New biofuels process promises to meet all US transportation needs

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Purdue University chemical engineers have proposed a new environmentally friendly process for producing liquid fuels from plant matter - or biomass - potentially available from agricultural and forest waste, providing all of the fuel needed for "the entire U.S. transportation sector."

The new approach modifies conventional methods for producing liquid fuels from biomass by adding hydrogen from a "carbon-free" energy source, such as solar or nuclear power, during a step called gasification. Adding hydrogen during this step suppresses the formation of carbon dioxide and increases the efficiency of the process, making it possible to produce three times the volume of biofuels from the same quantity of biomass, said Rakesh Agrawal, Purdue's Winthrop E. Stone Distinguished Professor of Chemical Engineering.

The researchers are calling their approach a "hybrid hydrogen-carbon process," or H2CAR.

"Further research is needed to make this a large-scale reality," Agrawal said. "We could use H2CAR to provide a sustainable fuel supply to meet the needs of the entire U.S. transportation sector - all cars, trucks, trains and airplanes."

The process, which would make possible the dawning of a "hydrogen-carbon economy," is detailed in a research paper appearing online this week in the Proceedings of the National Academy of Sciences. The

paper was written by Agrawal, chemical engineering doctoral student Navneet R. Singh, and chemical engineering professors Fabio H. Ribeiro and W. Nicholas Delgass.

A conventional method for turning biomass or coal into liquid fuels involves first breaking down the raw material with a chemical process that "gasifies" it into carbon dioxide, carbon monoxide and hydrogen. Then those constituents are turned into a liquid fuel with other processes.

In the H2CAR concept, hydrogen would be harvested by splitting water molecules, possibly with a well-known method called electrolysis. Then the hydrogen would be added during the gasification step, making the process more efficient by suppressing the formation of carbon dioxide and converting all of the carbon atoms to fuel.

When conventional methods are used to convert biomass or coal to liquid fuels, 60 percent to 70 percent of the carbon atoms in the starting materials are lost in the process as carbon dioxide, a greenhouse gas, whereas no carbon atoms would be lost using H2CAR, Agrawal said.

"This waste is due to the fact that you are using energy contained in the biomass to drive the entire process," he said. "I'm saying, treat biomass predominantly as a supplier of carbon atoms, not as an energy source."

Power for the electrolysis would be provided by carbon-free energy sources, such as solar, wind or nuclear power. And, unlike conventional methods of producing liquid fuels from plant matter and coal, H2CAR would not emit carbon dioxide into the atmosphere.

"The goal is to accomplish the complete transformation of every carbon atom in the feedstock to liquid fuel by supplementing the conversion process with hydrogen from a carbon-free energy source," Agrawal said.

Other researchers have estimated that the United States has a sustainable supply of about 1.4 billion tons of biomass each year that could be used specifically for the production of liquid fuels. With conventional methods, that quantity of biomass would provide 30 percent of the fuel required for the nation's annual transportation needs. But the same quantity of biomass would provide enough fuel to meet all transportation needs using the new H2CAR method, Agrawal said.

"This is possible without using any additional land," he said.

A federal study indicates that 1 billion tons of biomass is potentially available every year from agricultural sources such as crop wastes, animal manure, grains and other crops. The remaining biomass could come from sources including fuel wood from forests, wastes left over from wood processing mills and paper mills, and construction and demolition debris.

The process also offers potential advantages over producing liquid fuels from coal using conventional methods, which emit carbon dioxide. Because H2CAR would not emit this additional carbon dioxide, the process would eliminate the need for proposed carbon dioxide "sequestering."

Sequestering would involve pumping carbon dioxide emissions into saltwater aquifers and hollow underground pockets that used to contain oil, natural gas and coal deposits. But the procedure poses several potential pitfalls.

"Clearly, massive quantities of carbon dioxide would be sequestered during a century-long production of liquid fuels from coal," Agrawal aid. "This would place extreme demands on the carbon dioxide capture, storage and monitoring systems."

The new process also would be more practical than all-electric or hydrogen-powered cars, in part because of the limited storage capacity of batteries and hydrogen storage tanks.

"The tremendous convenience provided by the existing infrastructure for delivering and storing today's fuels is a huge deterrent to introducing technologies that use only batteries or hydrogen alone," Agrawal said. "A major advantage of our process is that it would enable us to use the current infrastructure and internal combustion engine technology. It is quite attractive for hybrid electric vehicles and plug-in hybrid electric vehicles."

To grow enough biomass for the entire nation's transportation needs using the conventional method for producing biofuels would require a land area 25 percent to 55 percent the size of the United States, compared with about 6 percent to 10 percent for the H2CAR process.

"This large reduction of land area needed for H2CAR provides an opportunity for sustainable production of hydrocarbon fuel for the foreseeable future," Agrawal said.

A major reason less land would be needed is because of the overall higher efficiency of generating hydrogen by splitting water molecules using solar energy to drive the electrolysis. Usually, the hydrogen in liquid fuels made from biomass comes from the plant matter itself. But it typically takes more than 10 times the solar energy to grow crops than it does to produce the equivalent quantity of hydrogen possessing the same energy content by using the solar-power electrolysis method, he said.

"So providing hydrogen derived from water through solar electrolysis reduces the amount of biomass needed," Agrawal said. "The average energy efficiency of growing crops is typically less than 1 percent,

whereas the energy efficiency of photovoltaic cells to split water into hydrogen and oxygen is about 8-10 percent. I am getting hydrogen at a higher efficiency than I get biomass, meaning I need less land."

Using coal exclusively to produce liquid fuels for the nation's transportation sector could deplete all coal deposits in the United States in about 90 years, whereas H2CAR would enable the known coal reserves to last 140 years.

The researchers suggest in the paper the chemical processing steps needed to make the new approach practical. But making the concept economically competitive with gasoline and diesel fuel would require research in two areas: finding ways to produce cheap hydrogen from carbon-free sources and developing a new type of gasifier needed for the process.

"Having said that, this is the first concept for creating a sustainable system that derives all of our transportation fuels from biomass," Agrawal said.

Purdue has filed a patent for the concept. The approach is in the conceptual stages, and a plan for experimental research is in progress.

Source: Purdue University