Researchers find high energy output from algae-based fuel, but 'no silver bullet'

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Algae-based fuel is one of many options among the array of possible future energy sources. New University of Virginia research shows that while algae-based transportation fuels produce high energy output with minimal land use, their production could come with significant environmental burdens.

For farmers looking to maximize profits, algae would produce considerably more transportation energy than canola and switch grass for every hectare planted, and can also be grown on poor-quality marginal land that cannot be easily used to grow food crops such as corn, according to a report by Andres F. Clarens and Lisa M. Colosi, both assistant professors of civil and environmental engineering in the U.Va. School of Engineering and Applied Science, and Mark A. White, professor in the McIntire School of Commerce.

From an environmental impact standpoint, however, algae-based fuel has mixed performance, compared to other biomass sources. Algae-based biodiesel production uses more energy – in the form of petroleum-powered processes – than other biofuels. Additionally, algae-based biodiesel and bioelectricity production processes also require substantial amounts of water and emit more greenhouse gases.

The report, "Environmental Impacts of Algae-Derived Biodiesel and Bioelectricity for Transportation," is available online on the website of *Environmental Science and Technology*, a leading environmental research journal and will be published in an upcoming print edition. Hagai Nassau

and Eleazer P. Resurreccion, civil and environmental engineering graduate students, contributed to the research.

"We're looking at the entire landscape of biofuels, and asking 'What are the options?'" Colosi said.

She hopes the research will inform public policy debates, allowing people to make the best decisions about alternatives to petroleum.

"It comes down to value-driven questions," Colosi said. "Do we value driving long distances in SUVs that require a lot of fuel? If so, we need to look at algae so we can produce as much fuel as possible. If we are concerned about energy use, climate changes and water supply, then we need to think more strongly about how we can best use canola and switch grass."

The U.Va. researchers relied on what is known as a "well-to-wheel" life-cycle assessment of algae-based biofuel and bioelectricity production for transportation fuels. The research began with examining how the source crops are grown and continued through the point of their transformation into useable fuels for vehicles. They expressed energy output of the various biomass sources by showing how many kilometers a car could travel per the amount of energy harvested from a hectare of land.

The current paper builds on the modeling results the U.Va. team reported in a 2010 paper in *Environmental Science and Technology*. In that work, they looked at the inputs such as fertilizer, water and petroleum power used to produce algae-based biodiesel. They compared this data to the amount of energy produced by other biomass stocks. The current paper accounts for variables throughout the entire production process.

Another important finding in the current paper shows the relative

favorability of using biofuels to generate electricity rather than liquid fuels (i.e. biodiesel) for internal combustion engines. The process has a higher energy return than other algae-based biofuels because it involves fewer steps to transform the biomass into a usable energy form. Energy generated in this manner could power electric vehicles, but the authors acknowledge that the limited number of those vehicles currently in use could reduce the overall benefit of bioelectricity for transportation.

For the next phase of their research, the team plans to monetize environmental costs and benefits associated with production of the various bio-fuels.

"Ultimately there is no silver bullet for replacing petroleum as a transportation energy source," Clarens said. "We've seen that alternatives typically come with unforeseen burdens. We saw it with ethanol, and we're seeing it now with shale gas. Our hope is that work like this will help us avoid similar pitfalls if algae-based fuels are ultimately deployed on large scale."

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