# DISCOVERY IN ACTION


**In the 1990s, PNNL researchers used this equipment to explore and advance the use of hydrothermal processing to convert wet biomass streams into fuel gas. Today, this equipment is at the site of a Florida-based industrial partner that will use it to convert algae to biocrude oil. PNNL researchers will help with the startup of the equipment in support of the effort.**

# Better bio-based products and fuels through science

*This is the sixth of a 12-part series that features some of the scientific challenges PNNL has tackled over its 50-year history and highlights its vision for the future. PNNL is one of 10 national laboratories overseen by the U.S. Department of Energy's Office of Science and has been managed by Battelle since its inception in 1965. Through this enduring partnership—and by working closely with sponsors and collaborators—PNNL builds upon its legacy to advance science and solutions that improve the lives of Tri-Citians and people around the world. This edition is focused on PNNL's biological and chemical sciences and engineering capabilities and how they are being applied to produce products and fuels from renewable biomass rather than petroleum.*

Owned by the U.S. Department of Energy; operated by Battelle; and supported by academic, industrial and governmental collaborators, Pacific Northwest National Laboratory is celebrating 50 years of inspiring and enabling the world to live prosperously, safely and securely. Interdisciplinary teams at PNNL address many of America's most pressing issues in energy, the environment and national security through advances in basic and applied science. With an annual budget of about $1 billion and nearly 4,300 staff members, Battelle is the largest employer in the Tri-Cities.

Learn more about PNNL at **www.pnnl.gov** and through stories to commemorate 50 years of scientific discovery contributed by employees, retirees and the community at **www.celebrate.pnnl.gov**.

## PACIFIC NORTHWEST NATIONAL LABORATORY

Finding cleaner energy sources and reducing our nation's dependence on imported oil are among the national priorities on the Department of Energy's Pacific Northwest National Laboratory's to-do list.

Researchers at PNNL are addressing those challenges by applying their broad capabilities in biology, chemistry and engineering to help deliver the environmental and economic benefits of using renewable resources to produce high-value industrial and consumer products.

"PNNL has been developing and applying novel thermal, chemical and biological processes to convert biomass to industrial and consumer products, fuels, and energy for four decades," said Jud Virden, associate laboratory director for PNNL's Energy and Environment Directorate. One of PNNL's first biomass projects involved a pilot plant in Albany, Ore., that tested a process called liquefaction to convert wood into biocrude oil.

### From trash to treasure

In the 1990s, PNNL researchers were working on methods for turning agriculture commodities, byproducts and wastes into higher-value products. Many of these efforts focus on agricultural residues such as wheat straw and corn stover left behind after harvest, forest residues, and byproducts from food processing. For example, researchers have explored the potential of using hulls, peelings and pulp—often discarded by food processing plants as waste—as valuable bio-based feedstocks.

In collaboration with other national labs, PNNL developed a process that converts sugars from corn processing into a cost-effective, environmentally friendly source of chemicals used to make a number of products, including textiles, paints and inks, food additives, and automobile parts. In this process, the sugars are fermented to produce succinic acid. With the help of catalysts, the succinic acid is then converted into the chemicals used to make an assortment of industrial and consumer products.

Considering another agricultural waste as a potential feedstock, PNNL and Washington State University began a two-year project in 2001 to develop technology that would generate higher-value products from dairy manure solids. The team used the chemical building blocks from the waste to produce a range of products, including chemicals commonly used to manufacture antifreeze and certain plastics.

### Starting with the basics

Much of PNNL's bioproducts and bioenergy research centers on the fundamental understanding of the underlying chemistry and biology at play during biomass conversion. This research is enabled by advances in computation and unique surface science tools at the Environmental Molecular Sciences Laboratory, the DOE national user facility at PNNL.

For example, researchers are looking at how to make the catalysts that drive important reactions more durable because they often can't survive the hot water generated during conversion processes. In one project, PNNL researchers studied the catalysts used in a process called steam reforming, which turns methane from biomass into a mixture that can be further converted into transportation fuels. Through experimental and theoretical approaches, they were able to better understand the performance of the catalysts and can potentially develop longer-lasting catalysts.

In another project, scientists studied the behavior of specific atoms during the process of converting a bio-based feedstock into biofuel. While the reaction where oxygen atoms are removed has to be quick and efficient, it is a complex reaction with a lot of intermediate steps. Researchers discovered that the starting size of the molecule affects how and when the oxygen atoms are split from the hydrocarbon chain, an important step in the speed of the reaction.

"This highlights the hallmark of PNNL's research in this area," said Doug Ray, associate laboratory director for PNNL's Fundamental & Computational Sciences Directorate. "It's just one example of years of research focused on the underlying chemistry of catalysts and development of novel catalytic processes that convert sugars and organic acids to higher value products and chemicals."

In another project, scientists from PNNL and WSU investigated the possibility of using bacteria rather than oil as a source of isoprene—a chemical compound that is used for aviation fuel and to produce synthetic rubber. With the help of computer modeling, researchers predicted how environmental changes ultimately affected the volume of isoprene produced by the bacteria and can determine how to optimize production.

### Advancing solutions

In addition to basic science, PNNL leverages its scientific capabilities to conduct applied research and develop products that address industry needs.

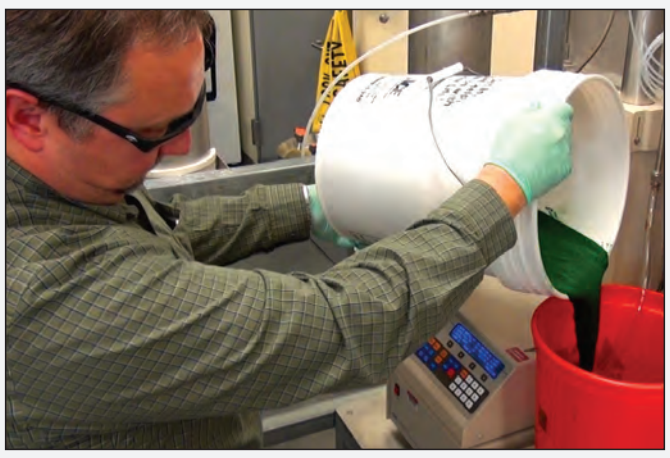
In 2004, PNNL researchers who contributed to the development of the Degradable by Design Deicer™ were recognized in a national award from *R&D Magazine* that highlights the year's top 100 innovations. The award acknowledged the family of biodegradable fluids used to remove and prevent the formation of ice on aircraft, runways, roadways and pavement. In addition to the reduced environmental impact, these bio-based materials are less corrosive and less toxic than conventional deicers.

In another technology transfer success story, PNNL partnered with Archer Daniels Midland Company (ADM) to quickly move a bio-based product breakthrough from development to full-scale deployment. PNNL developed a catalytic process to convert glycerol, which is a low-cost byproduct of biodiesel manufacturing, into propylene glycol, a chemical that is typically made from petroleum and found in common household products. ADM licensed the process and built a production facility in 2011 that produces 100 million metric tons of propylene glycol a year.

On the fuel side, PNNL developed a continuous process to produce biocrude oil from algae that has been licensed to Genifuel. Unlike traditional extraction methods that require drying the algae and separating out the energy-rich oils, this process converts whole, wet algae into biocrude oil. This development's roots can be traced back to the 1975 wood liquefaction project. Today, researchers are extending this process to convert other wet, carbon-rich and low-cost byproduct streams, like food processing waste and waste water sludge, into biocrude oil.

"Along with DOE as our primary sponsor, we work with private industry, academia and government to advance scientific discoveries and develop technologies for clean, cost-effective alternatives to conventional products and processes that rely on imported oil." Virden said. "These efforts address national and global energy independence and help grow and diversify the state and local economy."

**With DOE's support, Battelle, PNNL and WSU teamed up to fund and build the Bioproducts, Sciences, and Engineering Laboratory on the WSU Tri-Cities campus, which opened in 2008. It includes teaching laboratories and classrooms as well as advanced research laboratories and a high-bay facility for pilot-scale research.**



**PNNL scientists and engineers created a continuous process to produce biocrude oil from green algae. The biocrude can be then be used in conventional refinery processes to produce aviation fuel, gasoline or diesel fuel. Genifuel Corp. licensed the technology and built a pilot-scale production plant in Colorado to further test and advance the process.**

**PNNL researchers have developed novel catalysts and catalytic processes for converting biomass into valuable products and fuels. In 1999, PNNL and Massachusetts-based Biofine were recognized with a Presidential Green Chemistry Award for their roles in developing a cost-effective technology for converting paper mill waste into a useful fuel additive.**