PHOTO2FUEL

Turning Sunlight, Microorganisms & CO_2 into Sustainable Fuels & Chemicals

THE RESULTS BOOKLET

Funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

THE PROJECT

Photo2Fuel develops innovative biohybrid systems that combine microorganisms with organic photosensitizers to convert CO_2 into valuable fuels and chemicals using sunlight. Focusing on acetic acid and methane production, the project optimizes biohybrid catalysts and scalable photobioreactors to advance sustainable, solar-driven chemical and fuel production. This booklet presents the key achievements and progress toward clean, sunlight-powered CO_2 conversion.

1 HYBRID MICROORGANISM–ORGANIC SEMICONDUCTOR SYSTEMS

GOAL

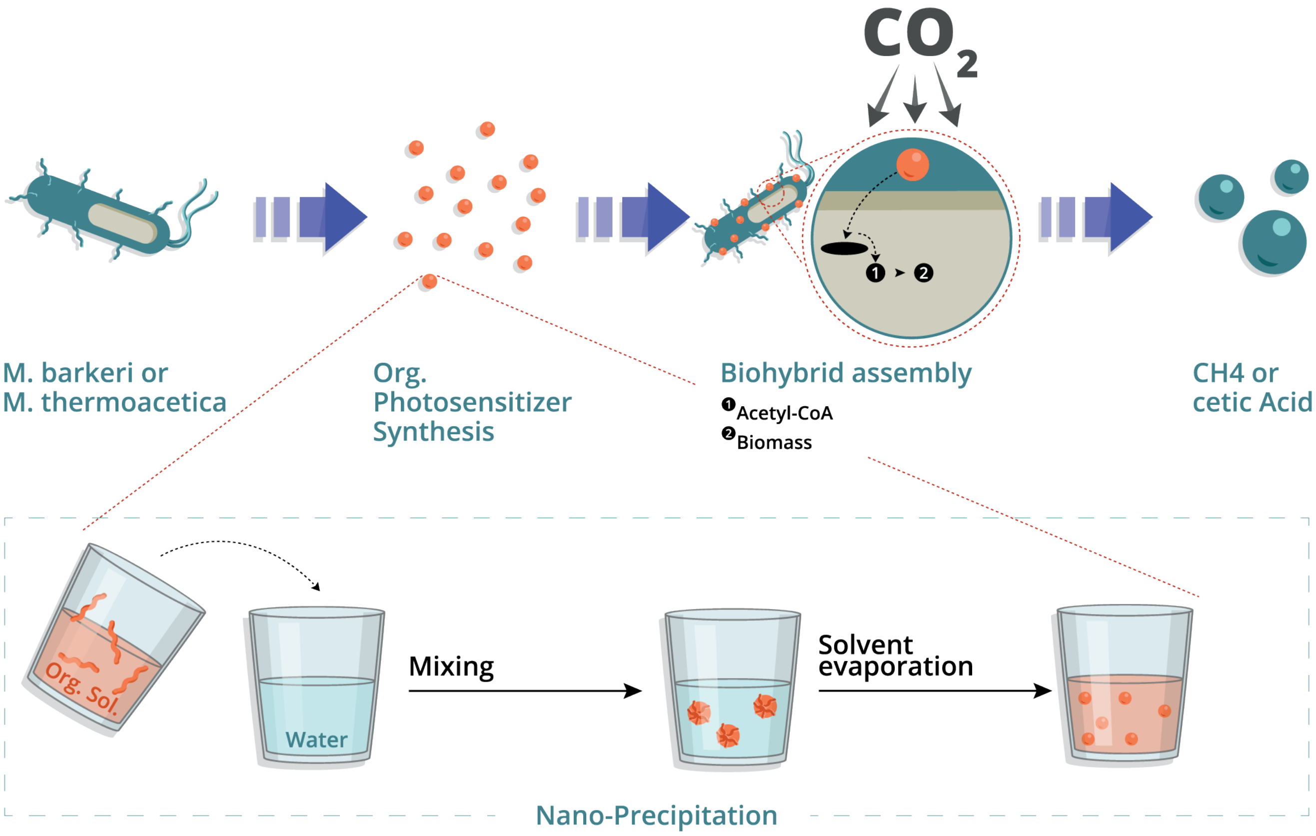
Photo2Fuel aimed to develop hybrid systems combining microorganisms and organic photosensitizers to convert CO_2 into acetic acid and methane—using sunlight.

- **System 1:** *Moorella thermoacetica* for acetic acid production
- **System 2:** *Methanosarcina barkeri* for methane production

TECHNICAL APPROACH

- Synthesis of biocompatible organic photosensitizers (polymer dots, small molecule nanoparticles, carbon dots).
- Integration with microorganisms to promote close interaction and efficient electron transfer.
- Optimization of catalytic conditions for sunlight-driven CO_2 conversion.

PROCESS OVERVIEW



KEY RESULTS & ACHIEVEMENTS

- **Efficient photosensitizer–microorganism binding** using positively charged NPs
- **Successful electron transfer** from photosensitizers to microorganisms
- **Clear winner:** Acetic acid system showed higher efficiency than methane system
- **Optimized biohybrid systems** using *M. thermoacetica* with:
  - **Polymer dots:** 1.2 mM acetic acid
  - **Small molecule NPs:** 0.4 mM acetic acid

2 UPSCALING THE ACETIC ACID SYSTEM

GOAL

Develop and test a self-sustaining mini solar plant for light-driven chemical production of acetic acid.

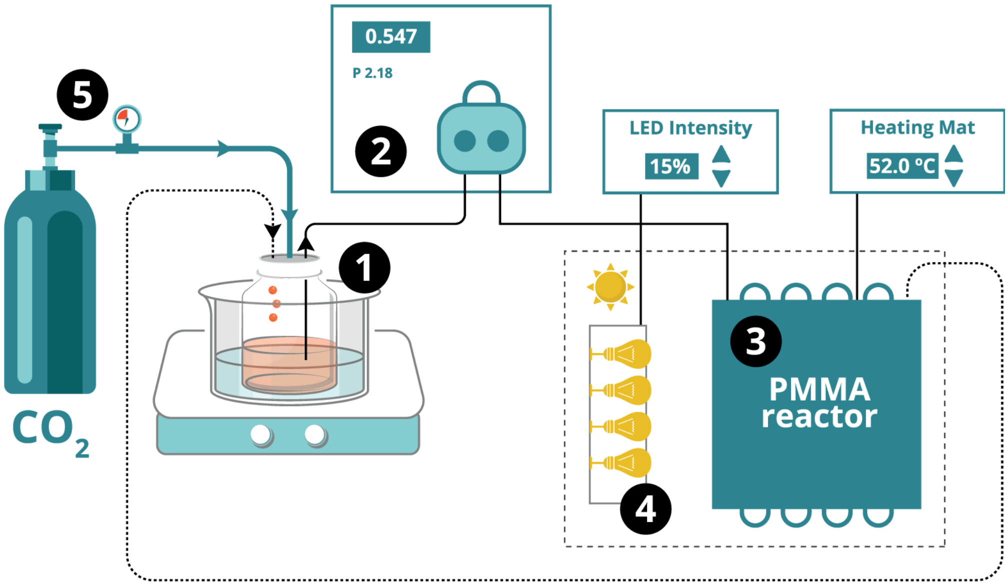
TECHNICAL APPROACH

- Constructed a scaled-up photobioreactor using cost-effective materials.
- Integrated precise controls for temperature, pressure, lighting, and fluid flow via a peristaltic pump to maintain a closed-loop system.
- Designed modular solar-simulated photobioreactor optimized for anaerobic microbial activity and light-driven catalysis.

PROCESS OVERVIEW

The reactor includes:

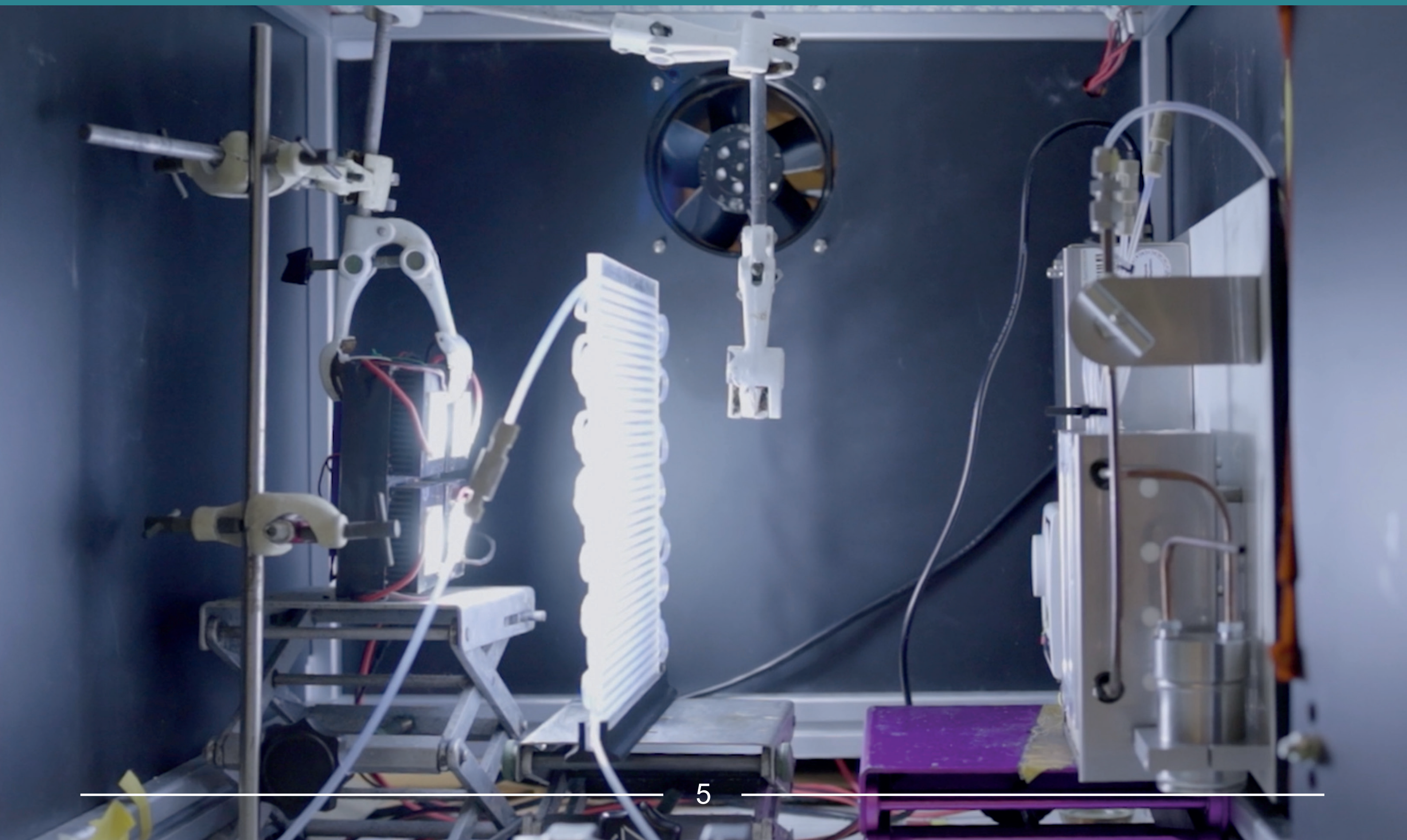
1. Incubation reservoir
2. Fluidic circuit with peristaltic pump
3. Microfluidic photoreactor embedded in PMMA slab
4. Programmable high-power LED lighting array
5. CO_2 inlet



Simplified depiction of the reactor design.

KEY RESULTS

- NMR analysis showed only trace acetic acid production, indicating biological rather than reactor design limitations.
- Validated critical system features: light management, energy autonomy, and environmental controls.
- Provides foundation for iterative system improvements toward a fully autonomous solar chemical production platform.



3 SEPARATION TECHNOLOGIES

GOAL

To recover and purify acetic acid from extremely diluted solutions (~100 mg/L) in the presence of inorganic contaminants.

TECHNOLOGIES EVALUATED

- Ion exchange resins
- Liquid-liquid extraction using ionic liquids
- Electrodialysis

KEY RESULTS & ACHIEVEMENTS

✔ Ion Exchange Resins Approach Delivered the Best Performance

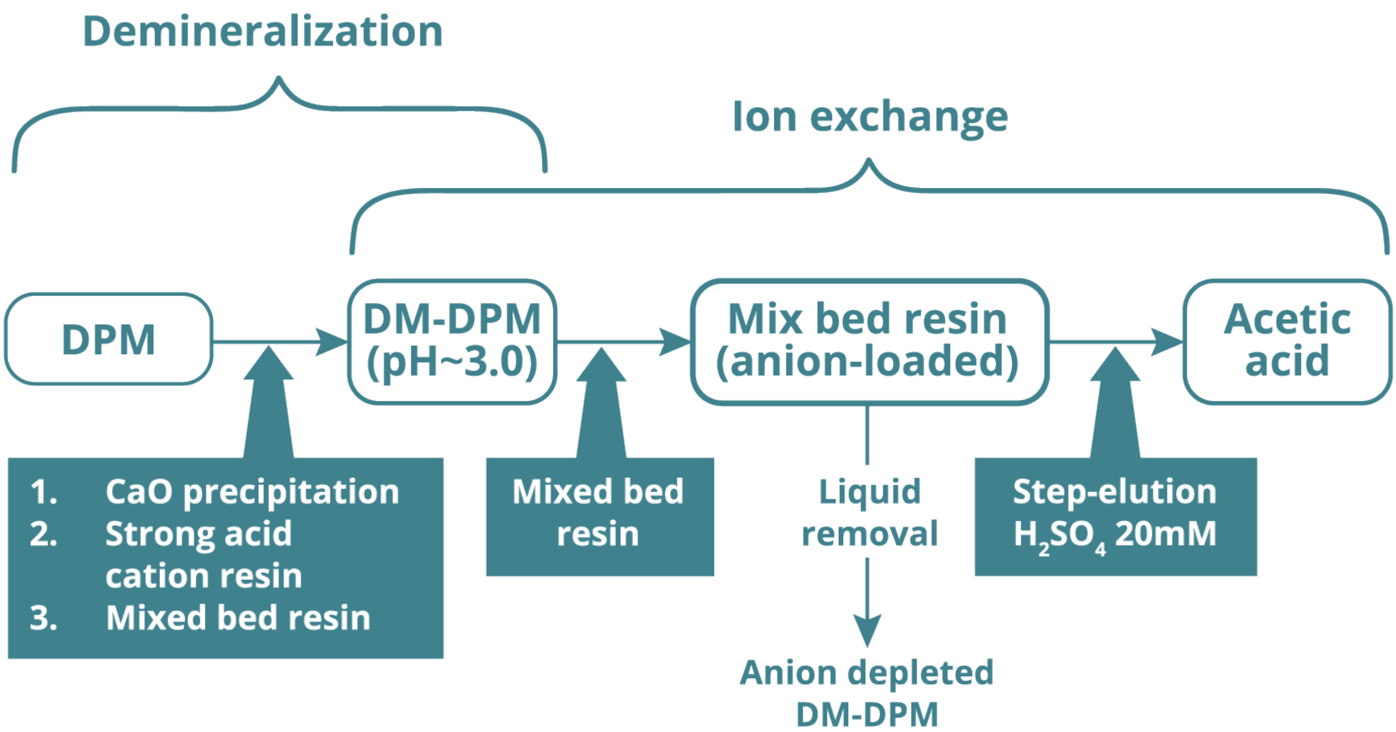
A two-step process was developed using Amberlite™ resins.

STEP 1
Demineralization

- Calcium precipitation
- Acidification using Amberlite IR-120
- Followed by treatment with the mixed-bed ion exchange resin Amberlite MB20

STEP 2
Final Polishing

- Additional ion exchange with Amberlite MB20
- Selective elution of acetic acid with diluted sulfuric acid (H_2SO_4)



OUTCOME

- **Purity of acetic acid:** 96.9% to 99.2%
- **Final concentration:** >1500 mg/L
- **Recovery yield:** 68.5% to 82.2%

PHOTO2FUEL

photo2fuel.eu

Funded by
the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.