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Clean Energy Breakthroughs: Solar Fuels

Bicameral Task Force on Climate Change

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About the Series

The Bicameral Task Force on Climate Change is issuing a series of fact sheets examining emerging energy technologies that could play a significant role in the clean energy economy of the future. The transition to a clean energy economy presents many challenges for which scientists and researchers across the country and the world are developing solutions. Each fact sheet in the Clean Energy Breakthroughs series will examine a technical challenge, describe the opportunities it presents, and highlight new technologies that are being developed to address the challenge. Some of the profiled technologies will ultimately succeed in the commercial market while others may not. Below we examine the progress being made on solar fuel technologies.

The Challenge

The sun delivers more energy to the earth in one hour than humans use collectively in an entire year.[1] Solar power is an essential source of clean, renewable energy, but its intermittent availability poses a challenge. Solar energy cannot be generated at night and its use is limited on cloudy days. If solar energy could be stored in an inexpensive and stable form, then this abundant source of carbon-free energy could be used more effectively and efficiently. Liquid fuel is a promising form of storage because it is stable, compact, transportable, and works within the existing energy infrastructure. Additionally, liquid fuels are required for the approximately 40% of current global transportation, like jet propulsion, for which a switch to electrification through batteries is impractical.[2] Solar fuel technologies use the energy of the sun to catalyze the conversion of water and carbon dioxide to fuels such as hydrogen or syngas, a fuel precursor that can be fed into commercial processes to produce fuels like kerosene. Solar fuel technologies can mimic the natural process of photosynthesis, which also converts carbon dioxide and water into fuel (sugars) and oxygen.

The Technologies

Teams of scientists and researchers are developing a number of solar fuel technologies that have great potential. This fact sheet describes two of these technologies, which are in an exciting stage of initial development, pushing the boundaries of knowledge and engineering.

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[1] Royal Society of Chemistry, *Solar Fuels and Artificial Photosynthesis: Science and Innovation to change our future energy options* (Jan. 2012) (online at www.rsc.org/solar-fuels).

[2] *Solar energy: Springtime for the artificial leaf*, Nature (June 5, 2014) (online at www.nature.com/news/solar-energy-springtime-for-the-artificial-leaf-1.15341).

University of Florida Solar Fuels Reactor

Researchers at the University of Florida are developing a solar fuel reactor to generate hydrogen from water using the energy from the sun. The technology is being marketed by a private company, the Solar Fuels Corporation. First, the sunlight is concentrated to very high temperatures, exceeding 2200°F, like that of a glowing white hot filament in an incandescent light bulb. This heat is then used with an iron or ceria catalyst to produce hydrogen from water. The hydrogen can be stored and used in fuel cells to generate electricity. The same system can also catalyze the reduction of carbon dioxide to carbon monoxide, a precursor to common fuels like gasoline. The lab has successfully demonstrated over 2,000 cycles of these high temperature reactions, an important attribute considering the extreme stress that the high temperatures put on the materials in the reactor.

The University of Florida team's ten kilowatt reactor is small – the size of a small dorm fridge – and can be used as a "drop-in" source of clean energy storage. Including the dish used to collect sunlight, the system is about 12 feet in diameter. The system's small footprint is ideal for providing local energy storage or grid stabilization.

The team is now developing plans for a 75 kilowatt reactor that could potentially be used in tandem with additional units for higher energy needs. However, the most likely application is to store energy on the micro-grid scale. The team expects its 75 kilowatt reactor to have a footprint of approximately 30 feet in diameter, including the dish needed to collect the sunlight. The reactor could serve as a modular, distributable, and flexible means to store the sun's energy and manage the grid at the local scale, even when the sun isn't shining.

Georgia Tech Solar Fuels Reactor

Most of the inefficiencies with current solar fuel reactors stem from the wasted heat that escapes the system and therefore can't be used to accelerate the fuel production reaction. A team of researchers based at Georgia Tech are designing a novel solar fuel reactor that uses the energy of the sun to melt metal into a liquid form which can be used to efficiently apply heat at just the right time. The reaction to produce fuel requires two steps. The first step uses intense heat to drive the oxygen out of a molecular lattice. Next, the lattice is cooled and carbon dioxide or water is added, which allows the lattice to soak up an oxygen molecule and leaves behind pure hydrogen or carbon monoxide which can be used as syngas. These steps are repeatedly cycled between hot and cold. Hot liquid metal can be efficiently pumped through the reactor to apply very high temperatures (over 2,700°F) at precisely the right time and place. This process allows quick and efficient reaction cycling with little wasted heat.

The researchers are currently testing various metals that meet the criteria to melt, but not vaporize, at the extremely high temperatures. They have already demonstrated the robustness of their reactor including pipes and pumps that can efficiently pump liquid metal, withstand the high temperatures, and not corrode over time. Ultimately, the team plans to produce the next generation of solar fuel reactors with greater efficiencies than the current designs.

The Potential

Solar has the potential to be earth's most abundant source of clean-energy; and liquid fuels are the most energy dense and stable means of storage, making solar fuels a promising avenue for research and development. Solar fuel is carbon-neutral and can be part of the transition to a clean energy future, particularly in sectors in which electrification may not be feasible, such as aviation. Additionally, solar fuel could potentially be produced in tandem with traditional power plants by converting some of the waste carbon dioxide emissions into liquid fuel, reusing the carbon in fossil fuels.