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Growing Michigan's Bioeconomy

looking into futures

Growing Michigan's Bioeconomy

In early 2006, gasoline prices skyrocketed, and Michigan's economy was reeling from several years of downturns. MSU President Lou Anna K. Simon knew her university had one of the country's top plant science research programs, as well as extremely strong engineering programs. She also knew that the state had a strong manufacturing base, as well as a strong agricultural base. It seemed a natural part of its land-grant mission that MSU should more formally unite the power of its research with the state's proven assets and develop sustainable solutions to the nation's dependence on petroleum-based products that would help boost the state's economy. So she created the MSU Office of Bio-based Technologies (OBT).

"If you think about what Michigan could be good at and what Michigan could be known for, then the bioeconomy arises as a real possibility," Simon said. "The question becomes how to combine Michigan's assets with the cutting-edge research being conducted at Michigan State University in ways that can make a real difference for the state. So the bioeconomy idea for Michigan emerged from an established, thoughtful understanding of Michigan's current strengths and active considerations of Michigan's future potential."

The terms "bioeconomy" and "bio-based economy" describe a future in which people rely more on renewable resources to meet society's needs for energy, chemicals and raw materials. Instead of an economy dependent on the planet's limited supply of nonrenewable resources, such as petroleum and coal, plant material and municipal and livestock waste — biomass — would be converted into electricity, fuels, plastics and the basic components of chemical processes.

Ethanol and biodiesel are two of the most well-known products of the bioeconomy, but the concept is much broader than biofuels.

"There is more to the bioeconomy than just fuel," said Steven Pueppke, director of both the OBT and the Michigan Agricultural Experiment Station (MAES). "The bioeconomy is about making crop plants more valuable and providing consumers with products from renewable resources."

In this issue of *Futures*, you can read about MAES scientists from various disciplines who are all working to enhance Michigan's economy and environment by creating products from plants and other renewable resources.

In an in-depth interview, President Simon talks about the importance of the bioeconomy, what it could mean for the state and MSU's role in shaping it.

As OBT Director Pueppke said, there's more to the bioeconomy than fuels. But the promise and potential of biofuels for the economy and the environment have captured the attention of politicians, the public and the media like no other bioproduct. MAES chemical engineering scientist Bruce Dale has been studying how to convert cellulose into ethanol for 30 years. His AFEX process seeks to make the conversion more efficient and cost-effective.

Looking at the other end of the bioeconomy spectrum, MSU scientists want to understand the genes that control plant metabolism and the compounds that are produced as a result. MSU's expertise in systems biology, metabolic engineering and biotechnology of plant systems is important to the bioeconomy's success because that expertise can change the properties and composition of the plant raw material used to make products.

In a partnership between MSU, the DaimlerChrysler Corporation and NextEnergy, a nonprofit organization that supports alternative energy research and development, MAES researcher Kurt Thelen is exploring two intriguing possibilities: Can a brownfield site produce crops that have the quality and yield for biodiesel or ethanol production? And can the biofuel crops help clean up the contaminated soil?

Kirk Dolan, MAES researcher, studies processing techniques for new food products. He and graduate student George Nyombaire have developed an extruded bean product that may help ease some of the hunger and nutritional deficiency issues in Rwanda, Nyombaire's native land. This work is also part of the bioeconomy.

We hope you enjoy this issue of *Futures* and that it helps you understand a little more about the Michigan Agricultural Experiment Station and the research it funds. If you have comments about this issue or would like to subscribe (it's free!), send a note to *Futures* Editor, 109 Agriculture Hall, Michigan State University, East Lansing, MI 48824-1039, or send an e-mail to depolo@msu.edu. You can also call 517-355-0123.

For the latest information about MAES research and events, I invite you to subscribe to the free MAES e-mail newsletter. Sign up by visiting the MAES Web site at www.maes.msu.edu/news.htm. You also can view this and past issues of *Futures* on the Web site by clicking on the "research publications" tab.

::: Jamie DePolo

Thanks to Bob Ellerhorst, director of utility services at the MSU Power Plant, for his assistance with the cover. The power plant also is involved in the bioeconomy. The plant has been conducting experimental burning of biodegradable waste products (corn starch) to see if these products can be used as raw materials.

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In a bioeconomy, people rely on renewable resources such as corn, soybeans or sunflowers to meet their needs for energy, chemicals and raw materials. The MSU Office of Bio-based Technologies aims to combine the university's cutting-edge research with the state's assets to grow the bioeconomy in Michigan. *Top right photo:* Michigan Gov. Jennifer Granholm *(second from right)* visited the labs of several scientists on campus who received 21st Century Jobs Fund awards from the state. MAES chemical engineering and materials scientists Carl Lira *(second from left)* and Dennis Miller *(right)* received an award for research that will boost the bioeconomy. Ned Jackson, professor of chemistry *(left)*, also received an award. *Center photo:* Bruce Dale, MAES chemical engineering and materials scientist, who is also associate director of the Office of Bio-based Technologies *(left)*, explains his research on producing ethanol from cellulose to National Science Foundation Director Arden Bement during Bement's visit to the MSU campus in October.

Growing a New Economy

The MSU Office of Bio-based Technologies aims to integrate innovations in the lab with advances in the marketplace to enhance the economy, the environment, and quality of life in Michigan and around the globe.

As a land-grant institution, Michigan State University prides itself on marshalling its sophisticated research and knowledge to meet the needs of the people of Michigan, enriching their lives and helping to improve the state as a whole.

In early 2006, gasoline prices skyrocketed, and Michigan's economy was reeling from several years of downturns. MSU President Lou Anna K. Simon knew her university had one of the country's top plant science research programs, as well as extremely strong engineering programs. She also knew that the state had a strong manufacturing base, as well as a strong agricultural base. It seemed a natural part of its land-grant mission that MSU should more formally unite the power of its research with the state's proven assets and develop sustainable solutions to the nation's dependence on petroleum-based products that would help boost the state's economy. So she created the MSU Office of Bio-based Technologies (OBT).

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"There is more to the bioeconomy than just fuel," said Steven Pueppke, director of both the OBT and the Michigan Agricultural Experiment Station (MAES). "The bioeconomy is about making crop plants more valuable and providing consumers with products from renewable resources."

Pueppke said that Michigan has the prerequisites in place to support a thriving bioeconomy. The state is home to an abundant supply of raw materials — wood and biomass crops — and has the land and natural resources available to grow crops dedicated to biomass production. Michigan automotive, chemical and furniture industries want to incorporate more bio-based materials into their products. A skilled labor force and a location strategically near tens of millions of consumers are two more plusses for the state.

OBT Director Steve Pueppke *(left)* discusses information presented at the Michigan Bioeconomy Summit with Chris Peterson *(center)* and Tom Kalchik, director and associate director, respectively, of the MSU Product Center for Agriculture and Natural Resources.

"Add to all that the strengths that MSU has in plant breeding, raw material processing and supply chain management and logistics, as well as the strengths of other institutions in the state," Pueppke said. "There aren't many places that can claim all those assets."

The Mission of the Office of Bio-based Technologies

Simply put, the mission of the OBT is to identify, encourage and support research programs that will position Michigan State University as a world leader in the development of the new bioeconomy.

"Our vision is that MSU will be the 'go-to' place for basic and applied research related to the development of the bioeconomy because of our outstanding faculty members, existing research strengths and strong private sector partnerships," said Bruce Dale, OBT associate director and MAES chemical engineering and materials science researcher. Dale is internationally known for his 30 years of research on processes to produce ethanol from cellulose.

"There was a lot of bioeconomy research already being conducted at MSU," Pueppke added. "But the OBT gives us a central place to focus attention on the subject and package all MSU's talents and expertise together. Private companies and citizens need one point of contact at MSU to meet all their bioeconomy needs. The OBT will be that point."

Pueppke and Dale agree that MSU is uniquely positioned to take a lead role in developing the bioeconomy for Michigan and for the country.

"A successful bioeconomy will require expert capabilities in manipulating plants at the molecular level," Pueppke said. "The cost and efficiency of producing biomass raw materials will come to be very important to the bioeconomy. MSU has one of the largest and strongest groups of plant scientists in the world — including six National Academy of Sciences fellows. Our researchers are developing new methods to grow plants that have the qualities and yields needed for bio-based products. They're also working on new varieties of plants developed specifically for bioprocessing. In the future, farmers could have the option of planting some crops for food and feed and other crops that would be used as raw materials for the bioeconomy."

"We also have very strong research programs in engineering, chemistry and business," Dale added. "This will help create new processing and production techniques and new supply chain strategies, and develop new products that can be made from biomass. Not many other institutions have the breadth and depth of MSU."

Though other universities have bioeconomy research programs and offices, Pueppke believes MSU has an advantage over all of them.

"What sets us apart is the value that MSU research infuses throughout the bioproduct supply

chain, from biomass production to bioprocessing to biomanufacturing," he said. "Many universities have specialized capabilities in specific sectors of the supply chain, but MSU has experts and research programs that add value virtually from the genome to the gas tank."

"Iowa is tied to corn and soybeans," said Satish Udpa, dean of the MSU College of Engineering. "Michigan and MSU are so much broader than that. With our first-rate plant science department, we can investigate crops that can give the best possible yield for bioproducts, such as switchgrass or miscanthus. This ties in nicely with MSU's strengths in materials science. For example, in the MSU Composite Materials and Structures Center, scientists are creating new materials that can be used for cars, buildings and other products. Also, the properties of biofuels are different than those of petroleum fuels. Vehicles will need different engines, and engineering scientists are working on that. We're also developing processes to produce and deliver biofuels. At MSU, we're looking at the entire range of technology needed, not just one portion of it."

The Bioeconomy Can Boost the State's Economy

The past several years have been very difficult for Michigan's economy. The slumping auto industry has deeply affected the state's finances, and downturns in other manufacturing sectors and record-high crude oil and gasoline prices have pushed the situation from bad to worse. Many state and federal legislators recognize that the bioeconomy may provide Michigan with a way out of its economic doldrums.

In her 2006 State of the State address, Gov. Jennifer Granholm acknowledged MSU's importance to the state's economy and announced plans to invest in alternative energy research through the 21st Century Jobs Fund.

"At Michigan State University, President Lou Anna Simon is positioning our state to lead the world, and her Spartans, in the new bioeconomy," Granholm said. "This is not 'The Jetsons,' folks. This is right here, now, today."

In September 2006, the state announced the 61 recipients of 21st Jobs Fund awards. Eleven MSU research projects — from basic research to applied research already spinning off Michigan companies — received funding. MSU submitted 22 proposals.

MSU projects were granted $13.1 million for research, some aimed at boosting the bioeconomy, such as mechanical engineering professor Harold Schock's proposal to develop ethanol fuel engines or MAES chemical engineering professor Dennis Miller's research on a continuous production process for biodiesel.

Steve Pueppke, director of the Office of Bio-based Technologies and director of the Michigan Agricultural Experiment Station, addressed attendees at the Michigan Bioeconomy Summit in Lansing in September. "Michigan is uniquely positioned to build a new, expanded bioeconomy that connects our strengths in agriculture, forestry and natural resources with commensurate strengths in industry and manufacturing to create a new, sustainable bio-based sector," Pueppke said. "This gathering is an important step in enhancing and expanding that connectivity."

"The 21st Century Jobs Fund shows that the state is serious about creating a new kind of economy in Michigan," Pueppke said. "MSU's success shows that we are serious about providing the novel technologies to help make it happen."

"These new research projects further strengthen an already robust campuswide effort in many aspects of the bioeconomy," Dale added.

Granholm also announced a $250,000 grant program to help owners defray the costs of installing or converting infrastructure at gas stations to provide ethanol and biodiesel fuel to Michigan drivers. The goal is to have 1,000 biofuel pumps by 2008.

Five ethanol plants are already producing fuel in Michigan, and two more are being constructed. Two biodiesel plants also are beginning production, and another plant is planned. MSU researchers estimate the total economic impact of the biodiesel plant in Bangor to be about $95 million and that of the ethanol plant in Riga to be about $75 million. MSU scientists helped the boards of directors of both plants during planning and start-up phases.

In northwestern Michigan, an area hard hit by business closings and layoffs, Kris Berglund, MAES chemical engineering and materials science researcher, helped start Diversified Natural

Satish Udpa, dean of the College of Engineering, says MSU is looking at the entire range of technology needed to drive the bioeconomy, not just one portion of it.

Products (DNP), a company that is using MSU biotechnology research to make new bio-based products. The company has two divisions — bio-based fuels and chemicals, and gourmet and nutritionally enhanced foods. The company's unifying theme is agriculture-based biotechnology that uses readily available natural resources. One of the company's first products is exotic specialty mushrooms, including the elusive morel. This is the first time morels have been mass-produced indoors. The company sells about 2 tons of mushrooms per week and expects to sell 800,000 pounds of fresh mushrooms per year. So far, DNP has brought 56 jobs to the area. DNP's bio-based fuels and chemicals division produces succinic acid from plant sources. Global demand for succinic acid is enormous — it's used in everything from industrial solvents and biodegradable polymers to airport runway deicers. DNP makes succinic acid from natural sugars derived from sources such as Michigan corn. Fifteen of DNP's patents have sprung from Berglund's research.

"The bioeconomy will yield new businesses, jobs and intellectual property in Michigan," Pueppke said. "We've had success, but there's an enormous potential for more. One of the objectives of the OBT is to spur economic development in the state."

"It's economically advantageous to farmers to grow crops that are used for products that have higher value than animal feed, such as ethanol and chemicals," Dale added. "It gives them options about what to grow. Farmers might grow a grass crop that would be used as a bioproduct raw material. Similarly, the stalks, leaves and stems of plants left over after a crop is harvested are now considered waste — this biomass would have value as a raw material."

Besides farmers, Dale said that other industries that would benefit from the bioeconomy include manufacturers of automobiles, chemicals, furniture and durable goods (including building materi-

OTHER MSU RESEARCH CENTERS THAT SUPPORT THE BIOECONOMY

MSU scientists have been investigating many facets of the bioeconomy for several decades. Besides the relatively new Office of Bio-based Technologies, which now serves as a clearinghouse for all bioeconomy information and research, other distinctive centers include:

MSU-U.S. Department of Energy Plant Research Laboratory (PRL)

The success of the bioeconomy depends in large part on the ability to manipulate plants at the molecular level. The PRL and related MSU departments have one of the largest and most skilled groups of plant scientists in the world. PRL researchers are creating more efficient and economical approaches to biodiesel production, including genetically modifying nonfood plants such as grasses to produce up to 10 times more biodiesel feedstock per acre than soybean oil. Other scientists have developed technology that allows plants to accumulate extremely high levels of starch, which is much easier to convert into fermentable sugars (the basic components of ethanol and many biochemicals) than cellulose.

Biomass Conversion Research Laboratory (BCRL)

Most of the energy in plant biomass is unavailable for liquid fuel production because the energy is in the form of cellulose and hemicellulose, the complex sugars that make leaves, stems and tree trunks rigid. Before these sugars can be fermented into ethanol, they must be broken down into simple sugars by enzymes. Breaking down cellulose and hemicellulose is a long-standing roadblock in biofuel production—it's difficult to do efficiently and can significantly raise production costs.

BCRL scientists are developing pretreatment, enzymatic and fermentation technologies to break down cellulose and hemicellulose more economically and efficiently. Bruce Dale, OBT associate director, serves as research adviser for the BCRL and con-

als such as flooring, roofing and drywall). Economists estimate that the bioeconomy will create thousands of jobs, in research, agriculture, forestry, equipment and product manufacturing, education and training, business management, marketing, sales and distribution.

As new businesses and products form, the MSU Product Center for Agriculture and Natural Resources serves as an important resource for the Office of Bio-based Technologies. The Product Center's mission is to be a catalyst for the creation of a profitable future for businesses and industries engaged in Michigan's agricultural, food and natural resource systems. Its experts are available to assist fledgling entrepreneurs and established companies.

"The MSU Product Center plays a large role in bioeconomy activities at MSU," Pueppke said.

"The Office of Bio-based Technologies has a mission to reach out across the whole of campus and bring together key researchers in a variety of areas," said H. Christopher Peterson, director of the Product Center and MAES agricultural economics researcher, who holds the Nowlin chair for consumer-responsive agriculture. "The OBT provides a complete focus point for all the university's activities in the bioeconomy arena — from research to education and outreach. The Product Center's mission is complementary, but we have a much narrower focus. We're studying the products and new businesses that may arise in the bioeconomy and can offer business planning and supply chain analysis for our clients."

According to Pueppke, the OBT might be the initial point of contact for a company looking for bioproduct licensing or research opportunities.

"If it were a small company or a newly established company that wanted help with bioproduct marketing or supply logistics, we would refer them to the Product Center," he said. "The role of the OBT is to develop partnerships with large companies and corporations that will benefit MSU, the company and the bioeconomy."

Depending on the type of product or business, Peterson said Product Center staff members can assemble a unique team of researchers from across campus to address supply, demand, packaging and a host of other issues involved with starting a new business or launching a new product.

Conversely, if a company came to the Product Center seeking sponsored bioeconomy research or research and development on a potentially patentable bioproduct or process, the Product Center would refer the client to the OBT.

In either case, the client, the university and the state will benefit.

"The bioeconomy adds value to Michigan's economy and Michigan's environment," Udpa concluded. "The days of $20 hydrocarbons are over. Our reliance on fossil fuels has brought both social and environmental strife. By becoming more dependent on renewable things — things that grow — I believe we will have a world more in harmony with the environment, and, perhaps, with one another."

::: Jamie DePolo

ducts much of his work on the ammonia fiber expansion (AFEX) process, a patented pretreatment method, there. BCRL researchers are also studying how to improve the sustainability of bioenergy systems.

Center for Microbial Ecology (CME)

CME scientists are internationally recognized for their research on how communities of microorganisms interact and how these interactions can be controlled and changed for practical purposes, such as cleaning up toxic spills and other pollution. Microbial communities also can be harnessed to do bioeconomy work, such as converting cellulose into more easily fermentable sugars or producing methane from coal beds.

Long Term Ecological Research (LTER) Site at the Kellogg Biological Station

The 200-acre LTER site was established in 1988 as part of the national LTER Network funded by the National Science Foundation. The MSU site is the only site in the network to focus on agriculture. Research at the MSU LTER site looks at biodiversity in agriculture and forestry and how this diversity affects the functioning of the ecosystem. LTER research will help address the delicate sustainability issues that will inevitably come up as biofuel systems are introduced — questions about carbon cycling, greenhouse gas dynamics and long-term soil health.

Product Center for Agriculture and Natural Resources

The Product Center's goal is to improve economic opportunities in Michigan agriculture and natural resources, and its experts are available to assist fledgling entrepreneurs and established companies. The center helps guide clients through the phases of conceptualizing, planning and actually starting a business. Product Center researchers conduct market research and write reports and working papers that clients can use when evaluating the uniqueness or marketability of their products. As new bioproduct companies form, Product Center research will offer invaluable guidance and information.

Q: *You've talked extensively about the importance of the bioeconomy. Would you describe the "ah-ha" moment when you realized that a bioeconomy was something that MSU should be more formally involved in?*

A: I'm not sure there was an "ah-ha" moment.

Because MSU has been thinking about the interface between the university's cutting-edge research and the needs of society for a long time, we immediately connected the recent advances in bio-based research and technology to potential applications. Recognizing that these applications could greatly affect the national and world economies was just the next step.

There are a couple of external factors that have helped to move us in that direction relatively quickly.

The first is the viability of this new technology to produce inexpensive, inexhaustible amounts of energy. As the price of oil has increased and the supply lines have become more tenuous, the possibilities of this new technology have become ever more significant to our economic future.

The second is the state's strengths. Clearly Michigan's manufacturing capacity, as well as its agricultural capacity, are powerful assets. Both of these assets are significant in developing and implementing bio-based technologies and products. So, if you think about what Michigan could be good at and what Michigan could be known for, then the bioeconomy arises as a real possibility.

The question becomes how to combine Michigan's assets with the cutting-edge research being conducted at Michigan State University in ways that can make a real difference for the state.

So the bioeconomy idea for Michigan emerged from an established, thoughtful understanding of Michigan's current strengths and active considerations of Michigan's future potential.

Q: *MSU is historically strong in all the areas involved in the bioeconomy. Why was it necessary to create the Office of Bio-based Technologies?*

A: Our strengths at Michigan State are very diverse.

Being home to one of the top-ranked plant sciences programs does not necessarily translate into research that might be used outside of traditional agriculture.

Bruce Dale has been working for 30 years with ethanol, but until alternate fuels became a felt need with the public, it was hard to anticipate the exact impact his work might have.

Now we're working on a model to integrate research from across the basic and applied plant sciences, engineering and economics to make ethanol a common product available at the gas pump.

By creating the Office of Bio-based Technologies, we're building a team around biotech and establishing a place where all this related work can come together in a way that integrates cutting-edge research with the public's interests and needs.

The office not only furthers that goal but also signals to the community that MSU is applying its progressive research to advancing the public good.

Michigan State University President Lou Anna K. Simon created the MSU Office of Bio-based Technologies in early 2006. Here she discusses the bioeconomy, what it could mean for the state and MSU's role in shaping it.

The Bioeconomy:

MSU President Lou Anna K. Simon

Q: *Do other universities have similar offices?*

A: Yes, but MSU's bio-based approach is much broader. It's not simply about creating alternative energies. It's a comprehensive vision to realize the potential for renewable biomass to replace a whole range of petroleum-based materials and products.

Q: *Why is it important that MSU (as opposed to the University of Michigan or Wayne State) lead the bioeconomy expansion?*

A: The secret behind the bio-based technology office initiative at MSU is the leadership of the Michigan Agricultural Experiment Station at MSU. And the Experiment Station is going to continue to lead the initiative.

To build on all our strengths in agriculture, I've decided that the person who runs the Michigan Agricultural Experiment Station also will be the director of the bio-based technology office — signaling to the world that research in agriculture is broad-based and extends beyond food crops.

However, when people hear the term "Michigan Agricultural Experiment Station," many of them think only of the agricultural production side of the biotechnology equation. But a bioeconomy has to include extensive knowledge of manufacturing and the economics of bio-based products as well as legal and business knowledge. MSU has broad reach in all these fields, making it the perfect place in Michigan to grow this idea.

Q: *Is the bioeconomy a topic discussed among your peers (presidents of other land-grant institutions and other Michigan universities)?*

A: When I attended the BIO 2006 conference a few months ago, there were other universities present in addition to Michigan State, as well as representatives from an array of select science and biotechnology firms. And, of course, there were people who just wanted to learn more about biomass alternatives to energy and materials. It was a very large and broad-scale conference.

Combining Michigan's Strengths with MSU's Cutting-edge Research

I went, not because there's a particular clear-cut role for a university president at a conference of this nature, but because it was important to let others who are engaged in biotech work know about MSU's commitment to this field right now. It's a priority for MSU because it corresponds to our unique land-grant mission and a priority for the state of Michigan as it positions itself among other Midwestern states that are also trying to build new economies around biomass.

So we saw representatives from the University of Chicago, Nebraska, Iowa, Illinois — basically the Corn Belt — because they also understand the potential of developing bio-based technologies.

But what makes Michigan unique is the diversity of plants we produce beyond just corn. And we need to play this to our advantage because we're never going to outproduce some of our neighbors in corn. We have to align our cutting-edge research and technology with a variety of commodity groups here in Michigan to make the most of assets we already have.

Q: *How do you think MSU's work in biotechnology ranks nationally and internationally?*

A: MSU has solid strengths on the national and international fronts.

But the value MSU brings to the rapidly evolving bioeconomy isn't just in its isolated strengths, though they are vast; it's in how MSU is putting the entire bioeconomy package together. No Midwestern state — including Michigan — has the corner on raw materials. But, in addition to state-of-the-art plant science research and development resources at MSU, Michigan has the manufacturing know-how and capacity that other states lack. It's simply a matter of retraining the current manufacturing industry and redeploying it.

It's also a matter of alignment to a new vision. Michigan could take a significant position — nationally and even globally — because of our existing asset base. But we have to be smart about what we do and how we do it. Right now our job is to realize the potential of Michigan's assets. We have to be more innovative, focused and intentional.

Building a bioeconomy in Michigan requires a purposeful strategy of aligning our assets and people on everything from public policy issues to the environmental to transportation concerns. Additionally, we must put our technical know-how forward to think and act strategically in terms of our land-grant mission to build a solid framework for economic development and growth of our intellectual, agricultural and manufacturing capital.

A lot of people don't realize that the bioeconomy goes well beyond biofuels. A good example of a non-fuel bio-based product with great potential is succinic acid, on which MSU holds the patent. Succinic acid is a fundamental intermediate chemical used to make plastics and other kinds of materials, and it can be used to replace petrochemicals in producing such products.

Jeffrey Armstrong, dean of the College of Agriculture and Natural Resources *(right)*, and Doug Buhler, associate director of the Michigan Agricultural Experiment Station, attended a presentation by Thomas Dorr, undersecretary for rural development for the U.S. Department of Agriculture, at the state's first Bioeconomy Summit in Lansing in September.

Right now, in addition to fueling our cars, oil is the main component of plastic products and goods. Fuel is important from an economic and homeland security perspective; we want to move our country toward oil independence. But the importance of finding an alternative to petrochemicals to create products that are potentially safer and cleaner and take less of a toll on the environment cannot be underestimated.

If bio-based products can replace oil-based products, ecologically based limits to economic growth and manufacturing development will all but disappear. The cleanliness and sustainability of bio-based technology offers growth and ecological health simultaneously.

At MSU, we're thinking of the bioeconomy as a long-term developmental strategy, not just a means to fix the high price of gas. Moving to a bioeconomy will be a paradigm shift for the entire world that will create long-lasting progress and change, ultimately ensuring better conditions for a global society.

Q: *Are we seeing international interest in biotech from any of the places currently driving the cost of oil?*

A: We're seeing the beginnings of this, but people everywhere are still struggling with how to embrace ethanol, even whether to embrace it at all. Some people see ethanol as the whole solution, and it's not. It takes a lot of energy to produce ethanol, which is one of the reasons MSU is looking at agricultural products other than corn and bio-based products other than just biofuels.

Q: *Thinking broadly, bioeconomy work has the potential to involve almost every department on campus. Are there certain areas that you think MSU should be focusing on first? Why those areas?*

A: We shouldn't limit our imagination by the parameters of today's problems.

At MSU, we're already looking for scientific and social

solutions to national challenges in ways that take advantage of our assets in people, land and technology. Beyond that, there's potential for more and greater innovation. Fifty years ago, who would have imagined computer chips or nanotechnology? Such unexpected innovation illustrates the real value of bringing together cutting-edge research and the energies of visionary people.

Biotechnology will take significant effort over a long period of time to make it a reality. And it will take time for Michigan to emerge as the epicenter. But Michigan's and MSU's commitment to long-term innovation has historical precedence. When Henry Ford started the automobile industry in Michigan, it wasn't a short-term innovation. It had to develop over time. And because the people of Michigan were persistent, it did.

Interestingly, back around 1930, Henry Ford believed industry and agriculture were natural partners, and that over time, industry would turn more and more to agriculture for raw materials. From our vantage point today, it's easy to look back and see that Ford was right — besides biofuels, we have folks such as Larry Drzal here at MSU working to make a bio-based fender.

At MSU, however, we want to determine how the bioeconomy develops as well as contribute to the innovations that are part of it. MSU is seeking to position itself at the front end of this innovation curve — the biotech equivalent of the Silicon Valley, the epicenter for bio-based developments.

To achieve this goal, MSU has to think about partnerships and competition at the same time. We have to think about local and global markets at the same time. We have to think near term and long term simultaneously. We have to worry about assets at the same time that we spawn ideas in different directions. We can't stop thinking, and we can't slow down.

Consequently, we'll continue to promote traditional and innovative Michigan agriculture in tandem with traditional manufacturing jobs, economic growth, new ideas and entrepreneurship.

Q: *As you look ahead, say 20 years from now, what do you see happening in the bioeconomy?*

A: If MSU and Michigan continue to innovate in research and technology and continue to retool traditional strengths in manufacturing to support biotechnology, Michigan could easily be at the epicenter of this revolution.

But we can't wait for someone else or the government to jump-start it. Government didn't get the automobile industry off the ground. Government didn't start the technology industry in Silicon Valley. Government didn't start agriculture.

Today at MSU, it is a matter of developing a vision, bringing together the best people from around the state, combining their spirit and energy, and figuring out what to do next to help this technology grow. MSU must work to become the 21st century's Microsoft. We have to be bold enough not to settle for incremental change.

MSU President Lou Anna K. Simon addressed the crowd at the Michigan Bioeconomy Summit in September, focusing on MSU's key role in the state's bioeconomy.

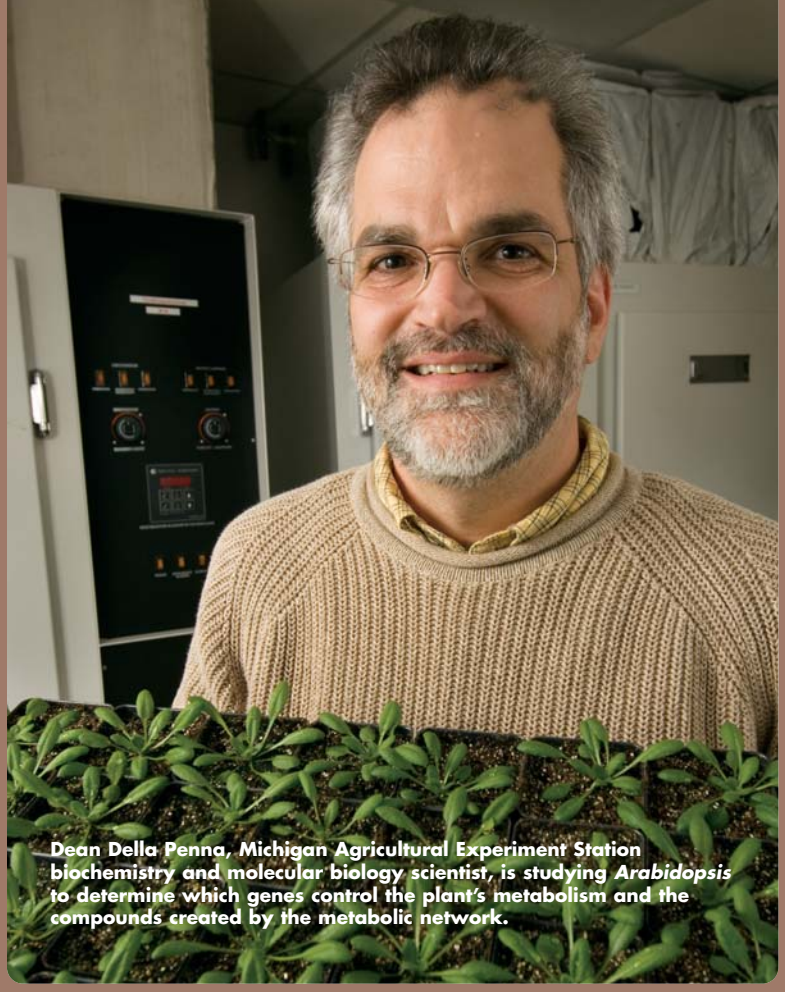
Twenty years ago, three quarters of the current *Fortune* 500 companies weren't on the *Fortune* list; some didn't even exist. These companies arose as the result of vision and innovation. A fundamental part of MSU's land-grant/world-grant mission is to connect people to ideas and the entrepreneurial spirit that results in invention. At MSU, we seek to bring ideas out of the labs and classrooms and into people's homes.

There are a lot of challenges and paradoxes in the world today. But I'm sure the people who founded this university back in 1855 faced tremendous challenges and paradoxes in their world as well. But they persevered. And MSU stands as a tribute to their strength and determination.

Like them, we recognize our place in history; we live and work in a time when change is taking place at a chaotic pace. But we embrace it. And in the field of biotechnology, MSU plans to be at the nexus of its advances.

Q: *Are we responding to the change in society or are we making the change happen in society?*

A: It's always a bit of both, always a bit of both.



Dean Della Penna, Michigan Agricultural Experiment Station biochemistry and molecular biology scientist, is studying *Arabidopsis* to determine which genes control the plant's metabolism and the compounds created by the metabolic network.

Understanding the genes that control how plants fuel themselves will allow researchers to create better bioeconomy crops.

Flexing Plant Muscle

When most people ponder metabolism, it's in terms of how fast or slow their own happens to be. A faster metabolism that burns up calories quicker, converting them to energy to fuel the body, usually results in lower weight.

Plants have metabolisms, too, and though there is no concern about speeding them up to make skinnier plants, two MAES scientists want to understand the genes that control plant metabolism and the compounds that are produced as a result. The ability to control the quantity of each compound produced is hugely important to the bioeconomy.

"To supply the amount of biomass that will be necessary for a thriving bioeconomy, a huge amount of basic research has to be done to prepare the way," said Bruce Dale, associate director of the Office of Bio-based Technologies and MAES chemical engineering and materials science researcher. "MSU's advanced expertise in systems biology, metabolic engineering and biotechnology concentrated in plant systems is important to the bioeconomy's success because that expertise can change the properties and composition of the actual plant raw material."

Dean Della Penna and Dan Jones, MAES biochemistry and molecular biology scientists (Jones also heads the MSU Mass Spectrometry Facility), along with Yair Shachar-Hill, MSU plant biology scientist, received a Strategic Partnership Grant from the MSU Foundation to do some of this basic plant research work. The scientists are studying *Arabidopsis* as a model plant to identify the key genes that control plant metabolism and determine the levels and types of compounds created by the metabolic network.

Plant Metabolism Basics

Instead of getting their nutrients from eating food as animals do, almost all plants get their energy from light and use it to take in carbon dioxide during photosynthesis. During the chemical reactions of photosynthesis, the plant produces sugars such as glucose, which are then made into a variety of necessary structural and functional components, such as oils, starch and cell walls.

"During metabolism, the plants make the sugars into many different compounds — phytochemicals, taxol, oils and antioxidants are just a few," Della Penna said. "If you picture the plant as having internal plumbing, it's similar to the plant sending the sugars down a network of pipes connected by valves, which represent different enzymes, into a number of vats. Each vat is a different compound, and you change what is in each vat by changing the enzyme/valve. In this project, we want to identify the genes — the valves — that control how much goes down each pipe, what the pipes look like and what type of sugar goes down each pipe. Ultimately, we want to understand how all the 'plumbing' works."

Della Penna's expertise is genetics (the pipes in his analogy). Jones's expertise is in analyzing the compounds that are

made (the vats), and Shachar-Hill's expertise is in determining how much of each compound is made (the valves controlling movement through the pipes).

A Vital Component of the Bioeconomy

As Dale emphasized, this work has huge implications for Michigan's bioeconomy. Some of the compounds the plant makes, such as oils and starch, are relatively easy to ferment or use in the production of biobased fuels and other chemicals. Other more complex structural components, such as cell walls, must be pretreated to be used for biofuel and biochemical production. Pretreatment can dramatically reduce efficiency and increases costs. The result is less competitive pricing for bio-based products.

Though the research is just getting underway, the possibilities it presents are tantalizing. If scientists know the genes that control which compound is made, as well as how much of each compound is made, breeders can then develop new varieties of crops that produce large quantities of readily available or easily fermentable compounds, such as oil or starch. Varieties could be created specifically for biofuel production, and in the future, farmers might have the option of growing one variety of corn for food and feed and another for biofuel.

"We're not the ones making the biofuel," Della Penna explained. "We're much further back in the system, trying to engineer plant metabolism on a scale that hasn't been attempted before, which is very exciting. Our work is at a very basic, fundamental level that involves the core components of all plants. What we do in *Arabidopsis* could be applied to almost any plant."

Della Penna also said that scientists aren't sure which plants ultimately might be the best producers of specific desirable compounds. Is corn a better starch producer than potatoes? What about switchgrass? This will require plant breeders to look for natural variation of compound levels among known varieties and then begin to amplify levels of desired compounds.

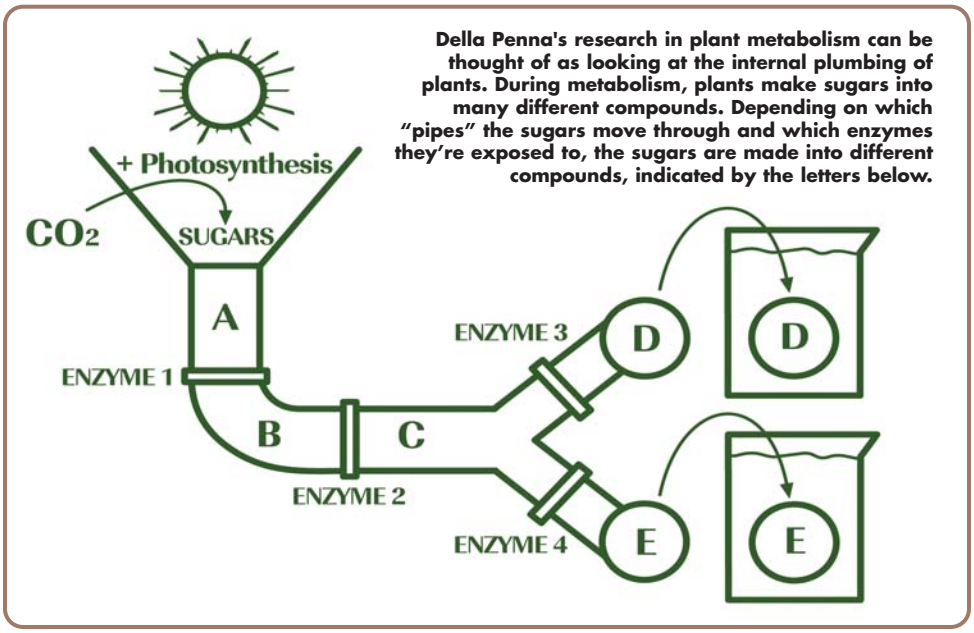
There are limits to how much of one compound a plant can produce, however.

"We could never have a plant produce 100 percent of anything," Della Penna said. "There is no way a plant could be all starch or all oil."

An ideal ratio, according to Della Penna, would be a plant that produced 30 percent oil, 30 percent starch and sugar, and 30 percent cell walls. As the research progresses, he believes that the changes in desirable compound levels will be incremental rather than dramatic.

"We're working synergistically with Bruce Dale and other scientists," Della Penna said. "A successful bioeconomy requires institutions to encourage collaboration among researchers along the entire continuum from basic plant science to applied engineering. The engineers and the biochemists are usually in different buildings and don't really interact. At MSU, we've broken down the silos and put together a group that meets the needs of this research. This innovative vision is necessary for institutions that are going to be leaders in the bioeconomy.

"It's also a question of stamina," he continued. "We won't have a fully vibrant bioeconomy in 3 years — it's going to take longer than that. I feel like we're in the early days of computers; institutions need to generate and push ideas, and then they will be commercialized by private industry."



Della Penna's research in plant metabolism can be thought of as looking at the internal plumbing of plants. During metabolism, plants make sugars into many different compounds. Depending on which "pipes" the sugars move through and which enzymes they're exposed to, the sugars are made into different compounds, indicated by the letters below.

How Vitamin E Helped the Bioeconomy

Della Penna is internationally known for his work on the synthesis and function of vitamin E in plants. It was research on vitamin E that led to the idea for a key part of this metabolic engineering work.

Della Penna found that when a key gene in vitamin E synthesis was disrupted, the movement of carbohydrates from plant leaves was also blocked, causing large amounts of starch (an easily fermentable carbohydrate) to accumulate in the leaves.

"This is a good example of a breakthrough that happened while we were looking at something else," Della Penna said. "You never know when it's going to occur. We made a desirable outcome happen — now we need to understand how it happened and how we can manipulate that to make other desirable things happen."

As more becomes known about the genes that control plant metabolism, the research will expand to involve agronomists. Understanding which varieties grow well in Michigan is an important component of the project's long-term goals.

"Michigan might not be the best place to grow some plants say, current varieties of corn for ethanol production," Della Penna explained. "But we can certainly grow crops that can be fermented into platform chemicals, and we certainly have excellent processing and refining capabilities. We can do a lot of things very well here. And down the road, perhaps new crop varieties will be developed that have higher levels of starch and grow very well in Michigan's climate. The possibilities are very exciting."

::: Jamie DePolo

Detoxing Our

MAES chemical engineering scientist Bruce Dale has been studying how to convert cellulose into ethanol for 30 years. As petroleum prices rise and concerns flare over dependence on imported oil, biofuels may be the antidote to the country's incessant craving for crude oil.

Oil Addiction

Bruce Dale believes that the time has never been more right for biofuel refining to come into its own. "I want to help design the processes so they're environmentally sound," he says.

"The United States has a serious problem."

Bruce Dale, MAES chemical engineering and materials science researcher and associate director of the MSU Office of Bio-based Technologies, is speaking calmly but strongly, and the standing-room-only crowd that has spilled out into the hallway at the 2006 BIO International Convention is hanging on every word. Dale cites the statistics: "In the words of President Bush, we're 'addicted to oil.' Our national and state economies are absolutely dependent on liquid fuels. The United States currently uses more than 140 billion gallons of gasoline and almost 40 billion gallons of diesel fuel annually. More than 60 percent of the petroleum we use is imported, and the percentage is rising."

There's more to the bioeconomy than fuels. But the promise and potential of biofuels for the economy and the environment have captured the attention of politicians, the public and the media like no other bioproduct.

"We really can't do without liquid fuels," said Dale, who has spent his entire career studying ways to turn plant leaves and stems — biomass — into ethanol. He also leads the MSU Biomass Conversion Research Lab at MSU. "Liquid fuels underpin our economy."

Aside from sustaining the country's transportation needs, liquid fuels are the basis of the food supply and the manufacturing, processing and recreation industries. Everything we touch depends on liquid fuels in some way — whether it's getting us to the store to buy it or allowing it to be grown, made or operated.

Compared with petroleum, biomass raw materials are inexpensive. Much of the raw materials are now considered waste — stems and stalks left over after plants are harvested. But the processing costs for turning plant materials into ethanol, biodiesel and other biochemicals traditionally have been much higher than the costs for turning crude oil into gasoline and diesel fuel. This has been a longstanding roadblock for widespread acceptance of biofuels. When gasoline was cheap and plentiful, not many people wanted to pay more for ethanol, despite its many environmental benefits. But as the cost of crude oil jumped and hurricanes Rita and Katrina caused gasoline shortages and spiking prices, ethanol began to look more and more attractive.

"At $20 per barrel, oil is still cheaper to refine than biofuels are," Dale explained. "But when oil costs $40 a barrel, biofuels are very competitive."

Now that oil prices are hovering around $60 per barrel, Dale believes the time has never been more right for biofuel refining to come into its own.

"I strongly believe that bio-based fuels and chemicals will become a reality," he said. "I want to help design the processes so they're environmentally sound."

If the interest in Dale's presentation at BIO 2006 — or interest in the whole of BIO 2006 — is any indication, his prediction may come true sooner rather than later. The annual international convention and exhibition is sponsored by the Biotechnology Industry Organization and is the largest biotechnology event in

the world. Countries, universities, private companies, entrepreneurs, venture capitalists and others attend to learn about new technology, business development, and licensing and partnership opportunities.

"Former President Bill Clinton spoke at BIO 2006," said Steven Pueppke, director of both the Michigan Agricultural Experiment Station and the Office of Bio-based Technologies, who also attended the conference. "He noted how one of the primary challenges of this current century will be to reduce our dependence on fossil fuels and grow our own. That's why all of us were at BIO 2006 — to talk to one another, to figure out where we are and where we need to go, and to kick the effort into high gear."

"The ultimate success of biofuels will be determined largely by the ability to manipulate plants at the genetic, seed and field level. MSU is the premier place for this work to be done." —Bruce Dale

Breaking Down Cellulose More Efficiently

Much of Dale's research focuses on technology to convert biomass from plant materials into ethanol.

Plants are a huge potential source of energy — each year plant biomass captures an amount of energy equivalent to about eight times the total energy used by people from oil, coal, natural gas, wind, water, etc. But about 90 percent of this biomass energy is unavailable for use because it's in the form of cellulose and hemicellulose, the complex sugars that make plant stems and leaves and tree trunks rigid. Cellulose and hemicellulose don't dissolve in water. This is good for plants but not so good for making biofuels. Before the complex sugars can be fermented into ethanol, they have to be broken down into simple sugars, such as glucose, by enzymes. Microorganisms are then used to ferment the glucose into ethanol.

Breaking down cellulose and hemicellulose into fermentable sugars cost effectively has been the main issue slowing ethanol production. It's difficult to do efficiently and can significantly raise production costs, and that makes ethanol more expensive to refine than gasoline.

Dale has developed a process, ammonia fiber expansion (AFEX), to pretreat biomass with ammonia. The AFEX process, for which MSU has received a patent, makes the breakdown of cellulose and hemicellulose more efficient. Using enzymes alone, about 15 percent of cellulose and hemicellulose are broken down into simple sugars; when AFEX is used before adding the enzymes, more than 90 percent of the cellulose and hemicellulose are broken down into fermentable sugars. After treatment, the plant material comes out looking a bit like popcorn — slightly puffed up and dry.

In July 2006, Dale received a $790,000 Strategic Partnership Grant from the MSU Foundation. This research will refine and enhance the AFEX process, integrating it with both commercially available enzymes and new enzymes being developed on campus. The sugars produced will be fermented into ethanol using microorganisms developed by top research groups. In September 2006, U.S. Rep. Mike Rogers, who has made several visits to Dale's campus lab, announced that MSU was to receive almost $400,000 from the Biomass Research and Development Initiative, a joint project of the U.S. departments of Agriculture and Energy. This grant money will be used to better understand and improve the environmental performance of ethanol and other biofuels.

Dale firmly believes in ethanol as an alternative to gasoline — as opposed to hydrogen fuel cells or solar-powered cars — because of both its quality and its form.

"The quality of the energy is important," he said. "Ethanol is a good quality fuel. We have about $10 trillion invested in the infrastructure for liquid fuels, so that's what we have to work with — we're not going to change that infrastructure anytime soon. Any fuel alternatives are going to have to be in liquid form."

The Supply Chain of Biomass

Most experts agree that ethanol isn't a niche fuel anymore. The 2005 Energy Act made ethanol a permanent part of the country's fuel mixture, and production is expected to rise from a current 4 billion gallons per year to about 7.5 billion gallons per year by 2012, according to Dale. Most of this will be made from corn grain.

"But construction of new ethanol plants is moving so quickly that we'll achieve the 7.5 billion gallon target much earlier than 2012," Dale said. "The Energy Act of 2005 also mandated that 250 million gallons of ethanol be produced from cellulose materials by 2012."

Ethanol continues to raise some questions, however. Some critics contend that corn grain, the primary crop currently used to make ethanol, needs more fertilizers and pesticides than other crops that could potentially be used. But because the corn lobby is so strong, the critics say, other crops aren't being studied as intensively as raw materials for ethanol. There are also concerns about potential air pollution coming out of ethanol refineries.

According to statistics from Dale, about 400 gallons of ethanol can be produced from an acre of corn grain. The technology for making ethanol from switchgrass isn't well developed yet, but he estimates that improvements will allow about 1,000 gallons to be made from an acre of switchgrass, more than doubling production from corn grain.

"Increasing interest in ethanol will encourage the United States to grow more perennial grasses, such as switchgrass," Dale

said. “Grasses are a good source of protein for animals and can also provide more ethanol per acre than corn.

“That’s why I believe MSU is the premier place for this work to be done,” he continued. “We have one of the top three plant science programs in the world. MSU is the foremost university worldwide in the field of plant metabolism and biochemistry. The ultimate success of biofuels will be determined largely by the ability to manipulate plants at the genetic, seed and field levels. MSU researchers such as Christoph Benning, John Ohlrogge, Dean Della Penna, Yair Shachar-Hill and Ken Keegstra are manipulating non-food plants — woody plants and grasses — so the conversion process from biomass to biofuel is more efficient. This research is going to fundamentally change biofuel production.”

Coupled with Dale’s work on pretreating biomass, all this MSU research on making cellulosic ethanol — ethanol from cellulose and hemicellulose from grasses, wood and other biodegradable material rather than grain — holds much promise. Bill Knudson, product marketing economist in the MSU Product Center for Agriculture and Natural Resources, said cellulosic ethanol would unhitch ethanol production from corn-producing areas and allow biorefineries to exist in a variety of areas.

“The potential with cellulosic ethanol is enormous,” Knudson said.

Cellulosic ethanol also may be better than corn-based ethanol for the environment. An article in the January 2006 issue of *Science* reports that production and use of cellulosic ethanol gives off about 90 percent less greenhouse gases than gasoline. The authors report that corn-based ethanol results in about 13 percent lower emissions than gasoline.

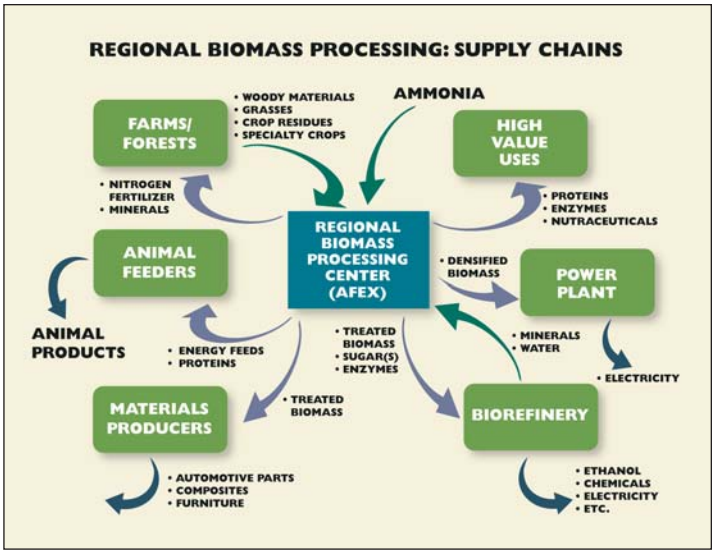
Creating Biorefineries

As new technologies are developed, the logistics of ethanol become more complex. Dale and other experts agree that when crude oil prices are $40 per barrel and higher, the cost of ethanol becomes very competitive for consumers. But a gallon of ethanol provides only about 75 percent of the mileage that a gallon of gasoline does in current engines. Satish Udpa, dean of the MSU College of Engineering, said that MSU engineering researchers are developing new engine technology that will reduce or eliminate this discrepancy. So exactly how much ethanol does the United States need to refine to meet current fuel needs? And do we have the land available to grow all this biomass?

“Those seem like simple questions, but the answers aren’t simple,” Dale explained. “The United States uses about 140 billion gallons of gasoline each year and about 40 billion gallons of diesel. If we had 140 billion gallons of ethanol at some time in the future, we could probably replace all of our gasoline because we’d be building cars with engines designed for ethanol. If we did it today, with current engine technology, we would need about 200 billion gallons of ethanol to replace all our gasoline.”

If only corn were used to make ethanol, this would translate into 460 million acres of the crop at 160 bushels per acre.

“That’s more than all of the cropland in the United States,” Dale said.



Bruce Dale’s concept of a regional biomass processing center supply chain shows how renewable materials such as crops, grasses and woody plant material will be turned into a range of products, from fuels to electricity, enzymes, composites and furniture, some of which will be used to power the processing center.

One ton of switchgrass produces about 70 gallons of ethanol, and researchers are aiming for an ultimate target of 100 gallons per ton. Right now, an annual yield of 5 tons of biomass per acre of switchgrass is the production standard. In the near future, Dale believes that it would be possible to produce 15 tons of biomass per acre of switchgrass. This is a significant increase that would mean about 130 million acres would be needed.

The supply chain particulars of providing biomass for ethanol production are as important to the biofuel’s future as the technology to refine it. To couple the two, Dale has developed a supply chain for biomass.

The hub of the operation, a regional biomass processing center, would contract with approximately 100 farmers to use the AFEX process to pretreat locally grown grass or residue for animal feed.

“The same physical and chemical barriers that slow down bioconversion of cellulose to sugars in a biorefinery also interfere with bioconversion in ruminant animals, such as cattle, and these barriers are broken down by AFEX,” Dale explained. “Preparing animal feed at a regional center will create the supply chain, logistics and economies of scale required to supply pretreated, densified biomass to a biorefinery, and perhaps higher value products and solid materials for other uses. Densified biomass might also be provided to an electric power plant for direct burning.”

The biorefinery would process about 5,000 tons of cellulosic biomass per day supplied by more than 1,000 farmers, Dale said. This would require about 500 farmers each growing 500 acres of switchgrass.

“The designs we’re developing assume that the scales are small enough so farmers can invest in them, just like a corn dry mill or cooperative,” Dale said. “This would be an economic boost for the farmers as well as the state. They wouldn’t just be the raw material providers — they would be part of the value-added process and would capture more of the economic benefits.”

::: Jamie DePolo

The Greening of Brownfields

Biofuel crops may provide alternative energy, clean up industrial waste sites and provide data for national B-20 specifications — a win-win-win situation.

On a 2-acre plot in northwestern Oakland County, Kurt Thelen, MAES crop and soil sciences researcher, is growing soybeans, corn, canola and switchgrass. Nothing unusual about that — except that the 2 acres are part of the 110-acre Rose Township Dump site, designated a Superfund site by the Environmental Protection Agency.

Industrial waste sites are also known as brownfields. Thelen's research is exploring two intriguing possibilities: Can the site produce crops that have the quality and yield for biodiesel or ethanol production? And can the biofuel crops help clean up the contaminated soil?

The research project is a partnership between MSU, the DaimlerChrylser Corporation and NextEnergy, a nonprofit organization that supports alternative energy research and development. If the results are successful, similar plots might sprout

Above: **Jim Croce, CEO of NextEnergy; Deborah Morrissett, vice president of regulatory affairs for DaimlerChrysler; and Kurt Thelen, Michigan Agricultural Experiment Station crop and soil sciences researcher, show off a Ram pickup truck that runs on biodiesel. The three hosted a harvest party at the Rose Township site in October so the media could see the biofuel crops growing on the brownfield site.**

Left: **Thelen grew soybeans, corn, canola and switchgrass on the brownfield site. The plots were replicated on campus and at the Upper Peninsula Experiment Station. Over the winter, the harvested crops will be analyzed for oil quantity and quality.**

across the state and the country on sites that are unsuitable for commercial or residential use.

"Right now, brownfields aren't productive and can be an eyesore for the local community," Thelen said. "We know we would need a lot of acres to produce the amount of biomass needed for biofuel production, so the scale-up of this research involves other types of agricultural lands that are marginal because of soil productivity, latitude and other limiting factors. This 2-acre site may seem like a drop in the bucket, but we're looking at the possibility of taking land that isn't productive and using it to both learn and produce. I know if I had a brownfield in my neighborhood, I'd prefer it be greened up and put to a productive use."

Developing Specs for B-20

In 1998, when Chrysler merged with Daimler-Benz AG to become DaimlerChrysler, the company became one of the largest producers of diesel engines in the world, according to Max Gates, DaimlerChrysler spokesperson.

"We want to promote the use of diesel and biodiesel as more efficient, environmentally friendly alternatives to gasoline and as a way to support the American economy," Gates said. "We knew that NextEnergy was studying renewable fuels, and we were very interested in what they were doing."

"NextEnergy was founded by the state to accelerate the research, development and commercialization of alternative energy in Michigan," said Jim Croce, NextEnergy chief executive officer. "In partnership with Bosch, Delphi, Biodiesel Industries, DaimlerChrysler, Wayne State and the U.S. Army Tank Command, we launched a national biofuel energy lab at our facility in Detroit."

Both groups would like to see national standards developed for what constitutes B-20, a blend of 20 percent biodiesel and 80 percent petroleum diesel, and they are providing data to government and private engineers who are working on the standards. As DaimlerChrysler and NextEnergy projects explored more efficient and effective biofuel production systems, researchers wanted to know how various crops functioned in these new systems. Because MSU is internationally known for its plant science work, the groups contacted the Michigan Agricultural Experiment Station for help and were referred to Thelen. The Rose Township research is funded by Project GREEEN, Michigan's plant agriculture initiative at MSU.

"As the chemical engineers work on developing national specs for B-20, we'll grow the crops in marginal areas and see if they can meet them," Thelen said. "We're replicating our study on campus on good agricultural land and plan to include plots at the Upper Peninsula Experiment Station in Chatham to compare yields and the quality of biofuel produced from agricultural land vs. marginal brownfield land, as well as comparing results from crops grown at different latitudes. We want to see if the brownfield environment affects crop yield or the quality of the biodiesel or ethanol produced from the crop."

Thelen *(center)* discusses the research with Croce *(left)* and Morrissett. The first phase of the research will determine whether the crops can be logistically and economically grown on the site.

"There are a number of feedstocks that can be used to make biofuels," said NextEnergy's Croce. "We need to know how each will fit in and comply with the national standard when it's developed."

Cleaning Up Underground

DaimlerChrysler has widely promoted the use of biodiesel in its diesel engine products, including several sport utility vehicle (SUV) and pickup truck models. But the company was criticized in Europe by people concerned that growing biofuel crops would take precedence over growing food crops and compromise food production. At the same time, the company knew that it had to do something about the Rose Township dump site. Thelen's research elegantly combined the two issues.

"Cleaning up the Rose Township land was something we knew we had to do," Gates said. "DaimlerChrysler is not responsible for all the pollution at the Rose Township site, but we negotiated an agreement with all the other parties whose waste was dumped at the site to clean it up. We're also very interested in growing fuel crops on nonproductive or northern land — nontraditional agriculture land. This research addresses both issues."

According to Thelen, no one is quite sure exactly what was originally dumped, although the cleanup has led to a good inventory of what remains at the site, which is classified as a mature Superfund site. Federal regulators have worked to remove much of the most toxic pollutants by removing and burning the soil. Groundwater from below the root zone is still being pumped out and cleaned by processing in an air stripper.

Thelen's phytoremediation (the use of plants to clean up contaminants) research has three parts.

"First, we'll be looking at 'proof of concept,' which means can we logistically and economically grow the plants on the site," he explained. "Then we'll look at the quality of the oil that is produced by the plants. One of the questions we want to answer is what happens to any pollutants that are taken up by the plants — do they affect the quality of the biofuel or byproducts that are produced from the biomass?"

The third aspect of the research is examining the phytoremediation process itself — its effectiveness and efficiency.

"The plants don't have to actually take up the contaminants," Thelen said. "Just by growing, the roots of the plants increase the biological activity of the soil, and that speeds up the bioremediation process. The plants could take up contaminants — we're just not sure to what extent and what effect that will have on fuel quality. That's going to take more research and investigation."

Thelen said the main focus of this first year of research is to compare how the various crops grow on the brownfield site and evaluate their yields and the quality of biofuel produced from each. MSU engineering scientists also will use his results because a number of parameters can be used to analyze and evaluate the plant oil. He hopes to have preliminary yield information by the end of December. Laboratory analyses of biofuel quality will continue through the winter.

"Biofuel production is going to require a significant land base to meet future production expectations," Thelen said. "Using marginal lands or sites that aren't preferable for food crops is a good idea that needs to be explored. Our hope is that it's something that can offer multiple benefits."

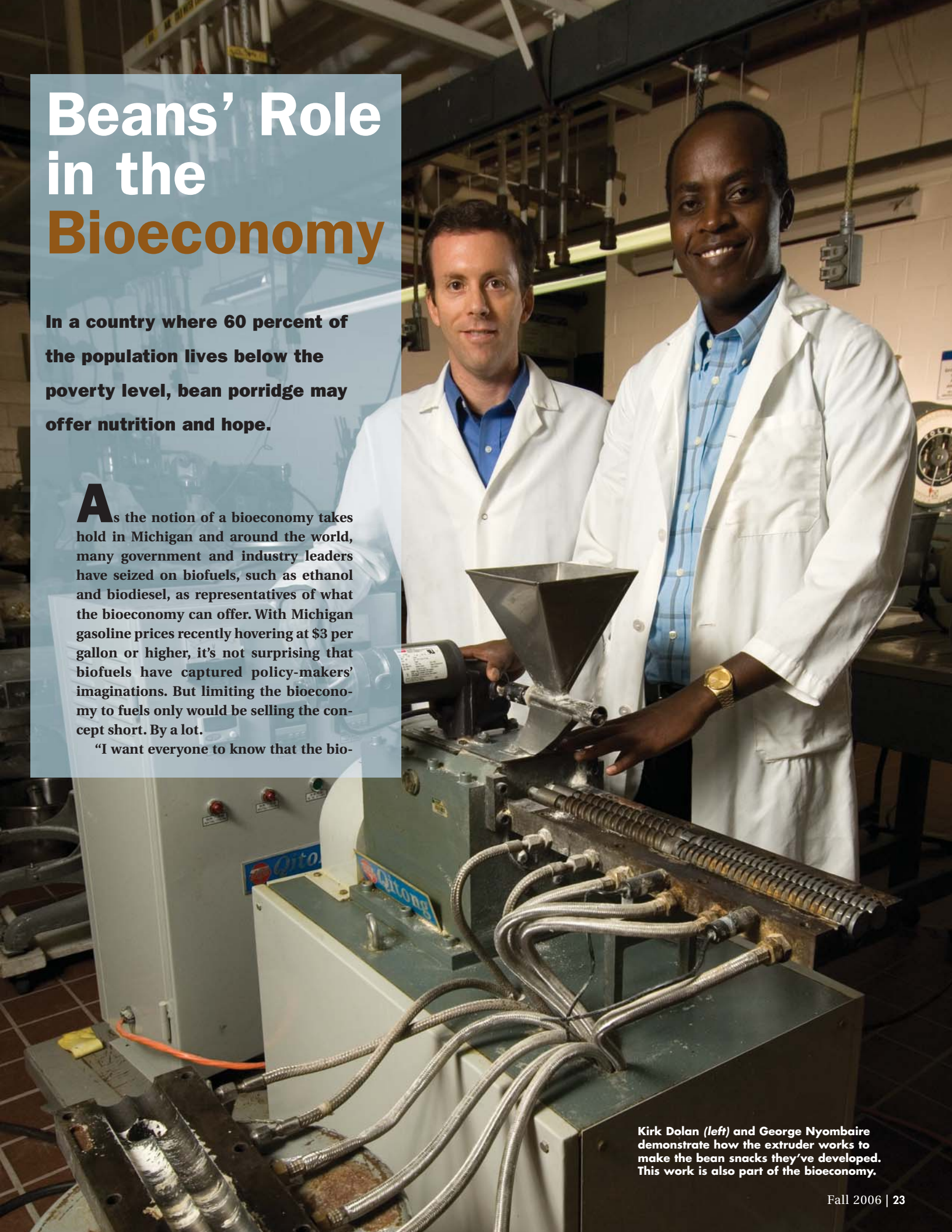
::: Jamie DePolo

Beans' Role in the Bioeconomy

In a country where 60 percent of the population lives below the poverty level, bean porridge may offer nutrition and hope.

As the notion of a bioeconomy takes hold in Michigan and around the world, many government and industry leaders have seized on biofuels, such as ethanol and biodiesel, as representatives of what the bioeconomy can offer. With Michigan gasoline prices recently hovering at $3 per gallon or higher, it's not surprising that biofuels have captured policy-makers' imaginations. But limiting the bioeconomy to fuels only would be selling the concept short. By a lot.

"I want everyone to know that the bio-



Kirk Dolan *(left)* and George Nyombaire demonstrate how the extruder works to make the bean snacks they've developed. This work is also part of the bioeconomy.

After the beans come out of the extruder, they're a crunchy snack that can be eaten as is or ground into a powder, which can be stored safely for long periods of time in plastic packets. The powder is mixed with hot water to make a nutritious porridge.

economy is more than just ethanol — it's more than just fuels," said Steven Pueppke, MAES director, who is also director of the MSU Office of Bio-based Technologies. "It's about making plants more valuable."

Kirk Dolan, MAES food science and human nutrition and biosystems and agricultural engineering researcher, studies processing techniques for new food products. He and graduate student George Nyombaire have developed an extruded bean product that may help ease some of the hunger and nutritional deficiency issues in Rwanda, Nyombaire's native land. This work is also part of the bioeconomy.

"George wanted to focus on a bean product because developing more products that use beans is one of Rwanda's priorities," Dolan explained. "But this is also a new healthy and nutritious product for Michigan consumers and represents a new market for Michigan bean growers. One of the ideas behind the bioeconomy is to offer farmers higher value uses for their crops."

Nourishing Rwanda's Recovery

Land-locked in the east African hill country, Rwanda is both one of the most densely populated and one of the poorest countries in the world. More than 60 percent of Rwanda's population lives below the poverty level.

In 1991, civil war erupted in the northern province of Byumba. In April 1994, the war exploded into one of the most tragic events in modern human history — more than 800,000 Rwandans were slaughtered by their countrymen from April to July.

Today, as the country struggles to emerge from the physical and emotional wreckage of genocide, feeding its people nutritious, healthy food is a top concern for Rwanda's leaders. At the same time, they also need solutions for environmental issues such as deforestation, soil erosion and soil nutrient depletion.

The extruded bean product offers an elegant solution to both nutritional and environmental issues, all wrapped up in one tidy plastic packet.

"Rwandans eat more beans than anyone else," Nyombaire said. Before he came to MSU, Nyombaire was an agriculture faculty member at the National University of Rwanda in Butare in southern Rwanda. His research is also funded by project PEARL (Partnership for Enhancing Agriculture in Rwanda through Linkages). PEARL was conceived and launched by Dan Clay, director of the Institute of International Agriculture at MSU. Backed by U.S. Agency for International Development funding, PEARL is working with Rwandan agricultural institutions to rebuild the country's educational and research capacities. "Each person eats about 60 kilograms [a little more than 130 pounds] of beans per year. In the United States, people eat about 3 kilograms [about 3.5 pounds] per year."

"Beans are to Rwanda are what breads are to the United States," Dolan added.

But beans also are contributing to the country's environmental woes. Because Rwandans don't soak the beans before cooking, the beans have to be boiled for about 5 hours. To cook beans, people are stripping the countryside bare, chopping down trees for firewood. Even though cutting wood has been outlawed, people continue to do it. They need to eat.

Storing the beans is also a problem.

"There's a huge weevil problem in Rwanda," Dolan explained. "About 40 percent of beans are lost each year to insects, animals or spoilage."

About 90 percent of Rwanda's people are subsistence farmers. Families have, on average, a half-acre of land on which to eke out a livelihood. Any crop loss means less food for people.

Nyombaire's innovative solution grinds the beans and then runs them through an extruder, a machine akin to a giant Play-Doh Fun Factory for food. Most processed foods — such as breakfast cereals, snacks and crackers — are made with an extruder. The extruder cooks the bean dough and then presses it out through a small hole known as a die. The bean product is fully cooked and looks somewhat like a small rope of dried cereal. It can be eaten as is or ground into a powder, which can then be stored safely for long periods of time in plastic packets.

Before Nyombaire's research, no one in Rwanda was using or had considered using an extruder to make food products. Typical American or European extruders can cost $100,000 or more, which is too expensive for Rwanda.

"That's really more than this project needed, both cost-wise and technology-wise," Dolan explained. "We wanted something simple and inexpensive that was easy to operate. I was having a

"The beauty of George's solution is that the bean product is a safe product. It's dry and fully cooked and is resistant to microbial spoilage, and animals and insects can't get into it." — KIRK DOLAN

conversation with Maurice Bennink [MAES food science and human nutrition researcher], and we started talking about inexpensive extruders made in China. We thought they would be very suitable for what we were doing in Rwanda, so we ordered one.

"This really isn't competition for U.S. extruders," he added. "It's like comparing a go-kart to a real car — there's no comparison."

After some modifications in the biosystems and agricultural engineering lab to make the extruder suitable for food use, Nyombaire was ready to begin production.

"The beauty of George's solution is that the bean product is a safe product," Dolan said. "It's dry and fully cooked and is resistant to microbial spoilage, and animals and insects can't get into it. Many times harvested beans are stored under tarps or piled in corners, so it's easy for them to become contaminated. The extruded bean product solves all those problems."

The powder can be mixed with some warm water and a little bit of sugar to make a rather tasty porridge, similar in texture to grits or Cream of Wheat. The bean product is also nutritious, containing 22 grams of protein, 1 gram of unsaturated fat and 24 grams of fiber per 100 grams of product.

"The protein in beans is rich, high quality protein," Nyombaire said. "We think this is a really nutritious product that people will enjoy eating. We are also investigating adding sweet potatoes to the mix. This would add beta carotene, a form of vitamin A, to the product, which would help reduce that nutritional deficiency."

Approximately 250 million children are at risk for vitamin A deficiency worldwide, and about 4.4 million preschool-age children have visible eye damage due to this deficiency. African countries have particularly high levels of vitamin A deficiency.

And though the extruder cooks the beans, it takes much less money, energy and firewood to make the extruded bean product and mix up the porridge than it does to cook the beans for 5 hours as people do now.

"Using electricity is far cheaper and safer than using firewood," Nyombaire said. "Using the extruder also reduces air pollution from the smoke from the cooking fires."

According to Dolan and Nyombaire, a company could be set up to make the bean product in Rwanda.

"You'd need a consistent electrical supply, three pieces of equipment — a grinder, an extruder and a packaging machine — and a room to put the equipment in," Dolan said. "It would probably cost about $20,000. It wouldn't be easy, but this gives entrepreneurs, or the government or even a cooperative of farmers a plan to follow. Creating information like this is a good role for the university — this can improve people's health, give them a better quality of life, and help the economy and the environment."

The Final Test: Do People Like It?

In May 2006, Nyombaire spent time in Rwanda conducting taste tests on the bean porridge and the dry extruded bean product as a snack. Though many Rwandans are accustomed to eating porridge, he wasn't sure how people would react to eating porridge made from beans or to the dry snack food.

"We got very good results," he said. "I made up the porridge and didn't tell people what it was made from. They liked it and guessed that it was made from corn, millet, sorghum or wheat — they didn't believe me when I told them it was made from beans."

The scientists had some concern that the porridge might have a bean flavor that wouldn't be pleasing to potential consumers.

"The anecdotal evidence points to a loss of bean flavor during extrusion," Dolan said. "We thought the cooking reduced the 'beaniness' of the porridge, but we weren't sure what the Rwandan consumers would think. All the testing went really well."

Nyombaire took the bean porridge and snack to the National University of Rwanda Hospital and asked women who had just given birth to try them. He also went to elementary and middle schools. The results were unanimous: everyone enjoyed them. Nyombaire didn't have the opportunity to test the product among adult men, but the results bode well because women make most of the meal selections in Rwanda.

"If the product is going to be marketed, you'd want to do a lot of demonstrations, especially for the snacks," Dolan said. "There might be a little education needed there because that's not really similar to anything Rwandans eat right now."

As Nyombaire finishes his degree, he is excited about the possibilities for helping Rwanda.

"People, especially women, can form associations and buy extrusion equipment," he said. "They can process and sell extruded bean products and make money to pay medical bills and school fees for their children. In doing so, they improve the nutrition of Rwandans and at the same time boost the economy of the country."

::: Jamie DePolo

Research *in the news*

Nugent Honored at Advisory Board Meeting

James Nugent, coordinator of the Northwest Michigan Horticultural Research Station and MSU Extension district horticulturalist, was honored for his work with the cherry industry at the quarterly MAES/MSUE State Advisory Council meeting in October.

Nugent received a letter of recognition from Mitch Irwin, director of the Michigan Department of Agriculture.

In the photo above, Nugent *(center)* is congratulated by Irwin *(left)* and Don Coe, managing partner of Black Star Farms and member of the Michigan Commission of Agriculture.

Pueppke Named to New Renewable Fuels Commission

Steven Pueppke, director of the MSU Office of Bio-based Technologies and the MAES, was named to the newly formed Michigan Renewable Fuels Commission by Gov. Jennifer Granholm. The commission will promote the production and distribution of alternative fuels in Michigan.

"As more E-85 and flex-fuel vehicles are produced, it is essential that we make biodiesel and ethanol products more widely available and encourage their use," Granholm said. "This commission will move Michigan one step closer to becoming the nation's leader in developing and producing alternative energy."

The Michigan Renewable Fuels Commission was established under the same act that reduced the gas taxes on ethanol and biodiesel fuel, provided grants to service station owners who renovate or expand their existing stations to make E-85 and biodiesel available, and allowed for the creation of new agriculture renaissance zones to help spur additional ethanol and biodiesel plants. Granholm has called for the state to have 1,000 biofuel pumps available by 2008.

The commission is charged with investigating and recommending strategies to promote the use of alternative fuels and encourage the use of vehicles that utilize alternative fuels. The commission also will identify mechanisms that promote research on alternative fuels.

MSU Names New Animal Ag Environmental Stewardship Director

A nationally recognized expert on odor control was named to head animal agriculture environmental stewardship at MSU.

Wendy Powers, associate professor of animal science and agricultural and biosystems engineering at Iowa State University, was named director of environmental stewardship for animal agriculture and professor of animal science and biosystems and agricultural engineering on Nov. 1. She also is a Michigan Agricultural Experiment Station and MSU Extension faculty member.

"I am excited to be joining Michigan State because of the caliber of the institution and the departments I am joining, and also because of the diversity of agriculture in Michigan," Powers said. "That diversity offers both unique challenges and unique opportunities. My goal is to facilitate a coordinated effort to address animal production environmental issues by working with clients to implement technology as it is developed and by working with policy-makers to convey science-based information so that relevant and effective policy can be developed."

A national expert on evaluating air quality for livestock, Powers uses a multi-species approach in her research to address environmental issues that affect animal agriculture. She will work closely with other MSU researchers to evaluate the impact of air and water quality on human health.

"Dr. Powers is developing a cutting-edge program that links animal agriculture, the environment and human health using an interdisciplinary, integrated approach," said Jeffrey Armstrong, dean of the College of Agriculture and Natural Resources. "Her work will provide science-based information that will ultimately benefit all animal producers in the state."

As director of environmental stewardship for animal agriculture, Powers is working to influence policy and practices that will mitigate and improve the effects of livestock production on the environment. She has a leadership role in developing collaborative, multidisciplinary research and outreach programs focused on enhancing environmental stewardship in Michigan's animal agriculture industry.

"I am thrilled that we were able to attract Dr. Powers to MSU," said Karen Plaut, chairperson of the Department of Animal Science. "Her expertise in air quality and her understanding of the environmental issues that are facing animal agriculture ensure that Michigan producers will continue to be seen as leaders in the stewardship of our land, air and water."

A prolific author and speaker, Powers is a member of numerous professional associations and government committees, including the Iowa State University College of Agriculture Concentrated Animal Feeding Operations Response Team, the Iowa State University College of Agriculture/University of Iowa Department of Public Health/State of Iowa Air Quality Task Force, the Iowa Nutrient Management Task Force, the National Academy of Sciences Committee on Air Emissions from Animal Feed Operations, the American Dairy Science Association/American Society of Animal Science Program Committee for Contemporary and Emerging Issues (chair in 2003-04), and the Environmental Protection Agency Safe Harbor Monitoring Plan Committee.

Powers has been at Iowa State since 1997, first as assistant professor, then associate professor. In 2006, she received a Standards Developer Award from the

American Society of Agricultural and Biological Engineers; in 2004, she received the Distinguished Scientist Award from the Iowa Academy of Science, and in 2003, she received the Iowa State University Foundation Award for Outstanding Early Achievement in Extension and the American Society of Animal Science Midwestern Section Young Extension Specialist Award.

Powers received her bachelor's degree in animal science from Cornell University in 1989 and both her master's degree in dairy science and her doctorate in animal science from the University of Florida, in 1993 and 1997, respectively.

MAES Researcher Traces Evolution of Honey Bee Gender

A first-of-its-kind evolutionary strategy discovered among honey bees shows how a complex genetic mechanism determines gender and maximizes gene transmission to the next generation of several bee species, according to Zachary Huang, MAES entomology researcher.

The research of Huang and his colleagues was featured in the Oct. 26 edition of the journal Genome Research.

"This research gives us a better understanding of the sex-determining system of honey bees, as well as the age and evolutionary history of the csd (complementary sex determination) gene," Huang said. "The various versions of the csd genes are shared among honey bees. They evolved before they became different species."

In addition, the findings also will allow breeders to design better and more efficient mating systems. Breeders more easily will be able to raise new queens to lead hives.

The research is supported by grants from the National Institutes of Health, Office of Vice President for Research of the University of Michigan, the University of Kansas General Research Fund and the Michigan Agricultural Experiment Station.

The csd gene determines the difference between a male and female honey bee, according to Huang. His research shows this method of sex determination first appeared in a shared ancestor of the European and three Asian honey bee species.

In humans, sex is determined by the combination of sex-determining chromosomes one has. In females, both sex-determining chromosomes are the same: XX; for males the two chromosomes are different: XY.

Honey bees do things a bit differently. Specific combinations of the csd gene regulate the gender and social roles of each honey bee.

In the past, scientists thought the sex determination of offspring was left purely up to the queen, Huang said. Scientists believed that after a queen bee returned to her hive from a mating flight she had a choice of laying fertilized or unfertilized eggs. The unfertilized eggs would develop into male drones. The fertilized eggs develop into female honey bees. But there's more to the story.

Alleles are different versions of the same gene. In humans, they dictate characteristics like eye and hair color.

If the bee has two different alleles, the csd gene will be female. If it has only a single version of the gene, it will become a normal, fertile male. Finally, if the bee has two identical csd types it will become a diploid male, which is infertile, Huang explained. The unlucky infertile males will never successfully reproduce so they are eaten by other members of the hive to save resources.

Aside from determining life and death, the csd mechanism is important to the overall function of the hive.

There's a big difference between the duties of a fertile male honey bee and those of a female. The males lead a life of luxury — their duties include eating, resting and mating.

After hatching, a female's life can take one of two directions. Fed a diet of royal jelly, the female hatchling will develop into a queen bee. If not, she will become one of the 20,000 to 60,000 worker bees tending to the needs of the hive, the drones, her queen and the next generation.

Ultimately the csd system shared by all honey bee species means increased genetic diversity and a better chance for their genes to carry over to the next generation.

"This is a matter of gene transmission," Huang said. "It is an evolutionary strategy to maximize gene transmission to the next generation."

MAES Researcher Cracks Genetic Secrets of Human Egg

The human egg's ability to transform into a new life, or into new cells that may someday save lives, is well documented. The mystery lies in the mechanics — in how a single cell can transform so nimbly.

A team of MSU scientists led by Jose Cibelli, MAES physiology and animal science researcher, reported in the Sept. 5 Proceedings of the National Academy of Sciences that they have identified genes unique to the human egg. The identification opens the way to understanding these genes' functions, which may lead to solving problems ranging from infertility to degenerative diseases.

"What's in the egg to have that power?" Cibelli asked. "Some of those genes are responsible for the magic trick that the egg has. This paper takes a peek at what genes are in the egg waiting to make these changes."

Combined with sperm, the egg divides and organizes cells to ultimately create a human being.

Combined with technology, the unfertilized egg might be coaxed to produce other specific cells, including stem cells, which can be directed to grow into new tissue. This potential could be used to combat diseases.

Cibelli said his team's mission is to grow stem cells without using fertilized embryos, which can be controversial. This work used only unfertilized human eggs that were obtained from women seeking fertility treatment at a clinic in Santiago, Chile. Women at the clinic must be reproductively healthy and no older than 35, and the cause of infertility must lie within the man. This meant the availability of exceptionally healthy eggs, Cibelli said. All the donors granted informed consent for their surplus eggs to be used for this research.

Cibelli worked with researchers in Chile to extract the RNA from the unfertilized eggs soon after they were harvested. That material, a treasure of genetic information, was frozen and shipped to MSU.

Cibelli's team — Arif Murat Kocabas, Pablo Ross, Zeki Beyhan and Robert Halgren — started analyzing the thousands of genes represented in the human egg to identify those that are unique to

the egg. They teamed with Beth Israel Deaconess Medical Center at Harvard Medical School in Boston to work with sophisticated bioinformatics software.

To make a comparison that would show which genes were uniquely active in the human egg, they used RNA of all parts of the human body except that of the ovaries, where eggs are produced.

Then the computer analysis began. In a highly sophisticated matching game, every gene in the egg that was found in other tissues was eliminated, so that only unique genes remained.

Cibelli said that the team identified 5,331 human genes that are overexpressed in the egg. Of those, 1,430 are mysteries — their function is unknown.

The group also compared the human egg genes with those of a mouse as well as human and mouse embryonic stem cells. On the final intersection, 66 genes were found to be common between the four sets of data.

"There are thousands of genes that are redundant. We found about one in a thousand genes that are unique to the eggs — and some of them, they don't have a known function yet," Cibelli said. "Now we can clone these genes and put them into cells and see if they may have a role in the creation of stem cells — without fertilization or destruction of human embryos."

Cibelli believes some of those genes know the big secrets, such as when a cell should slow down and later become a cell that can grow into any cell of the human body. The computer work of this preliminary search will lead to further experiments.

Multimillion Dollar Pickle, Melon Crops at Risk; MAES Researchers Work with Growers on Disease Management

A deadly fungal disease's second stopover in Michigan in as many years has the state's cucumber growers and processors bracing for another year of crop losses. Consumers may also see the ripple effect in higher prices for fresh cucumbers at the store.

The culprit? Downy mildew, first confirmed in Michigan last summer on cucumbers and yellow squash. Little did Michigan growers think that they would be dealing with a second consecutive year of crop losses from the disease. After all, *Pseudoperonospora cubensis*, the pathogen responsible for the disease, can't survive Michigan's harsh, cold winters.

It wasn't far into the 2006 growing season, though, when producers' worst fears were realized — in early June, downy mildew was confirmed in a field of slicing cucumbers in Monroe County. As harvesting time wound to a close for this year's crop, the fungal disease was confirmed on cucumbers and cantaloupes in 28 Michigan counties.

"Downy mildew is a devastating disease," said Mary Hausbeck, MAES plant pathology scientist. "It has caused devastating crop losses for growers in other regions of the country. Last summer was the first time that Michigan was ever affected by an outbreak of the disease, and it affected thousands of acres of cucumbers."

"People brushed it off last season as a one-time deal, but after this year, pickles have become a riskier crop than ever to grow in Michigan," said John Swanson, president of Swanson Pickle Company, Ravenna. "Until last year, cucumbers had historically been a safe crop to grow here. Aside from *Phytophthora*, we don't normally experience insect or disease problems. But after this year's bout with downy mildew, growing practices will need to change."

The downy mildew threat is particularly important to Michigan, which is the leading producer of processing cucumbers in the United States, accounting for one-third of the nation's pickle cucumbers. In 2005, growers harvested 38,500 acres of cucumbers for processing and another 7,600 acres of cucumbers for fresh use. The processing cucumbers had a farm gate value of $30.6 million; the fresh cucumbers, $20 million.

Once introduced to a field, uncontrolled downy mildew can kill a crop within seven to 10 days. The fungus reproduces via microscopic spores, and humid, wet weather — conditions common in the state in July and early August — promotes production of the spores. The disease spreads quickly under favorable environmental conditions — temperatures between 50 and 80 degrees Fahrenheit and moisture from dew or irrigation.

Once the disease hits an area, the only way to control crop damage is to apply fungicides. Preventive spraying outside the disease-stricken area helps to control spread of the pathogen to other parts of the state. Swanson says that this year's fungicide costs are well into the millions of dollars.

Swanson, whose family has been growing cucumbers for more than 50 years, had never had to use fungicides on his crop until last year. After downy mildew was confirmed in August, he sprayed his last two fields seven times.

"It's not a decision if you want to spray or not. Once the disease shows up, it's too late, you don't have a choice," he said. "Anytime you spray, it costs $20 per acre for the fungicide alone, and, depending on the disease pressure, you need to spray once every five, seven or 10 days. This year we had to spray every seven days."

A minimum of one spray every seven days from mid-June, when the first case of downy mildew was confirmed, through harvest the last week of August on 75 percent of the state's cucumber acreage translates into just under $8.3 million in fungicide expense; labor, fuel and equipment costs are additional. This figure doesn't take into account industry losses associated with crop shortages.

When downy mildew was confirmed last year, Project GREEEN (Generating Research and Extension to meet Economic and Environmental Needs), Michigan's plant agriculture initiative at MSU, awarded emergency funding to Hausbeck to identify which products were effective against downy mildew and develop fungicide application recommendations.

"Products that have historically worked against other diseases didn't work against downy mildew," Hausbeck said. "Without clear direction on which products to use, growers would have incurred additional expense and suffered further crop losses.

"It was because of the fungicide trials that I conducted last summer that I was able to respond quickly to growers with control recommendations when the first outbreak was confirmed early on this

year," she added. "The partnership between my lab, MSU Extension, processors, scouts, crop consultants and growers helped us get the word out about the disease so that growers knew what to do to protect their crops."

Project GREEEN once again stepped up with emergency research funding when the Monroe County case was confirmed in early June. This year's funding has been used to help support three fungicide trials in southeastern Michigan and to purchase and set up spore traps in six counties across the state to monitor movement of the fungal pathogen.

Agriculture's Conference on The Environment Set for January in Lansing

Every day environmental laws and regulations that influence producers and their farms are being created and enforced. Producers can learn how to address these issues, learn about management practices to control environmental risk, and find out what incentives and partnerships are available to them for compliance by attending Agriculture's Conference on the Environment: Managing Today for Tomorrow Jan. 30 at the Lansing Center in Lansing, Mich.

The conference runs from 9 a.m. to 4 p.m. and will feature more than a dozen sessions covering environmental trends, laws and regulations, management practices, marketing, and partnerships and incentives.

Keynote speaker David Kohl, professor of agricultural finance and small business management and entrepreneurship at Virginia Tech, will discuss the 10 best management practices — including environmental practices — that will position producers' businesses for sustainability to 2010 and beyond. His futuristic presentation will highlight how farms might work in the future.

Marketing consultant Jane Eckert, founder of Eckert AgriMarketing, will explain the importance of being a conscientious neighbor to nonfarm neighbors and suggest strategies for addressing their environmental concerns and maintaining good relations.

Bob Utterback, of Utterback Marketing Services, Inc., will show producers alternative strategies to meet marketing challenges in 2007. He'll explain how the new Farm Bill, foreign demand and a highly volatile market could affect a producer's bottom line and how to plan for such challenges.

The registration fee is $50 ($20 for students) before Jan. 22. It includes lunch, refreshments and parking. After that date, the registration is $75. To register by cash or check, go to www.maeap.org to print a registration form. To register by credit card, call Jim Van Arkel at 517-241-2232.

Agriculture's Conference on the Environment: Managing Today for Tomorrow is hosted by the Michigan Agriculture Environmental Assurance Program (MAEAP), Michigan Farm Bureau and GreenStone Farm Credit Services, and sponsored by Michigan State University Extension, the Michigan Agricultural Experiment Station and the Michigan Farm Radio Network.

Researchers Awarded $13.1 Million for Projects Aimed at Boosting Michigan Economy

Eleven Michigan State University research projects — from basic research to applied research already spinning off Michigan companies — are among the winners of the state's 21st Century Jobs Fund awards. Several projects are led by MAES scientists.

MSU projects were granted $13.1 million for research on topics ranging from ethanol fuel engines to laser-based molecular scalpel technology to ways to increase efficiency in pharmaceutical drugs.

"These 11 projects are wonderful representations of the breadth of applicable research that is positioned to benefit Michigan's economy," said MSU President Lou Anna K. Simon. "It is yet another example of how Michigan State, from the very beginning of basic research to the blossoming of new Michigan businesses, is contributing to our state's diversification."

The state announced that 61 awardees have been selected by the Michigan Strategic Economic Investment and Commercialization Board to share more than $100 million from the fund's first round.

MSU submitted 22 proposals.

MSU's projects span the fund's scope of life sciences, alternative energy, advanced automotive materials and manufacturing, and homeland security. Some of the MSU projects focus on bolstering the state's bioeconomy, such as mechanical engineering professor Harold Schock's proposal to develop ethanol fuel engines and MAES chemical engineering scientist Dennis Miller's research on a continuous production process for biodiesel.

Other projects include research to strengthen air and water safety, by Syed Hashsham in civil and environmental engineering and the Center for Microbial Ecology. Mitch Smith and Robert Maleczka, in chemistry, have developed a breakthrough with a patented chemical compound that makes drug synthesis more efficient and less costly.

MSU's engagement in the awards underscores the collaborative nature of the 21st Century Jobs Fund awards. MSU researchers and groups also are collaborators in nine other awards.

Moreover, several awardees are start-up companies that use MSU technology. For example, Diversified Natural Products, a company in Scottville, has 15 patents that have sprung from the research of MAES scientist Kris Berglund. AFID Therapeutics is the company of MAES biochemistry and molecular biology researcher Rawle Hollingsworth.

New Faculty Members

The MAES is pleased to welcome the following new faculty members with MAES appointments.

Jianjun Hao was named assistant professor of plant pathology in August. His research focuses on the epidemiology of soil-borne diseases, especially those caused by pathogens that form sclerotia, as well as understanding the microbial mechanisms of soil health by studying the relationships between pathogens, plants and other microorganisms in soil. He also is studying using non-chemical methods, such as soil amendments, crop rotation and naturally occurring beneficial organisms, to improve plant and soil health.

Prior to his MSU appointment, Hao was a project scientist for 2 years at the University of California-Davis, and from 1999 to 2004, he was a postdoctoral

researcher at the same institution. Hao received his doctorate in plant pathology from the University of California-Davis in 2000 and his master's degree in plant pathology and bachelor's degree in agronomy from the Beijing Agricultural University in 1991 and 1984, respectively.

Philip Howard was named assistant professor of community, agriculture, recreation and resource studies in August. His research focuses on investigating the relationships between food, agriculture and public health, as well as assisting communities to characterize and respond to changes in the food system. One facet includes examining national consumer interests in ecolabels as a potential strategy for improving the livelihoods of small- and medium-scale farms. He also is studying consolidation in the food system, particularly in the rapidly growing organic sector.

Since 2002, Howard has been conducting postdoctoral research at the Center for Agroecology and Sustainable Food Systems at the University of California-Santa Cruz. He is also a founding member of the Santa Cruz County Food System Network. Howard received his doctorate in rural sociology from the University of Missouri-Columbia in 2002, his master's degree in environmental studies from Evergreen State College in 1997 and his bachelor's degree in anthropology from the University of Missouri-Columbia in 1995.

Daniel Jaffee was named assistant professor of sociology in August. His research examines the effects of economic globalization and free trade policies on environmental and social conditions for rural communities and small agricultural producers in the global south, particularly Latin America. His work has focused on fair trade as an alternative model of international economic exchange, examining the benefits and limitations of participation in fair trade markets for peasant commodity producers.

Before coming to MSU, Jaffee was a member of the Nelson Institute of Environmental Studies at the University of Wisconsin. He received his doctorate and master's degree in land resources from the University of Wisconsin in 2004 and 1996, respectively, and his bachelor's degree in history from Oberlin College in 1987.

Gemma Reguera was named assistant professor of microbiology and molecular genetics and crop and soil sciences in August. Her research focuses on the adaptive responses of microbes to their natural environment, and she uses this information to find new biotechnology applications for microbial processes. Her lab is currently studying how the bacterium *Geobacter sulfurreducens* colonizes surfaces and lives as biofilms and how to genetically engineer *Geobacter* biofilms for applications in bioremediation, nanotechnology and bioenergy.

From 2002 to 2006, Reguera was a postdoctoral research associate at the University of Massachusetts-Amherst, and from 2001 to 2002, she was a postdoctoral research fellow at Harvard Medical School. Before that, she held research associate and assistant positions at the University of Massachusetts-Amherst and the University of Oviedo in Spain. Reguera received a doctorate and a master's degree in microbiology from the University of Massachusetts-Amherst in 2001 and 1994, respectively, and a doctorate and a bachelor's degree in biology from the University of Oviedo, in 2001 and 1992, respectively.

Jennifer Rivera was named assistant professor of community, agriculture, recreation and resource studies in August 2006. Her research focuses on developing state standards and curriculum for secondary agricultural science programs. She also studies accountability in career and technical education settings, including its history and how changes in educational policy are affecting accountability.

From 2000 to 2003, Rivera was an agricultural science, biology and computer technology educator at Page County High School in Shenandoah, Va. A member of numerous professional associations, she received the Outstanding Young Scholar award from the American Vocational Education Research Association in 2005. Rivera received her doctorate in learning, teaching and social policies from Cornell University in 2006, and her master's degree in career and technical education and her bachelor's degree in crop and soil environmental science from Virginia Tech University in 2000 and 1999, respectively.

Glyndall Tonsor was named assistant professor of agricultural economics in May. His research efforts are aimed at applied issues affecting the livestock industry. Some of Tonsor's current research includes analyzing domestic and international consumer preferences for various meat products, examining the design and effectiveness of animal identification programs, exploring the effect of expansion in the ethanol industry on the livestock sector, and investigating an array of livestock pricing, marketing and production issues.

Before coming to MSU, Tonsor was a U.S. Department of Agriculture National Needs Program graduate fellow and research assistant at Kansas State University from 2002 to 2006. He received his doctorate in agricultural economics from Kansas State in 2006 and his bachelor's degree in agricultural business from Missouri State University in 2001.

Sharon Zhong was named associate professor of geography in August. Her research focuses on micrometeorology, boundary layer meteorology, mesoscale atmospheric processes, regional climate and climate change, land-atmosphere interactions and fire-atmosphere interactions. She is currently a principal investigator for two NSF-funded projects to study the structure and evolution of cold air pools and boundary layer and mountain wave interactions. She is also the lead investigator for a U.S. Department of Agriculture Forest Service project that is developing tools to estimate how wildland and prescribed fires affect air quality. She has served as an editor for the Journal of Applied Meteorology and Climatology since 2003.

Zhong came to MSU from the University of Houston, where she served as associate professor and graduate director for the atmospheric sciences program from 2003 to 2006. Before that, she was a senior research scientist at the U.S. Department of Energy's Pacific Northwest National Laboratory in Richland, Wash. She received her doctoral and master's degrees in atmospheric sciences from Iowa State University in 1992 and 1988, respectively, and her bachelor's degree in atmospheric physics from Nanjing University in 1982.

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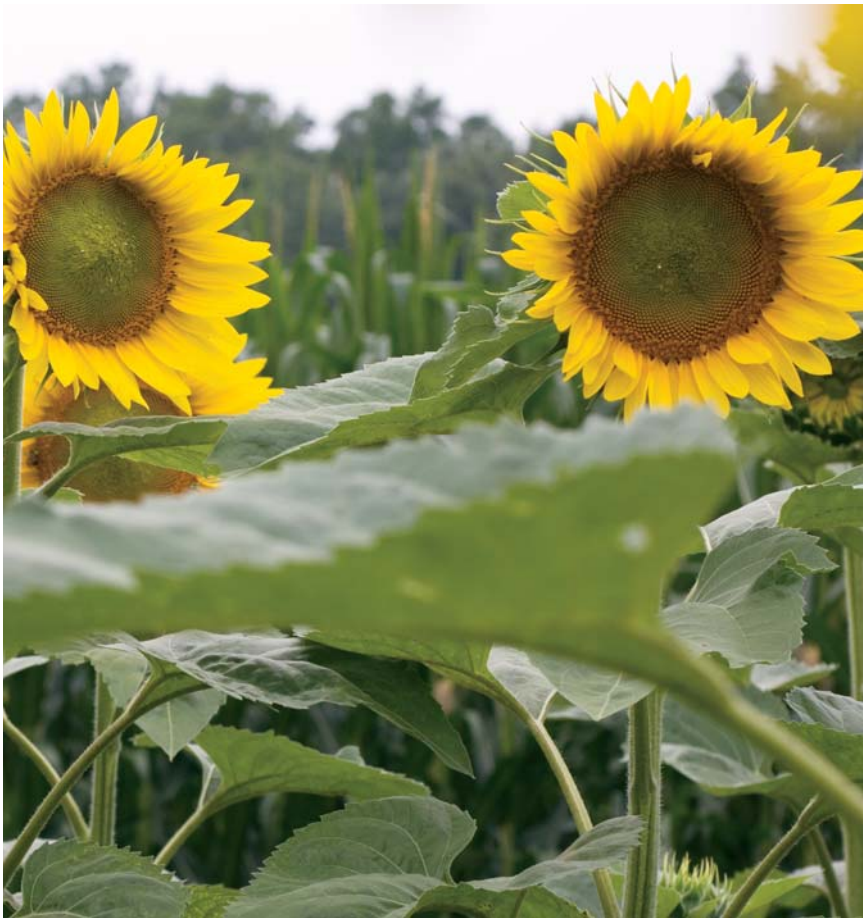

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