THE FIRST CENTURY FORWARD

Bioproducts and Biosystems Engineering at the University of Minnesota
1909-2009
They had never seen anything like it, these families who farmed the rolling land near the Mississippi River town of Red Wing. Bundled up on the W.A. Cady farm in the darkening Christmas Eve of 1923, they gazed expectantly at a tree. Strung with electric lights, it awaited the flip of a switch to burst into radiance.

The families were among the first beneficiaries of the Red Wing Project, an experiment to test the feasibility and value of bringing electricity to rural America. A University of Minnesota professor named E.A. Stewart had worked tirelessly with families of the Burnside community to make their new power line a reality, and soon feed grinders, water pumps, cream separators, grain threshers, and other farm implements would run on electricity.

When the switch was thrown, the Christmas tree lit up as if to symbolize rural electrification’s bright future – and the success of the Red Wing Project. It also launched a sterling tradition of service by Stewart’s academic home, the University’s then-Division of Agricultural Engineering.

Since its creation in 1909, the Division has proved flexible in the face of changes in agriculture, natural resources, the environment, and society. Today, as the Department of Bioproducts and Biosystems Engineering, it combines engineering with science, technology and management for the sustainable use of renewable resources and enhancement of the environment.

An affiliate department in the University’s Institute of Technology, BBE has its administrative home in the University’s College of Food, Agricultural and Natural Resource Sciences and has long worked cooperatively with University of Minnesota Extension and the Minnesota Agricultural Experiment Station. Through their research, BBE faculty are creating renewable and environmentally superior fuels, energy, chemicals, plastics, building materials, and land management practices for the next century and beyond.

For 100 years, this department has kept Minnesota at the forefront of agriculture and the environment through its innovations and forward thinking. Today’s scientists are working on issues that their predecessors could never have dreamed possible, but they are continuing the tradition of finding practical solutions to pressing problems. I look forward to even more exciting changes as the BBE department moves into its second century.

- Allen Levine, dean, College of Food, Agricultural and Natural Resource Sciences, University of Minnesota

### The BBE Timeline

- **1905**: William Boss appointed professor of Farm Structures and Farm Mechanics
- **1908**: Wood technology taught in the College of Agriculture
- **1908**: Division of Agricultural Engineering formed on July 1
- **1909**: J.T. Stewart appointed the head of new Agricultural Engineering division

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**A Promising Start**

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**CELEBRATING THE PAST, LOOKING FORWARD TO THE FUTURE**

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A visitor to BBE professor Roger Ruan’s lab can’t help notice the huge flasks of green algae.

“We want to produce algae for feed, but also for their oils. They’re an energy crop,” he says. The oils can be made into biodiesel and other fuels “that could replace a good deal of the gasoline and diesel now used.”

Eight decades after the Red Wing Project, the energy sources Ruan and other BBE faculty are creating promise to transform the farm again. Drawing on energy locked in cellulose and other fibers in plant cell walls, the new technologies will run on material like cornstalks, corn cobs, wheat straw, perennial grasses, wood, and algae from farmsteads, prairies, forests, or even waste disposal sites. Someday, farmers and others may even profit from power lines that carry electricity away from such sites to be sold.

Farmers already benefit from corn ethanol production, but high energy inputs make the process relatively inefficient. That’s why BBE professor Vance Morey wants to lower those inputs. He designs technologies to use biomass (plant material that supplies energy or chemicals) to heat and power ethanol plants.

“This will reduce the amount of fossil carbon that goes into producing ethanol from corn,” he says, the “corn” of the future being the inedible parts of the plant. Besides Morey and Ruan, several other BBE faculty are also actively researching new biomass-based fuels.

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We are proud to have a long-standing partnership with the department, first in agricultural engineering and more recently in bioproducts and biosystems engineering. Having the Department of Bioproducts and Biosystems Engineering as an affiliated department within our college helps us be a leader in educating future engineers needed to develop new products that enhance our lives while protecting our environment. - Steven L. Crouch, dean, Institute of Technology, University of Minnesota
If the founding fathers of BBE could see the department now, they would be amazed by how its direction has shifted over the years.

On the agricultural side, up until the late 1960s "the focus was on engineering in agriculture to improve or increase production and to make work on the farm less arduous," Morey says. No one epitomized that better than William Boss.

True to his name, Boss was a take-charge type who began as an instructor in carpentry and steam engineering in the 1890s and rose to professor of farm structures and farm mechanics in 1905. He secured legislative funding to construct the Biosystems and Agricultural Engineering Building, in which the various mechanical, engineering, and mathematical branches of agriculture were united to form the Division of Agricultural Engineering in 1909.

After a hiatus from the University, Boss led the Division from 1919 to 1938, during which time he promoted the benefits of mechanized agriculture and the expansion of farming. He accomplished the latter by such means as sending Extension scientists by train into rural areas, where they demonstrated land clearing using explosives to blow up stumps.

Likewise, J.T. Stewart, who became the Division’s first chief in 1909, was an expert in farm drainage. Though it allowed farming to expand, drainage was then carried out without concern for how the pipes and ditches might transport fertilizer and sediment into surface waters.

But in the last three decades of the 20th century, American farms produced surpluses and farming-related environmental damage became an issue. One means to reduce the harm was using natural organisms as the basis for farm-related technologies. Reflecting this interest, Agricultural Engineering (a department since 1953) changed its name to Biosystems and Agricultural Engineering in 1995.

Forest products, the other major BBE research component, shows a similar trend. Its lineage dates from the Forest Products program in the School of Forestry in the late 1920s. In 1971 the school became the College of Forestry and the Forest Products department was created, which then became Wood and Paper Science and finally Bio-based Products. On July 1, 2006, Bio-based Products merged with the Biosystems and Agricultural Engineering Department to form BBE.

"The creation of this new BBE Department was carefully planned and executed," says Marlene Mixa, who chairs the Advisory Council for the BBE Department. "Shri Ramaswamy and Kevin Janni, the two department heads, spent countless hours with faculty and staff and met with members of their respective advisory councils to determine curriculum content, course outlines, and the best path forward.

"The result is today’s BBE Department, with its focus on the key global concerns regarding the environment, energy, and sustainability."
The industry has seen plenty of change, too. Minnesota once supplied most of the lumber to giants like Weyerhaeuser, Blandin, and Potlatch, but by 1930 the rich stands of white pine, and the state’s lumber industry in general, had largely been depleted. An apt focus for the new era was wood deterioration and preservation, which happened to be the forte of Frank Kaufert, the University’s legendary forest products scientist. Director of the School of Forestry from 1947 to 1970, he served as dean of the College of Forestry from 1971 to 1974.

The forest products program can trace its origin to Kaufert’s early work in the 1920s. His multifaceted legacy includes work to pass the 1962 McIntire-Stennis bill, which mandated support for research in forest products, and spearheading construction of a new building, Kaufert Laboratory, in three phases between 1957 and 1974.

“Frank was one of a kind. He built the whole department,” says Jim Bowyer, a retired professor and former head of the Forest Products Department.

A second legendary figure was Roland Gertjejansen, whose work on wood composites in the early 1970s helped Minnesota become the leading producer of oriented strand board, a common residential building material still in use. Gertjejansen also launched the University’s teaching program in pulp and paper, another major state industry.

The department’s first head, a whirlwind named John Haygreen, came up with among other things—a way to test the internal bonding strength of wood composite materials.

“Later, he was one of the first people to get involved in burning biomass for power,” says Bowyer. “He got the idea of squeezing water out of wood chips like from a sponge.” Haygreen’s prototype device could apply 10,000 pounds of pressure per square inch to wood, but it was bulky. “We had to cut a hole in the roof of Kaufert Lab to install it,” Bowyer chuckles.

Haygreen’s work to reduce biomass moisture content came during a defining period in the forest products industry.

“A revolution started around 1972,” Bowyer recalls. “Instead of obtaining energy from the grid, the industry converted wood waste to steam and electric power to run sawmills, paper mills, plywood plants, and so on. Today, the forest products industry is about 70 percent energy self-sufficient in producing lumber and paper.”

Several BBE faculty are tackling the hydra-headed task of guiding industries toward greater energy efficiency. As a member of the National Green Marketing and Sustainable Products Roundtable, associate professor Tim Smith, director of the University’s Center for Sustainable Enterprise Development, helps industries and regulatory agencies set standards and policies for “sustainable” products.

A glance at the packaging and building materials industries reveals the need for an overhaul of current rules.

“Within a single product category you may have five to eight competing sets of rules for what a sustainable product is,” Smith explains. “And there are about 350 different certifications and labels for products that go into buildings.”

Smith and colleagues such as assistant professor Sangwon Suh (who is now working with the World Resources Institute on carbon footprinting standards) examine each stage of a product’s life cycle, drawing on information from people who gather raw materials as well as those who manufacture, sell, consume, and recycle products. What happens at every stage affects factors like greenhouse gas emissions, waste disposal, water quality, and a host of health and social issues.

Making a dent in environmental problems means looking beyond factories and facilities. “It has to be an across-the-board effort of all the players,” says Smith.
All BBE researchers strive for sustainability in meeting society’s needs. The heirs of Stewart’s legacy, for example, seek to build more environmentally responsible drainage systems, since fields must be properly drained to grow crops.

Recently, however, the biological desert, or “dead zone,” in the Gulf of Mexico has been tied to nutrients like phosphorus and nitrogen draining out of Midwestern farm fields, washing down the Mississippi, and harming marine life. Accordingly, says BBE associate professor and Extension engineer Gary Sands, drainage work now includes water quality and mitigation of large-scale “downstream” damage from nutrients and pollutants discharged into surface waters.

Sands’ research on novel drainage and tile systems shows that they can cut the losses of water and nutrients from the landscape. This improves productivity and benefits farmers, as well as aquatic life in the Gulf. In one example, he and his colleagues have found that optimal depth and spacing of drainage tiles can help.

Another drainage researcher, BBE professor Bruce Wilson, is working with Minnesota farmers to set up trials of self-sustaining drainage ditches, which would move both sediment and water much as natural streams do. "A river has a main channel and a floodplain," Wilson says. Self-sustaining drainage ditches would be sculpted with a deep central channel and “banks”; this would move sediment along and reduce deposits that can scour and destabilize a ditch. And plants growing on the banks would remove nitrogen and phosphorus from the water.

A second concern of Wilson’s is the loss of sediment from construction sites such as roads. He researches vegetation and plant fiber “blankets” used to control erosion and is part of a joint University of Minnesota-Minnesota Department of Transportation program to train and certify professionals in erosion and sediment control at construction sites.

“Any MnDOT contractor must be certified,” says Wilson. “We have six to eight people teaching at any time, and we typically certify about 2,000 people a year.”
Whether a palace or a pig barn, orchestrating all the systems in a home can be tough. Several BBE faculty are advancing the science of housing for both humans and livestock and sharing their knowledge with farmers, builders, and the general public.

With the recent burgeoning of poultry, hog, and dairy operations around the state, odor has become an issue. Larry Jacobson, a BBE professor and Extension engineer, helps farmers manage ventilation and heating systems to improve the air quality in and around barns for themselves and their animals.

One tool in his kit is the department’s olfactometry lab, where odors are quantified with the aid of trained panelists. These “paid sniffers” help the researchers find the threshold level of detectable odor. The data helps in establishing appropriate separation distances between residents and different sources of odor such as animals, barns, or manure storage areas.

“People around the country have used this model,” notes Jacobson.

To nip odors in the bud, Jacobson’s colleague and BBE professor Kevin Janni uses biofilters. These are large, porous screens containing bacteria that remove odors. Fans blow air through the biofilters, typically removing 90 percent of odors, Janni says.

“We have one sow farrowing facility with biofilters around three sides of the barns,” he adds. “They treat 100 percent of the air.”

Department faculty also work with farmers to find the best design for animal stalls, bedding, and manure management. The problems vary from farm to farm, which is why Janni takes the time to figure out options and tradeoffs. “People need choices about how to conduct farm business and what works best for them,” he says.

In a house, all systems must be “go” and working in harmony, using as little energy as possible. Helping builders and homeowners get it right is the business of the 23-year-old Cold Climate Housing Center, founded by Jim Bowyer and his Forest Products colleague Lew Hendricks.

“The center came to be because we can’t look at energy, moisture, air quality, and product durability separately,” says its current director, BBE associate Extension professor Patrick Huelman. “I sense an incredible interest in bringing up the energy efficiency of existing homes, but we have to do it in a systems approach, not piecemeal.”

A clearinghouse for information on how to build, the center practices what it preaches. In concert with partners, public and private, Huelman and his colleagues have built four award-winning “studless construction” houses that model low cost and high performance.

Huelman points with pride to Mat Gates, a graduate of BBE’s residential building science and technology program, who co-founded a company called Residential Science Resources. Working with builders, RSR helps them ensure they construct homes for maximum performance.

“RSR conducts energy modeling before the home is constructed, makes periodic visits during construction, and tests the completed home for house tightness, duct leakage, ventilation, and so on,” Huelman says. “They make sure it’s working the way it’s supposed to before the occupants move in.”
The forward-thinking members of this department have developed programs that will meet the needs of business, industry, and society today and tomorrow. And they continue to work with the BBE Advisory Council to ensure that their curriculum is relevant and up to date. It has been a pleasure to work with these faculty members, who are committed to have their department continue to excel for the next 100 years.

Congratulations! - Marlene Mixa, chair, BBE Advisory Council
Excellence By Extension

For a century, BBE faculty and University of Minnesota Extension have served the state together. Many faculty hold appointments in Extension, which also celebrates its centennial in 2009.

“For Extension, serving agriculture has been primarily through engineers designing machinery and facilities, and also processes such as getting grain to market or drying and storing crops,” says Michael Schmitt, senior associate dean of Extension. For example, BBE professor and Extension engineer William Wilcke, an expert in crop drying, and assistant Extension professor Harlan Petersen, a specialist in wood drying and wood products, have helped the farming and wood products industries take on that old demon, moisture.

Besides cutting usable crop yields, moisture can have devastating consequences for homeowners, explains retired professor Robert Erickson, who still keeps up his research on better methods of drying structural lumber to prevent warping.

“It could warp after being put in somebody’s house,” Erickson says. “Usually, that can be traced back to not being dried adequately beforehand.”

Also, Schmitt points out, engineers have designed grain elevators, combines, and hog and dairy facilities, as well as manure handling processes tailored to the animal. Lately, however, those roles have expanded and diversified. Schmitt offers the example of Jun Zhu, an associate BBE professor and Extension engineer who researches systems to generate methane from animal waste and turn it into an energy source for farmers.

And while engineers have always worked to ensure the efficiency and safety of machinery, they now deal with safety on a larger scale by helping communities plan for situations like epidemics or spills of dangerous chemicals.

“From farm to grain elevator to chemical storage to food processing and foodborne epidemics, our engineers have kept up with the times,” says Schmitt.
Out Of The Woods

“A plant pathologist and a forest manager can work together to keep trees healthy for 40 to 50 years. Then you can make wood out of them and lose it in one year from handling it improperly.”

Thus does Jonathan Schilling describe the fragility of wood. Schilling, an assistant BBE professor, studies how fungi digest wood in order to either help or hinder the process. After all, they’re pros at it, he says.

Yet wood possesses formidable self-preservation features. While two of its three major structural polymers (cellulose and hemicellulose) can be broken down into sugars, an organism can’t feed off those sugars unless it first breaches the protective barrier of lignin, the third and by far most resistant polymer.

In plant cell walls, lignin’s highly branched molecules fill the spaces between cellulose and hemicellulose, conferring strength, repelling water, and shielding against enzymatic attack by microbes.

Some fungi, however, manage to pull an end run around lignin. Schilling specializes in a common bane of buildings called brown-rot fungi, which can efficiently reach and degrade cellulose polymers. This weakens wood significantly, often before any visible sign of decay appears. To hinder this process, he is investigating the use of natural molecules found in heartwood (the nonliving core of a tree) that can deprive the fungi of the iron they need to degrade the tissue.

But fungi also serve as “ecosystem engineers” that clear away dead wood and recycle nutrients in forests. Mimicking this fungal talent in the lab could lead to new technologies, such as a means of producing “cellulosic” ethanol from plant material that humans can’t digest.

“Taking sugars out of the whole plant relieves you of the need to take them from edible fruits or vegetables,” says Schilling. “You could grow grasses, or perhaps even a crop of native plants.”

Still, the day of easy ethanol production from wood is not yet here. Changing or partially removing lignin is a necessary first step before hemicellulose and cellulose can be accessed by enzymes, digested into simple sugars, and fermented to ethanol. But treating lignin requires harsh chemicals and heat, and so presents an obstacle to making cellulosic ethanol in a cheap, environmentally friendly way.

Enter BBE professor Simo Sarkanen and his research subject, the white rot fungi. These fungi digest lignin, and Sarkanen is in a race to find out how. Working with Steve Gantt of the plant biology department, Sarkanen studies enzymes that may accomplish the task. In a second approach, he also investigates ways to make plants produce varieties of lignin that are easier to break down.

In trying to pry loose the secret of lignin digestion, Sarkanen is chasing a discovery that has eluded some of the best brains in science for 25 years. Whoever succeeds could revolutionize the field of biofuels by making cellulosic ethanol more economical to produce.

“This is about as exciting for us as life could be,” he remarks.
“Exciting” likewise describes the work of BBE associate professor Ulrike Tschirner, who also researches biomass conversion. Among her successes, she has found a way to increase by 3 to 4 percent the yield of fibers in paper mills that use a chemical pulping process. With most chemical pulp mills processing around 3,000 tons of wood into some 1,500 tons of fiber every day, that increase in yield would significantly increase efficiency. The method is now being tested in Europe.

In another project, Tschirner is researching a way to get added value from wood chips before pulping. Usually, when chips are pulped with alkali, the treatment removes not only lignin but about half of the hemicellulose, forming a mixture that is concentrated and burned for energy. But Tschirner and her colleagues have found a way to remove some of the hemicellulose before pulping; it can then be digested and fermented to ethanol.

“We can remove about a quarter to half of the hemicellulose and still have the same strength and yield of fiber for paper,” she states.

Noting the historical use of waste lignin and hemicellulose as an energy source, Tschirner sees the conversion of biomass for energy as a natural extension of what the paper industry is already doing.

“The paper industry is one of the few that have the infrastructure to handle biomass,” she says. “It could be the nucleus of the new biomass energy industry.”

But cellulose (the most abundant natural polymer) has even more possibilities. William Tze, an assistant BBE professor, explains that in plant cell walls, microscopic cellulose elements are arranged in stacks, neatly in some stretches and in unruly fashion in others. The neat parts are called crystalline cellulose, from which nanocrystals can be extracted.

“The crystalline cellulose gives support to wood,” says Tze. “Two things we want to take advantage of are their strength and small size.” One use is to strengthen plastics such as polystyrene, from which CD and DVD jewel cases are made. By adding just one percent by weight of cellulose nanocrystals to the plastic, Tze has increased its stiffness up to 70 percent.

He also researches the use of cellulose nanocrystals to reinforce polylactic acid, a biodegradable plastic, to make it more competitive with petroleum-based plastics. And, says Tze, their small size may someday make cellulose nanocrystals useful in worker protection masks to catch the minuscule particles generated by nanotechnology industries.
Growing up on the Red River, Sonia Maassel Jacobsen lived through numerous floods, including several in the early 1970s that came just as she was pondering a career. “I was fascinated by the whole flooding thing,” says Jacobsen, who graduated from the University in 1978 with a degree in agricultural engineering.

Now she deals with “anything to do with water” as an agricultural engineer in the U.S.D.A. Natural Resources Conservation Service, collaborating often with Gary Sands on managing controlled drainage projects to improve water quality and with BBE associate professor Jerry Wright on irrigation and drainage issues. And she remembers her student days fondly. “The best part of being a student was that classes were small, so you got to know everybody,” Jacobsen recalls. “The department had few women in my day. In a class of seven, I was the only one. Now, in a class of seven to 10, about half of the class is women. I think part of it is the change in name from agricultural engineering to biosystems engineering.”

Biosystems engineers combine living and nonliving components, as in stabilizing stream banks with vegetation as well as rock and concrete. “You must understand both the plants and the engineering principles and materials to produce an effective design,” says Jacobsen.

Currently, about one-third of BBE undergraduates are women; a significant increase from the past, it reflects changing student demographics and interests.

The male student population has also changed. For much of the 20th century, students on the St. Paul campus were typically young men from rural Minnesota. World War II saw an influx of Navy men, whom the agricultural engineering faculty trained as machinists and electricians. And the postwar years produced a bumper crop of students as ex-servicemen, many in their late twenties and with families, flocked to college.

Today, BBE boasts an international faculty and draws an increasing number of students from urban areas. But the most important thing isn’t what those faces are; it’s the direction in which they look. From an early emphasis on increasing yields of crops and improving the properties and performance of forest products, the department now embraces a future as global leaders in discovering, developing, and applying renewable resources and sustainable technologies to meet society’s needs. This must be done while simultaneously providing ecosystem services and enhancing the environment in Minnesota and beyond.

“We still have to provide food, feed, fiber, materials, and energy to meet a growing global need,” says Shri Ramaswamy, BBE department head. “The question is, how can we do all of that in an efficient, environmentally sustainable way to improve the quality of life?”

In its second century, BBE will show us.
Past and Present Department Heads

Agricultural Engineering/Biosystems & Agricultural Engineering

John Stewart 1909 - 1919
A. J. Schwantes 1939 - 1964
Fred Bergsrud 1983 - 1987
Vance Morey 1992 - 2001
Kevin Janni 2001 - 2006

William Boss 1919 - 1938
Landis Boyd 1964 - 1972
George Foster 1987 - 1991

Harry Roe (interim) 1938 - 1939
Arnold Flikke 1972 - 1983
Fred Bergsrud (interim) 1991 - 1992

Forest Products/Wood & Paper Science/Bio-based Products

John Haygreen 1971 - 1984
Jim Bowyer 1984 - 1995
Joe Massey 1995 - 2003

Shri Ramaswamy 2003 - 2006

Bioproducts and Biosystems Engineering

Shri Ramaswamy 2006 - Present
Current Faculty

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<td>Mrinal Bhattacharya</td>
<td>Biodegradable polymers, tissue engineering, nanobiosensors</td>
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<tr>
<td>Jonathan Chaplin</td>
<td>Machinery systems design and engineering safety</td>
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<td>John Chapman</td>
<td>Soil erosion and sediment control</td>
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<td>Charles J. Clanton</td>
<td>Livestock facilities and systems</td>
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<td>Patrick Huelman</td>
<td>Residential building and energy systems</td>
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<tr>
<td>Forrest Izuno</td>
<td>Southern Research and Outreach Center</td>
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<tr>
<td>Larry D. Jacobson</td>
<td>Livestock housing systems, air emissions</td>
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<td>Kevin A. Janni</td>
<td>Air quality, livestock systems, ventilation</td>
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<td>R. Vance Morey</td>
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<td>John L. Nieber</td>
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<td>Harlan Petersen</td>
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<td>Shri Ramaswamy</td>
<td>Transport processes, bio-based products, process and product engineering</td>
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<td>R. Roger Ruan</td>
<td>Biorefining, bioprocessing, biofuel, biomaterial and value-added process development</td>
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<td>Gary Sands</td>
<td>Water management and water quality</td>
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<td>Simo Sarkanen</td>
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<td>Jonathan Schilling</td>
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<td>David R. Schmidt</td>
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<td>Robert Seavey</td>
<td>Composites and wood moisture relationships</td>
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<td>Steve Severtson</td>
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<td>Timothy Smith</td>
<td>Corporate sustainability, product stewardship and marketing communications</td>
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<tr>
<td>Sangwon Suh</td>
<td>Industrial ecology and life cycle analysis</td>
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<tr>
<td>Ulrike Tschirner</td>
<td>Biomass conversion (pretreatment, saccharification, pulping, and bleaching)</td>
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<tr>
<td>William T.Y. Tze</td>
<td>Biocomposites, cellulose and nanomaterials</td>
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<td>Ping Wang</td>
<td>Enzyme engineering and nanotechnology; nanostructured biocatalysts for biotransformations</td>
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<tr>
<td>William F. Wilcke</td>
<td>Crop drying, handling &amp; storage; energy for agriculture, sustainable agriculture</td>
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<tr>
<td>Bruce N. Wilson</td>
<td>Hydrologic/water quality modeling of disturbed and agricultural watersheds; transport of surface water contaminants</td>
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<tr>
<td>Jerry A. Wright</td>
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<td>Jun Zhu</td>
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Special Thanks

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Credits & References

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