

IOWA STATE UNIVERSITY
College of Agriculture and Life Sciences

The Grand Challenge
Iowa State University's Vision for U.S. Agriculture and Forestry's
Contribution to the Energy Economy in 2017

A Vision for the Nation: Agriculture's Contribution to the Energy Economy

The bioeconomy is nothing less than a revolution in the way society will obtain vital sources of carbon and energy, in the process dramatically reducing America's dependence on imported petroleum. Agriculture will make this transformation possible. Agriculture in the broad sense will provide the biorenewable resources necessary for the production of biofuels, biobased products and bioenergy. As agriculture has been the key to economic vitality and food security for the nation, agriculture for the next century is poised to fulfill a new role in energy security. A transformed agriculture will provide sustainable food, feed, fiber, biofuels and environmental goods and services.

Substituting our own agricultural and forestry resources for imported petroleum will significantly improve national security by reducing the nation's dependence on resources from politically unstable regions of the world. The use of biorenewable resources also will improve environmental quality by reducing pollutant emissions associated with fossil fuels, especially emission of sulfur, heavy metals and greenhouse gases. Finally, the bioeconomy will literally transform rural development by introducing new crops, employment opportunities for skilled personnel and new value-added markets to the agricultural economy.

Just as the information age drove the economic boom of the 1990s, the bioeconomy could well drive the economy in the first part of the 21st century. Biorenewable resources and biomass energy sources offer a domestic product for domestic consumption. Global petroleum supplies are finite, and growing demand is putting pressure on supplies and prices. The USDA's estimate of available biomass materials documents that existing biorenewable resources could provide at least 33 percent of our fuel needs and 21 percent of our domestic energy needs, and even more if coupled to energy efficiency improvements and conservation efforts.

In our vision, the Midwest becomes self-sufficient in production of automotive transportation fuels and eventually becomes a net exporter of renewable energy to the rest of the nation. The United States becomes a model for sustainable agriculture and renewable energy production, leading to a better quality of life for people around the world. The Midwest becomes the world hub of renewable energy technology, supplying international markets with solutions to problems in renewable fuels, biobased products and greenhouse gas reductions and carbon sequestration.

In our vision, farming becomes an economically sustainable enterprise without recourse to expensive and market distorting farm subsidies. American farmers adopt new cropping systems that are capable of sustainable production of biomass crops for bioenergy. Beginning farmers and the next generation of agriculturists are able to enter agriculture and participate in opportunities associated with the emerging bioeconomy. Animal agriculture becomes more efficient and profitable through integration with biofuels and bioenergy production. The livestock industry takes greater advantage of bioprocessing feedstuffs. Integrated crop and livestock systems diversify income, improve producer profitability and enhance the environment — as well as keeping American agriculture globally competitive and profitable.

In our vision, rural communities gain population and restore their vibrancy as a result of new commercial opportunities in biofuels and biobased products. Young people hoping to work in the emerging bioeconomy find both educational and occupational opportunities in their home states. Rural America is able to supply food, feed, fiber and biofuel to American consumers.

In our vision, the bioeconomy drives a new wave of entrepreneurial spirit in the United States, leading to the establishment of new businesses in biorenewable resources and technologies. New economic opportunities arise through growth of plant and animal industries, including high-value products and processes.

In our vision, agriculture enhances its natural resources base while maintaining high performance and competitiveness. Environmental management programs emphasize local solutions for local benefits. Natural resources are conserved to sustain productivity and quality of life. Clean air to breathe and clean water to drink are assured for generations to come. American agriculture's role in the bioeconomy will be a significant benefit in achieving greenhouse gas reductions.

In our vision, Iowa State University and America's other land-grant universities work together with their partners — federal agencies, private industry, state collaborators, stakeholders and more — to develop and deploy technologies that drive the bioeconomy and provide a sustainable supply of bioenergy crops.

In summary, the vision for 2017 presents an epochal opportunity for science to make a major impact to improve agriculture, communities, businesses and the environment.

Achieving the Vision: Address Biorenewable Resources and Complex Systems

The bioeconomy will change the face of American agriculture and revolutionize the production of energy and other products across the United States. To achieve the vision will require organization and cooperation of universities, nongovernmental organizations, federal agencies and industry to develop a systems-level analysis of the complex interactions involved in the emerging bioeconomy.

First, the vision for the bioeconomy in America benefits from the well-established, nationwide partnership of land-grant university scientists and extension faculty such as those found at Iowa State University and federal scientists. It's a partnership that works — with cooperation and responsiveness — to tackle new challenges like those presented for the new bioeconomy. Economic analyses conducted by Iowa State University and Yale University economists found a 50 percent annual rate of return to society for the benefits of publicly funded agricultural research. It's a rich dividend to the American economy; for the bioeconomy, the partnership of land-grant and federal science will translate into improved energy security, quality of life in communities and enhanced competitiveness worldwide. Extension will continue to provide the application of new knowledge to real-world problems. And the value of land-grant university research in bioeconomy on the education of students is an enormous public benefit. Science and technology-savvy and society-ready graduates will keep our nation's economic engine running at top performance.

Our aspiration is to establish a sustainable bioeconomy that benefits the United States as a whole. In our vision, instead of trying to out-compete each other, states should collaborate in ways that benefit the vision and in which states such as Iowa, where agriculture is integral to the economy and society, can provide national leadership. Collective efforts by partnerships of Iowa and other states to achieve the vision of a national bioeconomy would produce a roadmap that includes the following “stops”:

- States must work with automobile manufacturers and fuel marketers to offer 85% ethanol blends (E85) to consumers to assure continued expansion of the renewable fuels industry.
- Incentive programs must be established to encourage early investment in new cellulose-based refinery technology. The first cellulose-based biorefineries will be facilities in which new technologies must be proven out.
- Government must develop transitional support programs targeted at energy crops to facilitate agriculture's shift to these crops. Agricultural producers will be more likely to shift to nontraditional crops when they believe the market for these crops can provide an income comparable to their current income.
- Policies must be developed that protect markets for renewable fuels, chemicals and biobased products against drops in petroleum prices that may occur during early periods of transition.
- Educational programs must be developed to prepare a highly educated workforce for the bioeconomy. Bioeconomy workers include producers trained in new agronomic and forest practices, technicians skilled in advanced manufacturing methods, engineers able to design cellulosic-based biofuels plants and scientists working on the next generation of biorenewables technologies. Emphasis should be placed on preparing K-12 students in mathematics and science and offering world-class educational opportunities at colleges and universities.
- States must encourage expanded research to improve the nutritional value of DDGS for animals (particularly poultry, swine and fisheries), and Extension programs will be required to help transfer this knowledge to feed manufacturers,

- distributors and livestock producers. We must assure a strong livestock industry in the U.S. to utilize the co-products of corn ethanol production.
- Additional economic and policy analyses must be conducted to guide federal and state policy development to achieve desired agricultural production, manufacturing and environmental services to support the bioeconomy.
 - Cropping systems that produce feedstocks for biofuels and other biobased products must be designed, not only for high productivity, but also for soil conservation, water and air quality protection, carbon sequestration and energetic efficiency.
 - Biomass harvesting, handling and transportation technologies must be developed to substantially reduce the cost of biomass feedstock. More efficient harvesting and density of feedstock would reduce handling, transport and storage costs making biomass feedstocks more economical. The transportation infrastructure must be improved for more efficient delivery of feedstock to plants and products to market.
 - Biomass storage strategies and infrastructure must be developed to guarantee year-round supply of high quality feedstocks.
 - Innovative extension and demonstration programs must be developed to provide farmers with training and decision-making tools to produce large amounts of biomass while sustaining the environment.
 - Innovative programs must be developed to provide incentives for retiring farmers, during their lifetime, to transition their businesses to beginning farmers. Investment in the next generation of farmers and agriculturists is needed through programs that provide access to low-cost capital, risk management and entrepreneurial training.

Achieving the Vision: The Role of Iowa State University and Contributions in Research, Extension and Education

Iowa State University knows its way around a revolution. For 150 years, Iowa State scientists have been turning ideas into revolutions — and realities — in agriculture. Iowa State and its partners in federal laboratories and private sector have played a key role in revolutionary changes in agriculture, including the development and adoption of hybrid corn, animal and plant genetics and genomics for improved performance of crops and livestock, agricultural biotechnology, agricultural mechanization, agricultural economics and policy analysis, value-added agriculture and sustainable agriculture.

Today Iowa State University faculty and students deeply involved in the study of biorenewable fuels, products and co-products, as well as related connections in animal and plant genetics and genomics, biotechnology and risk assessment, food safety and security, and clean air and water.

Iowa State has an integrated portfolio of expertise in agricultural, life sciences and engineering to bring to bear on the challenges of the bioeconomy. Iowa State scientists think broadly and work collaboratively across disciplines to solve multi-faceted problems spanning molecular to production levels. Systems approaches are key to complex issues

impacting agriculture and the life sciences. Research that benefits agriculture doesn't happen in just one college, center or institute. It's conducted across campus and with many external partners. Progress is the result of partnerships that wed expertise wherever it's found —the result of cooperation among faculty, staff, students and stakeholders.

Success translates into a strong agriculture and vital rural economy. Iowa State University's Bioeconomy Institute and College of Agriculture and Life Sciences are committed to helping Iowans make their communities better places to live and work. We are determined to be a catalyst for new ideas and technologies, and a resource for identifying opportunities and setting strategies for the future.

Iowa State University's Bioeconomy Institute

The vision of ISU's Bioeconomy Institute is to be internationally recognized for its highly collaborative, mission-oriented programs that integrate strengths in both basic and applied research in biorenewables; to be the preferred source of professionals for the growing bioeconomy; and a national leader in biorenewables outreach and continuing education.

The Bioeconomy Institute advances the use of biorenewable resources for the production of chemicals, fuels, materials and energy, while moving toward economic, environmental and social sustainability. The Institute is an outgrowth of the university's Bioeconomy Initiative — a campus-wide effort, launched in 2002, to investigate the use of biorenewable resources as sustainable feedstocks for producing chemicals, fuels, materials, and energy. Today, the Bioeconomy Institute has more than 140 faculty affiliated members engaged in 15 departments in five colleges and 13 research centers. These faculty contribute to research, extension and education, with more than \$37 million in cumulative sponsored research funding from industry and federal agencies ranging from the U.S. Department of Agriculture to the National Science Foundation.

Those involved in the Bioeconomy Institute realize that in the process of moving beyond our current dependence on petroleum depends on agriculture and forestry. Just as petroleum refiners have been inextricably connected to places and cultures where oil was deposited in the earth, the biorefiners of the future will be inextricably connected to agriculture and forestry. However, unlike petroleum drilling, biorenewable feedstocks are produced from an ecosystem that needs to be conserved and renewed in order to ensure future production capacity. Therefore, the bioeconomy will require tight linkages between plant breeding, soil fertility, sustainable crop production, biomass transportation and logistics, rural communities, bioprocessing, distribution, and marketing services.

Like many land-grant institutions, Iowa State's faculty has been engaged for many years in both fundamental and applied research projects related to biorenewable resources and biobased products. What distinguishes ISU is its early recognition that single objective, single investigator approaches to problems in this field have stymied progress toward commercialization of biobased technologies. The Bioeconomy Institute was established

to provide cohesion among the diverse efforts in biorenewable resources on campus and to encourage collaboration among departments, colleges, and research units.

The College of Agriculture and Life Sciences

For 150 years, Iowa State University research, extension and education has worked to serve the needs of agriculture. Iowa State has applied science that is relevant to the needs of agriculture and highly relevant to all Iowans. Today, ISU's College of Agriculture and Life Sciences works on the frontiers of science, including biorenewables. The College provides significant leadership and resources for the Bioeconomy Institute to achieve the goals of Iowa State University in the bioeconomy. More than 100 College faculty are actively engaged with research, teaching and extension activities related to the bioeconomy. The College of Agriculture and Life Sciences also brings strong, long-time working relationships with the state's leading agricultural organizations that have a presence and influence in every corner of the state.

The College established a Livestock and the Bioeconomy working group of university faculty, extension specialists, commodity group representatives and renewable fuels industry representatives to regularly interact with the states' livestock industries on issues of importance. The group emphasizes that the bioeconomy is not a choice between livestock and biorenewables; it's an integration of the bioeconomy and animal agriculture with similar goals of expanding the biofuels industry and feeding more animals, as well as opening up new opportunities for young people to get involved in agricultural fields.

The College of Agriculture and Life Sciences has taken the leadership in developing the New Century Farm. The emerging bioeconomy and the emphasis on renewable fuels produced from plants presents our nation — and especially rural areas — with an opportunity to develop new industries and to diversify its agriculture. Key to the success in attracting the development of biorefineries will be the ability of producers to grow the kind and quantities of feedstocks needed by the industry. It is widely recognized that the renewable fuels economy cannot be supported by traditional grains alone — that a variety of annual and perennial cellulosic crops must be grown to complement corn and soybean production. If carefully designed and implemented, a transformed agriculture will serve the bioeconomy, as well as provide food and feed; conserve soil, water and other natural resources; and strengthen rural communities and improve the quality of life for those who produce and supply biomass materials.

Achieving this vision of sustainable bioenergy and bioproducts production will require new crops and new cropping systems. It will require the integration of disciplines in the agronomic and biological sciences, social sciences and engineering into teams focused on biofuels and bioproducts. It will require, at all stages of the research and development process, input from producers, industry representatives and policy-makers.

Iowa State University's New Century Farm — the first integrated and sustainable biofuel feedstock production and biomass processing system of its kind — will play a critical role in fulfilling this vision. It will serve as a living laboratory for developing and testing

sustainable biomass systems through rigorous integration of agronomic, environmental and socio-economic research. It will be directly linked to molecular and traditional plant sciences as well as to advanced processing research. Basic and applied research will be conducted to achieve short-term and long-term advances in biorenewable fuels and biobased products. The New Century Farm also will provide a needed venue for education and training. The vision for ISU's New Century Farm encompasses: research that brings together scientific expertise to address biomass cropping systems, biofuel processing along the biochemical and thermochemical technological lines, logistics of biomass supply and positive environmental effects such as recycling nutrients back to the land; teaching that serves as a laboratory and resource for training future scientists, producers and extension experts; and extension that demonstrates economic, social and environmental viability of biorenewable energy and bioproducts production to producers, policy-makers and the public.

Research

Iowa State University's Bioeconomy Institute has developed six broad program areas. Many of the projects are organized as cross-disciplinary, systems-oriented research and collaborative learning:

- Feedstock Production: This platform encompasses projects that cross several platforms or involves technologies that cannot be classified as oleochemicals, carbohydrates, natural fibers or thermochemical. Among the projects are agricultural production, life-cycle analysis, value-chain studies and anaerobic digestion.
- Harvest, Storage, and Transportation of Biomass: Iowa State is bringing together industries across the value chain to combine resources to perform research in the areas of harvest, storage and transportation of biomass. The starting point will be biomass composed of cellulose, hemicellulose and lignin derived from agricultural residues of grain crops, dedicated energy crops and woody/herbaceous crops. The end point will be feedstocks that are suitable for either thermochemical or biochemical processing. Research will include field trials on harvest, experimental investigations of storage options and technical and economic analyses.
- Advanced Corn-to-Biofuels: This platform aims to improve the efficiency of producing biofuels from corn, including the use of new enzymes to more fully take advantage of available carbohydrates, development of new lines of corn with increased fermentation productivity, development of new uses for co-products and reduction of processing and energy costs.
- Soybean Biorefinery: The goals include development of soybean-based biorenewable source of fuels and lubricants; advanced biorefinery feedstocks; and development of soy/corn plastics.
- Thermochemical Biorenewable Chemicals: Thermochemical processing of biomass not only offers opportunities for renewable process heat and energy integration in biorefineries but also represents a unique alternative to enzymatic hydrolysis of lignocellulose for the production of renewable fuels and chemicals.

- Iowa State offers a comprehensive research program in thermochemical processing, which employs elevated temperatures to process biomass.
- Biorenewable Chemicals. New, valuable products from the conversion of biomass may help replace similar products made currently from fossil fuels.

Extension

Iowa State University, through the College of Agriculture and Life Sciences, the Bioeconomy Institute and many other programs, is involved in numerous extension and outreach activities related to the bioeconomy. Each year, the Bioeconomy Institute and Iowa State University Extension sponsor the annual Growing the Bioeconomy Conference that attracts hundreds of economic development professionals, lenders, venture capitalists, biobased product manufacturers, bioprocessing engineers, agricultural producers, fuel producers, energy providers and elected officials. The Growing the Bioeconomy Conference features distinguished speakers from around the region and the nation. Iowa State works closely with the BioEconomy Working Group, an organization that encourages the growth of a sustainable biobased industry in Iowa.

Iowa State University Extension works closely with researchers to help provide the information and tools that people need to make decisions about the bioeconomy. ISU Extension works in areas of importance to the vision of the emerging bioeconomy. Extension provides the agricultural sector with vital information from biorenewable research labs of Iowa State. Extension will help community planning and strategic planning efforts, including comprehensive water plans and projections for sustainable growth. Extension will study employment tradeoffs and realities and share the information widely. Conservation of natural resources will be a major emphasis of extension programs, as well as consumer-wide basic energy conservation.

A key extension resource at Iowa State University to address bioeconomy issues is the Center for Industrial Research and Service, which provides more than 5,000 manufacturers with educational seminars and individualized technical and business assistance in engineering, management practices, procurement, quality management, biorenewables and productivity to increase competitiveness. The Center for Industrial Research and Service is working with the USDA to build a national biobased products program, the Federal Biobased Products Preferred Procurement Program, designed to open potential federal markets for biobased products. Iowa State has been working to identify manufacturers and products; develop testing standards and coordinate designation procedures; and has identified hundreds of biobased product manufacturers producing more than 3,400 products that could receive preferred procurement status.

Another key resource is Extension to Agriculture and Natural Resources, which is the primary source of unbiased, research-based information and education for farmers and agribusinesses to maintain the economic basis of agriculture. Extension to Agriculture and Natural Resources is the largest unit in ISU Extension, with 96 campus faculty and staff members across 10 departments and 48 field specialists. Nine ISU centers also serve to support extension work.

ISU Extension, in cooperation with the state Farm Bureau Federation and a consulting firm, is working to help producers better understand their farms' energy consumption and patterns. The work will help reduce energy consumption and improve farms' bottom line.

Other extension initiatives at Iowa State include:

- Development of an analytical tool to help producer groups or cooperatives better understand the expected risks and returns of investing in biodiesel plants.
- Development of a user-friendly dairy economic model to help producer-owned businesses evaluate distillers dried grains and solubles (DDGS) in a dairy start-up or expansion.
- Helping firms become certified in the new national biodiesel industry quality standard.
- Conducting feasibility studies and reviewing business plans to help secure funding for start-up bio-businesses.

Education

Iowa State University is committed to education of students to prepare them for the new world of biorenewables. The Biorenewable Resources and Technology (BRT) graduate program offers students from a wide variety of science and engineering backgrounds advanced study in the use of plant- and crop-based resources for the production of biobased products, including fuels, chemicals, materials and energy.

The BRT program is the first-in-the-nation graduate program in biorenewable resources. ISU offers M.S. and Ph.D. degrees in this new field, as well as a minor for students obtaining degrees in other majors. Today, many of the current students are co-majors with existing disciplines. ISU also makes available an online graduate certificate and online M.S. programs.

With a USDA Higher Education Challenge grant, Iowa State is developing new courses for the Biorenewable Resources and Technology graduate program using a Virtual Education Center model, in which video lecture materials are shared among multiple institutions. This type of online lecturing keeps instructors in the classroom, but leverages the disciplinary expertise that is spread across the country.

With funding from Cargill, Iowa State is enhancing laboratory spaces for undergraduate students to learn about biorenewables, developing a new senior design sequence focused on biorenewables, making hands-on experiences available to freshman students (as well as high-school students) to learn about processing biorenewables and facilitating a two-week-long intensive program in biorenewables where students from across the nation and the European Union will come to learn about biorenewables from world-class experts — Iowa State University faculty and faculty from other U.S. and EU institutions.

Other educational initiatives planned at Iowa State include:

- Developing a new interdepartmental graduate minor in biorenewable chemicals, focusing on linkages between biological and chemical catalysis.
- Establishing a new major in biological systems engineering, which would integrate life sciences with engineering to solve problems.
- Establishing an undergraduate certificate in biorenewables and bioproducts to enable students to discover opportunities in a bio-based economy.

Summary

We need to re-imagine and transform agriculture to address the new opportunities arising today. That's what the "25 by 25 Program" is all about. The leaders and supporters of the program have set our sights high on how agriculture can power America's future. In our vision, the potential outcomes include:

- New economic opportunities for producers, investors and rural communities to take advantage of bioeconomy revolution.
- More secure, domestic biofuel products and supplies for the nation.
- Iowa, the Midwest and the nation prepared to be "feedstock ready" for attracting and supporting the biorefineries of the future.
- Growth in animal agriculture through use of bioprocessing feedstuffs.
- Enhance environmental quality through biorenewable, nonpetroleum products.

The best way to predict the future is to invent it — in our vision, through a collaborative, systemic and integrated model for success. America has had its oil fields and rich coal deposits. Both are classic examples of a destiny influenced by natural resources. America, and particularly In Iowa, also has incredibly fertile soil that has defined our past. But today, that same resource, used in new and different ways, has the ability to define our future — a continually renewable future that champions new technologies, new processes and new products. In a state such as Iowa, agriculture is a biological system poised for a revolution in the biosciences.

The rewards are reserved for those with the vision and the capabilities in science and technology to develop new uses for our natural resources. Achieving our vision depends on our scientific ability to discover new uses and processes that will complement our agricultural resources — biorenewables, sustained growth in the livestock industry, water quality and environmental stewardship. American agriculture has served as a powerhouse economically in many ways; now, it may literally be the powerhouse for our energy security.

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