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Coupling Carbon Sequestration with Novel Cellulosic Ethanol Technology

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Opportunities to make money and do well at the same time don't come along often. Right now, however, America's need for greater energy independence—and a growing international desire to curb global warming—provides the U.S. ethanol industry and American agriculture with exactly that prospect. In particular, two significant advances will enable ethanol to widely replace fossil fuels in an environmentally beneficial way: cellulosic ethanol production and carbon sequestration.

Carbon dioxide released from this biomass feedstock during processing could be converted and sealed within blue-green algae and sent into the ocean depths.

According to most climatologists, the Earth is at a crossroads with global warming. The optimists among these scientists believe it will, at most, take 10 years to roll out the necessary technologies that will keep global warming within "tolerable limits." Although it will take more than a decade for the full effects of global warming to develop, those effects will be locked in within that same time period if proper action is not taken soon. One strategy is to quickly and widely deploy a number of "first-round" technologies that will, in essence, buy the time for the occurrence of necessary changes and technologies that will take longer to deploy.

These first-round technologies are a special sort. They must be constructed with existing elements of technology because there's no time left to do longer-term research and development. For first-round technologies, we must go with what we already have.

Carbon-Negative Biofuels Explained

The production and use of fossil fuels—and for that matter ethanol, too—release carbon dioxide into the atmosphere. While some ethanol advocates say about as much carbon dioxide is absorbed by the corn plant itself as is released when the feedstock is converted into ethanol, the process is, in our view, carbon positive because of the liberal use of agricultural chemicals and fuel during cultivation.

Today, the carbon dioxide produced during ethanol production is either vented into the atmosphere or captured as a by-product and processed into a commercial-grade, liquified form or dry ice. Suppose, however, that rather than venting or capturing ethanol plant carbon dioxide in this traditional way, the gas was instead channeled through a "bubbler" of blue-green algae—a process already used to capture carbon dioxide and nitrogen oxides from the smokestacks of power plants. This would be an example of one aspect of producing carbon-negative biofuels.

A bubbler is a series of transparent parallel tubes that contain blue-green algae growing in a nutrient solution. In the case of capturing carbon dioxide from an ethanol plant, one of those nutrients would be carbon dioxide itself. The gas would be bubbled through the device and transformed by algae—through photosynthesis—into nonvolatile carbon compounds that don't evaporate. Algae would grow in the bubbler as it feeds on carbon dioxide and other nutrients introduced into the solution.

The blue-green algae that grows naturally in the ocean is responsible for much of the photosynthesis on Earth that changes carbon dioxide into oxygen. Knowing that, it's easier to accept the idea of taking the used algae from a bubbler and dumping it several thousand feet deep into the ocean. The carbon contained in the algae would effectively be sequestered for thousands of years—just as it is in the lifecycle of algae growing naturally in the ocean.

Suppose an ethanol plant's carbon dioxide was captured and sequestered in this way. Taking the sequestered carbon into account, a lifecycle analysis of the renewable fuel would show that the photosynthesis of the biomass used for ethanol production—with either grain or cellulosic feedstocks—pulls more carbon dioxide out of the atmosphere during the feedstocks' cultivation than is returned to the atmosphere in the production and use of the fuel. That is, a carbon-negative ethanol production and use process, one that pulls net carbon dioxide out of the atmosphere, is created.

It can be shown that, other things being equal, the extent to which ethanol can be made carbon negative increases as the energy gain of the entire process—biomass cultivation, ethanol production and use—increases.

It may be logistically too complex to attempt to capture the last bit of carbon dioxide at all of the sites that would eventually burn a carbon-negative biofuel (e.g., stationary power generation, motor vehicle engines, etc.), for this would require bubblers of blue-green algae everywhere. The same objection applies to continued widespread use of fossil fuels. It would require bubblers everywhere to collect the carbon dioxide on the "back end" at all the locations where fossil fuels are burned. If, however, most fossil fuels were replaced with biofuels and carbon dioxide from the biofuels production process was captured and channeled into bubblers, civilization's overall energy infrastructure would be changed in a way that would be hardly noticeable.

It would, however, still be desirable to equip power plants that produce huge quantities of carbon dioxide with bubblers. This would be true whether those plants burned carbon-negative biofuels or continued for a while to burn fossil fuels. Doing so would capture large additional amounts of carbon dioxide at the back end where the fuel is burned, without requiring bubblers everywhere. Other large producers of carbon dioxide such as ships, could also be equipped with bubblers.

Cellulosic ethanol may someday be produced from dedicated energy crops such as miscanthus.

Finally, the carbon-negative process outlined here can control the rate at which mankind's contribution of carbon dioxide from the burning of biofuels is pulled from the atmosphere. Early on, a maximum rate would be desired. However, after several decades, reducing the rate by simply capturing and sequestering less carbon dioxide during biofuels production would be an option.

Although these concepts can be used during the production of most biofuels to render them carbon negative, they assume much greater importance when used with a biofuel that is otherwise capable of widely replacing fossil fuels. Texas-based GreenSea has developed such a process.

The GreenSea Way

The energy gain ratio of GreenSea's process for making ethanol is greater than 11:1. The value for corn ethanol, by comparison, is 1.38:1. One of the reasons for this large difference is that GreenSea's process uses the entire plant to make ethanol, whereas corn ethanol uses only the starch content of the corn kernel. There are other reasons, as well. Energy gain, of course, is the amount of energy created by burning a unit of biofuel compared to the energy needed to make the biofuel, including feedstock cultivation and biofuel production. To get a large energy gain, the "energy-out" must be as large as possible and the "energy-in" must be as small as possible. For GreenSea, maximizing energy-out means growing as much biomass, sugar and carbohydrates per acre of land as possible. GreenSea's strategy is to also grow a crop that requires as few inputs per acre as possible—fuel, as well as energy intensive materials like fertilizer and pesticides—to reduce the energy input.

One of the best crops, in appropriate climates, is the plant maralfalfa, used for cattle feed in Colombia. It requires minimum cultivation and produces enough biomass to yield 20,000 gallons of ethanol per acre annually for any process that uses the entire plant to make ethanol. Another high-yielding plant is a miscanthus sugarcane cross developed at Texas A&M, which yields 10,000 gallons per acre with a process that uses the entire plant. Other suitable biomass crops are also available that grow across the nation.

The other requirement of GreenSea's strategy is to minimize the amount of energy to produce ethanol from biomass, and here the GreenSea process is unique. It is thought to be the only low-temperature, low-pressure cellulosic ethanol process that, in turn, saves a considerable amount of energy. One energy-saving technique employed in the GreenSea process is the use of microorganisms instead of mechanical grinding, to break up biomass into tiny pieces, so it can undergo chemical reaction.

Finally, GreenSea uses microorganisms to decouple cellulose molecules into sugar, a process that requires little energy. After cellulose is turned into sugar, it is fermented in the usual way to make ethanol. Enzymes, of course, are used to decouple cellulose into sugar. Finally, ethanol must be separated from water in the mash, which is energy intensive. GreenSea has developed a proprietary low-energy process to achieve this separation. GreenSea's use of microorganisms to accomplish various steps in its process is highly energy efficient because nature has had millions of years to develop microorganisms that do their jobs efficiently. The overall energy efficiency of the GreenSea process results in low-cost ethanol. That, GreenSea believes, should be an economic driver for the adoption of the process.

Many of those following the enzymatic path to the commercialization of cellulosic ethanol hope to have their processes developed within five years. However, the nation and the world cannot afford to wait another five years. Widespread deployment of first-round technologies must be immediate in order to hold global warming to tolerable levels.

Other Considerations

There are two other important considerations that aren't directly factored into the energy gain. Say, for example, that a goal has been established to replace all 10.1 million barrels of imported oil used daily in the United States with ethanol. If too much acreage is required to grow the biomass needed for this fuel, the nation would be forced to choose between acreage devoted to food and fiber versus biomass production. In addition, too much acreage devoted to any form of agriculture would have negative environmental consequences.

Assuming 4,000 gallons of ethanol can be produced per acre annually on average with the GreenSea process (a conservative estimate), 32 million acres of farmland per year—only about 10 percent of all U.S. agricultural acreage—would be required to replace all the (imported) oil used in America each year. This is a major advantage over current ethanol production processes.

Finally, there is the question of sustainability. Many successive crops will deplete the soil, especially after oil- and gas-based fertilizers are gone or the use of oil and gas has to be curtailed because of global warming. GreenSea's process can give back the inorganic portion of fertilizer to the soil. In addition, if agricultural acreage is fallowed with nitrogen-fixing plants, and food and fuel crops are rotated, both food and ethanol production can be maintained in the future—a future we must immediately prepare for if global warming is to be kept in check.

Putting back the inorganic portion of fertilizer into the soil from which it came is aided by locating the ethanol plant close to the fields that grow the biomass. Close proximity would also minimize the amount of energy needed to transport the biomass to the ethanol production facility.

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