



**The Dawn of the
BioEconomy**

BIOBASED PRODUCTS AND BIOENERGY VISION AND ROADMAP FOR IOWA



OCTOBER 2002

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Iowa

Biobased Products and Bioenergy Vision and Roadmap

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Vision and Roadmap

Biobased Products and Bioenergy

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EXECUTIVE SUMMARY

The Iowa Industries of the Future (IIOF)/Agriculture project was launched with the purpose of developing a vision for converting agricultural crops and residues into biobased products and bioenergy and charting a roadmap for achieving this vision. The project was a collaborative effort among a diverse group of stakeholders, including producers, commodity groups, private industry, financial institutions, state agencies, environmental advocates, and university researchers. The U.S. Department of Energy, through the Iowa Department of Natural Resources, and the Iowa Energy Center funded the cost of organizing this effort, bringing together stakeholders and assimilating the input from these many groups.

An industry-led steering committee for the IIOF/Agriculture project was established in July 2001. The steering committee, comprised of representatives from the various stakeholder groups, created a draft vision statement for the Iowa BioEconomy, set up a plan of action, and produced the deliverables required for completing the project. A subset of the steering team met biweekly during the year to plan and implement steering committee and focus group meetings, develop the vision and roadmap survey instruments, plan the symposium, and develop the vision and roadmap document from focus group and steering committee input.

Using input from the visioning and roadmapping workshops and Web site survey responses, the IIOF Steering Committee developed the following Iowa Vision statement:

Results: A Vision for the BioEconomy in Iowa in 2020

Iowa leads the nation in developing the BioEconomy. Growth of the BioEconomy has led to an unprecedented period of sustained economic growth in the state and has allowed Iowa to develop abundant amenities and a quality of life rated among the highest in the United States. Iowa biorefineries enjoy widespread support from Iowans because they consistently

- **produce superior products**
- **capture significant value for all segments of bioproduct value chains**
- **provide high rates of return to investors**
- **attract local and outside capital**
- **provide exciting, challenging, and lucrative jobs**
- **improve environmental conditions and ecological diversity**

The IIOF Steering Committee also developed directional targets for biobased products and bioenergy as follows: Iowa will produce and process 3 percent of the U.S. basic chemical building blocks from biorenewable resources by 2020, which will increase to 15 percent by 2050. Iowa will produce 3 percent of the U.S. liquid motor fuel from biorenewable resources by 2020, which will increase to 15 percent by 2050. Iowa biorefineries will obtain 100 percent of their heat and power requirements from co-products of biorefining or from agricultural residues and dedicated energy crops by 2020. Iowa will rank first among states in tonnage of carbon annually sequestered in agricultural lands. By 2020, Iowa will increase production of biobased materials by a factor of 20 compared to today.

The Iowa IOF process identified issues that need to be addressed in order to increase the availability and use of biomass to produce biobased products and bioenergy. They include:

- Science and Technology

Plant Science—improve processing functionality, expression of desirable characteristics, plant vigor, durability of feedstocks, manure characteristics, uniformity of raw materials, pest resistance, yields, environmental impact, genomics capability, bioinformatics, metabolomics capabilities

Production—understand impact of crop residue removal; develop best management practices; expand planting and harvest windows; develop cost-effective methods of harvesting, transporting, and storing biomass; adopt appropriate farm policies; develop marketing system for crop residues and specialty crops

Processing—improve plant component separation, conversion processes, management and financing systems that reduce feedstock costs, quality and availability of feedstock; develop decentralized preprocessing technologies

End Use—design biorefineries that enhance functionality/performance of local biomass resources; exploit specific markets for local/regional biobased products; adopt policies that encourage domestic consumption of biobased products; establish certification programs that verify biobased content and product performance

- Capital Investment—encourage private investment; develop strategies to attract local investment and venture capital; explore co-investment with existing industries; raise public awareness of the need for infrastructure development and scientific study

- Market Development—encourage federal and state mandates on the use of biobased products, financial incentives for developing biobased products, procurement policies that promote biobased products, incentives to mitigate risk of developing supply and distribution infrastructure for biobased products, public financial support for promising biobased technologies

- Policy—establish national policies on carbon sequestration credits, transportation and infrastructure regulations and funding, U.S. Department of Agriculture regulations and incentives that encourage production of biorenewable resources, educational and training programs, incentives for farmer-owned cooperatives in licensing technologies developed with government support

- Standards and Incentives—adopt standards and incentives to verify performance and improve marketability; include machinery and management practices, environmental quality of feedstocks and conversion technologies, biobased content and performance, procurement policies

- Education and Outreach—explore new business arrangements between agricultural producers; develop creative business relationships between links of biobased supply chains; streamline the negotiation of intellectual property rights between industry and university

INTRODUCTION

Objectives

In 1994, a publication on biomass energy distributed by the United States Department of Energy (DOE) highlighted an agricultural community in Iowa that revitalized its markets for agricultural products by diversifying into energy crops. The response to this publication was immediate; the DOE received numerous inquiries from people across the United States and from abroad who wished to visit this biomass success story in Iowa [1].

In fact, this community only existed on paper. It was created to illustrate what might be achieved if biomass products and energy were incorporated into the rural economy. However, because of Iowa's preeminence in agricultural production, there were and continue to be national and international expectations for innovations in agriculture to emerge from Iowa.

The Iowa Industries of the Future (IIOF)/Agriculture project is designed on the premise that an inspiring vision, effectively communicated, can shape the future. This document represents the result of a disciplined effort in Iowa to ***envision a new BioEconomy, explore its implications, communicate its potential, and outline issues that need to be addressed in order to increase the availability and use of biomass to produce biobased products and bioenergy.***

Modeled after the national process that created the national vision and roadmap documents, a diverse group of people contributed knowledge and expertise to this document. The group was led by biomass growers as well as leaders in industry, research, academia, and government. Their objectives were to [2]

- create an inspiring vision of a vibrant, integrated biobased products and bioenergy industry in Iowa
- pose challenging, yet achievable, “stretch” goals and milestones for reaching the vision
- outline the technology, policy, education, and market support required for the growth of an integrated BioEconomy in Iowa
- spur the innovative thinking, vigorous debate, investment, and action necessary to realize this vision

The Iowa Industries of the Future/Agriculture project was guided by the same set of objectives as it set out to develop a vision and roadmap for the BioEconomy of Iowa.

1. Peters, G., U.S. DOE National Renewable Energy Laboratory, private communication, 22 August. 1994.
2. Department of Energy. *The Biobased Products and Bioenergy Vision* (draft, 7/18), 2001.

Biomass Resources

Biomass resources are defined as source material that is available on a renewable or recurring basis, including agricultural crops and crop residues, trees, and waste streams from the animal feeding, food, feed, and fiber industries.

The Hydrocarbon Economy

In the past century, modern society has developed an enormous and sophisticated infrastructure for extracting, processing, storing, distributing, and utilizing products and energy from fossil fuel resources. The infrastructure for this hydrocarbon economy includes physical assets and intellectual assets (cumulative knowledge gained through many billions of dollars in public and private research).

The hydrocarbon economy has served the world well—providing abundant products, fuels, energy, and materials at a reasonable cost for the developed countries of the world. However, many are questioning whether the hydrocarbon economy is sustainable. Potential problems for the petroleum economy may include

- supply of petroleum being interrupted
- price of petroleum skyrocketing
- environmental impacts of continued increase in use of petroleum products and of extraction
- increase in demand for industrial and consumer products, fuels, and materials from third-world countries and developed countries

The potential problems listed above could create significant negative impact on any or all of the following:

- national security
- standard of living
- environmental quality

The BioEconomy

Biomass resources are a strategic option to meet the growing need for industrial products and energy. Developing biobased industries can help the U.S. maintain both a leadership position in science and technology and a high standard of living.

Expansion of biobased industrial production in Iowa will require an overall scale-up of manufacturing capabilities, diversification of processing technologies, and reduction of processing costs. The development of efficient “**biorefineries**”—integrated processing plants that yield numerous products—could reduce costs and allow biobased products to compete more effectively with petroleum-based products.

The 21st century will see many petroleum-derived products replaced with less expensive, better-performing biobased products made from renewable materials grown in farm fields and forests. The opportunity for Iowa and the U.S. is clear. However, it will

require vision, integration of stakeholders, coordination of research, and investment in new approaches.

Iowa and Resources for the BioEconomy

When the infamous bank robber Willie Sutton was asked why he robbed banks, he is reported to have replied, “Because that’s where the money is.” By the same token, the reason Iowa will lead the nation in developing the BioEconomy is because “that’s where the biomass is!”

Iowa combines fertile soils, abundant rainfall, warm and sunny growing seasons, and a highly skilled agricultural workforce to provide the most concentrated source of agricultural production anywhere in the world. One-fourth of the world’s most productive land (class A soils) is located in Iowa. Iowa leads the nation in corn and soybean production, produces 25 percent of the nation’s pork, and is ranked in the top ten producing states in egg, dairy, turkey, and beef production.

An Oak Ridge National Laboratory (ORNL) report dated January 2000 provided data on the 48 contiguous states regarding the volume of available biomass. Figure 1 below shows that Iowa and Illinois are clearly the leading states, with 50 percent more biomass available than third-ranking Nebraska.

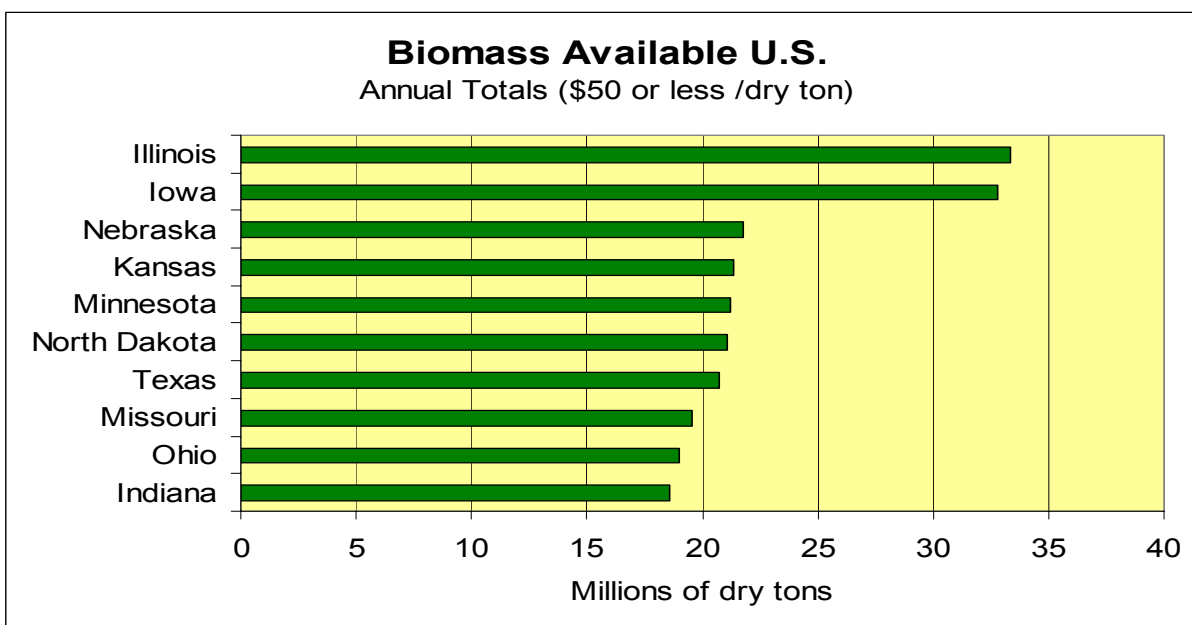


Figure 1. Biomass Availability in the United States.

The ORNL study [3] includes the following:

- Forest wood residues (i.e., logging residues; rough, rotten, and salable dead wood; excess saplings; and small pole trees)
- Residues generated at primary wood mills (i.e., mills producing lumber, pulp, veneers, and other composite wood fiber materials)
- Agriculture residues (i.e., corn, wheat, soybeans, hay, cotton, grain sorghum, barley, oats, rive, and rye); in general 30–40 percent of the available residues were included based on state-specific calculations
- Dedicated energy (i.e., short rotation woody crops such as hybrid poplar and hybrid willow and herbaceous crops such as switchgrass)
- Urban wood wastes (i.e., yard trimmings, site-clearing wastes, pallets, wood packaging, and other miscellaneous commercial and household wood waste and demolition and construction wastes)

However, leading the way into the BioEconomy is about more than just having an abundant supply of raw material. Other resources that enhance Iowa's ability to lead this effort include

- efficient agricultural production systems
- a solid base of small- to medium-sized manufacturers and processors dispersed throughout the state
- an efficient and dedicated workforce
- a system of educational and research resources of very high quality

The combination of all these resources positions Iowa to be the leader in the formation of a vibrant BioEconomy in this country.

Current Utilization of Biomass in Iowa

While the term "BioEconomy" may be a new one, many of the business activities that make up a biobased economy are not. In fact, many businesses in Iowa are already processing biomass to produce products like industrial chemicals, enzymes, lubricants, biocomposites, kitty litter, and much, much more. In the fuel category, ethanol is being produced in three facilities in Iowa; additional facilities are in the planning and/or construction phases in Iowa. Biodiesel is also starting to flow, and biomass is being used to generate power. The best example is the Chariton Valley RC&D project involving switchgrass being co-fired with coal to generate electric power at the Alliant Energy Ottumwa Generating Station.

Iowa compares favorably with nine other states in the upper Midwest for the current level of biobased activity. Refer to Table 1 below. Based on sales dollars, Iowa ranks #1 in biobased products, #2 in fuel (behind Illinois), and #4 in power.

3. Walsh et al., *Biomass Feedstock Availability in the United States: 1999 State Level Analysis*, January, 2000.

Table 1: Midwest Biobased Sales (dollars) and Ranking

	Power		Fuel		Products	
	Sales (\$1000)	Rank	Sales (\$1000)	Rank	Sales (\$1000)	Rank
Illinois	118,370	3	980,847	1	1,418,951	2
Indiana	22,100	5	115,830	6	1,011,995	3
Iowa	54,100	4	414,555	2	1,804,231	1
Kansas	0	8	236,995	4	14,228	9
Minnesota	1,902,751	1	283,375	3	706,485	4
Missouri	4,400	6	66,000	7	64,157	6
Nebraska	3,000	7	231,400	5	25,198	7
North Dakota	0	8	5,600	10	22,800	8
South Dakota	0	8	55,097	8	134,670	5
Wisconsin	650,650	2	6,200	9	1,000	10

IOWA VISION AND ROADMAP PROCESS

Overview

The IIOF project was a collaborative effort, funded by DOE through the Iowa Department of Natural Resources and facilitated by Iowa State University Extension. The project was titled “*Industries of the Future/Agriculture*” and has focused specifically on using biomass to produce biobased products and bioenergy.

Steering Committee

An industry-led steering committee for the IIOF/Agriculture project was established in July 2001. The steering committee is comprised of individuals representing industries that are leading the way in refining biomass including agricultural producers and commodity organizations, processors, equipment manufacturers, financial institutions, development organizations, and the university research community. The steering committee created a draft vision statement for the Iowa BioEconomy, a plan of action, and a list of deliverables for the project. A subset of the steering team met biweekly during the year to plan and implement steering committee and focus group meetings, develop the vision and roadmap survey instruments, plan the symposium, and develop the vision and roadmap document from focus group and steering committee input.

Regional Focus Groups

Eight regional visioning and roadmapping focus group workshops were held in Iowa from March through June 2002. Locations for the meetings were Harlan, Jefferson, Boone, Amana, Mason City, Cedar Rapids, Mount Ayr, and Des Moines. Over 250 farmers, industry leaders, economic development professionals, environmental advocates, and public officials participated in a process to develop a vision and roadmap to **grow the BioEconomy in Iowa.**

Participants at the regional focus group workshops

- completed vision and roadmap surveys
- participated in small group discussions about the BioEconomy
- prioritized ideas and research concepts for the BioEconomy

The vision and roadmap survey instruments were also included on the IIOF Web site for those who wanted to provide input for the process but were unable to participate in one of the workshops.

Findings from Focus Groups

The top five items on the Vision Survey with which the respondents agreed follow:

- Iowa should develop technologies and infrastructure to use dedicated crops and co-products from food and feed processing to produce biobased products.
- Reducing petroleum dependence should be a key consideration in an Iowa vision for biobased products.
- It is essential to have the cooperation of lending and venture capital institutions if biobased products are to become an important part of the Iowa economy.
- Iowa should develop the technologies and infrastructure to use crop residues in the production of biobased products.
- Improving farm profitability should be a key consideration in an Iowa vision for biobased products.

The top five priorities on the Roadmap Survey according to respondents regarding what needs to happen in Iowa to make the BioEconomy a reality include the following:

- Explore and implement creative strategies for attracting investment capital to biobased industries.
- Develop a long-term strategic plan for maximizing the economic returns of the BioEconomy for Iowa producers and rural communities.
- Educate lenders in Iowa about biobased products so they are comfortable lending money to producers for purchasing new equipment and investing in biobased industries.
- Develop mechanisms for coordinating the efforts of producers, processors, and academic researchers.

Using input from the visioning and roadmapping workshops and Web site survey responses, the IIOF Steering Committee developed the Iowa Vision statement and directional targets for the Iowa BioEconomy.

IOWA VISION

A Vision of the BioEconomy in Iowa in the Year 2020

- Iowa leads the Midwest in developing the BioEconomy. Iowa citizens **embrace the vision** of the BioEconomy and consistently **exploit conditions and events** that support the development of the BioEconomy in their communities.
- Iowa citizens and businesses have developed mechanisms to **capture significant value from all segments of bioproducts and bioenergy value chains.**
- Iowa is experiencing **significant economic growth**. Iowa's **quality of life is rated among the highest of any state in the United States** due to its pristine natural environment and its investments in other amenities.
- Iowa biorefineries provide **exciting, challenging, and lucrative jobs** in Iowa that attract young people to Iowa's communities.
- Iowa's **superior resource base** of (1) quality land, (2) weather conducive to crop production, and (3) transportation and information infrastructure are combined with its **social resource** of well-educated, hard-working, skilled people to serve as underpinnings for the biobased economy.
- Iowa has created an **attractive tax structure** for business development in the state that has led to huge **infusions of capital** from both local and outside sources for biobased businesses.
- Iowa biobased businesses create **superior products** that enjoy tremendous worldwide demand.
- The **economic benefits** of the biobased products and bioenergy industries are widely dispersed among the people of the state and nation.
- Iowa biorefineries model production, processing, and merchandising practices and technologies that consistently **improve the environmental conditions and ecological diversity** of the state.

Directional Targets for Successful Progress of the BioEconomy in Iowa

Chemicals

1. *By 2020, Iowa will be producing and processing 3 percent of the U.S. basic chemical building blocks for industry from biorenewable sources (30 percent of the national goal).*
2. *By 2050, Iowa will be producing and processing 15 percent of the U.S. basic chemical building blocks for industry from biorenewable sources (30 percent of the national goal).*

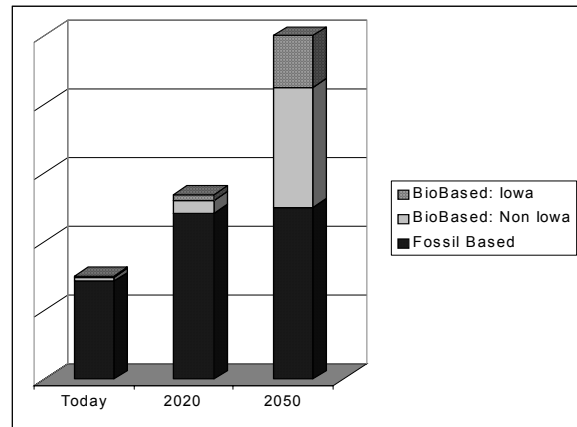


Figure 2: Directional targets for biobased chemicals

Fuels

1. *By 2020, Iowa will be producing 3 percent of the U.S. liquid motor fuel from biorenewable sources (30 percent of the national goal).*
2. *By 2050, Iowa will be producing 15 percent of the U.S. liquid motor fuel from biorenewable sources (30 percent of the national goal).*

Power

1. *By 2020, every Iowa biorefinery will produce 100 percent of its power requirements from co-products of the biorefinery processes or from agricultural residues and dedicated energy crops.*
2. *Iowa will rank first among states in tonnage of carbon annually sequestered in agricultural lands as a result of new land management practices.*

Materials

1. *By 2020, Iowa will increase production of biobased materials (from 2000 levels) by a factor of 20.*

Resources and Products in the Iowa BioEconomy

Iowa's soil and climate make it ideally suited to produce crops and livestock. Iowa is a leading producer of corn in the United States. Although there is some debate as to whether corn is the ideal crop for production of fuels and chemicals, there is no doubt that it will be a mainstay in the early development of the BioEconomy of Iowa. The infrastructure for production, transportation, and handling of this biorenewable resource is already in place. The work force of Iowa is prepared to work with this resource. Thus, corn presents the most immediate opportunity for production of biobased products.

Agricultural processing of corn and oats leaves large quantities of hulls, a high-fiber material currently of relatively little value. Because it has already been collected and is a clean, uniform material, it is attractive as an early entrant among lignocellulosic feedstocks in Iowa.

Corn stover, the agricultural residue left over from the harvesting of corn, will find increasing application in bioenergy and biobased products. Every bushel of corn harvested leaves 50–80 lbs of stover in the fields. Some experts believe up to half of this can be collected in many fields without compromising soil conservation. However, methods must be developed to cleanly harvest stover and store it before it becomes an economical source of lignocellulose. Lessons learned in developing corn stover as a biorenewable feedstock will also improve the longer-term prospects for dedicated energy crops such as perennial grasses, trees, and industrial oilseed crops.

The incentive to use manure as a biorenewable feedstock will increase as environmental regulations become more stringent in livestock operations in Iowa. Processing of manure into bioenergy and biobased products has the added benefit of eliminating it as an environmental pollutant. Technologies are immediately available to convert it into biogas (a methane-rich gaseous fuel) with long-term prospects for extracting industrial chemicals, such as organic acids and alcohols. However, transportation and storage are challenges in exploiting this resource.

Crops modified through traditional or transgenic breeding programs could also become important resources for the BioEconomy. Increasing the plant's natural production of a specific component already found in the crop, such as protein or fatty acid, can increase the ultimate yield of that component and thereby improve efficiency and reduce the cost of biobased product production. New breeding programs could also change the chemical composition of plants to produce crops with new chemical compositions that are much closer to the final industrial product. It will be important to carefully evaluate the environmental, political, and social considerations of these crops before they are grown and processed.

Focus products for Iowa biorefineries will include

- industrial chemicals
- ethanol
- enzymes
- biodiesel
- hydrogen
- carbohydrate-based chirals
- building materials such as fiber board, ceiling tiles, etc.

Stakeholders in the Iowa BioEconomy

Since corn and soybeans are primary biorenewable resources for Iowa, corn and soy producers and wet and dry grain millers (corn, soy, and oats) will be among the first rank of stakeholders to be affected by feedstock supply-chain issues. The collection and movement of increased volumes of biomass feedstocks from farms to processing facilities will create increased pressure on transportation infrastructure, which will be of interest to federal, state, and county transportation departments. Equipment manufacturers will also be important stakeholders. Fiber processors have immediate concerns about year-round storage of relatively fragile agricultural materials used as sources of fiber. Chemical and pharmaceutical processors will become increasingly involved as markets develop for a wider range of biobased products. Environmental

advocates and rural development professionals must be included in developing policies for plant breeding and production practices and sifting the infrastructure for transporting and storing biorenewable resources. Researchers will play an important role in developing technologies that allow increased economical transportation and storage of biorenewable resources without adversely affecting the environment or the quality of life in rural areas.

IOWA ROADMAP

Target Areas for Iowa Roadmap

The IIOF project focused on three specific areas for the purpose of defining the Iowa roadmap for the BioEconomy.

- Optimization of biomass and/or crop-based material production (including co-products from existing and new processing) to fit projected use situations
- Addressing facilities, location, handling, and delivery issues for plant-based feedstock supply chains, including mechanisms to enhance the economy of rural regions
- Accelerated development of new processing routes based on modified chemistry and/or bioprocesses that are aligned with utilization of plant/crop-based renewable feedstocks

Technical Goals of Each Target Area

I. Optimization of biomass and/or crop-based material production (including co-products from existing and new processing) to fit projected use situations

Plant Science

Plant breeding programs should be employed to produce desirable traits for specific characteristics including

- improved processing functionality
- improved expression of desirable characteristics
- improved plant vigor
- improved durability of feedstocks
- improved manure characteristics

The impacts of genetically enhanced crops should be assessed on a species-specific and ecosystem level to ensure there are no negative impacts associated with the genetic alteration.

Production

Research is needed initially to better understand the results of crop residue removal. Environmental benefits should be codified and any related environmental issues must be appropriately addressed. Developing and integrating best management practices for identity-preserved crops and crop residues are critical (including handling systems for input materials and cultural systems for production). New concepts to accommodate the seasonal nature of feedstock generation, expand the growth of energy crops, and assure the quality of feedstocks need to be explored. Cost-effective methods of harvesting, transporting, and storing large amounts of biomass (including manure) also need to be developed and demonstrated.

Processing

Research is needed to enhance the process of fermentation and hydrolysis of fiber, oil, starch, and protein fractions of crop components and processing co-products. New fermentation technologies are needed to produce base chemicals, pharmaceuticals, and chemical intermediates from the wide range of existing crop components.

Low-cost chemical and biological process methods need to be developed and/or demonstrated, including new chemistry and thermochemical syntheses that can treat and break down molecules and separate the resulting components into purified feedstock streams. Specifically, new fractionation and separation technologies are needed to

- fragment plant parts
- exploit fractionated components
- recover high yields of relatively pure chemical streams
- enhance functionality and performance

End Use

Biorefineries that include multiple processing businesses/systems *could* efficiently produce a diverse and flexible mix of conventional products, fuels, power, chemicals, and materials from biomass. Research is needed to further evaluate, develop, and deploy the biorefinery concept *at the local/regional level* that will

- enhance functionality/performance of local biomass resources
- define applications that exploit specific local/regional products and markets

II. Addressing facilities, location, handling, and delivery issues for plant-based feedstock supply chains, including mechanisms to enhance the economy of rural regions

The areas of plant science, production, processing, and utilization all impact the development of plant-based feedstock supply chains. Iowa has identified specific goals for each of these areas.

Plant Science

Advances in plant science will contribute to the development of reliable and cost-effective supply systems. Among the most prominent goals in plant science are the following:

- achieve uniformity of raw materials through high and consistent expression of desired traits
- develop pest resistance including weed, insect, and disease resistance, which contributes to reliability of feedstock supply
- increase yield of crops, which reduces the length of the supply chain
- attain positive environmental impact, which improves public acceptance of additional transportation and storage infrastructure

Production

A successful BioEconomy will not only expand output and profitability of production, but also eventually change its character. Important goals in production include

- crop management systems that are adaptable over wide geographical regions to allow rapid expansion of the biobased products industry by providing adequate feedstock supplies
- technologies that broaden the window for planting and harvesting biorenewable resources to improve the reliability of supply
- storage systems that limit degradation and maximize desired traits and components
- improved field-to-market transportation systems so the state's highway system is not overburdened
- increased yield of crops, which reduces the length of the supply chain
- agricultural machinery suitable for clean harvest of agricultural residues
- modified federal farm policy to encourage production of biorenewable resources
- established marketing systems for crop residues and specialty crops

Processing

Unless adequately addressed, transportation and storage will present a bottleneck to processing biorenewable resources. Improved processing technologies can contribute toward the solution of problems in transportation and storage. Key goals in this area are

- improving plant component separation, which may simplify storage and transportation of biorenewable resources
- making conversion processes more robust to variations in feedstock composition and quality
- establishing management and financing systems that encourage improvements in feedstock price, quality, and availability
- developing decentralized preprocessing technologies that increase feedstock density for transportation or feedstock durability for storage

End Use

End use impacts transportation and storage only peripherally. Policies and programs that encourage consumption of biobased products will accelerate the construction of

transportation and storage infrastructure needed for the BioEconomy. In this regard, specific goals related to end use include

- development of national policies that encourage domestic consumption of biobased products
- development of national policies that promote export of value-added products from agriculture
- establishment of certification programs that verify biobased content and product performance

Other Important Considerations

In addition to plant science, production, processing, and end use goals, other important considerations were identified:

- development of highly integrated biorefineries that produce chemicals, fuels, power, and materials and generate no waste streams
- analysis of rural development opportunities/challenges
- analysis of land use options
- analysis of long-term environmental impacts of various technologies and cropping systems

III. Accelerated development of new processing routes based on modified chemistry and/or bioprocesses that are aligned with utilization of plant/crop-based renewable feedstocks

The integration of scientific areas will accelerate the pace of biobased product development. Some necessary research objectives for Iowa universities and Iowa companies are described below.

Plant Science

The enhancements in plant science will have an impact on processing and plant production and utilization. Some areas of opportunity include the following:

- enhance genomics (DNA analysis) capability
- develop better bioinformatics (computer-based search for commonalities in genetic composition) and advanced computer systems
- advance metabolomics (profiling plant composition) capabilities

Production

Improvements in plant production will give rise to new opportunities in processing. This is a key area for the operation of biorefineries. Some areas of study include the following:

- lower use of inputs (water, fertilizer, pesticides)
- create wider planting and harvesting window
- expand no-till technology
- develop improved storage systems
- improve transportation infrastructure

Processing

Of the four areas, this area was viewed as needing the most work. Iowa universities and industry have the necessary capabilities to make important advances. Some areas of investigation include the following:

- process new materials with existing processes
- create new catalysts (both biocatalysts and chemical catalysts)
- develop new separations methods

End Use

The utilization area was also viewed as needing considerable enhancement in Iowa. Groups need to work together to

- identify markets (commodity vs. niche)
- show the advantages of biobased products as compared to existing products (cost, durability, biodegradability).

Cross-Cutting Issues

Key cross-cutting issues in developing biobased supply systems include capital investment, policy, market development, standards and incentives, and technology development. Iowa has identified specific issues in each of these areas.

Capital Investment

Iowa does not have the investment capital resources of many other states. Thus, for Iowa to take a leadership role in the nation's emerging BioEconomy, it must address issues of capital investment. These include

- developing public support for infrastructure development
- developing public support for research and development
- raising private investment
- identifying and implementing strategies to attract local investment
- identifying and implementing strategies to attract co-investment (from petroleum companies and others)
- identifying and implementing strategies to attract national sources of venture capital
- identifying and implementing strategies to create market "pull" to encourage investment

Market Development

Achieving the ambitious goals outlined in the Iowa Vision will require creative strategies to develop solid market "pull." Options could include

- federal and state environmental mandates that encourage the use of biobased products
- financial incentives for biobased products
- implementation of procurement policies that promote biobased products
- incentives to mitigate the risk of developing the supply and distribution infrastructure needed for biobased products

- public financial support for promising biobased technology at the proof-of-concept stage
- investment programs designed to stimulate small businesses in the area of biobased product development

Special care must be taken when evaluating the instruments described above to insure that federal and state incentives encourage a mix of biobased products that have high value (or potential highest value) in the marketplace. Poorly designed incentives and/or mandates could skew technological development in harmful ways (i.e., special programs for large manure systems could create incentives for large manure structures that may have negative environmental consequences).

Policy

Federal and state policies that encourage the development of the BioEconomy will be important in the initial stages of development. Products from fossil resources are typically cheaper than those derived from biorenewable resources if an accounting is not made of environmental impacts, national security, and economic development. Some policy issues that should be considered include the following:

- adoption of carbon sequestration credits
- review of transportation and infrastructure regulations and funding
- establishment of rural development policies consistent with the BioEconomy
- establishment of U.S. Department of Agriculture regulations and incentives that encourage production of biorenewable resources
- adoption of environmental regulations and incentives that make biobased products more attractive
- establishment of new educational and training programs
- increase in federal and state funding to develop the industry
- creation of special incentives for farmer-owned cooperatives in licensing technologies developed with government support

Standards and Incentives

A range of standards is needed to verify performance and improve marketability.

Examples of standards include

- machinery and management practices
- environmental quality of feedstocks and conversion technologies
- energy content
- quality of feedstocks
- certification of biobased products for biobased content and performance
- fleet standards, production tax credits, and federal procurement policies

Education and Outreach

Educational/pilot outreach programs need to be designed and implemented to

- assist (model) new business arrangements *between* agricultural producers (co-ops and/or alliances) that provide the necessary quantities of biomass for biorefineries
- develop creative business relationships between links of biobased supply chains

- negotiate intellectual property rights between industry and university research (with special consideration to farmer-owned cooperatives or alliances in licensing technologies developed with government support)
- develop education initiatives to broadly inform consumers and the general public of the environmental sustainability and product-performance benefits associated with the increased use of biobased products and bioenergy systems.

FOLLOW-THROUGH

The vision for Iowa's role in the BioEconomy tells us *what* we want to achieve in Iowa with respect to bioenergy and biobased products. The roadmap lays out *the route*. Specific *action steps* were identified by *action teams* at the ***Biobased Products and Bioenergy Symposium*** held in Ames, Iowa, on September 4th, 2002.

Science and Technology

Biobased science and technology developments will require multidisciplinary research efforts in order to address the complex requirements of integrated biobased products and bioenergy industries. It also seems clear that new relationships need to be developed between public and private entities. The Science and Technology Action Team outlined the following strategies for implementation in Iowa:

- design federal and state funding programs to encourage collaboration between public and private organizations
- develop and implement government mandates for purchasing renewable products
- develop a virtual system for people to share ideas and search for sources of biobased products
- design government funding programs to encourage the development or expansion of cooperatives and joint ventures between companies
- develop a regional center that would combine the resources of industry, research, and public support

Capitalization and Markets

Developing the BioEconomy will require huge investments in physical assets and intellectual assets. What are the options for capitalizing biobased products and bioenergy industries? How can Iowa take advantage of market niches where biobased products and bioenergy applications can be cost effective? The Capitalization and Market Development Action Team identified the following strategies for implementation in Iowa:

- establish an entity with a specific "networking mission" that will facilitate the linkage of customer and industry relationships with the science and enterprise opportunities available or developing in Iowa (the idea is to get a head start in expanding biobased industries in Iowa)
- establish an entity to identify, communicate with, and build relationships with private sources of early stage funding (Friends of Iowa or Friends of Energy oriented venture capital firms)

- research, develop, and execute networking concepts as they might apply to value-based enterprise development in agriculture re execution of business relationships and the “science” of producer networks and their role in enterprise development.

Policy and Education

Policies governing a wide range of areas from transportation to rural development, from agriculture to commerce, from environmental protection to energy security, and from land conservation to education will have impacts on the future of biobased products and bioenergy. The Policy and Education Action Team outlined the following strategies for implementation in Iowa:

- establish a council that (1) analyzes effects of federal policy and rules, (2) coordinates and communicates information, and (3) works with state agencies re taxes, regulations, public expenditures
- develop and implement specific policies including (1) funding for research and development, and (2) incentives for producers, industries, and government to invest and purchase biobased products
- work with community colleges and industry to develop training programs for technicians that will be needed to work in biobased industries
- develop and carry out educational programs about the BioEconomy for state law makers, K-12 classrooms, and the general public.

CONCLUSION

To repeat, the Vision for Iowa’s role in the BioEconomy tells us ***what*** we want to achieve in the future in Iowa and ***where we want to go*** with respect to bioenergy and biobased products. The Roadmap lays out ***the route***. The action teams have identified ***plans for the trip***. The IIOF/Agriculture project has benefited from the working contributions made by many Iowans, and the team invites you to “join in the journey.”

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APPENDIX 3

Suggested Readings List

Biobased Industrial Products: Priorities for Research and Commercialization, National Research Council, National Academy Press, Washington, D. C., 2000.

Biobased Products and Bioenergy Roadmap, National Biomass Coordination Office, <http://www.bioproducts-bioenergy.gov>, 2001.

The Biobased Products and Bioenergy Vision, National Biomass Coordination Office, <http://www.bioproducts-bioenergy.gov>, 2001.

Biomass R & D Technical Advisory Committee Recommendations, National Biomass Coordination Office, <http://www.bioproducts-bioenergy.gov>, 2002.

Eaglesham, A., Brown, W. F., and Hardy, R. W. F., eds., *The Biobased Economy of the Twenty-First Century: Agriculture Expanding into Health, Energy, Chemicals, and Materials*, National Agricultural Biotechnology Council, Report 12, New York, 2000.

Fostering the Bioeconomic Revolution.... In Biobased Products and Bioenergy, Biomass Research and Development Board, <http://www.bioproducts-bioenergy.gov>, 2001.

Plant/Crop-based Renewable Resources 2020: A Vision to Enhance Economic Security through Renewable Plant/Crop-based Resource Use, Department of Energy, 1998.

The Technology Roadmap for Plant/Crop-based Renewable Resources 2020: Research Priorities for Fulfilling a Vision to Enhance U.S. Economic Security through Renewable Plant/Crop-based Resource Use, Department of Energy, 1999.



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