2018/2019

Bioproducts, Sciences, & Engineering Laboratory

BSEL NEWS

Plastic water bottles may one day fly people cross-country

Researchers develop viable, environmentally-friendly alternative to Styrofoam

WSU Tri-Cities prof receives Fulbright Distinguished Chair Award

Words from BSEL
Director Manuel Garcia-Perez

It has been more than 10 years since BSEL opened its doors. It is a great time to recognize the work of many WSU and PNNL researchers and administrators that worked through the Washington state legislative process to create BSEL, and that have supported the center throughout the last decade. It is also a good time to thank our previous two directors, professors Birgitte Ahring and Akram Hossain, for their leadership and contributions to BSEL. And finally, yet importantly, I want to thank BSEL faculty, staff and our students for their dedication to build a better world.

BSEL is truly a bridge between WSU and PNNL and a major investment from the citizens of the state of Washington to develop new technologies, products and knowledge to make better use of our biological resources, fight global warming and build a circular economy. These efforts are not possible without the financial support from our local, state and federal agencies - Port of Benton, the U.S. Department of Energy, the National Science Foundation, the U.S. Department of Agriculture, the Washington State Department of Ecology, the Washington State Department of Agriculture, the Washington State Department of Commerce, Sun Grant, Washington River Protection Solutions, and the Joint Center for Aerospace Technology Innovation, just to name a few.

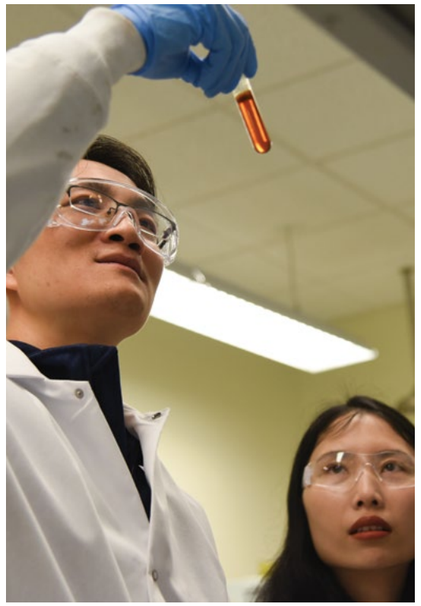
The results of our work can be measured by the number of grants received that amount to $12.5 million, by the number of peer review papers published at more than 300, the number of graduate students at 38, and the number of patents awarded at nine. BSEL also, however, wants to be known by the number of technologies and products commercialized and by the new theories and knowledge that we develop. In the coming years, BSEL will focus its energies on societal impacts - from creating internship programs for minorities, to building new pilot and demonstration plants. Important progresses have been made in pretreatment technologies for anaerobic digestion systems, in the development of engineered biochars for environmental services and on the use of nanocellulose in agriculture. BSEL is also known for its expertise in lignin chemistry, thermochemical conversion, biomass pretreatment and fermentation technologies.

Soon, BSEL will identify its signature technologies and bioproducts as a way to catalyze their commercialization. In three years, all BSEL faculty will likely be full professors. This status brings BSEL new responsibilities on the growth of the WSU Tri-Cities campus with new programs and on the mentoring of new tenure track faculty. Basically, BSEL needs to get outside of its physical space to become a catalyst for socio-economic growth.

I am humbled by the opportunity to lead BSEL in this new period. Clearly, our growth will depend on our fantastic faculty, staff and students, and of our capacity to remain relevant to solving the problems of the region, the state and the nation. In this regard, I applaud the creation of the PNNL-WSU Bioproducts Institute as an umbrella that will allow BSEL to better engage with our community, with our PNNL partners and state and federal agencies.

Since joining BSEL in Aug. 2018, it has been a splendid and productive time. I am very thankful for the kindness of the WSU Tri-Cities leadership team, BSEL faculty and staff, our PNNL partners and I look forward to continue working with all of them and our stake holders including private industry and our local, state and federal agencies to make sure that BSEL remains in the forefront to create a circular sustainable bio-economy.

As always, **GO BIO-COUGS!**



BSEL celebrates its 10th anniversary

By Birgitte K. Ahring, Professor

The Tri-Cities, as it is known today, has origins that are rooted deeply in energy and scientific discovery.

It is home to one of the largest technological feats in the world – the development of the world's first large-scale nuclear reactor. It is also the home of the Pacific Northwest National Laboratory, which also has origins rooted in the Manhattan Project, that is internationally-renowned for its discoveries and advancements in science, the energy sector and national security.

So when PNNL and Washington State University started to begin discussing what was next for the Tri-Cities community, a joint research facility only made sense.

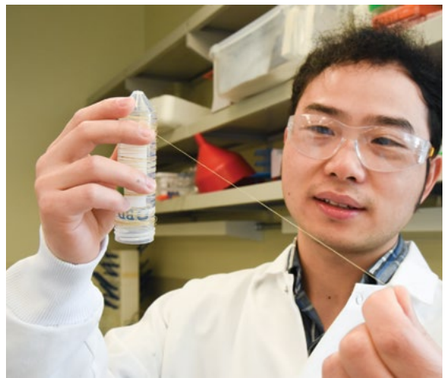
In the early days of this century, the Tri-Cities community was concerned about the time after Hanford. What would happen when the site no longer had major cleanup activities? Or would new priorities related to clean-up effort at Hanford get adapted? The area experienced lay-offs of Hanford workers and it affected the housing market and activity in the region. The community was on the look for new ideas to grow the region.

At PNNL and WSU, there were groups of scientists ready with new ideas on how to grow a new bio-based industry in the area. A plan was drafted between PNNL and WSU for collaboration in bioproduct and bioenergy research central to a new building that would house both PNNL and WSU scientists working together for growing the bio-economy in Washington state.

WSU Pullman professor Shulin Chen led an effort, establishing the WSU Center for Bioproducts and Bioenergy that was strongly supported by Ralph P. Cavalieri, director of the Agricultural Research Center, and Jim Petersen, vice provost for research at WSU. WSU submitted a funding request to the 2006 Legislature with support from other state agencies. The request was approved by the state and the center was decided to be housed in a new building named the Bioproducts, Sciences and Engineering Laboratory at WSU Tri-Cities, also now known as BSEL.

In the spring of 2007, engineer Birgitte Ahring was called at the Technical University of Denmark and asked if she would be interested in coming to Richland to give a talk. She was informed about the BSEL enterprise, which at that time was under construction through a $24 million investment from the state of Washington. During the following year, she attended several meetings during which she met administration members at WSU Pullman and then Gov. Christine Gregoire. In Feb. 2008, she accepted the position as director of BSEL and moved to the Tri-Cities in the summer of 2008.

From the summer of 2008 to 2009, the WSU sector of BSEL grew from a hall of empty laboratories to an active working research enterprise. The labs were equipped and put into operations. Staff and three postdoctoral researchers were hired and began their research together.
WSU then initiated a major search and hired three new assistant professors: Xiao Zhang, Hanwu Lei



and Bin Yang- who all started mid-Aug. 2009. With these hires, the BSEL team now covered different fields of biomass conversion with a broad research interest within the biomass field - submitting grants and receiving research funding. The graduate student body grew larger, featuring 8 to 10 graduate students that graduated year over year after 2011.

During these years, a pilot facility was built at Einstein Avenue, which contains a modern pretreatment and fermentation unit capable of producing biofuels and bio-products at conditions simulating industrial production. This facility delivered pretreated materials for a number of large U.S. Department of Energy projects, as well as the U.S. Department of Agriculture's Northwest Advanced Renewables Alliance program.

In 2010, BSEL faculty began teaching as part of the graduate program in the Voiland School of Chemical Engineering and Biological Systems Engineering program. Teaching is now broadcast from WSU Tri-Cities to other WSU campuses through a remote video conferencing system. BSEL faculty also assisted Walla Walla Community College in establishing a new Workforce Program in Energy and Food Processing and Wastewater Treatment programs, which have been active since 2013.

The BSEL partnership with PNNL was strengthened through a large number of collaborative projects. BSEL faculty have continued to work with the Environmental Molecular Sciences Laboratory at PNNL on several projects, including one of its first research campaigns – focusing on biochemical processes that have generated new analytical approaches and tools that are leading to high-value products from biomass sources. Two faculty members, Xiao Zhang and Bin Yang, achieved the status of adjunct senior researcher at PNNL and EMSL. Ahring was also appointed a Wiley Research Fellow. The tight connections between the two organizations have proven to work.

In 2015, all three assistant professors at BSEL were granted tenure and were promoted to associate professors. Mid-2016, after a successful tenure, Ahring stepped down to devote more time to her research, and Akram Hossain brought BSEL to a new level with a reorganization program focusing on safety. In Aug. 2018, BSEL received a new director, Manuel Garcia-Perez, with a mandate to further grow BSEL as a center of excellence in biomass processing and bioproducts.

After its first 10 years, the future for BSEL looks bright with the creation of the WSU-PNNL Bioproducts Institute, one of three joint institutes between PNNL and WSU to further strengthen research ties. We look forward to what the next 10 years will bring, from our world-class research, to our community support to prepare future STEM professionals, to our opportunities in solving local and global problems to advance our state, nation and society.

WSU Tri-Cities professor receives Fulbright Distinguished Chair Award

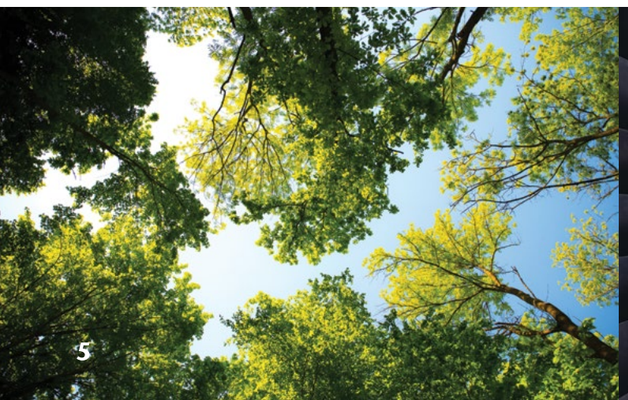
Bin Yang, an associate professor of Biological Systems Engineering at Washington State University, was selected for the Fulbright Distinguished Chair Award — the most prestigious appointment in the Fulbright Scholar Program. Yang marks the first professor in WSU history to be selected for the Fulbright Distinguished Chair in Energy and Sustainable Use of Natural Resources Award.

This month, Yang began the six-month Fulbright Program at Aalto University in Finland while on sabbatical leave from WSU. While in Finland, he will teach and focus on the development of novel lignin-based compounds that do not resemble an existing petroleum-derived compound in structure. However, he aims to use the material to create a range of bioproducts. Dr. Juming Tang, chair of the Biological System Engineering department at WSU said Yang is an outstanding contributor for the BSE graduate program, which was ranked 14th in the nation by U.S. News and World Report.

Yang's major research interests:
•Understanding fundamental mechanisms of bioprocessing technologies for advanced biofuels
•Advancing cutting-edge technologies and facilitating the commercialization process
•Improving knowledge of emerging technologies to meet near and long-term needs worldwide

He has authored more than 100 peer reviewed papers and book chapters and has five patents. He is also the recipient of the DARPA Young Faculty Award in 2011 and serves as an advisory editor board member for many leading biorefinery journals.

Bin Yang, an associate professor of biological systems engineering at Washington State University Tri-Cities



Four BSEL students awarded the 2018 WSU-PNNL Graduate Fellowship

BSEL graduate students Xiaolu Li, Fnu Fitria, Zhangyang Xu and Sudha Eswaran were selected for PNNL-WSU 2018 Distinguished Graduate Research Program (DGRP). Through the program, Ph.D. students work with faculty at WSU and scientists at PNNL while completing their graduate coursework and subsequently transfer to PNNL for the remaining years of their doctoral program to gain hands-on research experience with PNNL scientists.

Through the PNNL-WSU Distinguished Graduate Research Program, the Ph.D. students earn a stipend and benefits while working under a prestigious graduate committee on nationally relevant research. It is a unique opportunity to tap into the knowledge and world-class research infrastructure available at both institutions.

Graduate students awarded foreign fellowships

Evan Terrell, a graduate student serving in Manuel Garcia-Perez's group, was awarded the prestigious Chateaubriand Fellowship from the French embassy where he will complete a six-month internship at Lorraine University in France. "Being able to take in new perspectives and conduct research in a different cultural and work environment has been very eye-opening and made me a better researcher and collaborator. I have grown a lot by being put outside of my comfort zone and trying to solve familiar problems in new ways".

Evan Terrell

Lina Pilar Martinez

Lina Pilar Martinez, a graduate student serving in Manuel Garcia-Perez's group, had the opportunity to spend two summers at the National Renewable Energy Laboratory in Golden, Colorado. In addition to serving as a top-notch learning experience, Pilar Martinez also has the opportunity to interact in a work environment with top scientists, and share life and professional experiences with people from around the world.

Committed to the local community

A group of 10 WSU Tri-Cities TRIO Student Support Services Program students, led by Oliva M. Primera-Pedrozo, Ph.D, recently visited Birgitte Ahring's lab group as part of a WSU Tri-Cities course on academic research. This course is an introduction to scientific research through lectures, discussions, reading, projects, and presentations. The students learn about academic research, gain skills needed in any research environment, and prepare to start a research opportunity.

During the visit, the students received a general lecture by Ahring about research and its importance, which was followed by discussions with different graduate students about their specific projects and potential impacts.

Additionally, high school students in the Tri-Cities have seen success, not only at the state level in science fairs, but also at national and international competitions, after collaborating with researchers at BSEL and WSU Tri-Cities for their research projects.

Unique training opportunities with PNNL

Through previous work supported by the National Science Foundation, Xiao Zhang, associate professor of chemical engineering and bioengineering, worked with scientists from the Environmental Molecular Sciences Laboratory at the Pacific Northwest National Laboratory to develop reference biomass substrates with controlled physical and chemical properties that allows for the identification of specific deficiencies of ellulolytic enzymes in breaking down carbohydrate polymers.

Zhang's group collaborates extensively with PNNL. A number of Ph.D. students in Dr. Zhang's lab are co-supervised by PNNL scientists:

- Student Sudha Eswaran works on: "Quantitative structure property analysis of lignin macromolecule." The study is co-supervised by Dr. Robert Rallo, team lead for the Advance Computing and Data Science Department at PNNL.

- Student Mond Guo works on: "Catalytic Conversion of Ethanol on Atomically Dispersed Cu Supported on Metal Oxides to Higher Alcohols and Fuels." This study is co-supervised by Karthi Ramasamy, senior research engineer for the Chemical and Biological Processing Group at PNNL.

- Student Kuan-Ting Lin works on: "Design and evaluate deep eutectic solvents lignin extraction for advanced material application." The study is cooperated with Suh-Jane Lee, senior scientist for the Chemical and Biological Processing Group at PNNL.

- Student Senthil Subramaniam works on: "Ethanol Conversion to C5+ Ketones and Alcohols for Fuel Blend Stocks." This study is co-supervised by Karthi Ramasamy, engineer for the Chemical and Biological Process Development group at PNNL.

Student Fitria is working with Jian Liu, a senior chemical engineer at the PNNL, to study the impact that mineral components have on the pretreatment process. This program provides WSU graduate students the opportunity to gain hands-on experience in a U.S. Department of Energy national laboratory. She is working with Dr. Bin Yang to examine new ways of improving the pretreatment process. She recently received the PNNL-WSU Graduate Fellowship.

BSEL faculty research impacting locally, globally

Hanwu Lei, associate professor of biological systems engineering
Hanwu Lei's Efforts to create an environmentally friendly catalyst that will lower the cost and increase the efficiency in producing bio-based jet fuels netted WSU researchers a $500,000 grant from the U.S. Department of Energy and the National Institute of Food and Agriculture. He also recently received a Sun Grant of $150,000 to develop a process to produce jet fuels from forest biomasses and waste plastics.

Manuel Garcia-Perez, director of BSEL
Manuel Garcia-Perez, with Gregory Moller and Daniel Strawn from the University of Idaho, received a Sun Grant totaling $316,000 to develop engineered biochars to enhance the profitability of distributed energy systems and reduce the environmental impact of anaerobic digesters. In 2018, a team of WSU, PNNL and University of Dayton researchers led by Garcia-Perez, received a $2.7 million dollar grant from the U.S. Department of Energy to develop a hybrid HEFA-HDCJ process for the production of jet fuel blend-stocks. In order to reduce capital and operational cost of jet fuel production, the team proposed the utilization of existing HEFA units for the co-processing of the lignin-rich fraction of pyrolysis oils and yellow greases. The WSU-PNNL team will produce 100 gallons of jet fuel to be tested in combustion studies at the University of Dayton. As part of this project, WSU researchers will evaluate the technoeconomic viability of the concept proposed and how it could be implemented for conditions in Washington state.

Birgitte Ahring, professor of chemical engineering and bioengineering
Birgitte Ahring received a Program of Emerging Research Issues in Washington Agriculture grant totaling $85,000 to work on the reduction of methane from livestock production. Additionally, she was recently awarded a contract from the National Aeronautics and Space Administration (NASA) totalling $236,500 to investigate the cause of incomplete reductive dechlorination to support enhanced in-situ bioremediatiation.

Xiao Zhang, associate professor of chemical engineering and bioengineering
Xiao Zhang's group works on understanding the structures and properties of plant macromolecules (lignin, cellulose and hemicellulose), as well as devising chemistries and processes to transform plant macromolecules to market products. Ongoing work at Zhang's group is primarily funded by National Science Foundation, U.S. Department of Agriculture NIFA, U.S. Department of Energy and the Federal Aviation and Administration. In addition to the federal support, Zhang's group closely collaborates with partners in forest products, chemical and automobile industries. He received a U.S. Department of Agriculture National Institute of Food and Agriculture grant for $500,000 to support research in developing a dicarboxylic acids platform for biorefinery lignin valorization. He received a $500,000 USDA NIFA grant to support the development of cellulose nanocrystals for preventing frost damage in tree fruits and grapes. He received a $200,000 U.S. Department of Energy grant for research in the oxidative valorization of lignin. He is also the recipient of a $60,000 National Science Foundation grant to support research in developing lignin-derived compounds for the production of polyurethane plastics and foams.

Bin Yang, associate professor of biological systems engineering
Bin Yang is a member of a multi-institutional effort that was awarded a $2.7 million grant from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy for Multi-stream Integrated Biorefinery (MIBR) Enabled by Waste Processing where lignin containing IBR waste will be fractionated to produce lipids for biodiesel, asphalt binder modifiers, and quality carbon fiber. The MIBR will improve IBR sustainability and cost effectiveness. Furthermore, Yang was awarded a $50,000 grant from the Joint Center for Aerospace Technology Innovation to work on a Lignin-Based Jet Fuel Pilot Plant.

Marty Kroeger, research operations engineer
Marty Kroeger supports scientific and engineering research using advanced skills and knowledge to perform and modify complex investigative procedures; collect, process and analyze data; and run research protocols. Kroeger collaborated with a Hanford contractor to develop waypoint navigation for their 'Canary One' robot. He also developed a rover that crosses terrain and passed a first test near the Hanford SX tank during a field demonstration.

Forming a WSU-PNNL Bioproducts Institute

Embracing the 'power of partnerships,' the Department of Energy's Pacific Northwest National Laboratory and Washington State University announced the formation of the WSU-PNNL Institutes - a collection of three joint institutes that will advance discoveries and innovation in nuclear science and technology, advanced grid, and bioproducts.

The BSEL facility establishes the Tri-Cities as a center for world-class bio-based product research and development, creates a magnet for prominent scientists, and helps the Pacific Northwest agriculture industry be more competitive. The WSU-PNNL Bioproducts Institute offers collaborative research, specialized facilities, career opportunities, and educational and training programs for researchers and students.

Institute partners can access BSEL, a signature facility on the WSU Tri-Cities campus. There, WSU and PNNL conduct targeted research to develop, demonstrate, and commercialize bioproducts, bioprocesses, and bioenergy. BSEL's high bay is available for integrating and scaling processing steps for converting biomass to fuels and chemicals. BSEL also houses classrooms, teaching and research labs, and office space for PNNL researchers and WSU faculty and graduate students.
As a member of the multi institutional efforts, Xiao Zhang, associate professor of chemical engineering and bioengineering, in collaboration with scientists from the Environmental Molecular Sciences Laboratory at PNNL, have developed a set of biomass reference substrates with controlled physical and chemical properties that can be used to identify specific deficiencies of cellulase enzymes in breaking down carbohydrate polymers. In a new study, the researchers used these reference substrates to test the effectiveness of three commercially available enzyme mixtures—Novozymes Cellic® Ctec2, Dupont Accellerase® 1500, and DSM Cytolase CL—using X-ray photoelectron spectroscopy, X-ray diffraction and an atomic force microscope at EMSL, a DOE national scientific user facility.

WSU President Kirk Schulz (right) chats with U.S. Sen. Maria Cantwell (center) and Steven Ashby, director of the Pacific Northwest National Laboratory, during the launch event for the WSU-PNNL Institutes at WSU Tri-Cities.

Welcoming new BSEL Scholars

Dylan Cronin is a research chemist from Australia who attained his bachelor's and Ph.D. at the Queensland University of Technology in Brisbane. He specializes in the thermochemical fractionation of biomass and lignin valorization.

Frederik juhl Pedersen is an International graduate student from Aalborg University, Denmark. Birgitte Ahring, professor of chemical engineering and bioengineering, gave him an opportunity to work in her BSEL lab as a visiting scholar. His work focuses on bioagumentation of a rumen reactor with the bacterial strain A. woodii.

Xiaona Lin is an assistant professor from Shandong University of Technology. She is working with Hanwu Lei, associate professor of biological systems engineering, as a visiting scholar at BSEL to study the catalytic co-pyrolysis of biomass and plastics with bifunctional carbon-based catalysts.

Qingfa Zhang is a graduate student from Shandong University of Technology, China. Hanwu Lei, associate professor of biological systems engineering, gave him an opportunity to work in his BSEL lab as a visiting scholar to work on the structural evolution mechanisms of biochar and utilization to prepare composites based on polymers.

Erguang Huo is a graduate student from Chongqing University in China. Hanwu Lei, associate professor of biological systems engineering, gave him an opportunity to work in his BSEL lab as a visiting scholar to work on fundamental studies and the development of nanocarbon and catalysis for high value chemicals and fuels.

Xiaojun Yang is a visiting professor from China. He is working in the lab of Bin Yang, associate professor of biological systems engineering, at BSEL as a visiting scholar. He is working on converting lignin to jet biofuel.

Xiaoyu Wu is a graduate student from China working in the lab of Bin Yang, associate professor of biological systems engineering, at BSEL as a visiting scholar. Her work focuses on multi-stream integrated biorefinery enabled by waste processing.

Columbia Basin College students receive hands-on experience at BSEL

As part of BSEL's commitment to have a positive impact in the Tri-Cities regional community, BSEL is hosting 11 students from the Columbia Basin College. The program began in Jan. 2019 and ends in Aug. 2019. These students are fully-funded by the Louis Stokes Alliances for Minority Participation and the Mathematics, Engineering, Science Achievement programs. They will be working with BSEL faculty and will visit the WSU Tri-Cities engineering laboratories. The opportunity includes a seminar/conversation with WSU Tri-Cities engineering advisors about this program.

Both opportunities have led to a variety of students transferring to WSU Tri-Cities after their experience with the BSEL programming.

Plastic water bottles may one day fly people cross-country

By Scott Weybright, WSU College of Agricultural, Human, and Natural Resource Sciences

RICHLAND, Wash. – A research group led by Washington State University Tri-Cities scientists has found a way to turn daily plastic waste products into jet fuel.

In a new paper published in the journal Applied Energy, WSU's Hanwu Lei and colleagues melted plastic waste at high temperature with activated carbon, a processed carbon with increased surface area, to produce jet fuel.

"Waste plastic is a huge problem worldwide," said Lei, an associate professor in WSU's Department of Biological System Engineering. "This is a very good, and relatively simple, way to recycle these plastics."

How it works

In the experiment, Lei and colleagues tested low-density polyethylene and mixed a variety of waste plastic products, like water bottles, milk bottles, and plastic bags, and ground them down to around three millimeters, or about the size of a grain of rice.

The plastic granules were then placed on top of activated carbon in a tube reactor at a high temperature, ranging from 430 degree Celsius to 571 degrees Celsius. That's 806 to 1,060 degrees Fahrenheit. The carbon is a catalyst, or a substance that speeds up a chemical reaction without being consumed by the reaction.

"Plastic is hard to break down," Lei said. "You have to add a catalyst to help break the chemical bonds. There is a lot of hydrogen in plastics, which is a key component in fuel."

Once the carbon catalyst has done its work, it can be separated out and re-used on the next batch of waste plastic conversion. The catalyst can also be regenerated after losing its activity.

After testing several different catalysts at different temperatures, the best result they had produced a mixture of 85 percent jet fuel and 15 percent diesel fuel.

Environmental impact

According to the Environmental Protection Agency, landfills in the U.S. received 26 million tons of plastic in 2015, the most recent year statistics are available. China has recently stopped accepting plastic recycling from the U.S. and Canada. Conservative estimates by scientists say that at least 4.8 million tons of plastic enters the ocean each year worldwide.

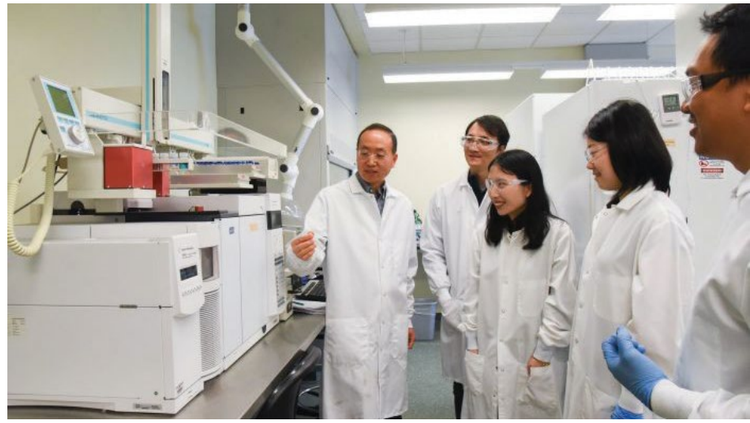
Not only would this new process reduce that waste, very little of what is produced is wasted.

"We can recover almost 100 percent of the energy from the plastic we tested," Lei said. "The fuel is very good quality, and the byproduct gasses produced are high quality and useful as well."

He also said the method for this process is easily scalable. It could work at a large facility or even on farms, where farmers could turn plastic waste into diesel.

"You have to separate the resulting product to get jet fuel," Lei said. "If you don't separate it, then it's all diesel fuel."

This work was funded by the Agriculture and Food Research Initiative Competitive Grant no. 2014-38502-22598, 2016-67021-24533, 2018-67009-27904 from the National Institute of Food and Agriculture, United States Department of Agriculture.



Hanwu Lei, associate professor in WSU's Department of Biological System Engineering, and his research team examine a sample in the Bioproducts, Sciences and Engineering Laboratory.

Researchers develop viable, environmentally-friendly alternative to Styrofoam

By Tina Hilding, Voiland College of Engineering and Architecture

RICHLAND, Wash. – Washington State University researchers have developed an environmentally-friendly, plant-based material that for the first time works better than Styrofoam for insulation.

The foam is mostly made from nanocrystals of cellulose, the most abundant plant material on earth. The researchers also developed an environmentally friendly and simple manufacturing process to make the foam, using water as a solvent instead of other harmful solvents.

The work, led by Amir Ameli, assistant professor in the School of Mechanical and Materials Engineering, and Xiao Zhang, associate professor in the Gene and Linda School of Chemical Engineering and Bioengineering, is published in the journal Carbohydrate Polymers.

Researchers have been working to develop an environmentally friendly replacement for polystyrene foam, or Styrofoam. The popular material, made from petroleum, is used in everything from coffee cups to materials for building and construction, transportation, and packaging industries. But, it is made from toxic ingredients, depends on petroleum, doesn't degrade naturally, and creates pollution when it burns.

While other researchers have created other cellulose-based foams, the plant-based versions haven't performed as well as Styrofoam. They are not as strong, don't insulate as well, and degraded at higher temperatures and in humidity. To make cellulose nanocrystals, researchers use acid hydrolysis, in which acid is used to cleave chemical bonds.

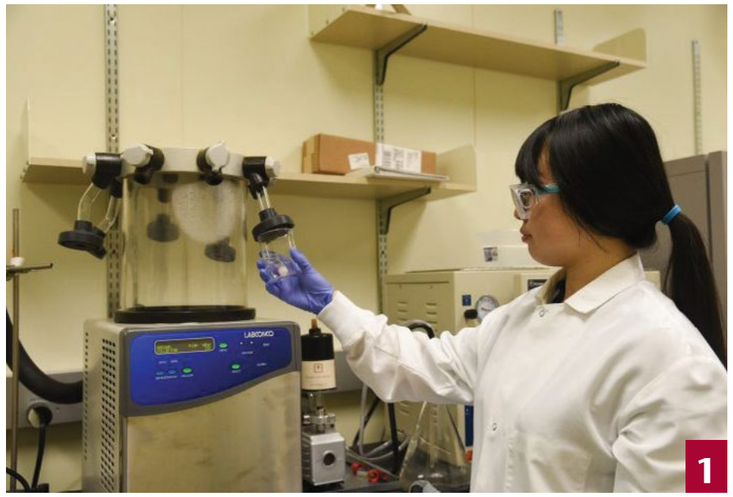
In their work, the WSU team created a material that is made of about 75 percent cellulose nanocrystals from wood pulp. They added polyvinyl alcohol, another polymer that bonds with the nanocellulose crystals and makes the resultant foams more elastic. The material that they created contains a uniform cellular structure that means it is a good insulator. For the first time, the researchers report, the plant-based material surpassed the insulation capabilities of Styrofoam. It is also very lightweight and can support up to 200 times its weight without changing shape. It degrades well, and burning it doesn't produce polluting ash.

"We have used an easy method to make high-performance, composite foams based on nanocrystalline cellulose with an excellent combination of thermal insulation capability and mechanical properties," Ameli said. "Our results demonstrate the potential of renewable materials, such as nanocellulose, for high-performance thermal insulation materials that can contribute to energy savings, less usage of petroleum-based materials, and reduction of adverse environmental impacts."

"This is a fundamental demonstration of the potential of nanocrystalline cellulose as an important industrial material," Zhang said. "This promising material has many desirable properties, and to be able to transfer these properties to a bulk scale for the first time through this engineered approach is very exciting."

The researchers are now developing formulations for stronger and more durable materials for practical applications. They are interested in incorporating low-cost feedstocks to make a commercially viable product and considering how to move from laboratory to a real-world manufacturing scale.

The work was supported by the US Department of Agriculture and WSU's Office of Commercialization.



1. WSU Tri-Cities post-doctoral researcher Peipei Wang attaches a cellulose mixture sample to a freeze dryer to be turned into an alternative for Styrofoam.

2. A visual representation of the styrofoam

3. The alternative to Styrofoam developed by WSU researchers is made after freeze-drying a cellulose mixture made from plant-based materials.

Indonesian Fulbright Scholar studying how to develop diverse, cost-effective biofuels technology

By Maegan Murray, WSU Tri-Cities

RICHLAND, Wash. – Fulbright scholar Fitria is using her educational experience at Washington State University Tri-Cities and the Pacific Northwest National Laboratory to find new and improved ways of creating successful biofuels and bioproducts.

In her home country of Indonesia, Fitria, who goes by one name, is a team member and former project leader in biomass process technology and bioremediation at the Indonesian Institute of Sciences Research Center for Biomaterials.

There, she works to convert lignocellulosic biomass—the cellulose and lignin-rich substances that give plants their rigidity—from agricultural residues to ethanol and other bioproducts such as wood adhesives, biocomposites, pulp, and paper.

In recent years, the Indonesian government has focused more heavily on the production of biofuels. And while ethanol, which in Indonesia is mostly made from cassava, a starchy root from a tropical crop, is readily available, they are exploring other options, especially lignocellulosic-based biomass from local vegetation. Cellulose from the remains of pressed, harvested oil palm fruit bunches could be a viable option, as Indonesia is the largest producer. Other potential products include rice straw and sugar cane bagasse.

In order to fulfill her career goals, Fitria joined a team led by Bin Yang, associate professor of biological systems engineering at WSU Tri-Cities, in August 2016. Over the past three years, she has worked in the Bioproducts, Sciences and Engineering Laboratory at WSU Tri-Cities to improve the understanding of fundamental mechanisms of pretreatment technologies for cellulosic-based fuels. Her work helps advance cutting–edge biomass conversion technologies and to facilitate the commercialization process.

At WSU Tri-Cities, she is studying several types of lignocellulose biomass, such as corn stover and wheat straw, which are among the most common agricultural waste products in the U.S.

“Wheat straw is abundant in eastern Washington,” she said. “The remnant material in the harvesting process is usually left on the field, and about 60 percent is used for ground cover. But you can’t remove all of the residue on the field. We want to use the remaining material to make biofuels.”

Fitria is specifically examining how to improve the pretreatment process in turning remnant lignocellulosic materials into biofuels with Yang.

In the early stages, cellulose, which is the main component of cell walls in plants, must undergo a pretreatment process to separate it from other major components, hemicellulose and lignin, to help enzymes convert it to sugar. After that, it is fermented into ethanol. Other components in plants, such as mineral components, however, might hinder this process, which she is now investigating.

Fitria is also working with Jian Liu, a senior chemical engineer at the Pacific Northwest National Laboratory, to study the impact that mineral components have on the pretreatment process. She will also start as part of the WSU-PNNL Distinguished Graduate Research program this fall. This WSU-PNNL collaboration not only aids in her doctoral study, but also provides her with the opportunity to gain hands-on experience in a U.S. Department of Energy national laboratory.

“Working at the Pacific Northwest National Laboratory will be very important to her future research career,” Yang said. “Fitria has displayed remarkable skill in science, engineering and leadership, and she will continue to grow and make significant contributions to the field of biomass to bioproducts.”

Fitria’s research at WSU Tri-Cities is in line with WSU’s identified Grand Challenges of providing sustainable resources and in sustaining health. It is also in line with WSU’s Drive to 25.

“Fitria has displayed remarkable skill in science, engineering and leadership, and she will continue to grow and make significant contributions to the field of biomass to bioproducts.”
- Bin Yang

Peer Reviewed Publications

1. Geleynse S, Brandt K, Garcia-Perez M, Wolcott M, Zhang X: The Alcohol-to-Jet Conversion Pathway for Drop-in Biofuels. 2018. Techno-Economic Evaluation. ChemSusChem, 9, 3728-3741

2. Miao Ch, Marin-Flores O, Tao D, Gao D, Wang Y, Garcia-Perez M, Chen S. 2018. Hydrothermal Catalytic Deoxygenation of Fatty Acid and Bio-oil with Insitu H2. ACS Sustainable Chemistry & Engineering, 6 (4), pp 4521–4530

3. Botella L, Sanchez JL, Arauzo J, Garcia-Perez M. 2018. Bio-Oil Hydrotreatment for Enhanced Solubility in Biodiesel and the Oxydation Stability of Resulting Blends. Frontiers in Chemistry. 1(83): 1-13.

4. Pelaez-Samaniego MR, Smith M, Zhao Q, Garcia-Perez T, Frear C, Garcia-Perez M. 2018.: Charcoal from Anaerobically Digested Fiber for Removal of Hydrogen Sulfide with Biogas. Waste Management, 76, 374-382

5. David GF, Haber-Perez V, Rodriguez-Justo O, Garcia-Perez M. 2018. Thermochemical Conversion of Sugarcane Bagasse by Fast Pyrolysis: High Yield of Levoglucosan Production. Journal of Analytical and Applied Pyrolysis, 133, 246-253

6. Pires APP, Han Y, Kramlich J, Garcia-Perez M: Chemical Composition and Fuel Properties of Alternative Jet Fuels. Bioresources, 2018, 13 (2), 2632-2657.

7. Zhang Y, Lei H, Yang Z, Duan D, Villota E, Ruan R. 2018. From Glucose-Based Carbohydrates to Phenol-rich Bio-Oil Integrated with Syngas Production via Catalytic Pyrolysis over Activated Carbon Catalyst. Green Chemistry, 20, 3346 - 3358.

8. Zhang Y, Lei H, Duan D, Villota E, Liu C, Ruan R. 2018. New Insight into Mechanism of Hydrogen Evolution Reaction on MoP (001) from First Principles. ACS Applied Materials & Interfaces, 10(24): 20429-20439.

9. Villota E, Qian M, Yadavalli G, Sun H. 2018. Production of Renewable Phenol from Catalytic Pyrolysis of Douglas Fir Sawdust over Biomass-derived Activated Carbons. Applied Energy, 220, 15, 426-436.

10. Chen P, Anderson E, Addy M, Zhang R, Cheng Y, Peng P, Ma Y, Fan L, Zhang Y, Lu Q, Liu S, Zhou N, Deng X, Zhou W, Omar M, Griffith R, Kabir F, Lei H, Wang Y, Liu Y, Roger R. 2018. Breakthrough Technologies for Biorefining of Organic Solid and Liquid Wastes. Engineering, 4(4), 574-580.

11. Ding K, He A, Zhong D, Fan L, Liu S, Wang Y, Liu Y, Chen P, Lei H, Ruan R. 2018. Improving Hydrocarbon Yield via Catalytic Fast Co-Pyrolysis of Biomass and Plastic Over Ceria and HZSM-5: An Analytical Pyrolyzer Analysis. Bioresource Technology, 268, 1-8.

12. Zhu L, Lei H, Zhang Y, Zhang X, Wang L, Bu Q, Wei Y. 2018. Production of Hydrocarbons from Biomass Through In-Situ Microwave-Assisted Catalytic Pyrolysis Using Biomass Carbon Catalyst. Sustainable Energy & Fuels, 2, 1781 – 1790.

13. Yang Z, Qian K, Zhang X, Lei H, Xin C, Zhang Y, Qian M, Villota E. 2018. Process Design and Economics for the Conversion of Lignocellulosic Biomass into Jet Fuel Range Cycloalkanes. Energy, 154, 289-297.

14. Zhu L, Lei H, Zhang Y, Zhang X, Bu Q, Wei Y, Wang L, Yadavalli G, Villota E. 2018. A Review of Biochar Derived from Pyrolysis and its Application in Biofuel Production. SF Journal of Material and Chemical Engineering, 1(1):1007.

15. Zhang Y, Lei H, Yang Z, Qian K, Villota E. 2018. Renewable High-Purity Mono-Phenol Production from Catalytic Microwave-Induced Pyrolysis of Cellulose over Biomass-Derived Activated Carbon Catalyst. ACS Sustainable Chemistry & Engineering, 6 (4), pp 5349–5357.

16. Yang Z, Lei H, Qian K, Zang Y, Villota E. 2018. Renewable Bio-Phenols from In-Situ and Ex-Situ Catalytic Pyrolysis of Douglas Fir Pellet Over Biobased Activated Carbons. Sustainable Energy & Fuels, 2, 894-904.

17. Duan D, Ruan R, Lei H, Liu Y, Wang Y, Zhang Y, Dai L, Y. Zhao, Q. Wu, S. Zhang. 2018. Microwave-assisted co-pyrolysis of pretreated lignin and soapstock for upgrading liquid: Effect of pretreatment parameters on pyrolysis behavior. Bioresource Technology, 258, 98-104.

18. Wang L, Lei H, Liu J, Bu Q. 2018. Thermal Decomposition Behavior and Kinetics for Catalytic Pyrolysis of Douglas Fir. RSC Advances, 8, 2196-2202.

19. Villota E, Lei H, Qian M, Yang Z, Villota SMA, Zhang Y, and Yadavalli G. 2018. Optimizing Microwave-Assisted Pyrolysis of Phosphoric-Acidactivated Biomass: Impact of Concentration on Heating Rate and Carbonization Time. ACS Sustainable Chemistry and Engineering, 6 (1), 1318–1326.

20. Morgan Jr HM, Xie W, LiangJ, Mao H, Lei H, Ruan R, Bu Q. 2018. A Techno-Economic Evaluation of Anaerobic Biogas Producing Systems in Developing Countries. Bioresource Technology, 250, 910-921.

21. Oliveira, FC, Srinivas K, Helms GL, Isern NG, Cort JR, Goncalves AR, Ahring B. (2018). Characterization of Coffee (Coffea arabica) Husk Lignin and Degradation Products Obtained After Oxygen and Alkali Addition. Bioresource Technology, 257, 172-180.

22. Ahring B, Murali N, Srinivas K. (2018). Fermentation of Cellulose with a Mixed Microbial Rumen Culture With and Without Methanogenesis. Fermentation Technology, 7(1), 1-7.

23. Callister SJ, McCue LA, Boaro AA, Lamarche BL, White RA III, Brown JM, Ahring B. (2018). Identification of metabolite and protein Explanatory Variables Governing Microbiome Establishment and Re-Establishment Within a Cellulose-Degrading Anaerobic Bioreactor. PLoS One, 13(10).

24. Selwitz JL, Ahring BK, Garcia-Perez M, Morrison J. (2018). Engineering an Associate Degree-Level STEM Workforce Education Curriculum. Community College Journal of Research and Practice, 2018, 1-17.

25. Weyda I, Sinha M, Soerensen A, Lubeck PS. (2018). Increased Production of Free Fatty Acids and Triglycerides in Aspergillus Carbonarius by Metabolic Engineering of Fatty Acid Biosynthesis and Degradation Pathways. SciMed Central, 6(1), 1049-1059.

26. Fernandez S, Srinivas K, Schmidt AJ, Swita MS, Ahring B. (2018). Anaerobic Digestion of Organic Fraction from Hydrothermal Liquefied Algae Wastewater Byproduct. Bioresource Technology, 247, 250-258.

27. Daochen Z, Haibing S, Peipei ZAlei G, Weimin Z, Bin Y, Jia G, Weijun Q, Murillo G and Jianzhong S. (2018). “Genomics and Biochemistry Investigation on the Metabolic Pathway of Lignin-Derived Aromatic Metabolites of Comamonas Serinivorans SP- 35”. Biotechnology for Biofuels, 11:338.

28. Shen R, Tao L, and Yang B. (2018). “Techno-Economic Analysis of Jet Fuel Production from Biorefinery Waste Lignin”, BioFPR, .

29. Yang X, Hu Y, Bai H, Yan MFZ, Cao S, and Yang B, (2018). Tuning of Oxygen Species and Active Pd2+ Species of Supported Catalysts via Morphology and Mn Doping in Oxidative Carbonylation of Phenol”. Molecular Catalysis, 457:1-7.

30. Wang H, Yuhua, Duan, Qiang, Zhang, and Yang B. (2018) “Effects of Sugars, Furans, and Their Derivatives on Hydrodeoxygenation of Biorefinery Ligninrich Wastes to Hydrocarbons”. ChemSusChem, 11, 2562 – 2568.

31. Qin Y, Hongliang, Ruan H, Feng M, and Yang B. (2018) “High Catalytic Efficiency of Lignin Depolymerization over Low Pd-zeolite Y Loading at Mild Temperature”, Frontiers in Energy, 6:2-7.

32. Song Z, Yan Z, Yang X, Bai H, Duan Y, Yang B, Leng L. (2018). First Principles Density Functional Theory Study of Pb doped α-MnO2 catalytic materials. Chemical Physics Letters, 695: 216-221.

33. Yang B, Tao L, and Wyman CE. (2018). “Strengths, Challenges, and Opportunities for Hydrothermal Pretreatment in Lignocellulosic Biorefineries”, BioFPR, 12:125-138.

34. Lin K, Ma R, Wang PP, Xin J, Zhang J, Wolcott M, Zhang X. (2018). “Deep Eutectic Solvent Assisted Facile Synthesis of Lignin-based Cryogel” Macromolecules.

35. Alhamid J, Mo C, Wang PP, Zhang X, Whiting M, Zhang Q. (2018). “Cellulose Nanocrystals Reduce Cold Damage to Reproductive Buds in Fruit Crops”, Biosystems Engineering, 172:124-133.

36. Ma RS, Zhang XM, Wang Y, Zhang X. (2018). “New Insights Toward Quantitative Relationships between Lignin Reactivity to Monomers and Their Structural Characteristics”, ChemSusChem. 11(13):2146-2155.

WASHINGTON STATE UNIVERSITY
TRI-CITIES

2710 Crimson Way
Richland, WA 99354
509-372-7000 | info@tricity.wsu.edu
tricities.wsu.edu/bsel