DOE awards $4.5 million to ASU teams to discover new ways to harness carbon dioxide for reducing cost of biofuel

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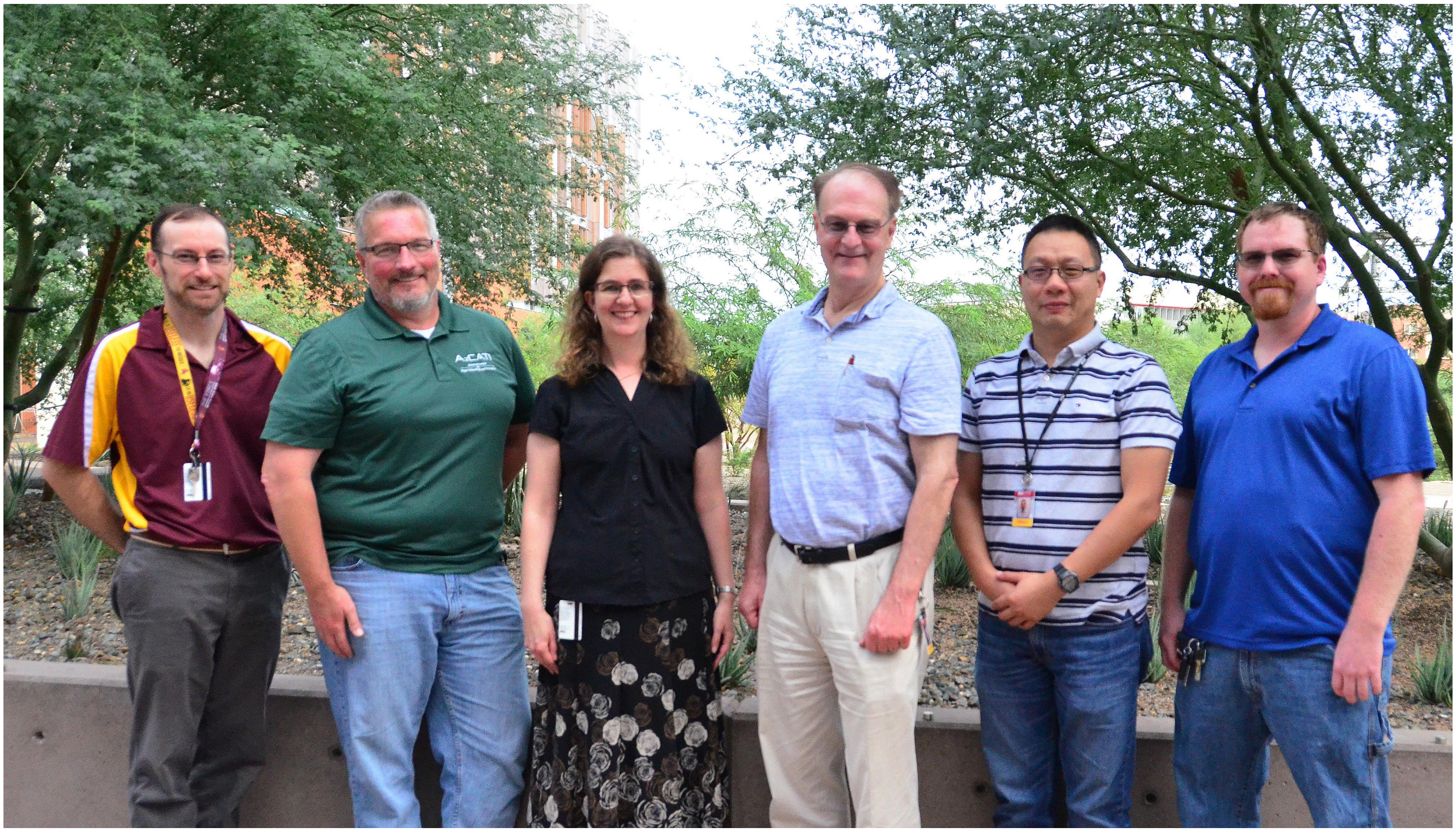
The U.S. Department of Energy has announced 36 projects that together have been awarded $80 million to support early-stage bioenergy research and development. Two ASU research teams are among the grantees, with the grants to ASU totaling about $4.5 million.

The two teams are headed by Wim Vermaas, Foundation Professor in the School of Life Sciences and a member of the Center for Bioenergy and Photosynthesis, and Bruce Rittmann, director of **Biodesign Swette Center for Environmental Biotechnology (https://biodesign.asu.edu/environmental-biotechnology)** and

Regents' Professor in the School of Sustainable Engineering and the Built Environment.

The DOE is investing $80 million to reduce the cost of algae-based, drop-in fuels to $3 per gallon by 2022, providing consumers with affordable, reliable transportation energy choices.

"The selections announced today highlight some of the most innovative and advanced bioenergy technologies that have the potential to produce new sources of reliable and affordable energy for American families and businesses," U.S. Secretary of Energy Rick Perry said. "Developing all of our domestic energy resources is critical to keeping our nation prosperous and secure."



Bruce Rittmann (center right, pictured with his research team) is the director of Biodesign Swette Center for Environmental Biotechnology and Regents' Professor in the School of Sustainable Engineering and Built Environment.

Both ASU projects are developing innovative approaches for improving the efficiency of microalgae to capture waste carbon dioxide and convert it into transportation fuels like biodiesel. Sustainable products like healthy animal feeds, nutritional supplements and green chemicals can also be produced in this manner.

"Carbon dioxide is the costliest feedstock for cultivating microalgae, so it is imperative that we deliver it at a high efficiency to help bring down overall production costs," Rittmann said.

Rittmann was awarded about $2 million to explore ways to make carbon dioxide delivery to algae more efficient. Traditional methods involve sparging (bubbling) carbon dioxide within the liquid used to grow the algae, which releases about 60-80 percent of the carbon dioxide back into the atmosphere. This wasteful process defeats a major goal of using microalgae to remove this greenhouse gas from the atmosphere and decreases cost efficiency.

Rittmann and his team developed a process called membrane carbonation, which uses inexpensive plastic fibers to deliver the carbon dioxide directly to the microalgae.

The team has demonstrated that this process can deliver pure carbon dioxide with nearly 100 percent efficiency, but pure carbon dioxide sources are costly. An alternative involves adapting these fibers to deliver carbon dioxide from abundant industrial waste streams, such as emissions from power plants, cement plants and wastewater treatment plants. These sources have much lower amounts of carbon dioxide mixed with other gases, but the technique would ensure that about 90 percent will be used by the microalgae. The team estimates that the technology will capture fourfold more carbon dioxide than traditional sparging methods.

The team is partnering with the Salt River Project to develop methods for harvesting carbon dioxide from power plant emissions. They are also partnering with the city of Mesa to remove carbon dioxide from the biogas generated from anaerobic digesters at their wastewater treatment facilities. Rittmann's team will investigate whether the fibers can be used with microalgae to remove carbon dioxide from the biogas, which would leave nearly pure methane. This methane could be distributed through existing natural gas pipelines.

"The city of Mesa is very excited to partner with ASU for developing innovative solutions for managing the city's waste in a sustainable manner and (to) generate new sources of revenue for the city," said Scott Bouchie, director of the Environmental Management and Sustainability Department with the city of Mesa.

Wim Vermaas (fifth from left, pictured with his research team) is a Foundation Professor in the School of Life Sciences and a mer of the Center for Bioenergy and Photosynthesis.

Vermaas and his team were awarded $2.5 million to pursue an innovative multipronged approach toward improved carbon dioxide utilization.

One approach is to increase the solubility of carbon dioxide in growth medium by developing a nanobubble gas delivery system, a project in partnership with Nano Gas Technologies, which is located in the Chicago area. Unlike the large bubbles created by sparging, which wastes most of the carbon dioxide, nanobubbles are very stable, delivering more carbon dioxide to the liquid before reaching the surface.

A second approach is to utilize amines in the medium, which greatly enhance the solubility of carbon dioxide, allowing the gas to be taken up by photosynthetic microbes for producing biofuel.

The Vermaas team is also adapting the inner workings of the photosynthetic microbe, the cyanobacterium Synechocystis, by means of metabolic engineering. Specifically, the team is engineering the bicarbonate transport proteins to improve the cellular uptake of dissolved inorganic carbon.

Further, carbon fixation rates will be increased by genetically modifying cellular metabolism rates to increase the amount of carbon dioxide used during both daylight and nighttime phases, and to increase the net carbon dioxide utilization efficiency.

Through a combination of these approaches, the researchers anticipate at least a 50 percent increase in the efficiency of carbon dioxide use with advanced biofuel production under industrially relevant conditions.

The advantages of Synechocystis are (1) that it naturally has a very efficient carbon-concentrating mechanism, taking up carbon dioxide and bicarbonate, (2) that it is easily engineered to make useful products, and (3) that it readily excretes products that it generated, thus eliminating the need to break open cells to extract the product.

Vermaas's cyanobacteria are "mini factories" that use solar energy and carbon dioxide to produce and export compounds like the fatty acid laurate (biofuel precursor), which is useful for the soap and cosmetics industries and can also be chemically changed to fuels such as diesel, jet fuel and gasoline.

With improved carbon uptake and utilization, the cyanobacteria will be even more efficient in producing biofuels and green chemicals.

Co-principal investigators on the Vermaas team include David Nielsen, an associate professor in the School for Engineering of Matter, Transport and Energy; Xuan Wang, an assistant professor in SOLS; John McGowen, the director of operations and program management for the Arizona Center for Algae Technology and Innovation at ASU's Polytechnic campus; Taylor Weiss, an assistant professor in the Environmental and Resource Management program at the Polytechnic campus; Al Darzins, an independent representative with Nano Gas Technologies; and Jason Quinn, an associate professor in mechanical engineering at Colorado State University, specializing in sustainability modeling and techno-economic assessment.

Rittmann is joined by McGowen; Rosa Krajmalnik-Brown, a professor of SSEBE and faculty in BCEB; Yen-Jun (Sean) Lai, a research scientist in BCEB; Everett Eustance, a postdoc in BCEB; Robert Stirling, a technoeconomic analyst with BCEB and LightWorks; and Justin Flory, a project manager with the **Biodesign Center for Applied Structural Discovery (https://biodesign.asu.edu/applied-structural-discovery)**.

Both Vermaas and Rittmann are affiliated with ASU's **LightWorks (https://sustainability.asu.edu/lightworks/)**, an organization that seeks to revolutionize how energy is conceptualized, produced and used. The researchers focus on discovery and design of energy systems that convert sunlight into useful and sustainable products.