The San Diego Union-Tribune.

The promise of biofuels

Hype or a real solution?

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February 17, 2008

EDEL RODRIGUEZ illustration

With gas prices approaching $4 a gallon and industries searching for new ways to reduce carbon dioxide emissions, biofuels – fuels such as ethanol derived from corn and other plant sources rather than petroleum – are becoming an increasingly attractive option to help mitigate the impacts of climate change and reduce our oil imports.

The promise of powering our cars exclusively with green energy from plants prompted President Bush to ask Congress recently for $225 million for biofuels research – a 19 percent increase over this year's federal spending level. And it brought more than 300 scientists and business leaders from around the nation to a meeting here recently hosted by the University of California San Diego to discuss new ways of producing ethanol from plants and other promising avenues of biofuels research.

Everyone seems to be touting the benefits of biofuels these days: Midwestern farmers, environmentalists, state and federal legislators, Gov. Arnold Schwarzenegger, business leaders, venture capitalists and university scientists. But can corn-based ethanol – the primary focus of current biofuels efforts – deliver what we need to accomplish? And are the promises of biofuels more hype than real?

We now know that the Earth's climate is changing, caused by the accelerating use of fossil fuels that started at the time of the Industrial Revolution. The dramatic changes in land use – the conversion of natural ecosystems to agricultural fields – that accompanied the growth of human population also contributed substantially by releasing carbon stored in the vegetation and in the soils. These activities caused an increase in atmospheric carbon dioxide such as has not been seen in the past 400,000 years. This increase is responsible for the so-called greenhouse effect, the warming of the land and the oceans with resulting changes in wind, rain and storm patterns. The evidence supporting this interpretation is both overwhelming and unequivocal.

Biofuels can help mitigate this global climate change phenomenon because they are made from plants and algae that absorbed carbon dioxide in the process of photosynthesis. When we burn fossil fuels, we add carbon dioxide to the atmosphere, but burning biofuels releases carbon dioxide that was taken out of the atmosphere by plants or algae a few days, weeks or years earlier. So, we create a carbon cycle, helping to prevent further buildup of carbon dioxide in the atmosphere. The United States has a strong biofuels industry based largely on ethanol derived from corn grain and made possible by the high price of petroleum, generous farm subsidies and a stiff tariff on imports of sugar and ethanol.

Unfortunately, all biofuels are not created equal when we look at the extent to which they mitigate greenhouse gas buildup. The reason is that growing plants and converting plant material into biofuel also takes energy. And at the moment that energy comes mostly from electricity generated by fossil fuels. So much energy is required to produce the two main biofuels now being utilized in the United States – ethanol made from cornstarch and biodiesel made from canola and soybeans – that the net effect of their use on greenhouse gases is negative rather than positive.

The reasons are complex: corn and canola require a lot of nitrogen fertilizer to grow, and making nitrogen fertilizers is very energy intensive. In the case of corn ethanol, distilling the ethanol requires energy. We don't have ethanol pipelines, so ethanol has to be transported in trains and trucks. For these and other reasons, the greenhouse gas balance – greenhouse gases removed from the atmosphere minus greenhouse gases released – is unfavorable for corn ethanol. In Europe, opposition to biofuels derived from food crops is already developing because they contributed to the recent rise in food prices. When fuel is derived from crops, food prices rise.

Fortunately, new technological developments are on the horizon. Ethanol can also be made from cellulose, the large linear molecule of plants consisting entirely of glucose that is the most abundant natural material in the world. Cellulose is the main ingredient in wood and in the new so-called biomass crops such as miscanthus that do not require much nitrogen fertilizer and have yields of 20 tons of biomass per acre.

Scientists reported at our biofuels conference that sugar can also be fermented directly into gasoline-like molecules, such as alkanes, that do not need to be distilled. This would require us to create new superbugs. Remember the superbugs that ate oil spills? Our new superbugs would produce oil-like molecules for transportation.

Also, oil can be produced by microalgae living in shallow ponds using the nutrients in municipal wastewater. With such plant and algal sources and with new industrial processes and fermentations, we could have a true greenhouse gas neutral transportation system that prevents further buildup of carbon dioxide and the two other greenhouse gases released as a result of agricultural practices – methane and nitrous oxide – into the atmosphere. Indeed, the other greenhouse gases have to be counted as well. Jeff Severinghaus, of UCSD's Scripps Institution of Oceanography, reported at the meeting that for those crops that require nitrogen fertilizers such as corn, canola and switchgrass, the release of nitrous oxide by soil bacteria may negate the positive effect of carbon dioxide absorption by photosynthesis.

So, when can we implement those solutions that promise to reduce greenhouse gases? Major technological breakthroughs are still needed to make these biofuels a reality. For one, the new crops need to be bred and selected – domesticated – for high biomass production. We still need to find the best genes and create the most efficient bacteria that would carry out these novel fermentations to produce alkanes rather than ethanol. We also need to develop more economical methods for the large-scale cultivation of algae and ways of extracting the new fuel molecules. Unfortunately, research on plants, algae and microbes has been woefully underfunded for decades as the nation focused its research dollars on human health and diseases.

By the end of the conference many in the audience realized that stark choices are being forced upon us. Fuel or tortillas, beef or biodiesel, which shall it be? When our lawmakers and the public at large understand that such choices are on our doorstep, then this funding trend could be reversed. Hopeful signs are the president's proposed budget already mentioned and a recent report by the National Research Council urging much greater funding for plant genetics, the basis of all crop improvement for food, fuel or fiber.

What should our focus be here in Southern California where transportation accounts for 40 percent of carbon dioxide release? Two research and development goals are clearly within the grasp of UCSD and other San Diego-area scientists: oil produced by microalgae and novel fermentations that convert cellulose-derived sugars into oil-like molecules. Our intellectual resources include world-renowned microbiologists, geneticists, engineers and experts on algae. San Diego biotechnology companies such as Synthetic Genomics, Verenium and Sapphire Energy have already acquired impressive expertise. We also have some unusual, but ideal, physical resources – degraded land around the Salton Sea that has become unsuitable for agriculture, but suitable for algae ponds – and abundant sunshine. The R&D done right here in San Diego can help our local energy company, Sempra Energy Utilities, meet California's mandated climate change guidelines for renewable energy.

So, are biofuels hype or can they be a real solution to climate change and carbon dioxide abatement? They will certainly play an important role, but let's not ignore the fact that society needs to simultaneously undertake many other initiatives to reduce carbon dioxide emissions and stabilize the climate. We will need to retrofit and redesign our buildings, emphasize mass transit, capture the carbon dioxide that is now emitted from our power plants and greatly increase the energy efficiency of all industrial processes.

The scientists and business leaders attending our conference came to the realization that these are challenging times. And those of us at UCSD and other research institutions on the Torrey Pines mesa who can contribute to the long-term development of new biofuels are now eager to get to work and meet that challenge. This is one case where biologists really can help save the world.

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