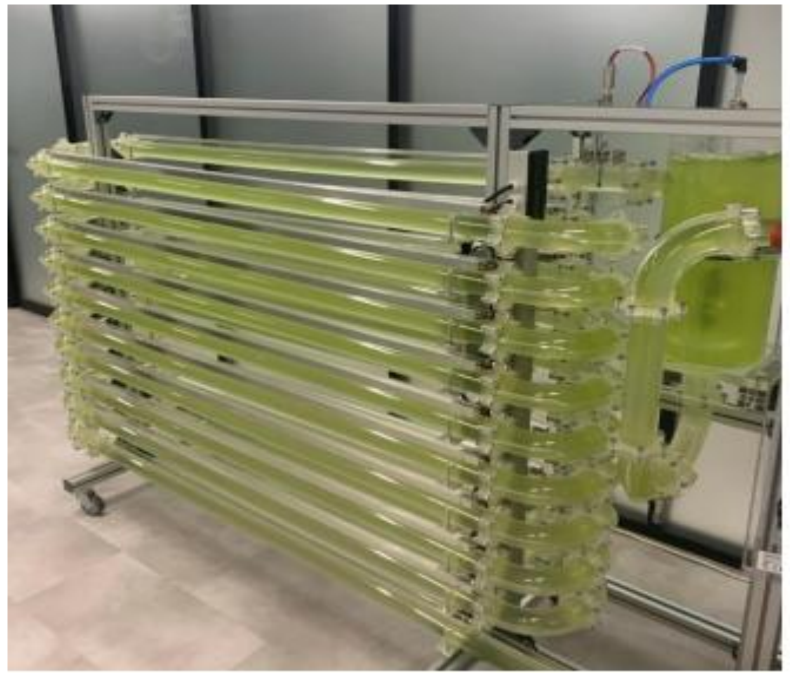
Chlorella at concentration 10 g/L

MHP

Plate photobioreactor



Tubular photobioreactor



AD test system

CONCLUSIONS

- Microalgae are listed in Annex IX-A of the EU RED II Directive as a sustainable feedstock for advanced biofuels, eligible for double-counting.

- They offer high biomass productivity, CO_2 capture, and nutrient recycling — ideal for integration with anaerobic digesters using digestate as growth medium.

- Co-digesting wet algae with dry agricultural residues like straw (for C/N balancing) ensuring optimal conditions for the anaerobic digestion process. Since biogas production through wet fermentation does not require biomass drying.

- Microalgae can convert sunlight into chemical energy with high photosynthetic efficiency (6%–8%) in comparison with land biomass (1.8%–2.2%).

- Innovate Ukraine project highlights that Ukraine is already engaged in pioneering research on the use of digestate and microalgae for sustainable biomethane production, in collaboration with leading UK institutions and supported by international funding.

- Additionally, the growth and cultivation cycle of microalgae is 15 days, in comparison to crops, for which the cycle occurs once or twice annually.

THANK YOU FOR ATTENTION

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