Bottling Sunshine:

Artificial Photosynthesis

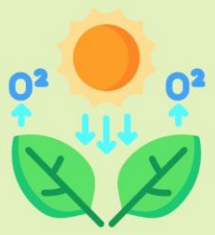
Author: Patricia Chioran
Theme: Energy
Subject Related: Chemistry

What is Artificial Photosynthesis?

Artificial photosynthesis is a chemistry-driven innovation inspired by nature's process of converting sunlight, carbon dioxide, and water into energy.

By designing catalysts and materials, primarily hydrogen or carbon-based fuels, that mimic photosynthesis, scientists aim to generate clean, storable fuels while reducing greenhouse gases.

This poster explores the chemical principles behind artificial photosynthesis, its potential role in addressing the global energy crisis, and the challenges that remain before large-scale adoption.



Background

Rising atmospheric CO_2 from fossil fuel combustion is a principal driver of global warming, highlighting the urgent need for sustainable, carbon-neutral energy systems. While solar and wind power are rapidly expanding, their intermittency necessitates efficient methods of chemical energy storage. Natural photosynthesis provides a blueprint for converting sunlight, water, and CO_2 into energy-rich products, but its efficiency is limited (~1%). Artificial photosynthesis aims to replicate and surpass this process using engineered catalysts and light-harvesting systems, producing fuels such as H_2 or methanol. This dual strategy addresses both energy demand and CO_2 mitigation, offering a promising route to sustainable energy.

6CO2+6H2O+sunlight→C6H12O6+6O2
(natural photosynthesis)
CO2+2H2O+sunlight→CH3OH+O2$CO_2 + 2H_2O + sunlight \rightarrow CH_3OH + O_2$CO2+2H2O+sunlight→CH3OH+O2
(artificial photosynthesis goal)

Methodology

Artificial photosynthesis works by mimicking natural photosynthesis using three key steps:

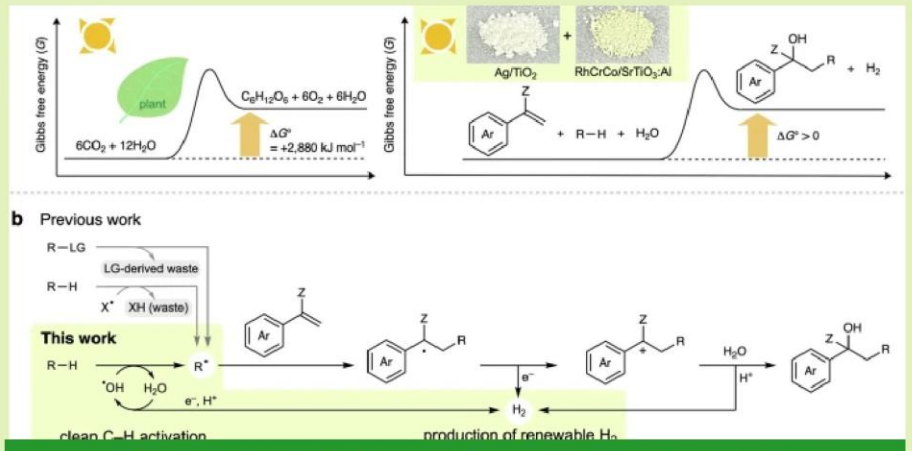
- Light Absorption:

Semiconductor materials or photosensitizers absorb sunlight. This excites electrons to a higher energy state.

- Charge Separation & Transport:

Excited electrons and holes are directed to different parts of the system. Preventing recombination is critical for efficiency.

Catalysis:
Water oxidation catalyst splits $H_2O \rightarrow O_2$ + protons + electrons. CO_2 reduction catalyst converts CO_2 (with protons + electrons) → fuels (e.g., H_2, CH_3OH, CO). [1]



Artificial photosynthesis enables clean organic synthesis by activating C–H bonds with H_2 evolution, avoiding wasteful radical pathways seen in natural systems

References

- [1] Y. Oyamada, "Artificial Photosynthesis: A dream technology, converting CO_2 into a resource," KAITEKI Solution Center, Mitsubishi Chemical Group, Feb. 1, 2023. https://www.mcgc.com/english/kaiteki_solution_center/our solution/01.html
- [2] Le, A. H.; Guillomaitre, N. Artificial Photosynthesis: A Review of the Technology, Application, Opportunities, and Challenges. J. Stud. Res. High Sch. Ed. 2022, https://pmc.ncbi.nlm.nih.gov/articles/PMC10807655/
- Diagram retrieved from Figure 1 of this research: https://www.nature.com/articles/s41467-025-56374-z

Features	Artificial Photosynthesis	Natural Photosynthesis
Energy efficiency	Higher (10–20%)	Low (~1–6%)
Carbon Fixation	Direct fuels (H_2, methanol)	Biomass (sugars, starch)
Scalability	Industrial-scale possible	Limited by land & climate
Environmental Impact	Oxygen + carbon capture	Can reduce CO_2 footprint

Discussion [2]

Strengths

- Converts CO_2, H_2O, and sunlight directly into fuels
- Carbon-neutral and sustainable.
- Potentially more efficient than natural photosynthesis
- Could reduce dependence on fossil fuels, shifting geopolitical power away from oil-rich nations. Encourages international cooperation on climate mitigation.
- Long-term potential for creating green jobs and sustainable industries.

Weaknesses

- Catalysts are expensive and often unstable.
- Energy efficiency still lower than needed.
- Scale-up from lab to industry is difficult.
- Competes with established renewables (solar, wind, batteries) for funding and policy support.
- Public acceptance may depend on trust in "engineered nature" solutions.