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Caltech, MIT Chemists Look for Better Ways to Use Chemical Bonds to Store Solar Energy

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With gasoline prices hovering at $3 per gallon, probably few Americans need convincing that another energy crisis is imminent. But what precisely is to be done about our future energy needs is still a puzzle. There's talk about a "hydrogen economy," but hydrogen itself poses some formidable challenges.

The key challenge is, of course, how to make the hydrogen in the first place. The best and cheapest methods currently available involve burning coal or natural gas, which means more greenhouse gases and more pollution. Adopting the cheapest method by using natural gas would merely result in replacing our dependence on foreign oil with a dependence on foreign gas.

"Clearly, one clean way to get hydrogen is by splitting water with sunlight," says Harry Gray, who is the Beckman Professor of Chemistry at the California Institute of Technology.

Gray is involved with several other Caltech and MIT chemists in a research program they call "Powering the Planet." The broadest goal of the project is to "pursue efficient, economical ways to store solar energy in the form of chemical bonds," according to the National Science Foundation (NSF). With a new seed grant from the NSF and the possibility for additional funding after the initial three-year period, the Caltech group says they now have the wherewithal to try out some novel ideas to produce energy cheaply and cleanly.

"Presently, this country spends more money in 10 minutes at the gas pump than it puts into a year of solar-energy research," says Nathan S. Lewis, the Argyros Professor and professor of chemistry. "But the sun provides more energy to the planet in an hour than all the fossil energy consumed worldwide in a year."

The reason that Gray and Lewis advocate the use of solar energy is that no other renewable resource has enough practical potential to provide the world with the energy that it needs. But the sun sets every night, and so use of solar energy on a large scale will necessarily require storing the energy for use upon society's demand, day or night, summer or winter, rain or shine.

As for non-renewable resources, nuclear power plants would do the job, but 10,000 new ones would have to be built. In other words, one new nuclear plant would have to come on-line every other day somewhere in the world for the next 50 years.

The devices used in a simple experiment in the high school chemistry lab to make hydrogen by electrolysis are not currently the cheapest ones to use for mass production. In fact, the tabletop device that breaks water into hydrogen and oxygen is perfectly clean (in other words, no carbon emissions), but it requires a platinum catalyst. And platinum has been selling all year for more than $800 per ounce.

The solution? Find something cheaper than platinum to act as a catalyst. There are other problems, but this is one that the Caltech group is starting to address. In a research article now in press, Associate Professor of Chemistry Jonas Peters and his colleagues demonstrate a way that cobalt can be used for catalysis of hydrogen formation from water.

"This is a good first example for us," says Peters. "A key goal is to try to replace the current state-of-the-art platinum catalyst, which is extremely expensive, with something like cobalt, or even better, iron or nickel. We have to find a way to cheaply make solar-derived fuel if we are to ever really enable widespread use of solar energy as society's main power source."

"It's also a good example because it shows that the NSF grant will get us working together," adds Gray. "This and other research results will involve the joint use of students and postdocs, rather than individual groups going it alone."

In addition to the lab work, the Caltech chemists also have plans to involve other entities outside campus--both for practical and educational reasons. One proposal is to fit out a school so that it will run entirely on solar energy. The initial conversion would likely be done with existing solar panels, but the facility would also serve to provide the researchers with a fairly large-scale "lab" where they can test out new ideas.

"We'd build it so that we could troubleshoot solar converters we're working on," explains Gray.

The ultimate lab goal is to have a "dream machine with no wires in it," Gray says. "We visualize a solar machine with boundary layers, where water comes in, hydrogen goes out one side, and oxygen goes out the other."

Such a machine will require a lot of work and a number of innovations and breakthroughs, but Lewis says the future of the planet depends on moving away from fossil fuels.

"If somebody doesn't figure this out, and fast, we're toast, both literally and practically, due to a growing dependence on foreign oil combined with the increasing projections of global warming."

The NSF grant was formally announced August 11 as a means of funding a new group of chemical bonding centers that will allow research teams to pursue problems in a manner "that's flexible, tolerant of risk, and open to thinking far outside the box." The initial funding to the Caltech and MIT group for the "Powering the Planet" initiative is $1.5 million for three years, with the possibility of $2 to $3 million per year thereafter if the work of the center appears promising.

In addition to Gray, Lewis, and Peters, the other Caltech personnel include Jay Winkler and Bruce Brunschwig, both chemists at Caltech's Beckman Institute. The two faculty members from MIT involved in the initiative are Dan Nocera and Kit Cummins.

Jonas Peters's paper will appear in an upcoming issue of the journal Chemical Communications. In addition to Peters and Lewis, the other authors are Brunschwig, Xile Hu, a postdoctoral researcher in chemistry at Caltech, and Brandi Cossairt, a Caltech undergraduate.

Source: California Institute of Technology