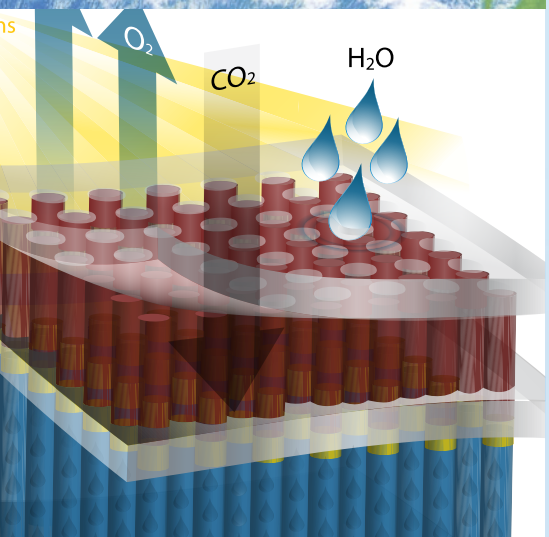
JCAP
JOINT CENTER FOR ARTIFICIAL PHOTOSYNTHESIS

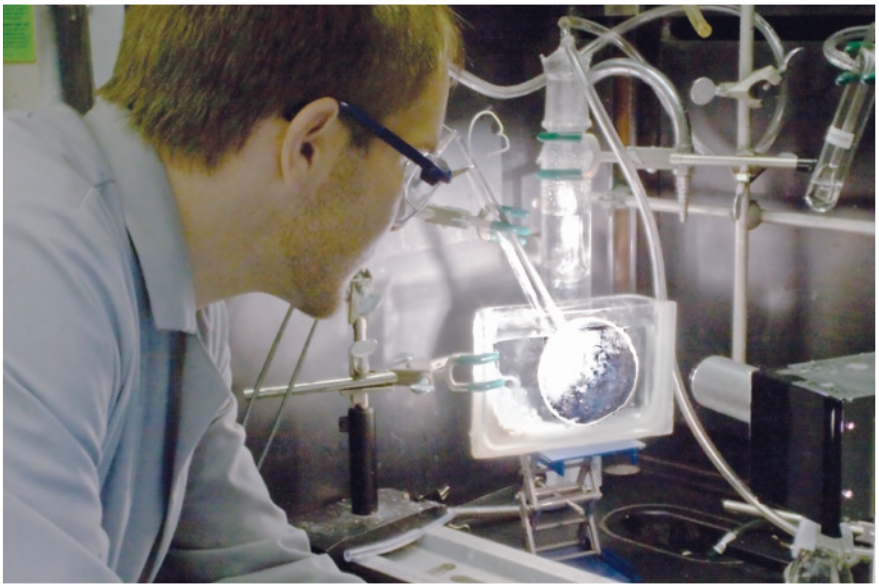
A Powerful Option in Plain Sight

Inspired by photosynthesis, scientists aim to invent materials that can produce fuels from sunlight, water, and $C0_2$.



A leaf isn't just beautiful—it is also a powerhouse. With only sunlight, water, and carbon dioxide as inputs, leaves produce fuel for plants via the process known as photosynthesis. Fossil fuels—derived from ancient decayed organic matter—and biofuels draw on energy converted by this process. But leaves point the way to another option: **We could gain greater energy independence if we could develop a fully artificial version of photosynthesis that produces fuels directly from sunlight, as leaves do.** Solar fuels could become abundant, sustainable successors to petroleum-based fuels.

With the United States as a pioneering investor, research into artificial photosynthesis has made steady progress. Now, remarkable breakthroughs in physics, chemistry, materials science, and nanotechnology have created opportunities to accelerate that progress. **By establishing the Joint Center for Artificial Photosynthesis (JCAP), the U.S. Department of Energy (DOE) has taken a key step to push direct solar fuels toward commercial viability.** JCAP researchers are working to make artificial photosynthesis efficient, inexpensive, and robust. JCAP will complete critical research and development and integrate the U.S. solar fuels effort to accelerate the delivery of this potentially transformational technology.



Caltech postdoctoral scholar **Shane Ardo** watches as light hits a silicon wafer submerged in water, causing hydrogen gas to bubble off from nanoscale electrocatalysts bound to the silicon.

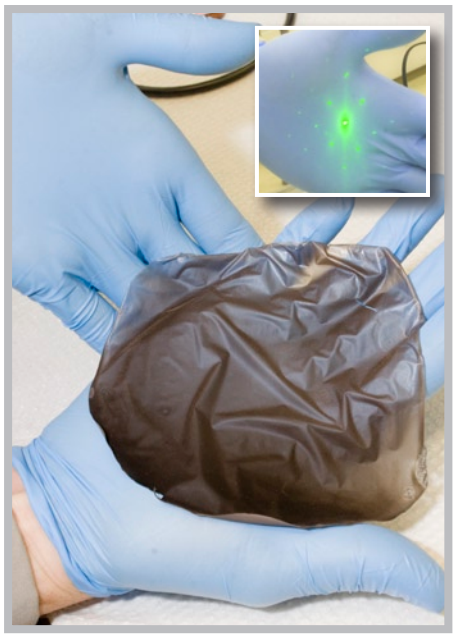
JCAP: An Energy Innovation Hub

JCAP's objective is to develop and demonstrate a prototype solar-fuels generator made of Earth-abundant elements. Along the way, JCAP must advance highly promising scientific research to the point at which a new manufacturable technology can be handed off to the private sector. It is anticipated that, with sunlight, water, and carbon dioxide as inputs, the target prototype will produce fuel with 10 times the efficiency of natural photosynthesis. JCAP will also incorporate research results from many labs investigating aspects of artificial photosynthesis—including 20 DOE Energy Frontier Research Centers—to speed the pace of development of a prototype solar-fuels generator. JCAP will truly be the nation's hub for breakthroughs in solar fuels.

JCAP's first experimental prototypes will expose gaps where new science is needed. The Hub will help close those gaps through the combined efforts of leaders in a host of fields, including chemistry, physics, materials science, mechanical engineering, nanoscience, fluid mechanics, catalysis, spectroscopy, and scalable manufacturing. The Hub's central experimental facilities will accelerate development of the components—light absorbers, catalysts, and membranes—needed to create a usable prototype. For instance, scientists will be able to discover, evaluate, and develop more catalysts each day than have been developed in human history. JCAP will also provide expertise needed to leverage and integrate components developed in other laboratories into a functional prototype.

The Joint Center for Artificial Photosynthesis is a DOE Energy Innovation Hub—a research effort built on the premises that a critcal mass of creative scientists and engineers working side by side can accomplish more, faster, than researchers working separately, and that a proactive approach to managing and conducting research is essential.

Led by the California Institute of Technology (Caltech), in partnership with the Lawrence Berkeley National Lab (LBNL), SLAC National Accelerator Laboratory, and a select group of universities, JCAP will involve scientists and engineers nationwide. JCAP will keep the United States at the forefront of solar-fuel research.



Microscale materials that capture and manipulate light—such as this array of silicon microwires supported in a polymer—can now be grown and produced overnight.

Inset: A similar array diffracts laser light into a pattern that indicates long-range order and fidelity in the material.

Solar Fuels

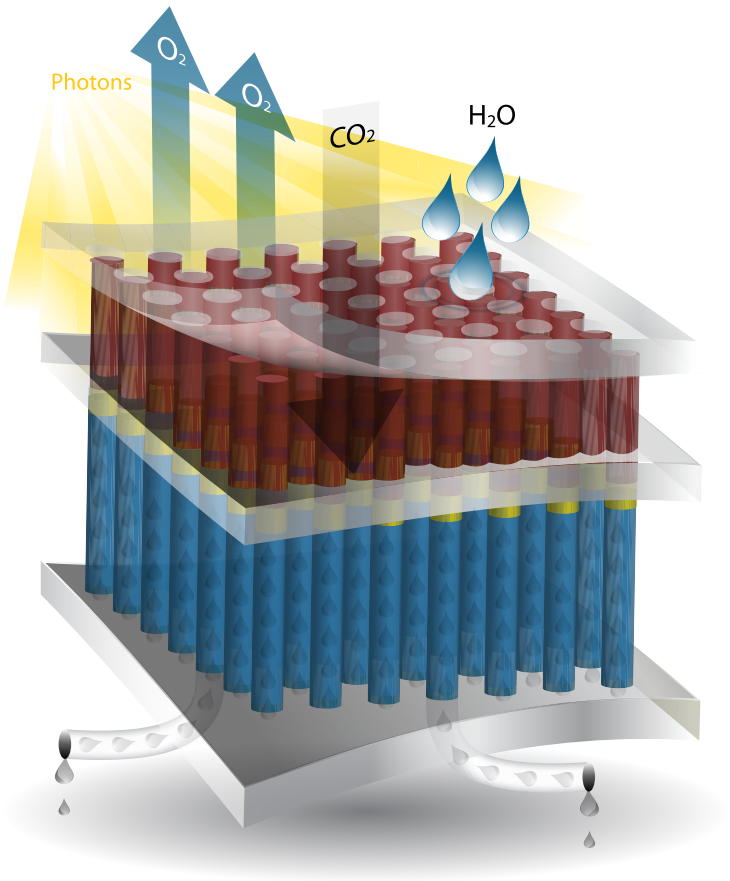
It's easy to take our sun for granted, but it is actually a star of prodigious power. The amount of solar energy that bathes Earth in one hour could power human activity on the planet for a full year. And yet, storage of this energy in the form of convenient, inexpensive fuels has remained technically elusive despite steady scientific progress. Basic research has provided enormous advances in our understanding of the subtle and complex chemistry behind natural photosynthesis. Yet we still lack sufficient knowledge to design solar-fuel generation systems with the required efficiency, scalability, and sustainability to be economically viable. It is just this sort of grand challenge that the DOE Energy Innovation Hubs are designed to address.

Today, JCAP is seeking new ways to produce carbon-neutral transportation fuels, including hydrogen, methanol, and fuels with high energy density for aircraft and other specialized vehicles, using only sunlight, water, and carbon dioxide as inputs. Artificial photosynthesis, once achieved and scaled up, could be significantly more efficient than biofuel production processes, and would not require arable land, agricultural feedstock, or substantial inputs of energy or water. Success could ultimately drive commercial development of solar-fuel systems designed from inception to be easily deployable almost anywhere.

A Fully Artificial Version of Photosynthesis

JCAP's revolutionary endeavor to harness the sun's power is possible because of new technologies that allow researchers to work at the scale of atoms and molecules, to synthesize catalysts, and to mass-produce nanoengineered materials. Taking inspiration from the way a leaf uses sunlight and its own specialized membranes and molecules to transform water and carbon dioxide into fuel, JCAP researchers aim to develop inorganic materials that produce fuel.

These materials would work like multilayer high-performance fabrics. An upper membrane would absorb light, CO_2, and water and would allow oxygen to escape. Customized molecules embedded in an inner membrane would catalyze reactions that produce the desired fuel. And the base layer would wick fuel away, directing it to collectors. Some of the elements of this process have been demonstrated in labs across the nation—but JCAP, with the resources to synthesize the whole process under one roof, will be in a unique position to develop a scalable prototype.



Fueling the Future

" We're issuing a challenge. We're telling America's scientists and engineers that if they assemble teams of the best minds in their fields and focus on the hardest problems in clean energy, we'll fund the Apollo projects of our time. . . . At the California Institute of Technology, they're developing a way to turn sunlight and water into fuel for our cars. . . . We need to get behind this innovation."

—President Barack Obama, State of the Union address, January 26, 2011

"The first step in winning the future is encouraging American innovation," President Obama said in his 2011 State of the Union address. The United States is positioned to be the global leader in solar fuels produced through artificial photosynthesis—a technology with the potential to deliver high performance while freeing us from overreliance on oil. The nation's investment in the JCAP DOE Energy Innovation Hub reflects its resolve to turn the promise of fuels from sunlight into reality.

JCAP
JOINT CENTER FOR ARTIFICIAL PHOTOSYNTHESIS

U.S. DEPARTMENT OF ENERGY | Office of Science

JCAP is one of three Energy Innovation Hubs initiated by the U.S. Department of Energy in 2010. Federal oversight of JCAP is provided through the Office of Science's Basic Energy Sciences program. JCAP draws on the work of scientists and engineers throughout the nation, and on the knowledge base and cutting-edge capabilities of the California Institute of Technology (JCAP lead), the Lawrence Berkeley National Lab, the SLAC National Accelerator Laboratory, Stanford University, and the University of California campuses at Berkeley, Irvine, Santa Barbara, and San Diego. JCAP is dedicated to creating globally scalable technologies that can produce multiple clean, targeted solar fuels from earth-abundant materials, achieving higher energy-conversion efficiency than is possible with current approaches.