Solar-driven fuels and chemicals

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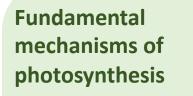
Department of Life Technologies University of Turku

> 10 May 2023 Otaniemi





From natural photosynthesis to biotechnology and circular bioeconomy





- Photosynthetic mechanisms
 - Biophysics
 - Biochemistry
 - Omics

- Natural Photosynthesis
- 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

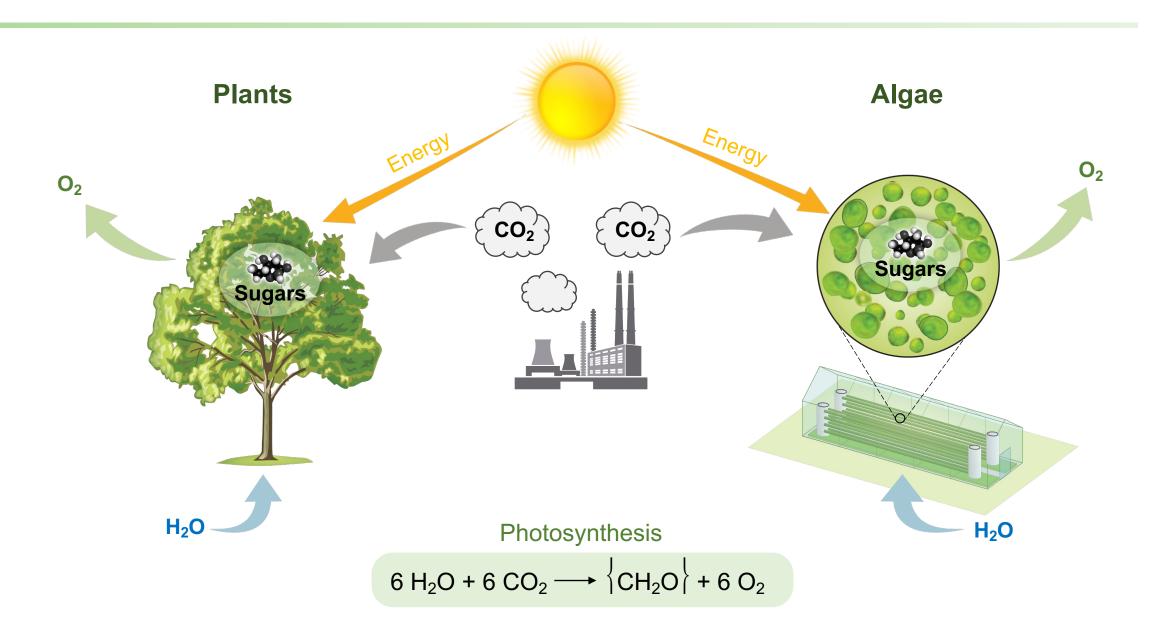
Towards sustainable production platforms

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



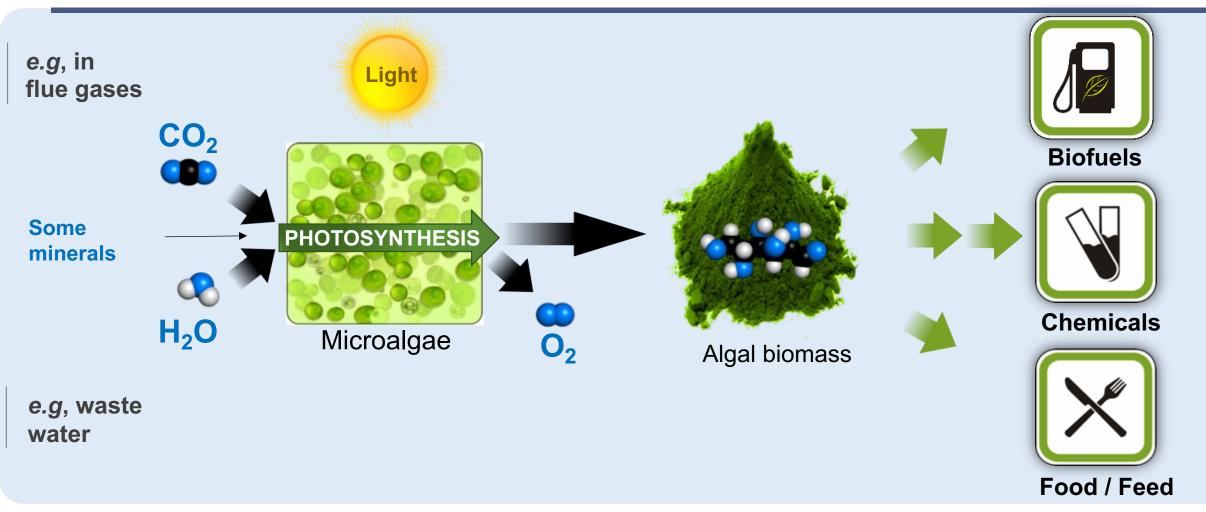
Sustainable biotechnology & circular (bio)economy

Starting point is Photosynthesis



Blue Bioeconomy Algae as a sustainable production platform

Nord



(i) the growth rate is very high and cultivation of these microorganisms do not compete with agriculture;

(ii) efficiently utilize CO₂, thus positively contributing to mitigation of CO₂ emission from industrial activities;

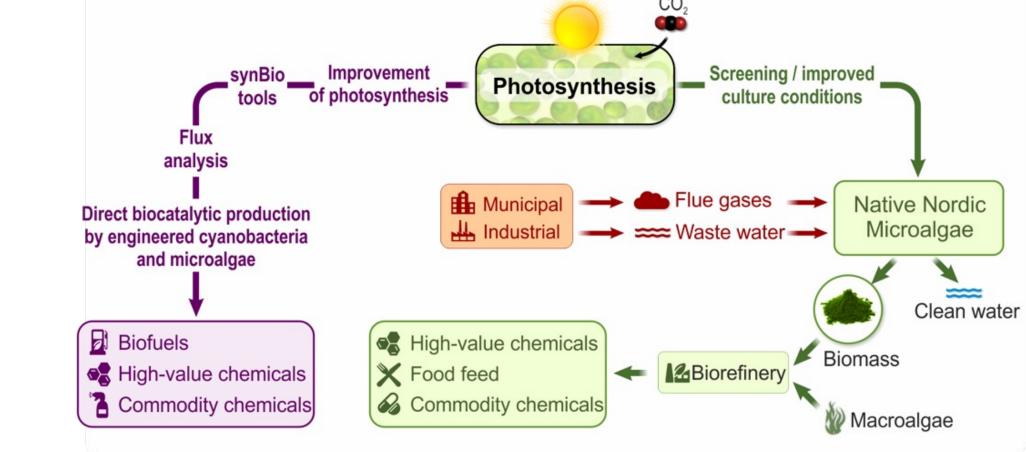
(iii) microalgae can utilize wastewater;





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)



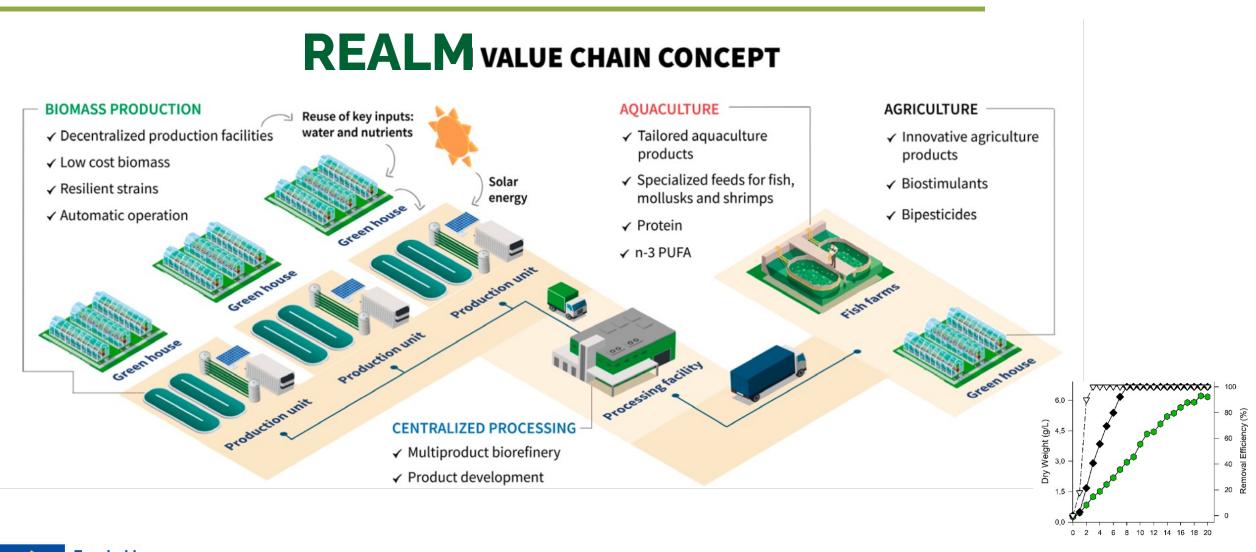
Allahverdiyeva et al. 2021 Physiol. Plant

Nordic Algae collection > 3000 algae



Nutrient recovery from greenhouse effluent & solar chemicals & aquafeed production





Funded by the European Union Data driven, fully controlled 1 m3 validation plant in Ruissalo greenhouse

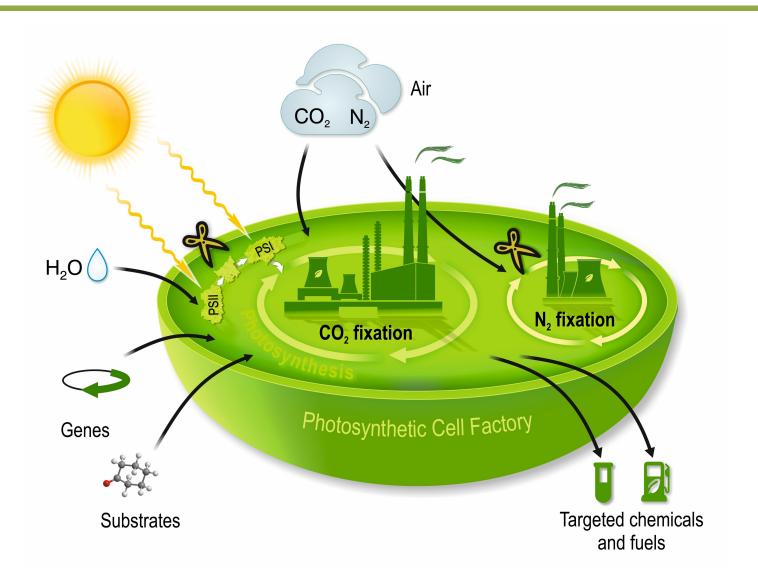
Salazar et al. 2021, 2023



Biocatalytic solar chemicals/fuel production by photosynthetic cell factories

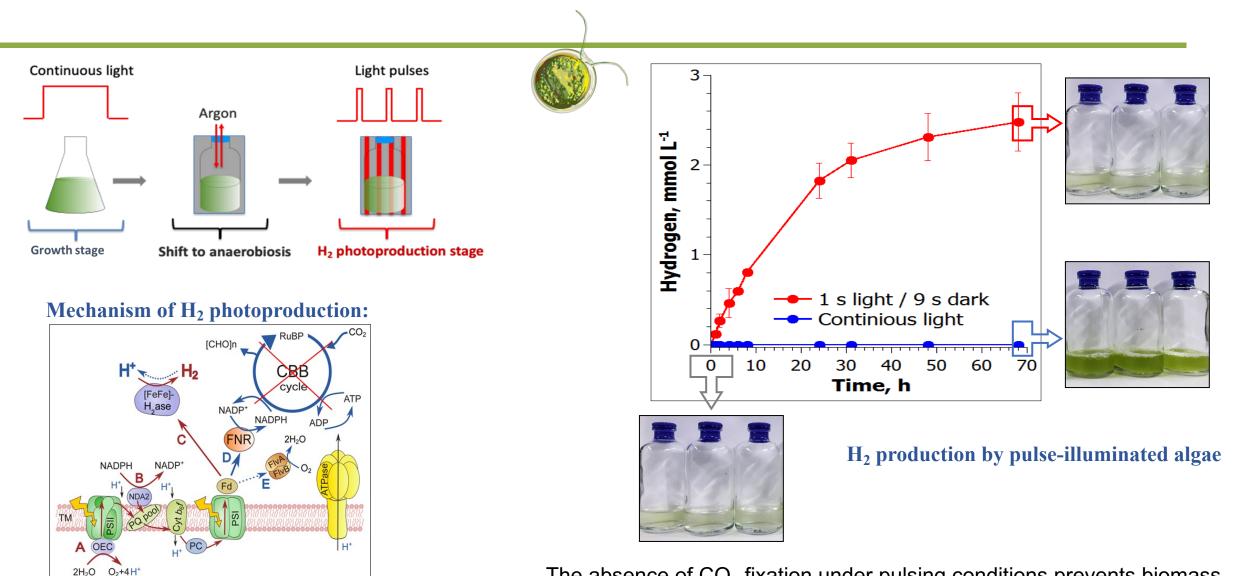
Photomicrobes

Research team





Pulse-illumination protocol for sustained H₂ photoproduction developed by Photosynthetic Microbes group



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

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

Photomicrobes

Research team



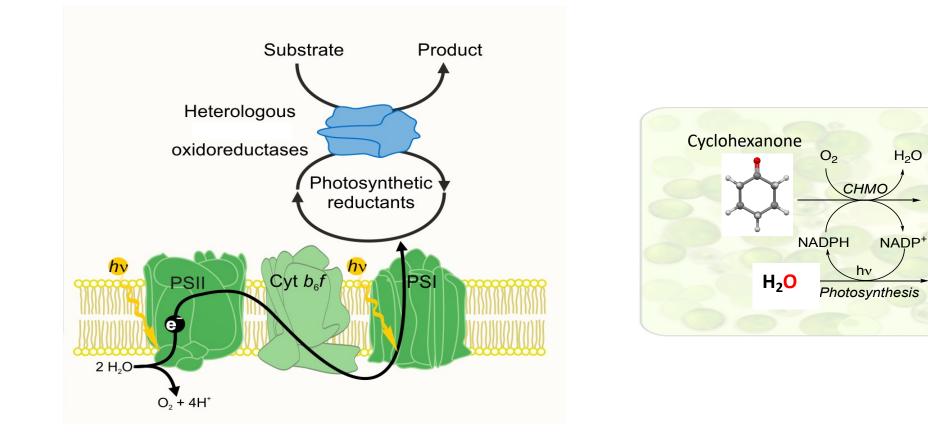
Photoautotrophic whole-cell biotransformation: Photomicrobes "substrate in - product out"

Advantage of photosynthetic organisms over heterotrophs: regeneration of reducing cofactors (NADPH, Fed) and O₂

Caprolactone

 $\mathbf{0}_2$

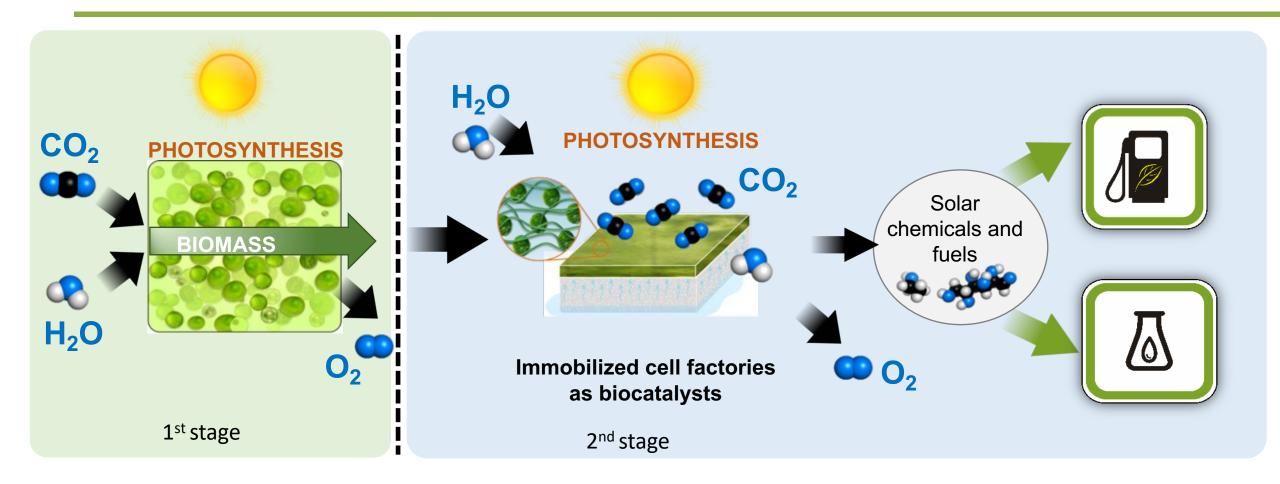
 $^{1}/_{2}$







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

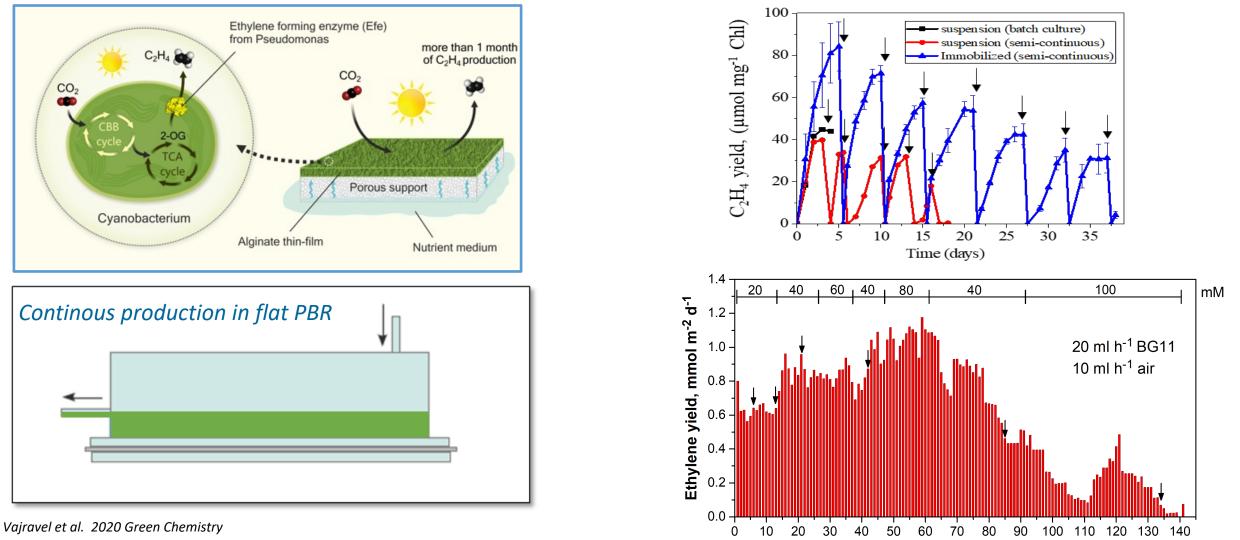


Two-stage process:

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

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



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

Time, d

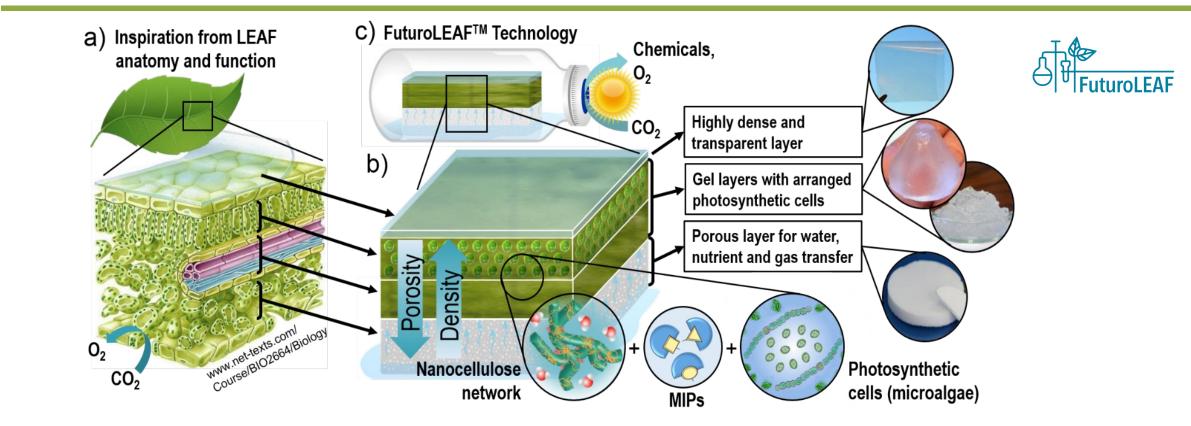
Photomicrobes

Research team



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















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



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

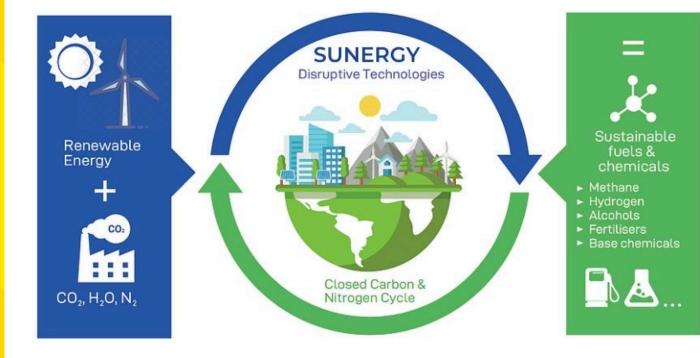


https://www.sunergy-initiative.eu

Suner-C Vision for a Fossil-free Future

To enable a circular economy through the sustainable production of fossilfree fuels and base chemicals from renewable energy and simple feedstock molecules (water, CO₂ and N₂).





- 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)

Network organizations (4 partners):

- ERIC (BE)
- DECHEMA (DE)
- CO₂ Value Europe (BE)
- EERA (BE)



- 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)

Societal (1 partner):

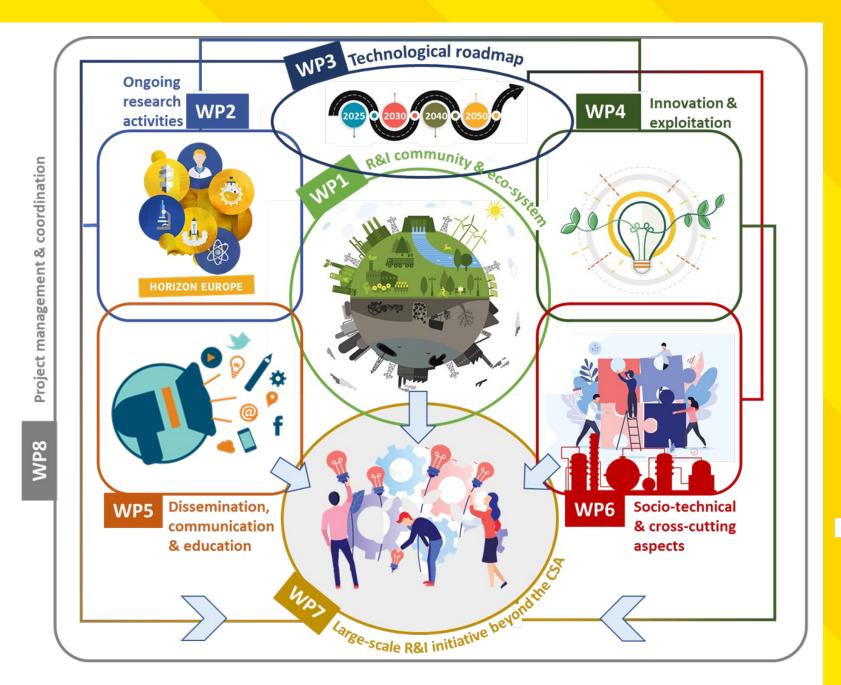
NGO Bond Beter Leefmilieu Vlaanderen (BE)
+ Specialized institutes / groups at Ghent and Utrecht Universities



SUNER-C CSA



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





Unlocking the renewable energy future

Strategic Research and Innovation Agenda

November 2022

THE CHALLENGE we are facing

Running our entire world strongly depends on fossil-based energy sources and raw materials. Their intensive use over the last decades not only depleted the Earth's resources, but also caused a significant increase of the carbon dioxide concentration in the atmosphere and therewith global warming, with tremendous consequences for ecosystems and society in general. In the EU, the energy and transport sector generate the major part of greenhouse gas emissions, with 54 % for energy and 24 % for transport-related activities in 2016. These sectors remain central for providing welfare, industrial competitiveness and quality of life. At the same time, the electrification of society continues to grow, with the urgent need for efficient storage solutions.

SUNERGY contribution

By combining energy from renewable sources with abundant molecules (carbon dioxide, water, nitrogen) and waste, we can produce fuels and chemicals that can contribute to stopping global warming. SUNERCY proposes a pipeline of high impact technologies that boost efficiency on the supply side by making fuels as well as base chemicals for industry and agriculture next to developing negative carbon dioxide emission technologies using resources abundant in Europe to enable a circular economy.

Lead authors Joanna Kargul (UWarsaw), Carina Faber (European Innovation Council) | contact@sunergy-initiative.eu

Authors Huub de Groot (Leiden University), Yagut Allahverdiyeva-Rinne (University of Turku), Gabriele Centi (University of Messina, ERIC), Frédéric Chandezon (CEA), Maximilian Fleischer (Siemens), Elena Guarneri (Utrecht University), Han Huynhthi (ENGIE), Hélène Lepaumier (ENGIE), Jean-Pierre Keustermans (ENGIE), Ann Magnuson (Uppsala University), Jan Mertens (ENGIE), Anastasios Perimenis (CO2 Value Europe), Linda Veldhuizen (Utrecht), Ton Wurth (Siemens) Towards new co-programmed EU partnership on "Synthetic renewable fuels and advanced biofuels"

SUNERGY initiative : <u>https://www.sunergy-initiative.eu/</u>

The Energy Conundrum

