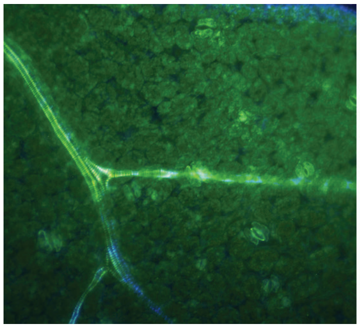
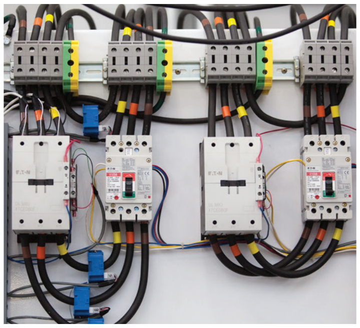
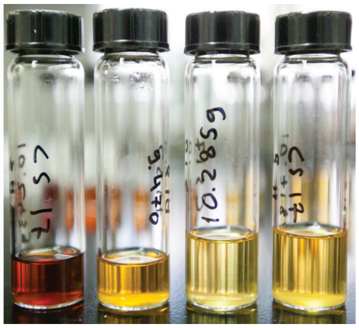
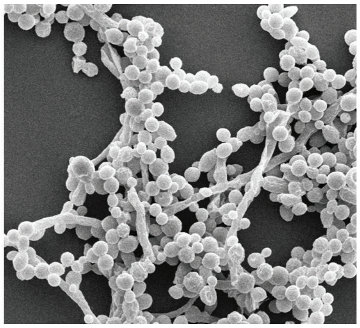
Wisconsin Energy Institute
UNIVERSITY OF WISCONSIN–MADISON

FORWARD IN ENERGY

The Wisconsin Energy Institute (WEI) is the collaborative home of energy research and education located at the heart of the University of Wisconsin–Madison campus. Together, we can move the state, nation, and world forward in energy. WEI is tackling one of the most critical challenges of our time – the transition to new clean energy systems and solutions. WEI is led by scientists and engineers committed to crossing traditional research boundaries and making major breakthroughs. A leader in clean energy research and a resource to the people of Wisconsin. WEI works closely with industry leaders to ensure that its technologies strengthen Wisconsin's economy, create jobs, and improve the health and wellbeing of its citizens.

PROMISING RESEARCH AT THE WISCONSIN ENERGY INSTITUTE

Zip-Lignin™ Technology
One of the key obstacles for extracting sugars from biomass is a complex polymer called lignin. Lignin, a major component of plant cell walls that gives plants their structural integrity, is the most difficult part of the plant to break down. Professor John Ralph and his team at UW-Madison discovered that it was possible to introduce weak bonds, or "zips," into the lignin polymer, which would make it much easier and cheaper to break apart. The researchers were successful in introducing these weak links into the lignin backbone of poplar trees, resulting in biomass that is much easier to degrade.

Bottom Line: Zip-Lignin technology has the potential to reduce the costs involved in deconstructing biomass, a cost-reduction with wide ranging effects on both the paper industries and the future of cellulosic biofuel and bioproducts production in Wisconsin.

Engineered Softwood
Hardwoods and softwoods are both utilized in the pulp, paper, and biofuels industries. Softwoods, such as conifers, have long fibers well suited for use in making strong paper products, but are also more difficult to deconstruct than hardwoods. In addition, the sugars in softwoods convert more easily and in higher volume to biofuels. Hardwoods, however, contain lignin that is easier to degrade. UW-Madison professor John Ralph has demonstrated the potential for softwoods to process more easily if engineered to incorporate key features of the lignin in hardwoods.

Bottom Line: By pairing the most economically desirable traits of each wood type, it's possible to decrease the intensity of processing techniques and increase yields across a variety of industries. Not only could this have a significant economic impact on the paper and pulp mill industry, it could also have the tangible environmental benefits of reducing the energy required for processing and the amount of waste produced.

Biomass-Derived Aromatics
Lignin comprises about 30 percent of most biomass. In most paper and pulping mills, lignin is a near waste product burned for process heat. UW-Madison professor Shannon Stahl, however, has developed a novel way to convert lignin into high-value chemicals. Stahl and his team discovered an efficient, cost-effective method for breaking down lignin's six-carbon rings – the "aromatics" – into individual components. Traditionally sourced from petroleum,

aromatics are used in a wide variety of products, including plastic soda bottles, Kevlar, pesticides, pharmaceuticals, and are essential components of jet fuel.

Bottom Line: Converting what has been a large volume waste product into a new source of renewable aromatics could transform the economics of industries that process wood and other biomass into paper and paper products. Stahl's method also helps open the door to a more economical way forward in replacing petroleum-based fuels and chemicals with biorenewable materials.

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GVL
Extracting sugars cost-effectively from biomass is a key barrier to producing fuels and chemicals from plants. Traditional methods of extracting the sugars involve the use of expensive chemicals such as concentrated acids and enzymes. UW-Madison Professor James Dumesic and his team have discovered that by using gamma valerolactone (or GVL), a chemical that can be produced from plants, they can deconstruct biomass and produce sugars that can be chemically or biologically upgraded into biofuels or chemicals. Since GVL is created from plant material, it's both renewable and more affordable than conversion methods requiring expensive chemicals or enzymes.

Bottom Line: GVL has the potential to create cost-disruptive biorenewable fuels and chemicals for a wide range of Wisconsin industries. This one-step process is much cleaner and more affordable than conversion methods requiring expensive chemicals or enzymes, and could thus "green" a number of industries – biofuels and paper and pulp chief among them.

Poacic Acid
A chemical compound called poacic acid discovered by UW–Madison researchers could eventually be used as a fungicide in both sustainable and conventional farming. Poacic acid may have the potential to replace copper sulfate, which is used as a fungicide in organic agriculture but accumulates to toxic levels in soil. In addition, it could also be used in combination with synthetic fungicides, to lower dosage or reduce the chances of developing resistance.

Bottom Line: Poacic acid may ultimately provide a natural fungicide option in a time when such options are not abundant, fungicide resistance is on the rise, and warming temperatures are increasingly causing fungal pathogens to spread northward.

Supercritical CO_2 Gas Turbines
Capital costs and power generation efficiency are two major hurdles in reducing the cost of generating electricity. Traditional power plants generate electricity by combusting fuel to heat water into steam, which in turn drives a steam turbine to generate electricity. However, the extraordinary properties of supercritical carbon dioxide – a fluid with qualities of both a liquid and a gas – make it an exciting prospect as a replacement for steam turbines as a way to generate electricity. UW–Madison professor Mark Anderson is doing research that will aid in developing large-scale supercritical CO_2 advanced power systems. Anderson is currently working with industry in Wisconsin to start production of key components for the supercritical CO_2 closed-cycle gas turbine.

Bottom Line: Replacing a steam turbine system with a closed-cycle gas turbine using supercritical CO_2 could increase power generation efficiency by 50 percent or more, resulting in a significant reduction in the cost of electricity. This technology could have significant impact on every power generation technology, including nuclear, natural gas, wind, and solar.

Microgrids
Microgrids are small, self-contained electric-power grids with the capability to connect and disconnect seamlessly from the traditional grid. Natural disasters such as Hurricane Sandy, which left many without power for weeks, have substantially increased interest in the Northeast and elsewhere in using microgrids to ensure resilience in electricity supply. U.S. military installations, forward operating bases, and naval ships are also deploying microgrids to save money and secure their energy supply. UW–Madison researchers have been at the forefront of developing a microgrid architecture that provides rapid and stable adaptation to new system dynamics, integrates distributed power sources into the electrical grid, and enables greater efficiency by moving power generation closer to the consumer, creating opportunities to utilize waste heat.

Bottom Line: Power outages and grid failures are estimated to cost American businesses more and $100 billion annually. Microgrids can enhance system reliability, stability, and resilience for their users. UW–Madison's expertise in microgrid research helps keep Wisconsin at the forefront of this expanding market and may provide new products and supply chains for electrical equipment manufacturers.