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Solar-driven fuels and chemicals

Prof. Yagut ALLAHVERDIYEVA-RINNE

Department of Life Technologies
University of Turku

10 May 2023
Otaniemi

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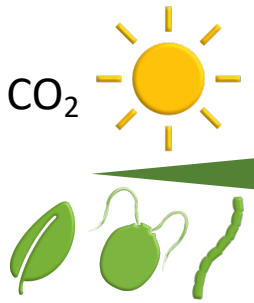
Photomicrobes Research team

From natural photosynthesis to biotechnology and circular bioeconomy



Natural Photosynthesis

Fundamental mechanisms of photosynthesis

- Photosynthetic mechanisms
  - Biophysics
  - Biochemistry
  - Omics
- Regulation of photosynthesis under different enviormntal conditions

Sustainable biotechnology by photosynthetic microbes

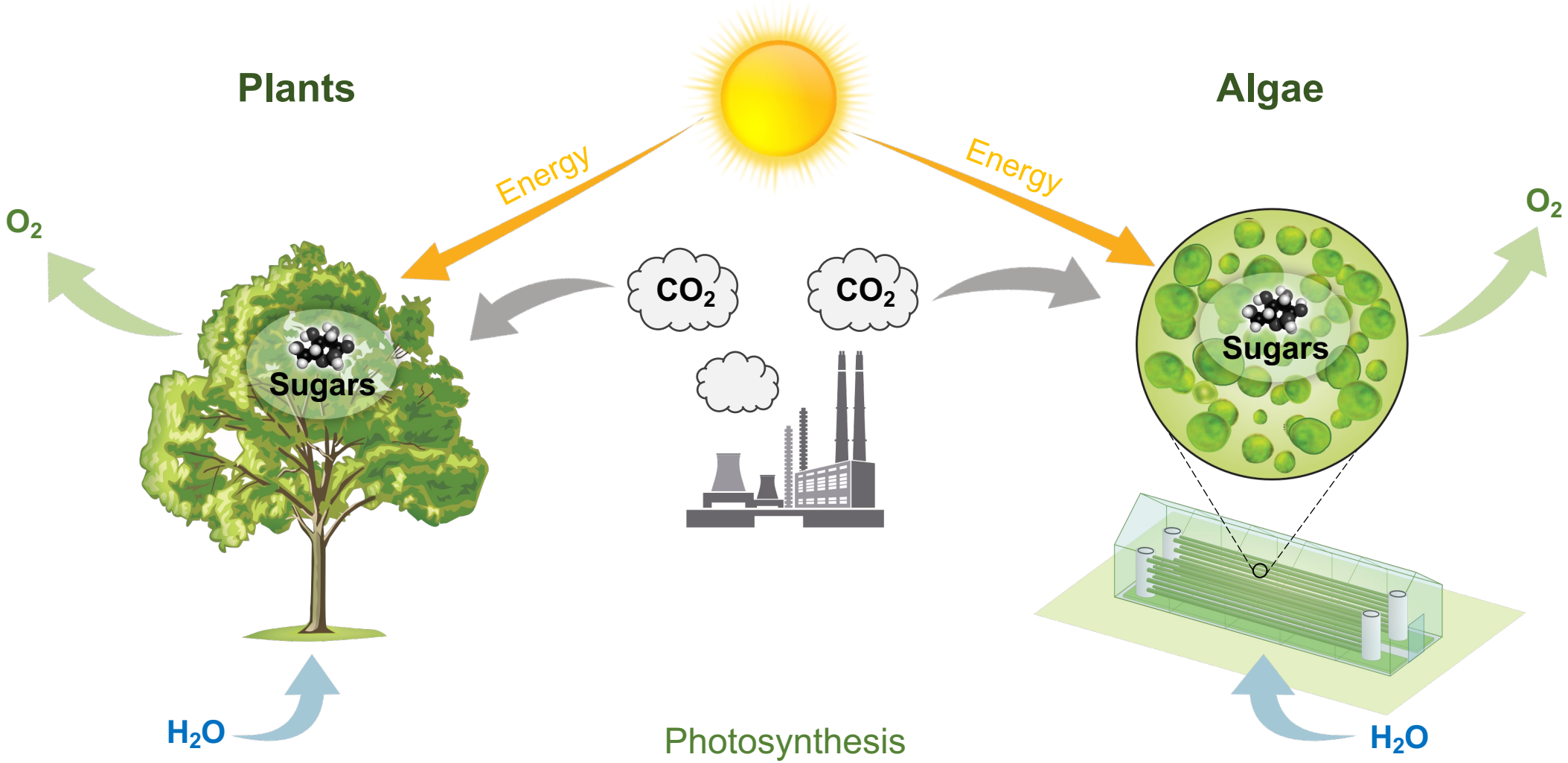
- **Biocatalytic** direct conversion of solar chemicals and fuels
  - **Solid-state** cell factories for production of **solar chemicals and fuels**
  - 3D printed living materials
- **Biological photovoltaics** for green electricity generaton

Towards sustainable production platforms

- Large-scale algae cultivation
- Nutrient recovery and waste-water treatment by algae
- Valorisation of algal biomass (novel agrichemicals, aquafeed …)
- Integration algae and crop production

Sustainable biotechnology & circular (bio)economy

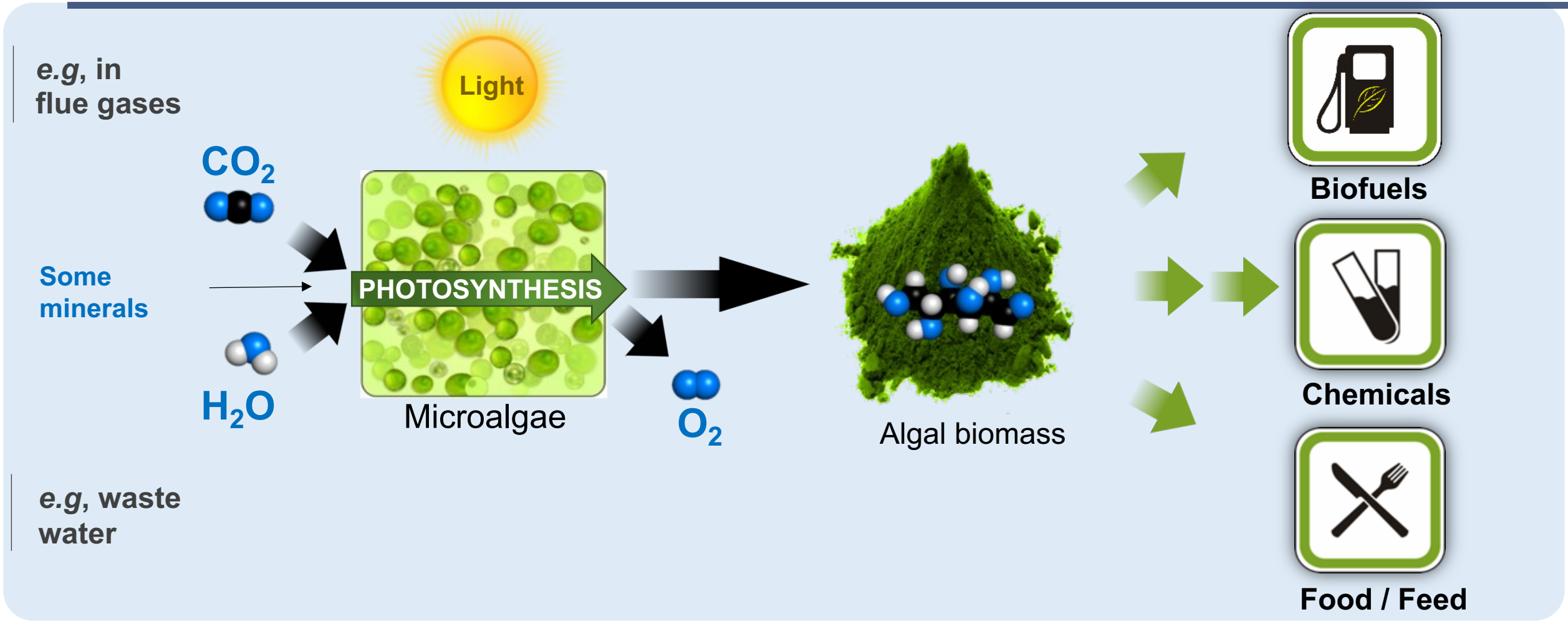
Starting point is Photosynthesis



Photosynthesis

$$6\ H_2O + 6\ CO_2 \longrightarrow \{CH_2O\} + 6\ O_2$$

Blue Bioeconomy
Algae as a sustainable production platform

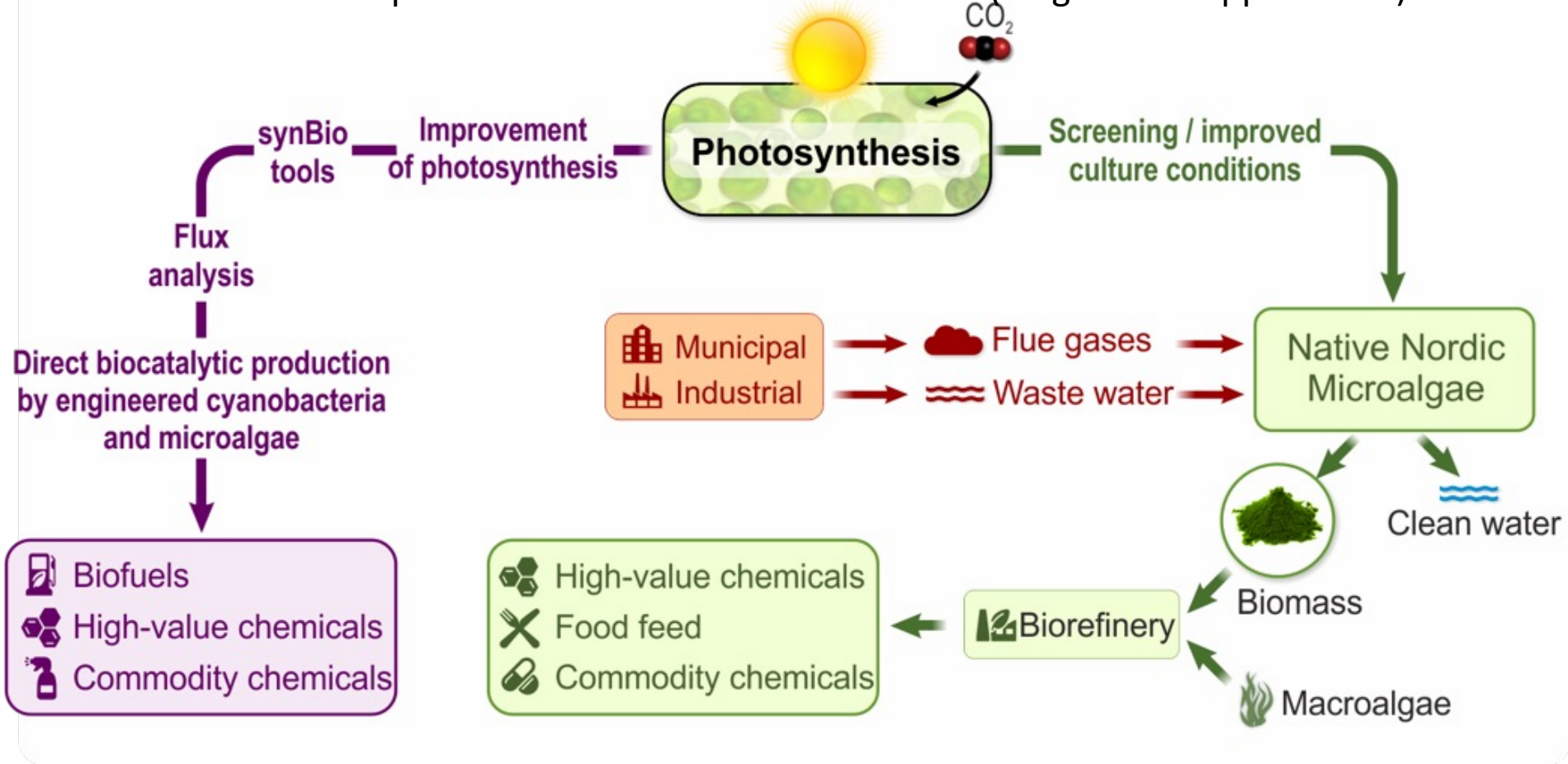


(i) the growth rate is very high and cultivation of these microorganisms do not compete with agriculture;
(ii) efficiently utilize CO_2, thus positively contributing to mitigation of CO_2 emission from industrial activities;
(iii) microalgae can utilize wastewater;

NordAqua develops sustainable aquatic **photosynthetic production platform**

i. production of algal **biomass, biorefinery, bioremediation** (near-term applications);

ii. **photosynthetic cell factories** for production of desired end-chemicals (longer-term applications)

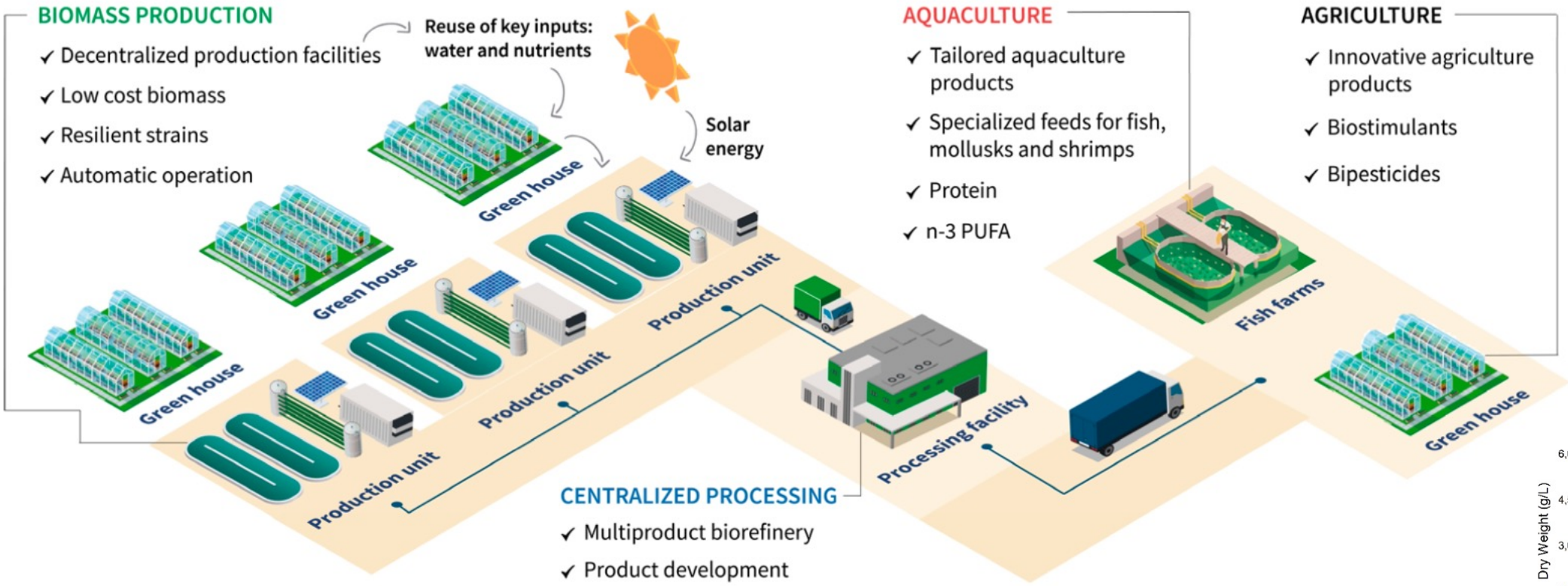


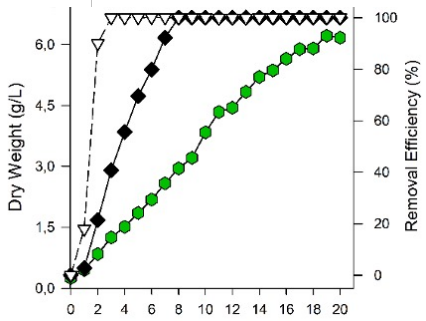
Nordic Algae collection > 3000 algae

Allahverdiyeva et al. 2021 Physiol. Plant

Nutrient recovery from greenhouse effluent & solar chemicals & aquafeed production

REALM VALUE CHAIN CONCEPT





Funded by the European Union

Data driven, fully controlled 1 m3 validation plant in Ruissalo greenhouse

Salazar et al. 2021, 2023

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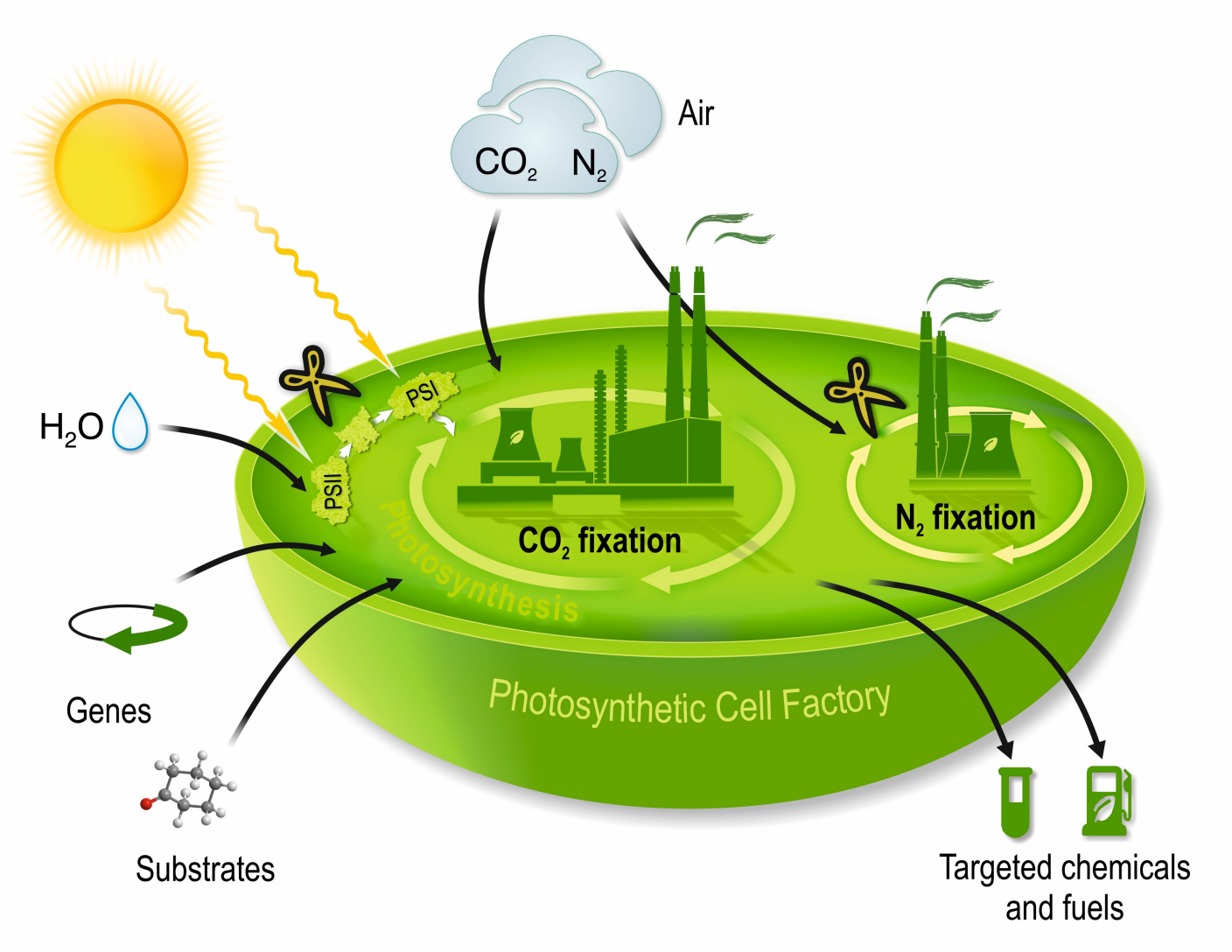
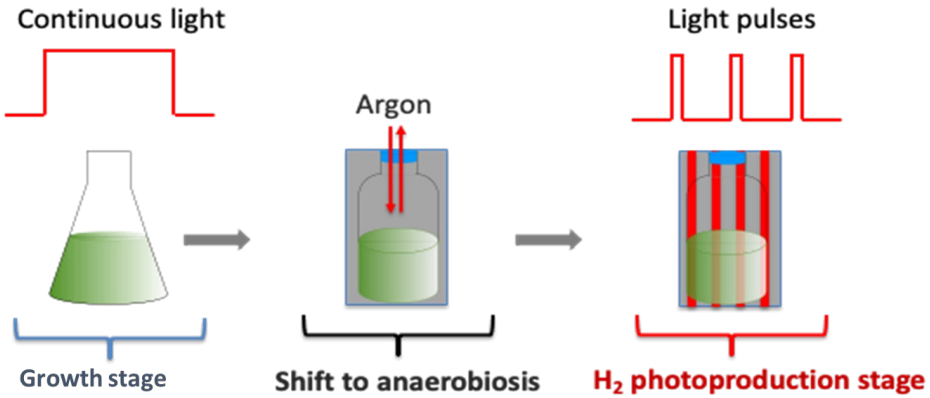
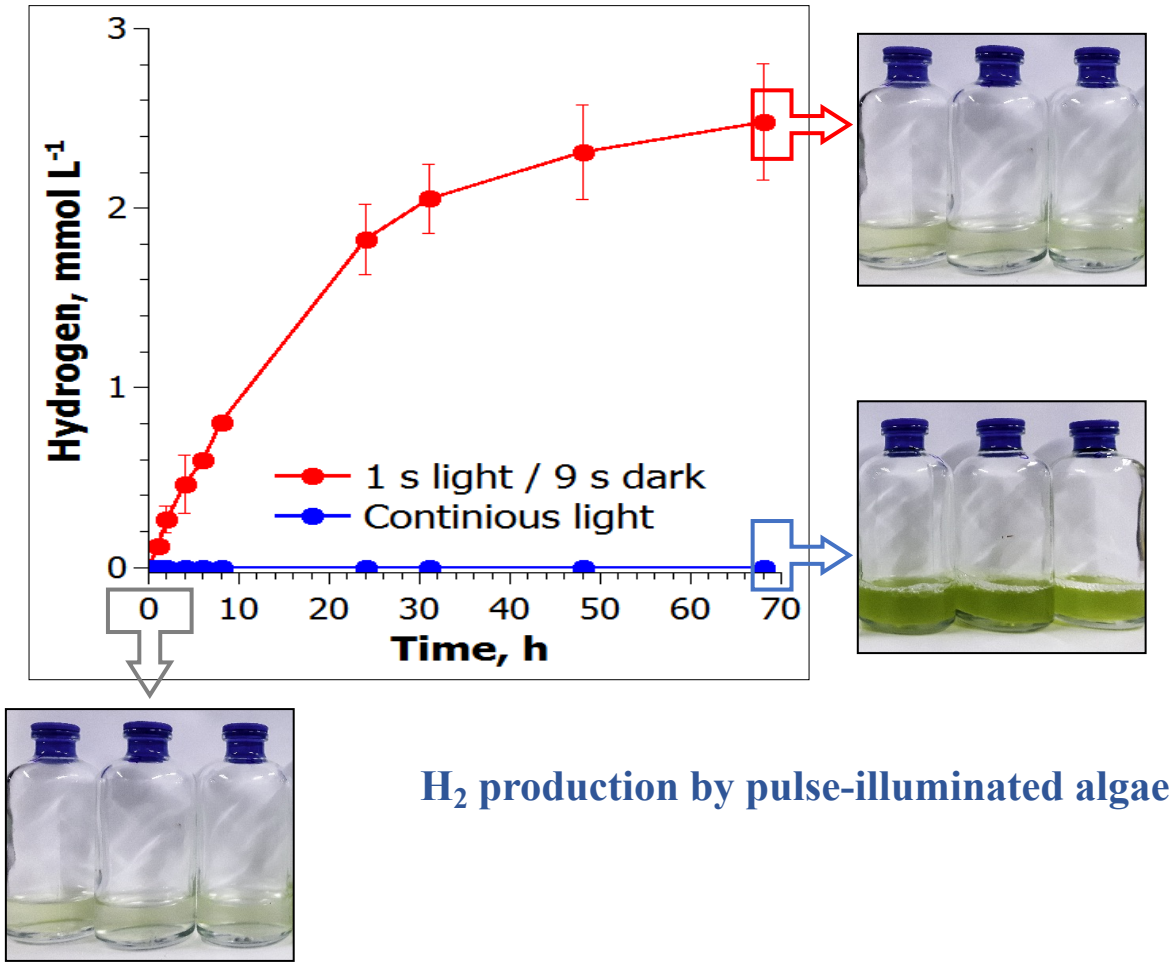
Biocatalytic solar chemicals/fuel production by photosynthetic cell factories

Photomicrobes Research team

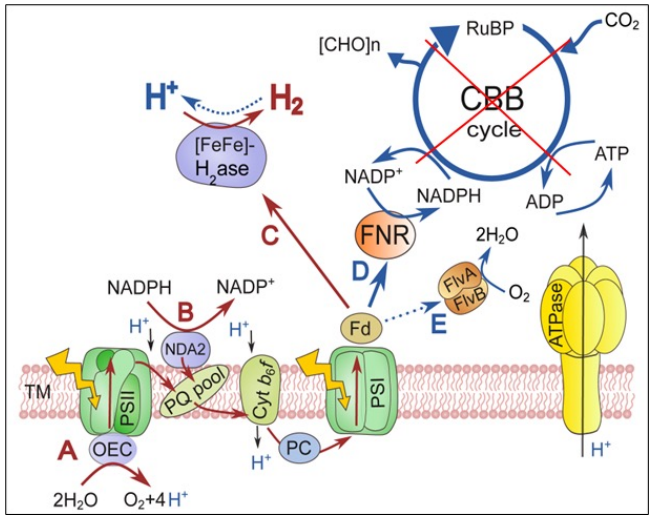


Pulse-illumination protocol for sustained H_2 photoproduction developed by Photosynthetic Microbes group





Mechanism of H_2 photoproduction:



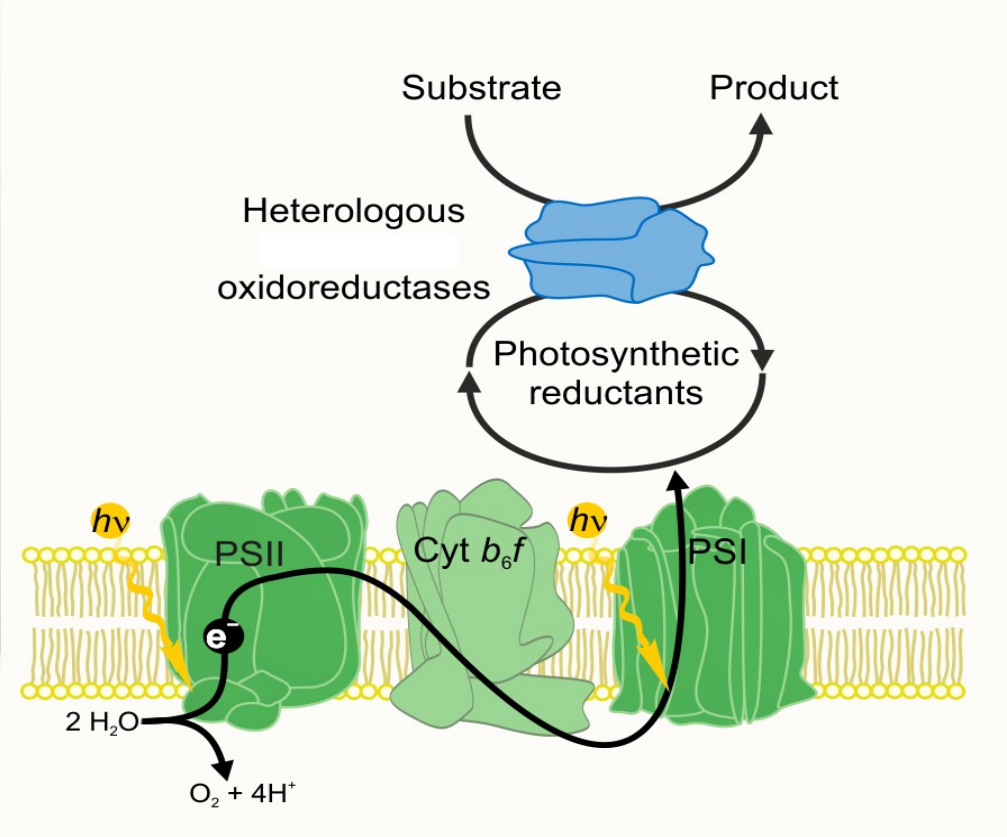
Kosourov et al. (2018) *Energy Environ. Sci.*,, 11, 1431–1436

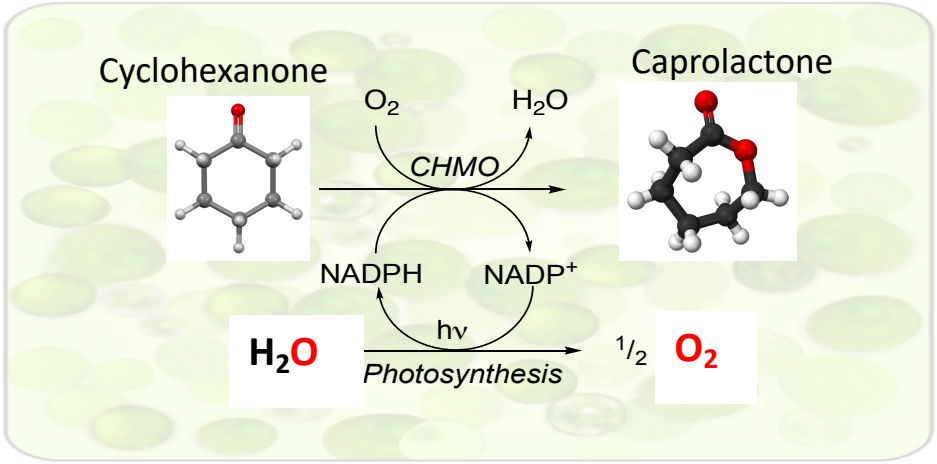
H_2 production by pulse-illuminated algae

The absence of CO_2 fixation under pulsing conditions prevents biomass formation and enhances H_2 production, prevents O2 accumulation

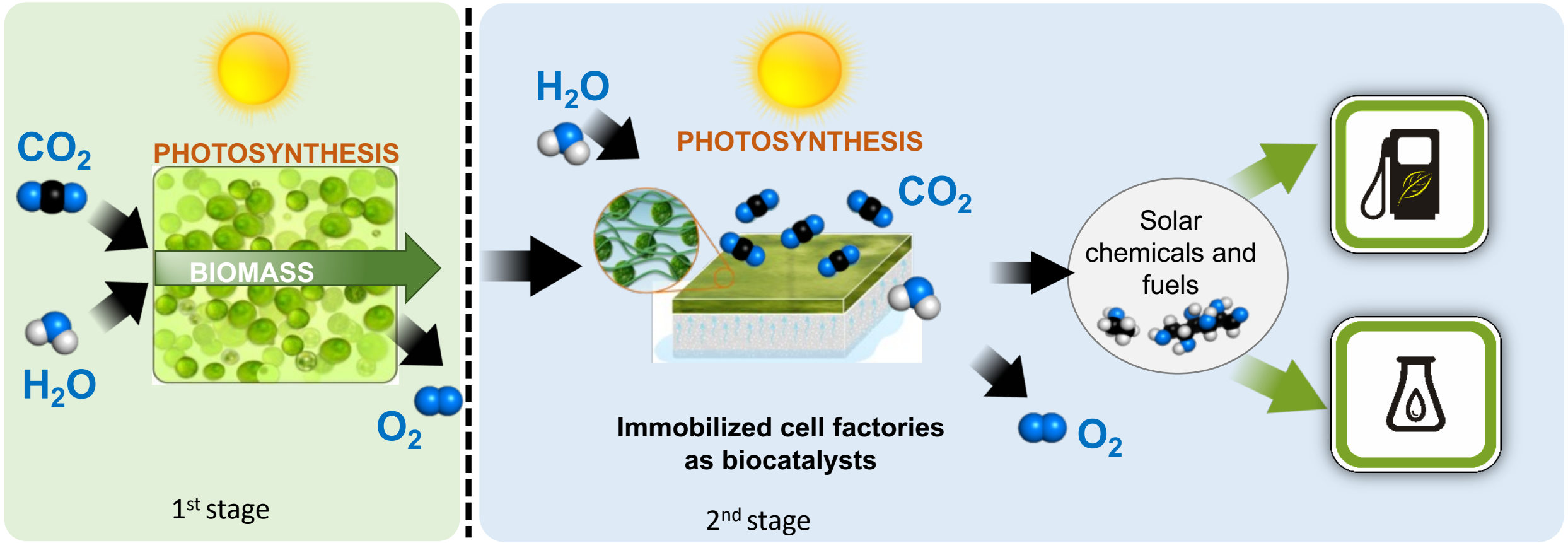
Photoautotrophic whole-cell biotransformation: „substrate in - product out“

Advantage of photosynthetic organisms over heterotrophs: regeneration of reducing cofactors (NADPH, Fed) and O_2





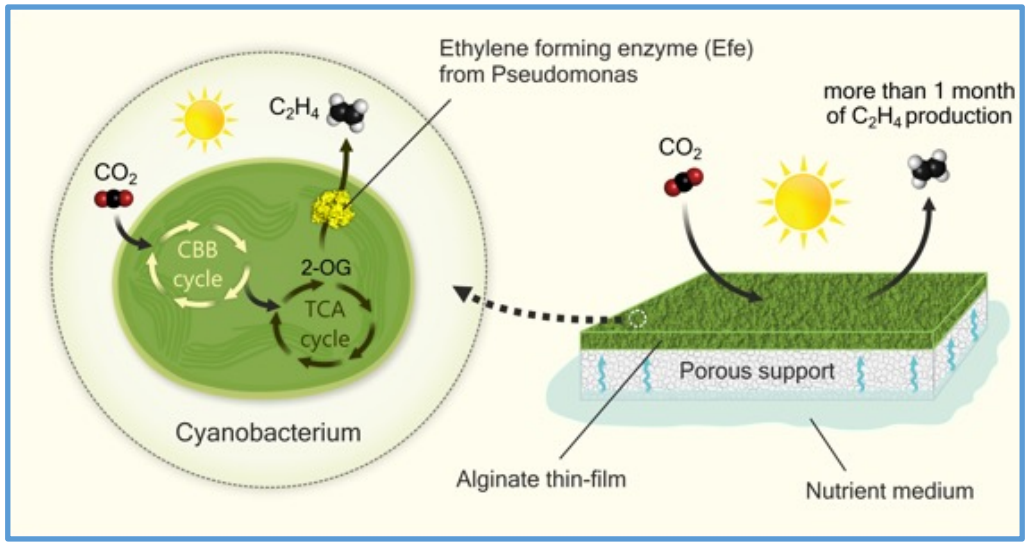
Photosynthetic solid state cell factories converting solar energy into energy-rich chemicals and fuels

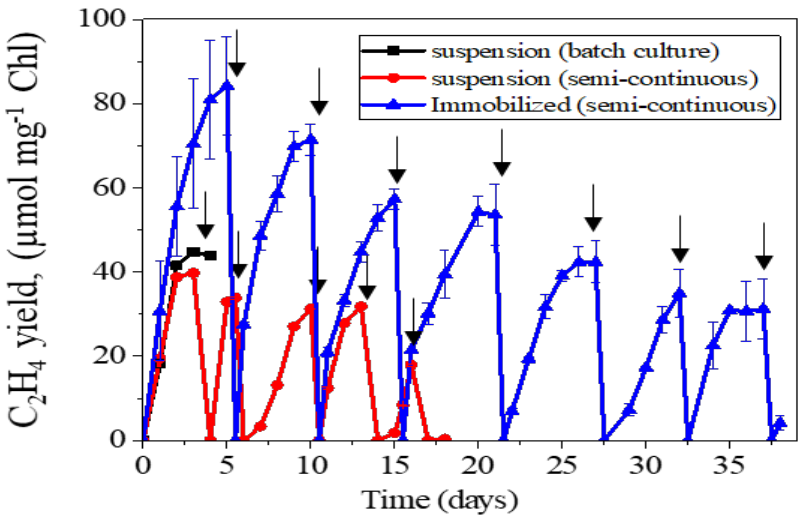


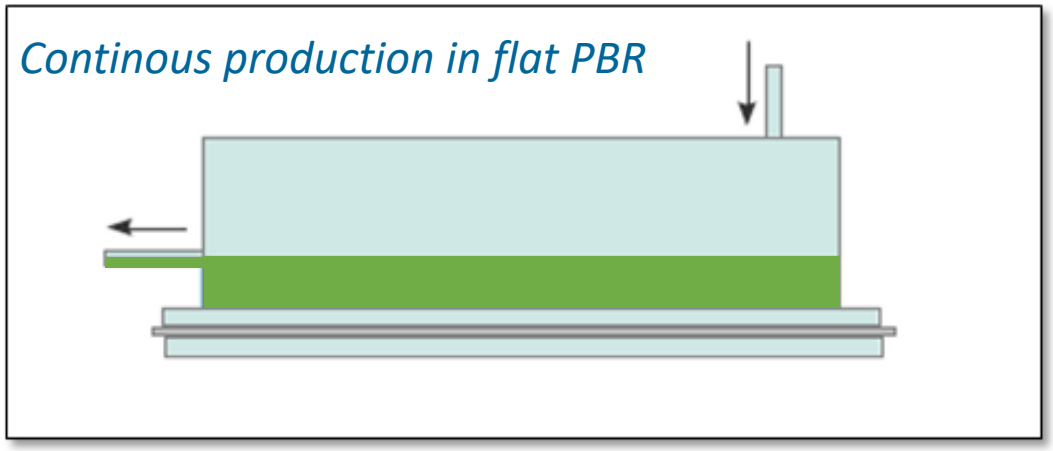
Two-stage process:

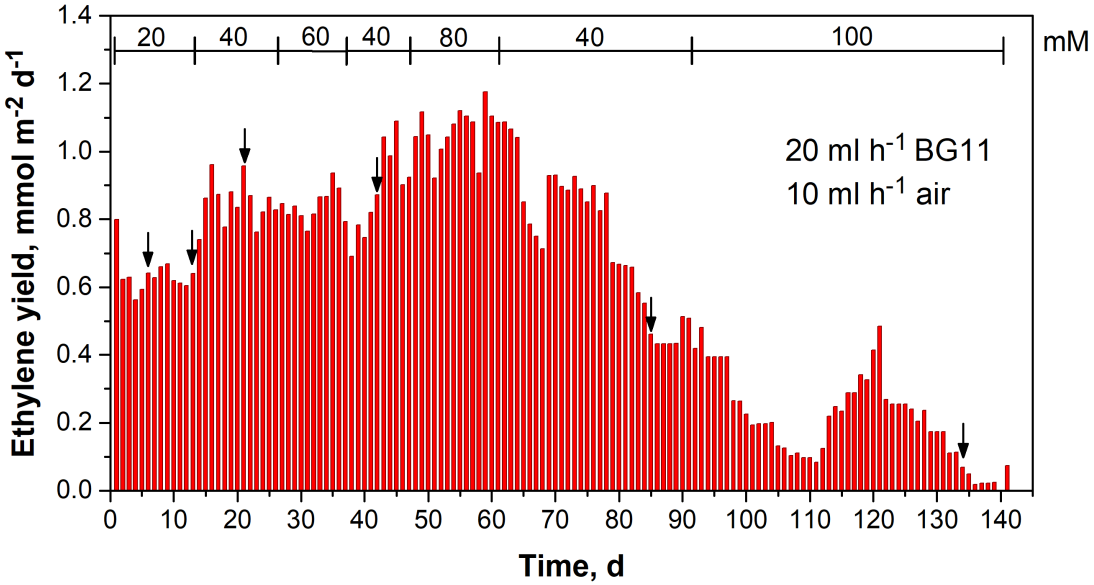
1st - biomass production stage and 2nd chemicals production stage in artificial biofilms (limited growth)

Long-term ethylene production by solid-state photosynthetic cell factories



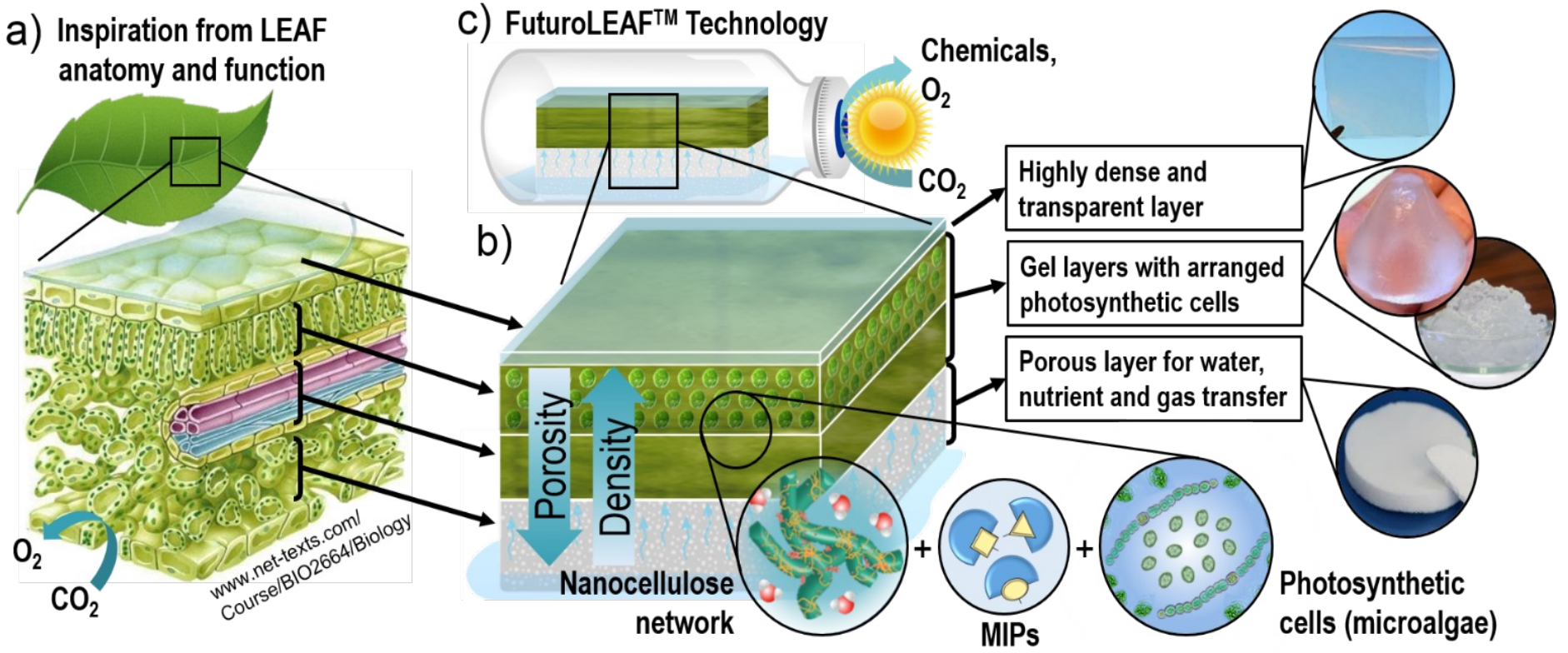






Vajravel et al. 2020 Green Chemistry
Rissanen et al. 2021 Green Chemistry
Thiel et al. 2018 Microb Cell Fact

A hierarchical, self-responsive and bioactive solid-state architecture - 'artificial leaf' concept



- efficient light utilization and controllable mobility of water, nutrients, substrates, gases and products

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Photomicrobes
Research team

SUNERGY Community and Eco-System for Accelerating the Development of Solar Fuels and Chemicals

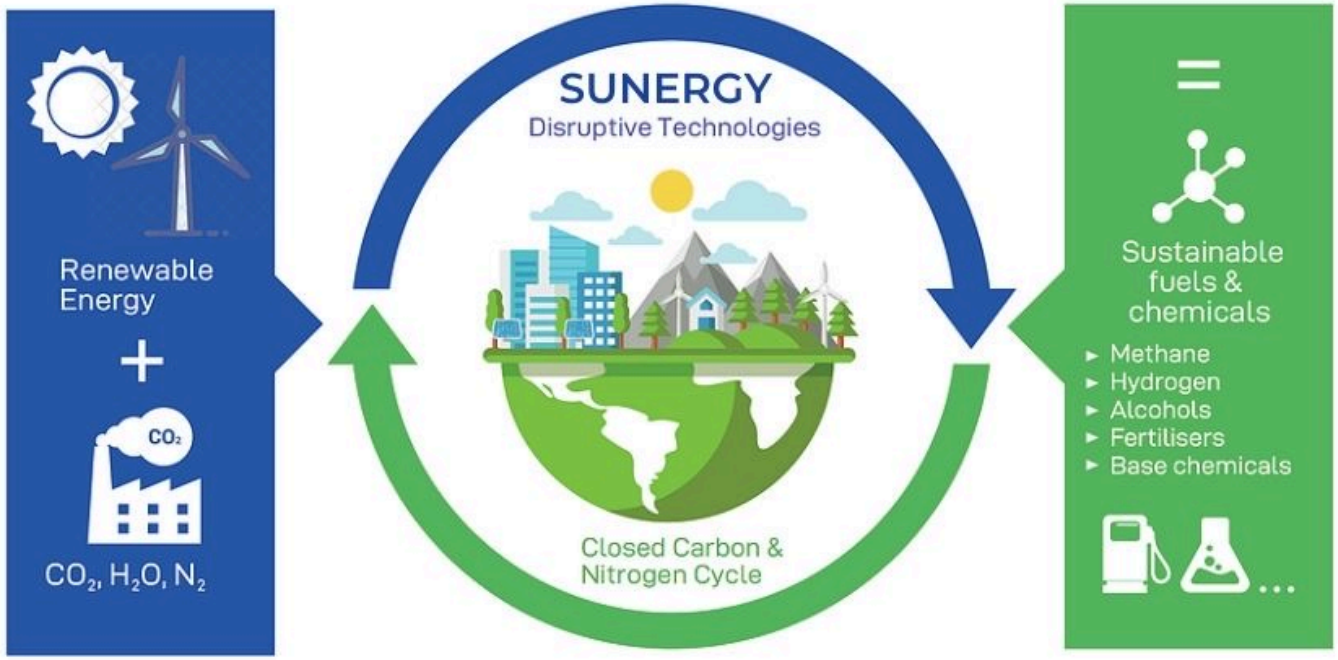
SUNER-C EU Coordination and Support Action (2022-2025)

European Commission

https://www.sunergy-initiative.eu

Suner-C Vision for a Fossil-free Future

To enable a circular economy through the sustainable production of fossil-free fuels and base chemicals from renewable energy and simple feedstock molecules (water, CO_2 and N_2).



31 participants from 12 EU countries:

- 13 academic partners
- 12 industrial partners
- 4 national & European networks
- 1 NGO

SUNER-C Consortium

Academia (13 partners):

- Utrecht University (NL)
- CEA (FR)
- Ghent University (BE)
- Leiden University (NL)
- University of Warsaw (PL)
- ICIQ (ES)
- Fraunhofer Gesellschaft (DE)
- **University of Turku (FI)**
- J Heyrovsky Institute (CZ)
- Uppsala University (SE)
- IMDEA Energy (ES)
- IMEC (BE)
- University of Bucharest (RO)

Industry (12 partners):

- Siemens Energy Global (DE)
- Carbyon (NL)
- Covestro Deutschland (DE)
- Alma digit (IT)
- Avantium Chemicals (NL)
- Next Chem (IT)
- Synest (GR)
- Arcelormittal Belgium (BE)
- TotalEnergies (BE)
- Vicat (FR)
- Engie (BE, FR)
- Solvay - Rhodia Operations (FR)

Network organizations (4 partners):

- ERIC (BE)
- DECHEMA (DE)
- CO_2 Value Europe (BE)
- EERA (BE)

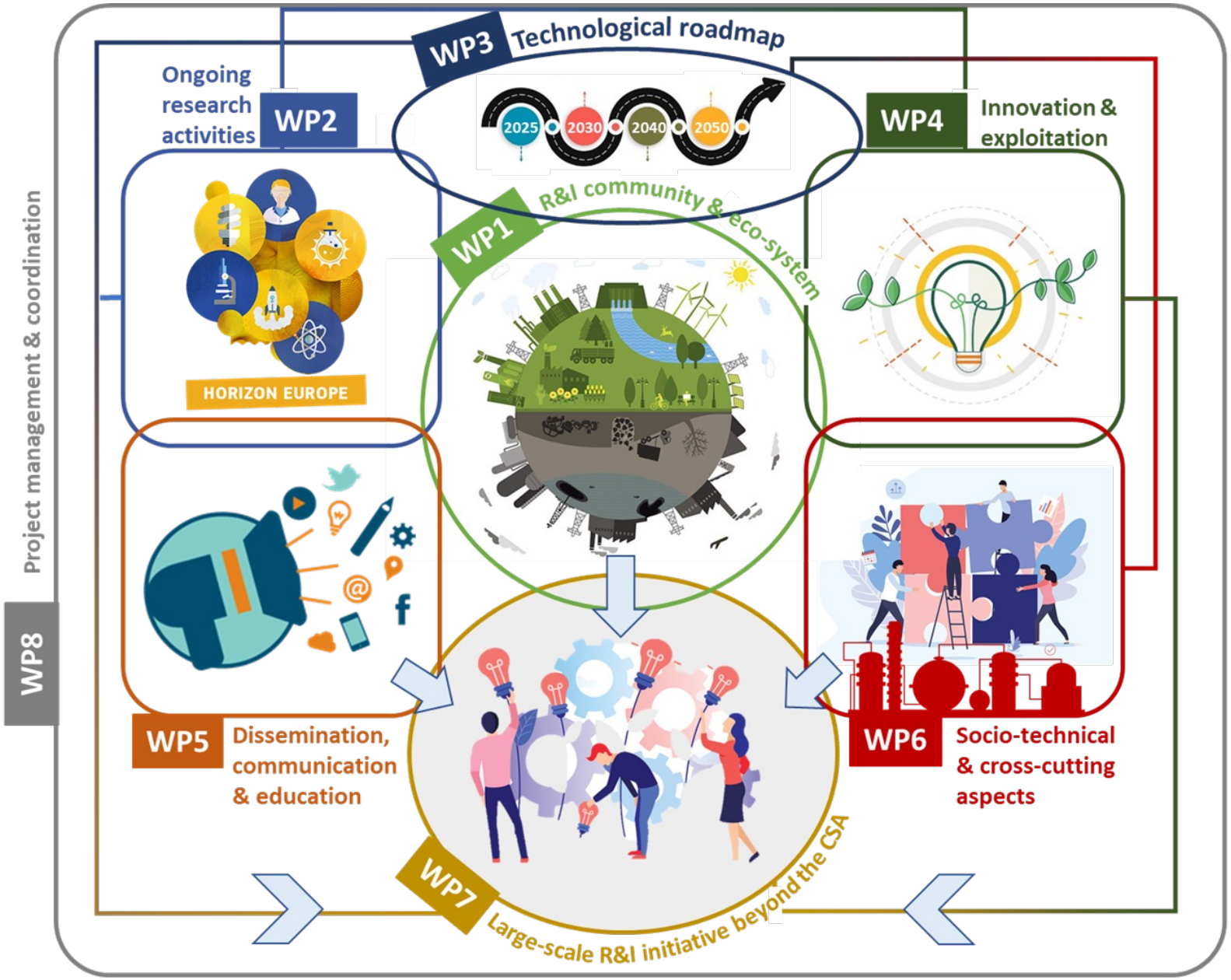
Societal (1 partner):

- NGO Bond Beter Leefmilieu Vlaanderen (BE)

+ Specialized institutes / groups at Ghent and Utrecht Universities

SUNER-C CSA

- Call: **HORIZON-CL4-2021-RESILIENCE-01-16**: Creation of an innovation community for solar fuels and chemicals
- Total budget: ≈ 4 M€
- Duration: 3 years (05-2022 → 04-2025)



Towards new co-programmed EU partnership on “Synthetic renewable fuels and advanced biofuels ”

SUNERGY initiative : https://www.sunergy-initiative.eu/

The Energy Conundrum