# SOLAR FUELS

*by Nianqiang Wu*

The total world consumption of marketed energy was 505 quadrillion Btu in 2008; this number is projected to increase by 53 percent in 2035.[1] In the U.S., fossil fuels supplied 85% of the nation's energy in 2008. The world energy-related carbon dioxide emissions were 30.2 billion tons in 2008, which in turn are predicted to increase to 43.2 billion tons in 2035.[1] Since fossil fuels are the main energy source and the energy consumption continuously increases, the "greenhouse" effect becomes progressively worse. According to the Global Historical Climate Network data provided by NASA,[2] the global mean surface temperature increased by about 0.5 °C from 1940 to 2011. Therefore, there is a strong incentive to exploit clean, renewable energy sources to address the challenges in sustainable global development.

Solar energy is the most abundant, clean, renewable energy source. Solar energy can be utilized in three ways: (1.) solar thermal systems that convert solar energy to enthalpy stored in working fluids, (2.) photovoltaics that convert sunlight to electricity, and (3.) solar fuels that convert solar energy to chemical energy stored in chemical fuels such as hydrogen and methanol. In 1972, Fujishima and Honda developed a titanium dioxide-based photoelectrochemical cell to split water to generate hydrogen, which opened up a new avenue for solar fuel production.[3] Besides water, carbon dioxide and biomass also have been exploited as the sources for solar fuel production. The products derived from carbon dioxide and biomass varies include methane, formic acid, methanol and etc., which depends on the reaction conditions.

Photocatalytic systems fall into two categories based on the configuration: (1.) photoelectrochemical cells (PECs), and (2.) particulate photocatalytic systems. PECs generally have higher energy conversion efficiency and are more convenient for separating $H_2$ and $O_2$ products. On the other hand, particulate photocatalytic systems are simpler and inexpensive. So far, no single commercial photocatalyst is available to catalyze water-splitting reactions with energy-conversion efficiency larger than 10% under "one-sun" radiation, which is the benchmark for commercialization of solar-photocatalytic systems.[4] The benchmark has not been achieved because current photocatalysts suffer from insufficient light absorption, inefficient charge separation, high charge recombination rate, low charge mobility, low catalytic activity, and high fabrication costs. Efforts are therefore being made either to develop new nanostructures or to search for new materials for photocatalytic production of fuels.

In this special issue of *Interface*, we highlight the research progress in photoelectrochemical cells (PEC) and particulate photocatalytic systems for solar fuel production. In the first feature article, Nathan Lewis proposes an integrated systems approach to the design and development of solar fuels generators. In the second article, Akira Fujishima, Kazuya Nakata, Tsuyoshi Ochiai, Donald Tryk, and A. Manivannan present a perspective on new generations of photocatalysts including developments on the workhorse material, titanium dioxide. In the third article, Kazunari Domen and Jun Kubota highlight oxynitride and nitride semiconductor photocatalysts for production of solar hydrogen. In the fourth article, Nianqiang (Nick) Wu and Scott Cushing provide new insights into plasmon-enhanced solar energy harvesting.

Relevant to the theme of this special issue of the magazine, a symposium on "Renewable Fuels from Sunlight and Electricity" was held at the 222nd ECS Meeting in Honolulu in October. This symposium focused on the development of materials and devices for hydrogen generation and $CO_2$ conversion to fuels. To round out the aforementioned perspectives on solar fuels, aspects discussed at this forum are summarized by Heli Wang, Deryn Chu, and Eric L. Miller in the last feature.

## References


1. International Energy Outlook 2011, U.S. Energy Information Administration, www.eia.gov/ieo/pdf/0484(2011).pdf, accessed on December 13, 2012.
2. GISS Surface Temperature Analysis, NASA, http://data.giss.nasa.gov/gistemp/, accessed on December 13, 2012.
3. A. Fujishima and K. Honda, *Nature*, **238**, 37 (1972).
4. A. J. Bard and M. A. Fox, *Acc. Chem. Res.*, **28**, 141(1995).


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