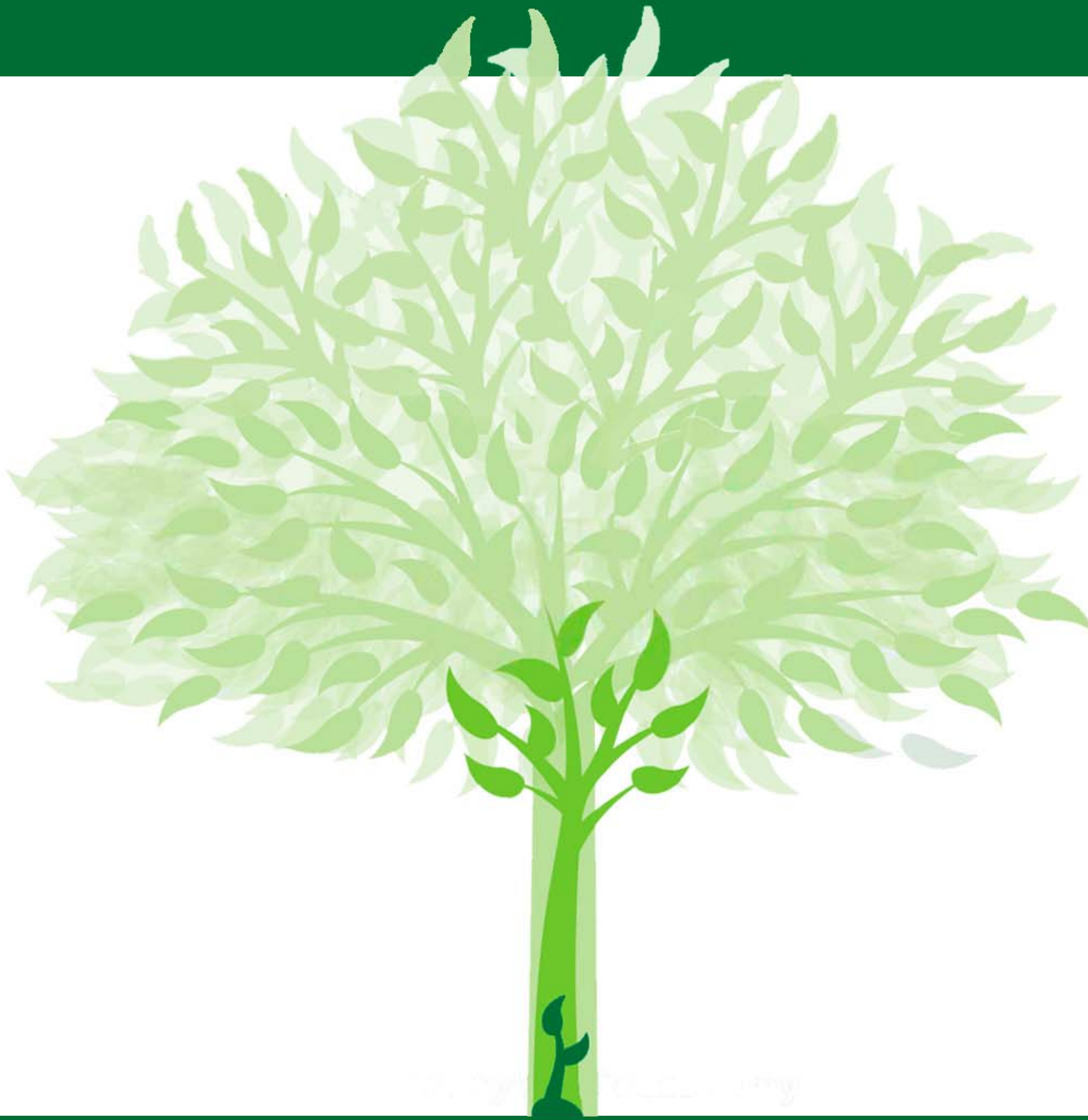
# Preparing for the Future of Michigan's Bioeconomy
# Recommendations for the Office of Biobased Technologies



Prepared for the Office of Biobased Technologies
by Centrec Consulting Group, LLC
in cooperation with
The Product Center
for Agriculture and Natural Resources

CENTREC
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UNIVERSITY

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## Executive Summary

Use of petroleum-based products has been a fundamental reality for much of the world's economic growth for the last century. In recent years, the prospect that future global growth can be solely tied to the use of petroleum resources has become increasingly uncertain:

- Relatively rapid increases in energy costs have put pressure on economic growth, challenged consumer expectations, and heightened political awareness of the pressures facing the current reliance on petroleum-based products.
- The pace of economic growth in developing nations, such as China and India, has both contributed to high and volatile market prices for fossil fuel products in the short run and raised serious questions about the nature of future competition for those products.
- Environmental concerns associated with use of petroleum-based products and fossil fuels have intensified, globally and nationally.

While presenting significant short-term challenges, these developments have intensified society's interest in the potential use of alternative sources of energy and materials.

One attractive area of potential interest is the use of biobased resources as sources for products currently developed from petroleum, a bioeconomy. Production of goods and services derived from materials from plants, animals, wood products, and other renewable resources, is technically feasible today. The potential for technological advancement offers the promise of more efficient processes in the future. However, as with any significant change, economic, societal and environmental issues need to be addressed to move from technological possibility to innovation driven success.

The land grant university was established to assist society in evaluating and making progress relative to issues and potentials such as those the bioeconomy presents. Michigan State University's President Simon has stated, "At MSU, research, development and entrepreneurship for the bioeconomy are fundamental to who we are and what we do." Recognizing these opportunities, Michigan State University (MSU) and its Office of Biobased Technologies (OBT) commissioned Centrec Consulting Group, LLC, with the assistance of MSU's Product Center for Agriculture and Natural Resources, to assist in evaluating the potential for the bioeconomy in Michigan and in developing approaches by which MSU could effectively assist in fostering a vibrant bioeconomy in Michigan.

The first phase of this effort resulted in a report titled "Linking Knowledge and Resources to Support Michigan's Bioeconomy" which was released in April 2006. As the title suggests, that report was focused on defining Michigan's physical resources and linking them to essential elements of knowledge creation. That report also included descriptive materials that have been used to support various meetings and presentations at the local, state, and national levels.

This second phase of the project focused on:

- Identifying key impediments to development of biobased value chains within Michigan and specifying actions to reduce such impediments. Special attention is directed to potential actions to reduce those impediments by the State of Michigan and by leading academic institutions such as MSU.
- Specifying opportunities by which MSU, through OBT could accelerate and solidify Michigan's position as a leader in the bioeconomy.

The popular use of the term, bioeconomy, is quite broad, encompassing everything from medical to industrial applications. The primary focus in this report, however, is on those parts of the bioeconomy that comprise mainly industrial biotechnology applications. This includes all of the supporting platforms for the production of fuels and chemicals from biomass.

The findings and recommendations contained in this report resulted from a number of informal and formal activities and sources. In addition to drawing from the growing academic and popular press literature on this topic, the project team conducted numerous one-on-one and small group meetings with key Michigan stakeholders, attended key conferences and workshops, developed quantitative models of potential bioeconomy value chains in Michigan and employed those tools in building scenarios, and conducted a two day Roundtable meeting with leaders of Michigan stakeholder groups. The results of those efforts were synthesized as findings and recommendations within this report.

Three concepts from the domain of strategic management are described in the report because they provide useful frameworks to both understand the justification for the report's recommendations and to implement those recommendations. One refers to *knowledge creation* and the reality that knowledge-based innovation is a process that extends beyond invention to include adoption and improvement over time. The second demonstrates that innovation doesn't occur in isolation but rather flourishes within an *innovation ecosystem* comprised of a set of interlinked entities. The third, *strategic intent* is an approach which can be employed to foster strategic change in the presence of extensive uncertainty from sources such as technological change or economic and social forces.

*Key Findings*

The report describes numerous findings relative to Michigan's potential to be a leading force in the emerging bioeconomy and presents a series of recommendations by which MSU's Office of Biobased Technologies could play a catalytic role supporting the state's leadership aspirations. This summary section will highlight six of the most important findings. Key recommendations will then be presented.

Summary Finding 1. A state or region's success within the emerging bioeconomy will be affected by key factors such as its physical resources, industrial infrastructure, intellectual capabilities, and leadership commitment. The State of Michigan scores well on many of those factors. However, the scale of its physical resources, especially with respect to grain-based biofuels, limits its ability to achieve competitive advantage based upon scale of operations. Relative to intellectual capabilities, industrial infrastructure (particularly related to potential non-fuel bioproducts), and leadership commitment, Michigan has the potential to be differentially competitive. Michigan's forest resources are extensive and, although development is likely to occur only in the longer run, could provide scale advantages.

Summary Finding 2. Job creation will be significant, but not at the same scale as the auto industry. Today, an efficient ethanol producing plant is expected to require fewer than 75 full-time employees. And, as indicated elsewhere, the prospects for a large number of plants to be built in the near term in Michigan are low.

Summary Finding 3. The economic, social, and environmental benefits of moving to a biobased economy will accrue over a long period of time. Markedly different time patterns need to be expected relative to feedstocks (grain, cellulosic, and forest product based) and products (fuel versus plastics or chemical replacements). The patterns of growth and of success will not be smooth, with the public and the media tending to focus on the inevitable conditions of capacity "overshoot" and "undershoot" that occur in commodity-oriented markets.

Summary Finding 4. For cellulosic and forest product-based value chains, lack of pre-startup investment in supply chain infrastructure could be a key impediment to rapid investment and development. Input streams do not exist for cellulosic and forest production applications. Yet when a large scale biorefinery comes online, it will need to consume vast quantities of inputs immediately if it is to achieve operational efficiency. Effectively managing these constraints could make a specific locale differentially attractive as a site for development.

Summary Finding 5. Diversion of grain and other livestock feed products to satisfy bioprocessing needs will be very disruptive to the livestock sector. This will have an impact on both the availability and price of livestock feed.

Summary Finding 6. The appropriate downstream infrastructure that can accept products from many different kinds of biobased businesses will be important. A downstream infrastructure that can participate in developing, as well as utilizing, innovative biobased industrial products is likely to provide competitive advantage.

Summary Finding 7. Business system innovation may be just as much a feature of the bioeconomy's future as is technological advances. Important research and outreach opportunities exist relative to fostering innovative business system arrangements that can facilitate supply chain development. Effectively doing so could provide a source of local advantage.

*Summary Recommendations*

Four summary themes emerged from the considerable dialogue and debate that occurred throughout the Roundtable meeting held as part of the project. These themes focus on:

- Public policy and communications,
- Research and outreach,
- The need for facilities, and
- Leadership responsibilities for the Office of Biobased Technologies.

These themes provide an effective organizational framework for the report's recommendations. These recommendations include both insights gained at the Roundtable and reflect findings from the other activities conducted during the project. Key recommendations under each of those themes will be presented here. More detailed discussion of the themes and the complete set of recommendations can be found in Sections 4 and 5 in the report.

Key Recommendations Associated with Theme 1.

Inform and enhance public understanding and public policy decision processes regarding the pace and nature of growth within the Michigan bioeconomy.

- Create the capacity to conduct focused policy research which investigates and suggests preferred means by which state and local governments can best support and enhance bioeconomy initiatives within Michigan. A comprehensive perspective would include considerations such as:
  - ✓ Examination and enhancement of state and local government regulations.
  - ✓ Identification of cost effective, bio-favorable procurement policies for state and local governments.
  - ✓ Rigorous analysis of alternative incentive mechanisms.
- Develop the capability to effectively inform and educate Michigan decision makers regarding the bioeconomy and Michigan's actual and potential roles within it. Mass

media would be only one of the targeted audiences for these efforts. Content development and communication methods also should target means to effectively inform local and state public officials and to support education at the K-12 levels.

- Conduct research and outreach efforts which identify actions that will assist in building forest bioproduct value chains.
- Sponsor OBT forums, which explicitly include participation from a wide range of stakeholders, on various topics as a way to communicate issues and gather information about the current status of relevant developments.

Key Recommendations Associated with Theme 2:
Foster interdisciplinary scholarship which acts as an innovation catalyst for Michigan's bioeconomy.

- Identify and support initiation of high priority research ventures. OBT should provide leadership by crafting a strategic intent that defines processes whereby interdisciplinary groups are provided the opportunity to form functioning research teams to pursue high priority efforts. Private sector input should be an essential feature of the process. "Triple bottom line" (economic, environmental, and societal) assessment capabilities can be incorporated within the interdisciplinary group structures. Discretionary dollars, from redirection of current resources as well as attraction of additional support, should be employed to support initial and early stage research efforts within the priority areas.
  - ✓ Where appropriate, the interdisciplinary teams formed need to stretch the boundaries of disciplinary perspectives. While contributions of scientists, engineers, and economists are essential, input from legal, environmental, social, and business disciplines also is needed.
  - ✓ Aggressively pursue research efforts to foster innovation where strong opportunities appear to exist within Michigan, such as novel downstream applications of bioproducts, use of perennial grasses and crop residues (corn stover) as feedstock, and implementation of high growth forest technologies to support biofuel and bioproduct supply chains.

Key Recommendations Associated with Theme 3:
Insure that the necessary research and development facilities, including commercialization and business development support infrastructure, are available to match the current and future needs of Michigan's bioeconomy.

- Specify facility needs associated with the high priority ventures identified within the Theme 2 recommendations. A comprehensive, innovation ecosystem perspective should be adopted examining both on and off-campus requirements. Aggressive collaboration with public and private sector ventures can enhance the timely access to key facilities. Public-private facility collaboration may require innovation relative to organizational interrelationships as well as foster alliance-based pursuit of additional resources.
- Even with effective and extensive collaboration, significant new resources are likely to be required to support leading edge research and outreach in support of Michigan's aspirations to excel as a leader in the emerging bioeconomy. Targeted public support for facility development likely is required. A significant public initiative is critically important as a signal that Michigan's leadership aspirations warrant investment from both public and private sources outside of Michigan.
- Establish the capability to provide business development and commercialization support for biobased products and business ventures as a key component of the enabling infrastructure available through the OBT.

- Establish and maintain a comprehensive internet web resource center to support collaboration and outreach efforts. While the physical resources referred to above are essential, a virtual infrastructure focused on the bioeconomy of Michigan and its innovation ecosystems will allow those physical resources to be leveraged more effectively.

Key Recommendations Associated with Theme 4:

Aggressively strive to ensure MSU's leadership role within the innovation ecosystem of the Michigan bioeconomy.

- Establish an "Office of Biobased Technologies Advisory Council". Active involvement from a broad cross section of stakeholder groups is essential to success of the Council. Although presumably more active in its initial stages, this group would meet at least semi-annually to enhance private sector collaboration, identify emerging issues, and provide recommendations for activities of the OBT
- With input from both the OBT Advisory Council and other stakeholders, establish an OBT statement of strategic intent which identifies:
  - ✓ an aggressive set of long-run desired objectives,
  - ✓ the specific collection of measures by which progress to attaining the desired objectives will be assessed on an ongoing basis, and
  - ✓ the individuals responsible for ensuring that the process operates on a continuing basis.
- Assess, on an on-going basis, the effectiveness of campus policies, procedures, and practices relative to the protection, transfer and commercialization of bio-related intellectual property. Establish means to score campus efforts so that economic development within Michigan is included as a relevant factor.
- Assemble a group of campus representatives and students to examine campus operations and to develop recommendations for policies that will encourage the use of biobased products and methods.

Proactively accept the responsibility to ensure that current and future undergraduates are extremely well positioned to appreciate, to be able to evaluate and to provide public and private sector leadership as the bioeconomy evolves by incorporating bioeconomy perspectives within appropriate curricula and by engaging campus student activity groups to champion bioeconomy opportunities.

# Preparing for the Future of Michigan's Bioeconomy
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## 1. Introduction

### 1.1. Purpose of this Report

The bioeconomy holds tremendous promise to create economic and environmental benefits around the globe. This is particularly true for countries such as the U.S. that have the advantage of highly productive lands. A future built on renewable resources is inevitable – the question is no longer if, but when?

As in many states across the country, leaders in Michigan are examining bioeconomy-related opportunities that exist for the state and what needs to be done to capitalize on those opportunities.

The objectives of this report are to:

- Identify key impediments to development of biobased value chains within Michigan and specify actions to reduce such impediments. Special attention is directed to potential actions to reduce those impediments by the State of Michigan and by leading academic institutions such as Michigan State University (MSU).
- Specify opportunities by which MSU, through its Office of Biobased Technologies (OBT) could accelerate and solidify Michigan's position as a leader in the bioeconomy.

The definition of the bioeconomy is quite broad, encompassing everything from medical to industrial applications. The focus in this report is on those parts of the bioeconomy that comprise mainly industrial biotechnology applications. This includes all of the supporting platforms for the production of fuels and chemicals from biomass.

Much is written and speculated about the technologies that will need to be developed to enable the bioeconomy. While extensive consideration was given to the technical aspects in the course of developing this report, the purpose here is not to assess the viability of these technologies or to set priorities for specific targets to pursue. Answers to those questions will come from ongoing technical research and practical experience. Rather, this report is focused on developing a systems view of the bioeconomy's potential and on formulating recommendations to the OBT for its role in helping Michigan take a leadership position in the bioeconomy.

This study's analysis, findings, and recommendations assume that the bioeconomy will attain significant size and scope as an economic sector nationally and globally. Of course, numerous uncertainties exist relative to the future evolution of this sector. Further, evaluation of alternative economic sectors and their potential for growth as a component of Michigan's economy was not part of this study.

### 1.2. Organization of this Report

This report is organized in five sections as follows:

Section 1 – Provides general background about the report and the activities involved in its development.

Section 2 – Identifies assumptions about the bioeconomy and describes the strategic frameworks that were used in developing recommendations.

Section 3 – Describes and evaluates three case studies representing different types of bioeconomy value chains of relevance to Michigan. These are used to provide tangible examples to help frame the impediments and opportunities for Michigan's bioeconomy.

Section 4 – Presents conclusions that emerged from work with the case studies and interactions with stakeholders and industry experts.

Section 5 – Presents recommendations for the Office of Biobased Technologies.

## 1.3. Project Background

### 1.3.1. Phase I Activities

The work in this report builds on an earlier report titled "Linking Knowledge and Resources to Support Michigan's Bioeconomy" which was released in April 2006. As the title suggests, that report was focused on defining Michigan's physical resources and linking them to essential elements of knowledge creation. That report also included descriptive materials that have been used to support various meetings and presentations at the local, state, and national levels.

### 1.3.2. Work Steps

The findings and recommendations contained in this report were derived from a number of formal and informal activities and sources. These included sources both within and outside of Michigan.

*One-on-one or Small Group Meetings*

Synthesis of meetings with various experts and stakeholders has provided a significant amount of the knowledge generated during this project. These meetings included individuals from three main groups:

- MSU researchers and administrators
- Private sector
- Community leaders

*Conferences and Workshops*

Members participated in regional and international conferences focused on various aspects of the bioeconomy as a way to obtain up-to-date information about developments. These events provided value beyond the presentations and published literature through interaction with industry experts, discussing challenges and strategies being pursued across the United States and in other countries.

*Model Building and Analysis*

It is challenging to study the bioeconomy and its future impacts because there is considerable speculation as to exactly what that system will look like. Examples of pieces of the system exist, but substantiated visions of the system as a whole are lacking. Further, the success of any component of the bioeconomy system will be dependent on a number of other components that must work together in an efficient and seamless fashion. These factors make it more difficult, and more interesting, to craft strategies at this time.

System modeling provides methods that help to define what major elements of the system will look like and how they might interact and evolve over time. System models were developed as a part of this project to better understand the interactions within biorefinery value chains.

It is important to note that the purpose of these models is not to document feasibility. Rather, they look broadly at the whole value chain and how it can evolve over time. Two versions of a "Biorefinery Value Chain Analysis" (BVCA) model were developed. One is focused on grass and crop residue feedstocks and the other on forest products feedstocks. Results from these models were used to develop the case studies used as the basis of discussion at the Office of

Biobased Technologies' Bioeconomy Roundtable and with other industry and stakeholder interactions. Insights from these models are described in Section 3.

In addition, a "Feedstock Footprint Calculator" model was developed. The purpose of this tool is to quickly compute the catchment area required for various feedstocks based on assumptions about production factors and farmer participation rates.

These models are designed so that they can continue to be updated as better knowledge is gained through research or actual experience. In the future, these models can provide the foundation for analysis of alternative scenarios.

*Literature Review*

An extensive literature review was conducted and a library of reference materials was assembled to support the findings of the research team.

### 1.3.3. Bioeconomy Roundtable

A key activity within the project was the conduct of an intense roundtable discussion meeting held over the two days, October 2 and 3, 2006. The meeting was sponsored by the MSU Office of Biobased Technologies and was attended by 19 participants, representing a cross section of interests from the private sector, non-governmental and public interest groups and from the university community. These individuals were selected and invited to participate because of their interests and experience relative to differing elements potentially relevant to the bioeconomy. The meeting objectives were to:

- Begin building a network of individuals and organizations who can work with MSU and the Office of Biobased Technologies to provide leadership in growing a robust bioeconomy sector in Michigan,
- Raise the level of awareness and knowledge about the potential of biobased technologies in Michigan,
- Build a common understanding of the challenges and opportunities to making Michigan a leader in biobased technologies, and
- Develop a list of priority actions that the Office of Biobased Technologies should consider pursuing in its quest to advance the bioeconomy in Michigan.

The roundtable meeting was conducted in a highly participative fashion. Early sessions focused on describing key concepts relating to the structure of supply chains that would need to exist in a functioning bioeconomy sector and on highlighting the key roles of the broader ecosystem that would need to develop to support that sector. Then the participants explored three alternative case settings that could exist within a Michigan bioeconomy. The primary feedstock differed in the three cases' settings. One case dealt with grain as a feedstock source, one with a cellulosic source and the final dealt with forest products as the feedstock. In each setting, quantitative information was provided relative to the size and scope of a viable sector. The participants then analyzed impediments, opportunities, and challenges in each case setting. Copies of the descriptive materials provided for each of these case studies are provided in Appendix A.

The culminating session of the roundtable focused on actions and initiatives that MSU and its Office of Biobased Technologies should pursue to develop an innovation ecosystem which would foster development of a bioeconomy within Michigan. The deliberations of the roundtable participants resulted in specification of potentially attractive actions that the Office of Biobased Technologies should pursue. Those actions can be summarized as four general themes:

1. Inform and enhance public understanding and public policy decision processes regarding the pace and nature of growth within the Michigan bioeconomy.

2. Foster interdisciplinary scholarship which acts as an innovation catalyst for Michigan's bioeconomy.
3. Insure that the necessary research and development facilities, including commercialization and business development support capabilities, are available to match the current and future needs of Michigan's bioeconomy.
4. Strive aggressively to ensure MSU's leadership role within the innovation ecosystem of Michigan's bioeconomy.

These themes are further described in Section 4.2. Recommendations linked to those themes are provided in Section 5 of the report.

## 2. Key Concepts and Scope

The growth of the bioeconomy will be evolutionary in some respects and revolutionary in others. Revolutionary changes will be driven by:

- The large scale of production necessary to achieve economies of scale.
- The extent of new technology development and the interrelation between technologies.
- The realization that growth often will involve changes throughout the value chain.
- The fact that solutions will be multidisciplinary in nature.

Many of these revolutionary elements involve discontinuities that will disrupt business as usual. Thus, novel strategic approaches will be needed to navigate through the change. The following provides a compilation of assumptions and conceptual frameworks that serve as the foundation for the final recommendations of this report.

### 2.1. Background Assumptions

The magnitude of impact that the bioeconomy will have and the timing of when it will occur are topics of ongoing and rapidly evolving debate. Developments are announced daily, whether it be a new technology that promises to change the landscape or the formation of an investment group to build another production plant. This environment makes it difficult to establish a solid point of reference. However, the following discussion summarizes some general assumptions underlying the recommendations of this report.

#### 2.1.1. Michigan Resources

The following table from the Phase I report summarizes Michigan's position in four key areas relative to other states based on feedback from interviews and other research.

| Natural Resources | Michigan's Relative Position |
|---|---|
| Diverse crop base | Very strong and second only to California in terms of diversity. |
| Forest resources | A strong contender - with capacity to grow. |
| Water | A diversity of water resources that are well managed. |
| Climate | Michigan has a number of different micro climates that support a diverse production base and potential. |
| Overall | Crop production is a good asset, but not sufficiently strong to put Michigan significantly ahead of other top ag states. Diversity and specialty production is a strong suit, but cannot compete with neighboring states to the south and west in terms of production quantity of grain crops. However, the overall combination of crop production and the significant forestry resources is somewhat unique. |
| **Industrial Infrastructure** | **Michigan's Relative Position** |
| Biomass handling capacity | Considerable experience with lots of underutilized capacity in the handling of forest products. |
| Labor | An abundance of skilled labor is available throughout the state - both in urban centers where manufacturing jobs have been lost, but also in rural areas among workers who previously commuted to urban centers and as a result of the economic slowdown in the forest products sector. |

| | |
|---|---|
| Manufacturing capacity | Significant amount of surplus manufacturing capacity that may be suitable for conversion to biobased products. |
| Transportation | Generally strong - nice balance of highway, rail, and water. Access to Canada and international waterways. |
| Overall | Fairly strong. Challenge is whether the bioeconomy will grow in time to utilize these resources before they exit (labor) or become obsolete (manufacturing capacity). |
| **Intellectual Capabilities** | **Michigan's Relative Position** |
| Public sector research | Strong, but other states and regions also have formidable presence in the areas of biomass conversion. |
| Private sector research | Strong overall and diverse. Not notably ahead of other states and regions in the area of biomass conversion. |
| Other research/incubator | Strong with MBI International and NextEnergy being unique assets. |
| **Leadership Commitment** | **Michigan's Relative Position** |
| Government | Strong support of the bioeconomy concept. Grant and incentive programs are available to be used for bioeconomy-related development. |
| University | Very strong and unique commitment on the part of President Simon from MSU. |
| Industry promotion groups | Strong and ready to respond - seems to be a willingness of these groups to work together, which is unique. |
| Private sector | Not clear. No notable examples of commitment to the bioeconomy on the part of the private sector were identified. |

In summary, Michigan is definitely positioned to be a contender in the bioeconomy, but overall does not have a sufficiently large physical resource base to make it exceptionally unique or to stand head and shoulders above other states or regions. Perhaps the most outstanding element is the level of commitment that has been expressed by the administration at MSU. While many other universities have identified the bioeconomy as an important part of their future, to our knowledge, none have made the level of commitment that Dr. Simon and her administration have made in recent months.

### 2.1.2. Policy Expectations

We assume that there will continue to be strong support of the bioeconomy at both the state and federal levels. As the public becomes more aware of the possibilities that the bioeconomy offers to offset dependence on foreign oil and to help address environmental concerns, they will continue to support the bioeconomy through legislation. This will likely result in the continuation or expansion of public programs for some or all of the following:

- Bioproduct use mandates
- Subsidies and incentives for the production of bioproducts
- Public funding for technology development
- Pressure to reduce carbon emissions

## 2.2. Characteristics of the Major Components of the Bioeconomy Considered

### 2.2.1. Biomass Production

The "fuel" of the bioeconomy is biomass inputs.

*Biomass Sources*

Biomass will come from a variety of sources, including existing and new types of production systems. The following identifies examples of five types of biomass feedstock with relevance to Michigan followed by a brief statement of opportunities and issues for each.

Existing biomass growth (not currently utilized)

Example: Biomass from forest resources that are not currently being harvested.

Opportunities: Michigan has an abundance of forest resources and an infrastructure to collect and deliver.

Issues: Getting access necessary to harvest from forests that are not currently being harvested. This is limited by policy in some cases (state or federal forest land policies), and personal preference in others (individual ownership desires to allow or not allow harvesting).

Existing biomass growth (currently utilized)

Example: Corn or other grains that could be diverted to bioprocessing uses. This could also include diversion of currently harvested forest products to bioprocessing.

Opportunities: Michigan has a diverse ag production base that could provide a variety of specific feedstocks.

Issues: Economics of competing with alternative (and established) uses. Also, at the bigger picture level, there may be some social stigma with regard to the “Food versus Fuel” debate.

Cultivation of new crops specifically for biomass

Example: Establishment of switchgrass or expansion of existing crop (Canola) to meet demands.

Opportunities: Michigan has a climate that is conducive to growing some of the more promising dedicated feedstocks and producers who are capable of growing a variety of crop types.

Issues: The time required to get new crops established and producing reliably. This includes agronomic, economic, and social impediments. If the new crops are being grown on land that is not currently cultivated, there may be environmental and ecological issues.

Gathering of biomass that is not currently fully utilized

Example: Stover from corn or other crops.

Opportunities: Michigan grows significant acres of crops that could provide these types of biomass to supplement other feedstocks.

Issues: Could change the balance of agronomic ecosystems by removing biomass that was otherwise left behind. Also, per acre yields tend to be lower, requiring broader catchment areas to achieve necessary volumes.

From recycled sources of biomass

Example: A wide variety of feedstocks ranging from waste from food processing and preparation, to municipal solid wastes (MSW), to livestock manure.

Opportunities: Michigan has concentrated population centers that could be a source for recycled materials.

Issues: Cost of gathering sufficient quantities from broadly distributed collection points. Basically, it is cheaper (in short-run economic terms) to send many of these materials to the landfill.

In addition, there are many other niche types of biomass production that could be used for specialty purposes.

*Local Biomass Utilization*

A fundamental "rule" of biomass utilization is that due to its bulk and relatively low value, biomass must be processed (or at least pre-processed) very near the location where it is harvested[1]. The general rule of thumb is that transportation costs will prohibit hauling raw biomass any farther than 40-50 miles. (For forest byproducts, proximity to the location of milling facilities is economically vital.)

At the same time, economies of scale will dictate that bigger plants will generally be more economically viable than smaller ones. This means that feedstock production for a given plant will need to be highly concentrated surrounding that plant.

*Feedstock Storage and Transportation Issues*

Like most manufacturing operations, the efficiency of a biorefinery is dependent on running 24 hours per day every day of the year. This continuous consumption of feedstock is quite different than the annual harvest cycles of the feedstocks. This will require that a full year of production will need to be stored and queued for delivery throughout the year.

On one hand, this is no different than what happens with most other crops. For example, corn is only harvested once per year, but livestock keep eating and processors keep processing corn all year long. However, there are a couple of key differences here. First, cellulosic biomass is very bulky when compared to corn. There is simply a lot more volume that must be handled for each dollar unit of value. Second is the ease with which corn can be stored and handled. It can be stored in bin, then sent through an auger or dumped in a receiving pit and moved efficiently from one place to the next as needed.

The storage and handling systems for grains have evolved over many years to become very efficient. Similar advances will need to occur in biomass storage and handling. The difference is that they will need to evolve much more quickly in a given location to support a single biorefinery.

### 2.2.2. Biomass Processing

At the core of the value chain is the biorefinery. The American National Renewable Energy Laboratory (NREL) defines this as follows, "A biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, and chemicals from biomass. The biorefinery concept is analogous to today's petroleum refineries, which produce multiple fuels and products from petroleum. Industrial biorefineries have been identified as the most promising route to the creation of a new domestic biobased industry."

Biorefineries will include a large range of processing technologies. This is particularly true for the conversion and/or separation of the wider range of components of renewable feedstock raw materials. Pre-processing involves breaking down the plant raw material into more concentrated/specific products. An example of a pre-processing technology being developed at MSU is the ammonia fiber explosion (AFEX) process. This involves heating and pressurizing cellulose fiber, ammonia, and water to expand the fiber and to enhance enzymatic hydrolysis.

Pre-processing may take place at the same location as the biorefinery, or at a separate location. Since much of the raw biomass material is bulky, having several pre-processing plants spread out around the actual biorefinery may provide an advantage. This would involve converting the raw material to more concentrated output to decrease transportation costs and logistical challenges. This leads to the "spoke and hub" pre-processing model which involved locating many pre-processing sites in a radius around a biorefinery which serves as the hub.

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[1] Hettenhaus, J. Biomass Commercialization and Agriculture Residue Collection. Biorefineries—Industrial Processes and Products. Status Quo and Future Directions. Wiley-VCH. 2006. p. 317.

The structure of the biorefinery is changing as time evolves and technology changes. The most basic biorefineries have limited capabilities of just a few products, while the more advanced biorefineries of the future will be capable of handling multiple inputs and producing multiple products to meet current market demands. This progression of capabilities is described as 1st, 2nd, and 3rd generation biorefineries.

1st Generation Biorefinery – These types of refineries accept raw product and turn it into one type of output through one available processing channel. A dry milling ethanol plant is an example of a 1st generation plant because it produces a fixed amount of ethanol, feed co-products, and carbon dioxide from grain. This type of biorefinery has little flexibility in processing and is very product specific.

2nd Generation Biorefinery – The technology in this type of biorefinery uses grain feedstocks to produce end products depending on demand. An example would be current wet milling technologies to produce starch, high fructose corn syrup, ethanol, and corn oil. This type opens numerous possibilities to connect industrial product lines with existing agricultural production units.

3rd Generation Biorefinery – These advanced biorefineries have not been built yet, but they will use a variety of agricultural or forest biomass to produce multiple products streams. A key difference will be the ability to change the mix of output products to meet current market demands.

The location of a biorefinery will also be critical to its success. To minimize transportation costs, the biorefinery needs to be near concentrated and reliable sources of the feedstock. The refinery should also be near a reliable water supply due to the vast amount of water needed for refining. The refinery also should be in a location with efficient transportation to deliver final products.

In order to be economically viable, biorefineries will need to integrate many technologies within the larger system. For example, byproducts such as lignin will be used to generate heat for refining processes. Also, due to the extremely large volumes of specialized enzymes that will be required, it is expected that enzyme production facilities will be located on-site to ensure a steady supply and to save on transportation and handling costs. This will involve combining many different technologies (old and new) into entirely new systems that have never been tested at a production scale.

In addition to the many functions that will take place at the biorefinery, it is generally accepted that biorefineries of the future will need to be very large in order to realize economies of scale. This size requirement combined with the sophistication of the equipment needed will lead to the need for extremely high investment. It is estimated that full-scale biorefineries will cost at least $300 to $500 million each.

### 2.2.3. End Products

A wide range of biobased products will be made from sugars, lignin, synthesis gas, pyrolysis oil, and other biomass-derived platform chemicals. These will be processed into a number of different biobased products including transportation fuels, commodity chemicals, and combined heat and power technologies for the utility market. Figure 1 summarizes the categories of products that could be produced.

| Plant Raw Material | Pre-Processing Output | Fuels | Chemicals | Polymers | Feeds & Foods | Monomers | Lubricants | Electricity | Steam | Fertilizer |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Final Processing Output | | | | | | | | |
| Grains | Carbohydrates | x | x | x | x | x | | | | |
| Crop Residues | Protein | | | x | x | | | | | |
| Oilseeds | Oil | x | | | | x | x | | | |
| Sugar Crops | Syngas | x | x | | | | | x | x | |
| Woody Crops | Lignin | | | | | | | x | x | |
| | Ash | | | | | | | | | x |

**Figure 1. Summary of Biobased Products**

Some of these output products will be able to replace their petroleum-based counterparts directly, while others will provide the foundation for entirely new products. Either way, it will be essential that these products can be produced at prices that are at or below the petroleum-based alternatives.

It will be important to understand the impact of increasing the supply of output products on the market price for those products. For example, consider a biorefinery that will be capable of producing significant quantities of a specialty chemical that sells for $100 per pound, based on current supply and demand in the market. Basic economics tell us that any significant increases in the supply of that chemical can have a negative impact on the market prices, especially if the product has limited downstream uses. Thus, it is conceivable that the added production from this biorefinery could cause the price to drop below $100 and cut into profits. This reinforces the importance of being able to change what is being produced based on downstream demand.

## 2.3. Strategic Frameworks

Conduct of the project and crafting of its findings and recommendations benefited from application of a number of frameworks from the strategic management literature and practice. In this section three of these frameworks, which are employed in later sections of the report are briefly detailed. The three frameworks are:

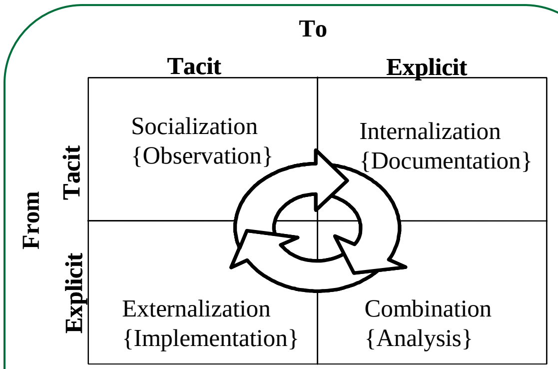
- Knowledge creation archetypes,
- Innovation ecosystems, and
- Strategic intent.

### 2.3.1. Knowledge Creation Archetypes

MSU aspires to be a research and development hub (R&D hub) within the knowledge-creating community necessary to support the emerging bioeconomy. This aspiration explicitly includes the goal of enhancing economic growth, investment, and employment within Michigan. In this context, research success is necessary but not sufficient. Research success, as measured by journal articles and even patents, does not necessarily translate into economic growth within Michigan. Knowledge, in these forms, is highly mobile. The innovations that emerge from research and the economic impact associated with exploiting that knowledge can occur in any locale. Therefore, it is important to address knowledge creation from the broad perspective of marketplace innovation, extending from the lab to its impact in society.

Nonaka and Takeuchi[2] (NT) provide a particularly useful description of the process by which firms employ systems to generate knowledge resulting in innovation. They advance two key concepts within this framework. One of these is the recognition that there are two types of knowledge: explicit and tacit. The second concept focuses on the necessary interaction within those knowledge types – to create the knowledge spiral that leads to innovation. Both of these concepts will be briefly described here.

Explicit knowledge refers to knowledge that is transmittable in formal, systematic language. Definitions, equations and theories in journal articles are examples of explicit knowledge. Structured educational experiences typically emphasize the value of explicit knowledge. NT makes an important contribution by stressing the key role of tacit knowledge within innovation processes. Tacit knowledge refers to the "mental models" that all decision makers possess of "how the world works". Tacit knowledge can be thought of as know-how, experience, and skill that all individuals use routinely.




*(Adapted from Nonaka and Takeuchi. The words within the brackets are interpretations of the NT terms)*

**Figure 2. The Knowledge Spiral**

NT emphasizes the interactive role of both explicit and tacit knowledge, stressing that managers can implement systems and processes that intensify the effectiveness of these interactions. When effective in fueling innovation, these systems lead to the knowledge spiral depicted in Figure 2. Although ideally a continual process, it is necessary to describe the knowledge spiral sequentially. The upper left-hand quadrant, labeled **socialization** by NT, deals with observation focused on recognizing problems and opportunities. This recognition often occurs through subtle non-verbal cues and conversation. The experienced plant manager who can sense when performance problems exist, even when not apparent to others, exemplifies the socialization phase. The **internalization** quadrant (upper right-hand quadrant) exists because tacit knowledge by itself often is not sufficient. The process of making tacit knowledge explicit is necessary for effective communication but also can clarify dimensions of the issue furthering the innovation process. The lower right-hand quadrant, **combination**, refers to the type of intensive study and investigation typically associated with the formal research process. The final, lower left-hand section of Figure 2 is labeled **externalization**. Formal research results typically need to be adapted to specific contexts, requiring and fueling the development of tacit knowledge.

The circular set of arrows emphasizes the active, dynamic component of the knowledge spiral. It highlights the notion that effective knowledge creation is a continual process, incorporating both tacit and explicit knowledge. NT conducts analysis in the context of the individual firm. However, this framework is relevant across a value chain as well. Indeed, the knowledge spiral of Figure 2 appears to be highly consistent with the historic effectiveness of the land grant university system in fostering innovation in U.S. agriculture.

The NT concepts provide an informative vehicle by which to contrast knowledge creation processes and expectations of the historic land grant university/agriculture system with those of today's research university. Within today's research university, research faculty excel at the combination phase of the knowledge spiral, where the emphasis is creation of explicit knowledge. The internalization phase also works well when the conversion of tacit to explicit

[2] Nonaka, I. and H. Takeuchi, The Knowledge Creating Company. Oxford University Press, New York. 1995.

knowledge is performed by a research expert such as program managers within government research institutes and/or corporate researchers. Success in this context is measured in terms of explicit knowledge artifacts such as journal articles, patents, and success in securing funds to support research. The externalization and socialization phases of the knowledge spiral typically are considered to be outside the purview and responsibility of research faculty.

The domain of the historic land grant system extended well further than that of today's research university. During the rapid transformation of U.S. agriculture in the early segments of the 20th Century, the state land grant university had active responsibility that extended beyond the conduct of explicit research. Success of the system occurred through productivity advances and economic development within the state's production agriculture and the rural communities that supported the ag sector. Through the Agricultural Extension Service, the land grant university had a tangible presence within the community, providing a communication channel to and from the university. Indeed, this communication channel performed the socialization and externalization phases of NT's knowledge spiral across public and private sector boundaries.

The historic land grant system operated as the R&D hub for production agriculture through a critical period of its growth and development. This perspective can be illustrative in the context of a potential role for MSU as an R&D hub for the bioeconomy and the value chains that will emerge as the bioeconomy expands. Excellence in the combination phase (where advances in explicit knowledge occur) is essential within an R&D hub. Discovery, however, is not sufficient to fuel innovation over time within a value chain. Mechanisms which can effectively accomplish the roles of the socialization and externalization phases of the knowledge spiral will be required for an R&D hub to support value chains within tomorrow's bioeconomy.

### 2.3.2. Innovation Ecosystems

Successful commercialization of new products and services is widely perceived as being of critical importance to economic growth, for firms and for regions. Typically, research and development activities are the source of those new products and services. However, there are numerous advances in the lab that never become useful products or services.

And even when a concept is expressed as a viable product or service, that doesn't mean that successful commercialization necessarily follows in short order. For example, HDTV products have been available for more than a decade but only now are starting to gain traction as a commercial innovation. Even though the technology has existed to produce and market HDTVs for many years, the supporting infrastructure was insufficient for much of that time. This example illustrates the notion that successful commercialization of an innovation often requires more than a technically feasible product offering.

The innovation ecosystem concept describes this phenomenon[3]. In Figure 3, the depiction of the bioeconomy supply chain used previously has been augmented to illustrate key notions of the innovation ecosystem. Here the biorefinery stage of the supply chain is at its center with input suppliers and customers on either side of that stage.

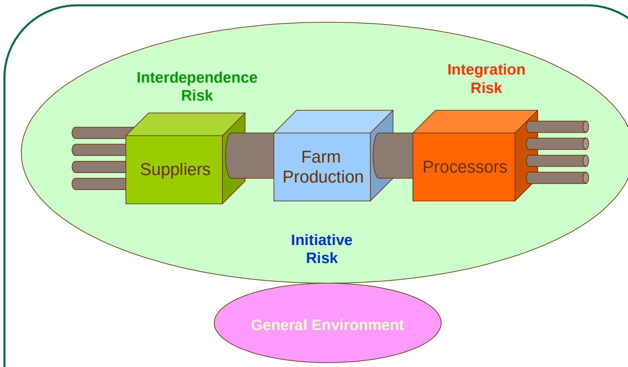



**Figure 3. An Illustration of the Innovation Ecosystem Concept**

[3] Adner, R. Match Your Innovation Strategy to Your Innovation Ecosystem. Harvard Business Review. April, 2006. 98-107.

Figure 3 lists three types of risk that relate to successful innovation:

- Initiative risk refers to the common perception of risk when contemplating a commercialization of a new concept. The questions here relate to whether the firm can successfully develop products or services which can be technically and financially successful from the original concept.
- Interdependence risk relates to the inherent uncertainties that exist when complementary innovations are necessary before the firm's innovation can be successfully employed in the marketplace. For example, a few years ago the technology to provide "real time" video through 3G wireless networks became available. Despite the presence of this capability and the widespread perceptions of consumer demand for it, actual adoption in the marketplace has been disappointing. Before this capability could be successfully employed, numerous other actors in this sector had to make technological advances to take advantage of 3G's performance benefits. When these advances were slow to develop, the adoption of 3G was similarly retarded.
- Integration risk results when firms and entities that stand between the innovating firm and its eventual customers have to alter their practices before consumers can benefit from the innovation. An example is Michelin's run-flat tire, which can signal to the driver that a tire has been punctured and will go flat within the next 100 miles. While an innovation that appears to have obvious consumer appeal, its use requires changes in automobile design and production systems, and special tools are required by mechanics to repair these tires. While the original innovation is ready, the need for change downstream in the supply chain can act to slow significantly its actual adoption.

The innovation ecosystem notion focuses on the supply chain surrounding the product or service of interest. Figure 3, however, explicitly recognizes the role of the general business and technology environment as a moderating factor. Technological advances in other industries, macroeconomic forces, and societal attitudes all can contribute to or retard adoption of new products and services.

The HDTV, 3G and "smart" tire examples all illustrate how the effects of the innovation ecosystem retarded innovation. However, innovation ecosystem events can work synergistically as well, advancing an innovation's adoption and impact. Figure 4 depicts, at a very general level, the innovation ecosystem structure as it relates to the dynamics of personal computer adoption over the last two decades. While innovating companies, such as Apple, IBM, and Dell to name a few, were central to this story, contributions of key suppliers (Intel, Microsoft) rapidly accelerated adoption.

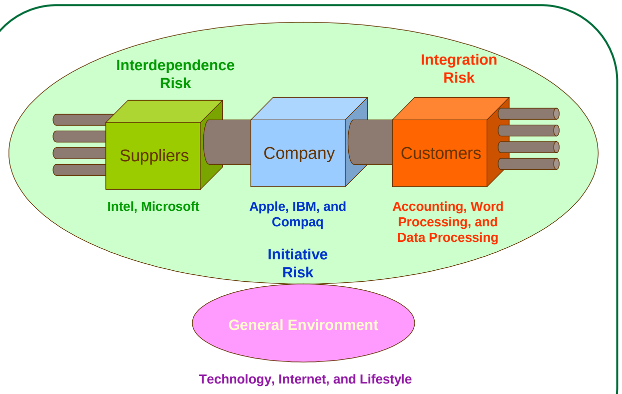



**Figure 4. Key Elements of the Personal Computer Innovation Ecosystem**

Customers, whether individuals or organizations, typically didn't want to own personal computers just to own something called a computer. Rather, they wanted the services that those tools could provide, when coupled with application software to do word processing, accounting, financial analysis, etc. Generally, different firms provided the software tools for these purposes and, typically, customers had to adopt their internal routines to most effectively use those tools. As the personal computer saga progressed, the advent of the Internet coupled with work and lifestyle changes facilitated by technological change drove the growing role of personal computers as communication devices.

The story of the personal computer, its phenomenal adoption experience, and its effects in society, therefore, is one that extends well beyond that of the firms which manufacture and sell personal computers. Instead, understanding this story requires consideration of the role of a complex, dynamic web of entities and forces. It is likely that the story of the emergence of a bioeconomy will be affected significantly by a similar innovation ecosystem.

While it has become natural to think about innovation and high tech products such as personal computers, the precepts underlying the innovation ecosystem do apply broadly. Indeed, technological change within agriculture can be affected by the same types of dynamics. Let's consider the soybean sector, particularly in the relatively early years of adoption of that crop.

Today, soybeans are one of the major crops produced within the United States. However, prior to the 1930s, soybeans were essentially insignificant as a crop activity, being planted on only a few thousands of acres in the nation. Today, soybeans are grown on more than 75 million acres and are a major source of economic activity for U.S. agriculture. Figure 5[4] shows the acreages devoted to soybean production over the last 70 years for the major soybean producing states in the Midwest. Examination of the early years of the soybean "miracle" provides an interesting illustration of innovation ecosystem concepts.

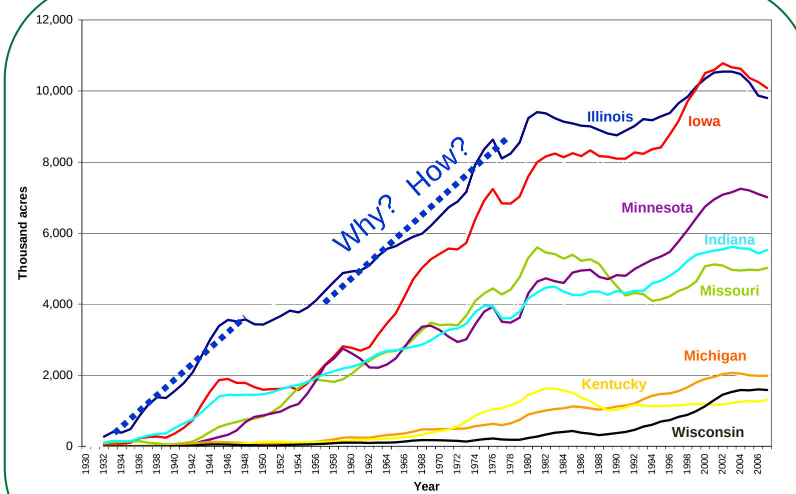


**Figure 5. Acreages Devoted to Soybean Production in 8 Key Production States in the Midwestern United States**

Today the soybean crop is harvested for its seeds which are then processed for the protein and oil products desired by society. Prior to the 1930s, however, most of the relatively few acres planted to soybeans were not harvested for the seed but were used as a source of forage for livestock. Outside of the soybean production sector, however, research and development was leading to change in the technology available to process soybeans into protein and oil. These developments fueled the demand for soybeans. Simultaneously, information was being developed which led to agronomic advances that allowed the soybean to be more effectively grown as a row crop, rather than as forage. The combination of these forces resulted in a sharp rise in soybean production, with the acreage devoted to soybean production by 1950 exceeding 15 million acres. And the production on nearly all of these acres was being harvested for the seed, not as forage.

Key locations that led in the application of soybean processing innovations were located in Illinois. As shown in Figure 5, the sharp increase in acres devoted to soybeans in Illinois during those early years can be directly correlated with the changes in demand for the crop. It is interesting that major drivers for change during that period were not constrained to agronomic and soybean production factors. Instead it was a combination of factors relating to suppliers, customers and supporting infrastructure entities that fueled and sustained those changes.

Figure 5 shows that another period of rapid increase in soybean production in Illinois occurred in the late 1950s and 1960s. Again, a combination of factors triggered those changes. Adoption

[4] http://www.nass.usda.gov

of new technologies in swine production and the movement to confinement production systems markedly increased demand for soybean meal as a source of protein. In tandem, advances in weed control, genetics, and fertility management allowed for changes in crop rotations so that soybeans could be effectively grown on more acres. Again, contributions from across the soybean supply chain and its supporting infrastructure were required to achieve these results.

#### 2.3.3. Strategic Intent

Technological, economic, and societal forces all suggest that the bioeconomy will be an important area of future growth. And, as detailed in this project's Phase 1 report, *Linking Knowledge and Resources to Support Michigan's Bioeconomy*, Michigan has a number of assets which can be important components of a vibrant innovation ecosystem for a bioeconomy sector. However, simply possessing assets doesn't insure that economic growth from innovation will occur. Further, there also are important asset areas in which Michigan's position is not one of relative strength. So, over the long term, we need to understand;

- How can Michigan's relative assets be enhanced to be exploited to serve as critical attracters of investment and growth?
- How can the asset areas which are not relative strengths for Michigan be enhanced or mitigated so as not to retard growth?
- What processes should be employed by the Office of Biobased Technologies to maximize the likelihood of achieving a vibrant biobased innovation ecosystem in Michigan?

It appears logical that the answer to the last question should be to develop a definitive strategic plan, which would identify the specific technologies to be developed, resources to be allocated, and markets to be targeted. While development of a typical strategic plan is apparently the obvious answer, extensive management research documents that this typical strategic planning approach is not the most desirable in these circumstances. There are two primary factors for this conclusion:

- Today our understanding of the evolution of the bioeconomy is fraught with uncertainty, not just relative to technology, but with respect to economic and societal forces. We all might be confident in predicting that the use of biobased materials will be significantly greater in 2020 than it is today. However, our confidence level will be much lower if we have to identify specific uses (as fuel, chemical substitutes, or industrial applications), specific feedstock sources, and precisely how much increased use will occur.
- The role of the Office of Biobased Technology is that of a catalyst and facilitator of change. The actual work of creating bioeconomy based economic growth (conducting research, developing technologies from research discoveries, and implementing new value chains) is outside the direct purview and resource base of the OBT. Yet, as with many chemical reactions, organizational change does not happen without an effective catalyst.

While specification of a comprehensive, detailed long term strategic plan has been shown to be relatively ineffective in such settings, academic research and industry practice have identified an appropriate set of activities that can be employed. An approach popularized by two scholars, Gary Hamel and C.K. Prahalad[5], is referred to as strategic intent. There are two key elements associated with effectively employing the strategic intent framework.

[5] Hamel, G. and C.K. Prahalad. Strategic Intent (HBR Classic). Harvard Business Review. July-August, 2005. 148-161.

- Developing and committing to a strategic intent which identifies an important and attractive future state and which will challenge the organization to achieve exceptionally high performance in attaining that state.
- Specifying a set of performance measures which can be used to routinely assess the organization's progress towards achieving its chosen strategic intent.

The process of developing the appropriate strategic intent is one which benefits from extensive participation. The input and critique of both internal and external stakeholders should be solicited. A natural tendency will be to aspire to achieve great success in all venues, therefore, the reality of resource and time constraints needs to be imposed to force assessment of alternatives. Identifying what won't be pursued is one of the high value steps in the process. While strategic intent development benefits from broad participation, commitment to a specific strategic intent is seldom best done by consensus or as a committee brokered compromise. The commitment step is the responsibility of the organization's leadership.

While much attention is typically devoted to specification of the statement of strategic intent, this effort will be effective only if there are processes put in place to identify progress towards achieving the organization's aspirations. That process must involve specification of criteria, objectives, and measures that can be utilized consistently over time. These factors should be tailored to the individual circumstances in each setting to best foster ambition and discipline. Four general areas for which factors typically are defined include:

- Financial perspectives, which include resource acquisition as well as revenue generation,
- Customer perspectives, which focus on how value is being created by those who are served by the organization,
- Internal process perspectives, which concentrate on enhancing internal practices and systems to foster new efficiencies, and
- Learning and growth perspectives, which foster a climate that encourages internal change, innovation and growth.

Over time, achieving a strategic intent will result from continued and disciplined assessment of the organization's progress relative to the criteria, objectives and measures it has outlined.

### 2.4. Systems View of the Bioeconomy

Figuring out how to stimulate growth of the bioeconomy is difficult due to the inherent complexity and interrelated nature of the system. Further, developing strategies around complex systems is especially difficult because different people view the elements of the system from their own perspective. This is a challenge on one hand. On the other hand, it is this diversity of knowledge that can collectively provide the insights necessary to yield effective strategies. Tools and methods are needed to describe the elements of the system in a manner that provides a common vision for discussion and strategy development.

System dynamics is a broadly accepted discipline that provides some tools that can help to understand complex systems and create such a common vision. These tools can be applied to identify key leverage points that can become the focal points of strategy.

One commonly used tool is a relatively simple method referred to as causal loop diagrams (CLD). This involves identifying elements of the system and visually showing how they are linked together. In this section, a CLD will be developed around a hypothetical biorefinery as a way to build a common vision of the elements of a biorefinery ecosystem as well as their interrelationships.

While we use the example of a biorefinery in this discussion, the concepts can be applied if the core element is a mega-scale biorefinery, a biodiesel plant, or a small-scale power generation facility. Obviously the scale changes, but the supporting elements are very similar.

Note that the terms “value chain” and “supply chain” are used throughout this report. They are largely interchangeable. However, “value chain” generally refers to the entire chain, whereas “supply chain” refers to the activities within a segment of the whole.

### 2.4.1. Core Elements of the System

Figure 6 can be used to depict the biorefinery value chain at a very general level.

The input supply chain depicted on the left side of the diagram represents all of the activities required to produce, harvest, store, condition, and transport the biomass feedstocks to the biorefinery.

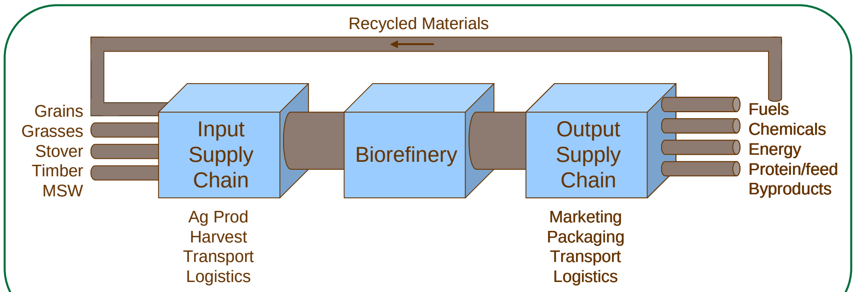



**Figure 6. Biorefinery Value Chain**

The icon in the center represents the biorefinery itself (or other bioprocessing activity). This is the plant where biomass is converted into fuels, chemicals, byproducts, heat, etc. When talking about the bioeconomy in Michigan, discussion most often leads to the importance of this component. In the course of interviews and discussions throughout this project, it is this component that most people wanted to talk about. Suggesting that “We need one of these”, or “The first state or region to get a full-scale biorefinery will create a tremendous competitive advantage, so this should be our focus.”

The icon on the right represents the output supply chain. The function here is to take the raw output from the biorefinery and further process, package, distribute, etc. In some cases where the output of the biorefinery is a direct substitute, the functions of this chain are identical to those of a petroleum-based value chain. In other cases, where the product is new or unique, the output supply chain will require development. Ethanol provides an example of the latter. On one hand, ethanol can be treated as a replacement for gasoline (if blended at 10% or less). On the other hand, if blended at the 85% level, changes are needed in the distribution and end use infrastructure (gas pumps and cars). Regardless of the level of blending, distribution and blending channels will require modification since ethanol cannot be handled in the same ways as gasoline.

Finally, the loop across the top represents the flow of recycled materials back to the input side of the system. This is an important element of the bioeconomy that is often overlooked. However, it is critical to the long-term sustainability aspect of bioeconomy.

### 2.4.2. Core Drivers and Linkages

This conceptualization of the biorefinery value chain can serve as the core of our depiction of the biorefinery ecosystem CLD. Many discussions about technical feasibility of the bioeconomy tend to focus on technologies that exist within the boundaries of the biorefinery. There also were numerous discussions about the needs for investment or a business environment that will support a facility such as this.

These elements can be added to Figure 7 indicating that the success of a biorefinery will be influenced by the level of each of them.

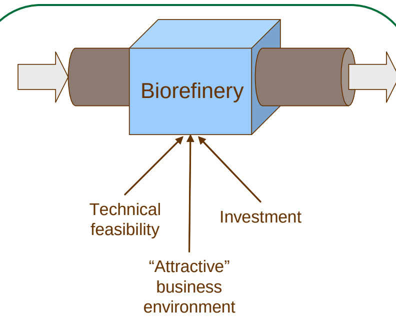


**Figure 7. Biorefinery Value Chain**

**Technical feasibility** – This relates to the myriad of technologies that need to be developed and deployed in order to process biomass inputs to their end or intermediary products. The technologies included here are very broad and include:

- Enzymes and other biological "tools"
- Mechanical processing systems
- Computerized monitoring and control systems
- Software systems (both production and business)

Challenges here include:

- Several individual components (many times each having their own Intellectual Property (IP) issues) need to come together and operate in a single system
- Many of the emerging technologies are proven at a lab scale only
- Much of the equipment must be custom-manufactured

**Attractive business environment** – This is a broadly defined category that includes all of those things that a large-scale business needs to reduce risk and insure success. Examples include:

- Local zoning ordinances that allow freedom to site and operate
- Support of the local municipalities
- Tax incentives
- Capable and reliable workforce
- Attractive living environment for employees (schools, recreation, housing, and other amenities)
- Reasonable legal environment
- Incentives and mandates that provide assurance of a long-term market for bioproducts

Challenges here include:

- The impact of such a facility is unknown, making it difficult for local municipalities to make prudent decisions (while erring on the conservative side could drive the business away)
- People with the expertise to run these kinds of facilities are scarce
- Most mandates and incentives have "sunsets" that have shorter cycles than the capital asset recovery periods

**Investment** – This is simply the dollar investment needed to build the plant and to initiate operations. This investment may come from individuals, cooperative investment groups, or existing businesses looking to diversify (common examples are chemical or energy businesses). Investment assistance may also come from local, state, or federal governments.

At a general level, these three elements capture the essence of what is needed to stimulate sufficient interest to build a biorefinery. The question is, how to build the substance within each of these elements to the levels necessary to provide investors with the confidence that they need to proceed with the decision to build a biorefinery.

**Investor confidence** – This driver represents the level of confidence that investors have in the concept of the biorefinery. As illustrated in Figure 8, the level of investor confidence will have a positive influence on the level of investment (that is, the higher the level of investor confidence is, the more likely that it will result in investment).

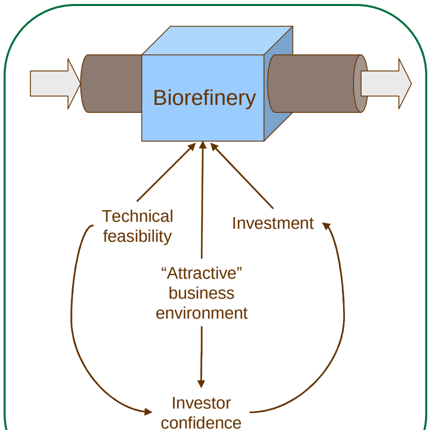


**Figure 8. Biorefinery Value Chain**

However, investor confidence does not exist in a vacuum by itself. It will be influenced by the levels of technical feasibility and attractive business environment. For example, a breakthrough or proof of technical concept would catch the interest of investors. A past example of this would be the Polylactic Acid (PLA) plant that was built in Nebraska by a joint venture of Dow Chemical and Cargill[6]. Even though it was a first of its kind plant, the investing firms were willing to make the investment in part because they had sufficient evidence that it was technically feasible.

Likewise, the investor will need to be convinced that elements in the attractive business environment are favorable to support the plant.

*Whole Chain Drivers and Linkages*

So far, we have been focused on the biorefinery segment of the chain. And as mentioned earlier, this is where much of the current interest and discussion is focused. However, the biorefinery will not be successful without equally functional input and output supply chains.

As depicted in Figure 9, investor confidence will also be a function of their perception of the capacity of the input and output supply chains.

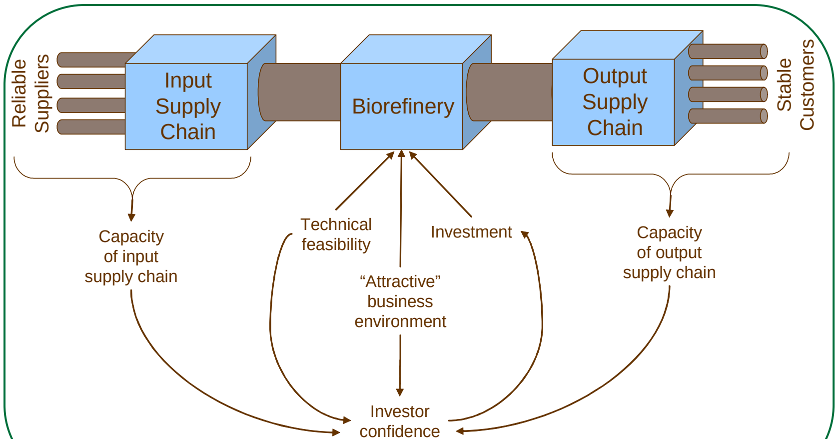


**Figure 9. Biorefinery Value Chain**

Biorefinery investors will carefully examine the robustness of the upstream and downstream supply chains before having the confidence to proceed. As an example, Dow and Cargill built their PLA plant in Nebraska where the supply of corn was very abundant. On the output supply chain, there was an existing transportation infrastructure to handle the product and a number of proven applications exist that can utilize PLA.

[6] Polylactic acid is a widely used polymer that can be melted it into fibers for a variety of uses ranging from packaging to clothing.

Figure 10 shows the expanded view which suggests that we not only have to focus on the technical feasibility, attractive business environment, and investment drivers for the biorefinery, but we also need to consider those factors in the upstream and downstream elements of the value chain.

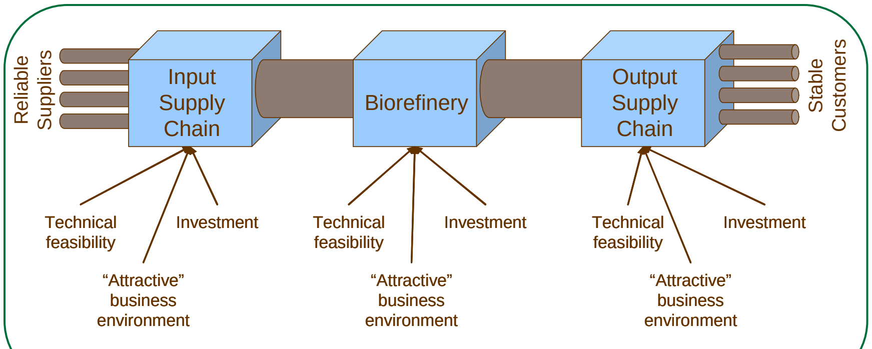


Figure 10. Biorefinery Value Chain

The level of complexity and degree of change required to the input and output supply chains will differ considerably, depending on the specifics of the biorefinery. For example, the level of change to the supply chain for corn-based ethanol is relatively minor. In this case, abundant quantities of corn are already being produced, handled, and stored, so it is a matter of using the same infrastructure to supply the corn to localized ethanol plants rather than to other markets.

Contrast this with a supply chain that provides cellulosic biomass from switchgrass. At a smaller scale, growing, baling, storing, and delivering switchgrass is relatively simple, and farmers have done similar production with hay and straw. However, the massive scale required to feed a single plant will require that an entire new supply chain be developed in concert with the establishment of the biorefinery. Likewise, a size-matched output supply chain will need to be developed.

Building these supporting supply chains around a biorefinery requires confidence that the biorefinery will be successful before investment will be made. As depicted in Figure 11, this leads to a "chicken or the egg" dilemma where the investors in the input and output supply chains need confidence based largely on their beliefs of the capacity and success of the biorefinery. And at the same time, the investors in the biorefinery need to have confidence in the capabilities of the input and output supply chains. When considering the scale of operations in a biorefinery value chain, this dilemma becomes quite significant.

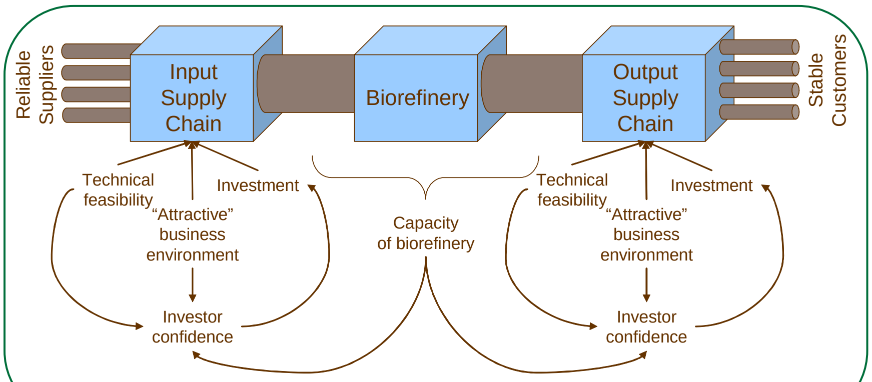


Figure 11. Biorefinery Value Chain

We believe that states or regions who can demonstrate that they truly understand these issues and are willing to make the necessary transformations will draw the attention of early investment. Accomplishing this is no small feat. It will require significant investments in research, education, coordination, and policy development.

*Input Supply Chain Considerations*

The input supply chains will evolve from the current agriculture production and forestry sectors. It is important to note that these are currently mature sectors and operating in relative stability.

Current situation

- The ag sector is producing a wide variety of crops that has been shaped by the physical environment and market demands.
- Land has been set aside in the Conservation Reserve Program (CRP) based on current rental rates and alternative economic options for production.
- Forest lands are not being harvested to their productive potential.
- The harvest, transport, and storage systems have evolved over years and are tailored to the current balance of production and market needs.
- The output finds its way into existing downstream markets.

Possible changes to support biorefineries

- New crops (dedicated energy crops) would be introduced and would replace existing crops.
- Existing crops would be used in different ways (corn and stover to ethanol or other chemical production).
- Some, but not all, CRP land would be converted to produce biomass crops as some owners of CRP ground are likely to regard non-economic factors as more important than economic returns from agricultural production.
- Increased intensity of forest harvesting.
- The harvest, transport, and storage infrastructure would need to be retooled to accommodate different product streams.
- New coordinated supply management systems would be developed to feed large biorefineries on a year-round basis.

There is little doubt that the natural resource base of Michigan is capable of providing significant amounts of biomass. However, the calculations of production capacity often overlook the fact that these resources are currently being utilized for other purposes. To introduce new crops into the mix at a large scale will require tradeoffs and will lead to economic or social stress.

Shifting acres from traditional crops to dedicated energy crops will largely be an economic decision for the farmer. For example, in the short run, it may make economic sense to move from producing crop X to grow a dedicated energy crop. However, as there is a large-scale shift away from producing crop X, the price offered for crop X will likely increase due to the reduced supply. As this happens, the economic advantages of growing the biomass crop will diminish, limiting the amount of acres that will be grown.

Similarly, CRP acres often are cited as an underutilized resource that could be used to produce biomass. While this may be logical from a short-term economic perspective, there will likely be strong social resistance to having CRP acres put back into production. Groups such as Ducks Unlimited and the National Resource Defense Council have already voiced concerns about the impact that this would have on natural ecosystems.

The retooling of the supply chain will be significant as well. Significant capital equipment costs will mandate that shared and coordinated arrangements be put into place to maximize efficiencies. This will not only require new types of equipment and physical handling techniques, but will also include new business models and contractual arrangements.

In the end, the most important attribute will be the reliability of supply. Reliability will be required in many dimensions – volume, quality, timing, and price.

*Output Supply Chain Considerations*

In some cases, the output supply chains will evolve from the current business models and in others it will require new models to be developed. Similarly to the input supply chains, the downstream value chains that will be impacted are well established and will have many forces that will resist change.

Current situation

- Fuels and chemicals come largely from petroleum-derived sources.
- Distribution systems are in place and built around existing refineries and processing facilities.
- Prices fluctuate based largely on supply and demand (actual and expected).

Possible changes to support biorefineries

- New players who specialize in biobased products will enter the market.
- Co-products will create the need for new "consumers."
- Distribution systems will need to be retooled and rerouted.
- Added supply will impact market prices.

Not long ago, it was believed that the big oil companies would be concerned about the evolution of bioproducts and they would take steps to keep it from happening. While some of this sentiment may still exist, it appears that the large oil and chemical companies such as BP and DuPont are poised to embrace biofuels and biobased chemicals. If this is true, it is very positive since it would be extremely difficult to penetrate those markets against their will. In fact, these large companies may be important sources of capital for the construction of biorefineries.

Even with cooperation from these players, the effort required for coordination of downstream markets and logistics will be significant. Just because a product is equal to or better than an existing product does not ensure its success. The products must either have significantly better qualities that lead to higher values that will cover the cost of conversion, or they will need to be easy to insert into existing processes.

### 2.4.3. External Drivers and Linkages

We can use this systems view of the biorefinery value chain to help organize thinking about what is needed to support those factors which ultimately lead to investor confidence. Figure 12 looks at a single sector generically and illustrates the key drivers needed to support the core factors that will support investment in that sector. While the details will be different, each of these factors can be applied in the three sectors.

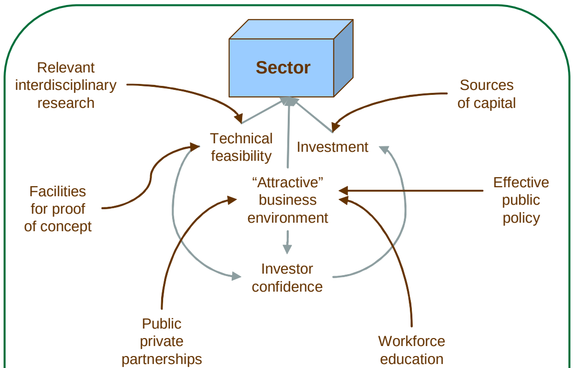



**Figure 12. Needed Drivers to Stimulate Investment**

**Relevant interdisciplinary research** – Technical feasibility for most all of the technologies will need to be multi-faceted. It is not about solving a single problem. It is about solving problems within the context of the larger system. For example, adding 20% to the biomass yield level could be insignificant if it comes at the expense of processing efficiency.

**Facilities for proof of concept** – Facilities are needed to support research and demonstration at a scale that allows a sound evaluation of feasibility. This includes demonstration facilities on or near the MSU campus as well as facilities built alongside existing production facilities where synergies exist. Infrastructure needs for a biobased innovation ecosystem are not solely physical in nature. New and emerging businesses in this sector will require on-going support relating to business development. Evaluating technological and market feasibility, developing new markets, and identifying value/supply chain opportunities all are activities that require considerable specialized expertise, especially when focused on an emerging economic sector. Both new and existing firms can benefit from university-based support for these activities and the existence of such support would signal MSU's commitment to the Michigan bioeconomy.

**Public/private partnerships** – In many ways, the magnitude of change that will be involved will be revolutionary rather than evolutionary. The private sector will need to have solid working relationships with the public sector. New partnership models will be needed.

**Workforce education** – A variety of new skills will emerge at all points along the value chain. This includes technical skills such as production/processing methods as well as education about new business arrangements that will emerge.

**Effective public policy** – Stability is the hallmark here. Companies need to know that they can rely on stable policies from the public sector. Currently, many corn-based ethanol plants are being built based on use mandates and tax incentives. These give the investors the confidence they need with respect to the future demand for the product within expected payback periods for those kinds of enterprises. However, the payback for a biorefinery value chain is expected to be significantly longer than the current corn-ethanol scenario, so longer-term assurances will be needed.

**Sources of capital** – This will need to include both private and public sources. In addition to direct investment capital, loan guarantees or other risk reduction tools will be needed from the federal government or other sources.

#### 2.4.4. Time Dimensions of the Bioeconomy System

In addition to understanding the components and linkages that comprise the system, it is important to consider the time dimensions of their evolution. Many different elements need to come together in order for a particular value chain to be viable. Understanding the time dimension of each of these elements individually as well as collectively will help the Office of Biobased Technologies to prioritize the focus and timing of various efforts.

For example, one of the core elements of the system just described is technical feasibility. If we apply this systems view to a particular situation, say a single biorefinery, there is a bundle of different technologies that need to be proven feasible in order to achieve success. These range from breakthroughs in biological processes to harvesting and handling equipment. It is not until technological feasibility is achieved and proven in all of the needed areas that the biorefinery will be viable. Add to this, the evolution of the elements of a business friendly environment and the need for investment over time, and the challenge becomes quite complex.

The other consideration about the time dimensions of the bioeconomy system relates to the overall pace of evolution of the bioeconomy. It is expected that individual technological advances will advance at a rapid pace. However, the number and complexity of the needed technologies will cause the overall pace of adoption to move more slowly than some might expect.

Larry Russo of the Department of Energy's Office of Biomass Programs provided a powerful illustration of the difference between corn-based ethanol and cellulosic ethanol. He asserted that for corn-based ethanol, the primary risk is market risk. This is because we basically have the technology[7] and business models figured out. On the other hand, the production of cellulosic ethanol, while technically feasible at a small scale, has many more risks. These include technological risk, financial risk, policy risk, project failure risk, and others.

For example, in the area of ethanol production, some industry experts suggest the following evolution:

- Short term (1-3 years) – continue to develop ways to enhance efficiency of grain-based ethanol production
- Intermediate term (3-8 years) – cellulosic production from stover and other ag residues, though probably not cost competitive until the latter part of this period.
- Longer term (beyond 8 years) – cellulosic production from dedicated biomass crops and forest biomass.

Keeping these timelines in perspective is a challenge in an environment where announcements are made almost daily about new technological advances. It is easy to see why people would come to believe that the technology is basically ready, and it is just a matter of getting plants built.

Managing realistic time expectations of stakeholders and policymakers will be very important to keep them from becoming discouraged. For example, if there is a perception that the feasibility of a forest-based biorefinery is just around the corner, there will be disappointment when the reality of an 8-10 year time lag plays out. At the same time, significant financial support and public policy actions will be needed throughout the evolutionary period if success is to be achieved.

### 2.4.5. Capturing Innovation Value Locally

As noted in Section 2.3.1, knowledge-based innovation is a process. Invention is the province of intensive analysis and produces explicit knowledge. Innovation, however, is only successful when commercial products and services compete effectively in the relevant marketplace.

Successful invention does not necessarily result in the benefits of innovation accruing within the locale where the invention occurred. For example, the web browser, Mosaic, was developed at the National Center for Supercomputing Applications at the University of Illinois. The vast proportion of the economic benefits that came from web-based innovation did not occur in central Illinois. Evidently the features of the innovation ecosystem necessary to move from invention to innovation were not present at the site where the invention took place. To capture the benefits of innovation, public and private sector decision makers need to recognize that systems to foster invention are not sufficient, in themselves, to guarantee that innovation occurs in the locale where the invention occurred.

## 3. Case Studies

### 3.1. Background and Purpose

Three case studies were developed to serve as benchmarks for discussions about Michigan's potential for the production of industrial bioproducts. The type and size of the case examples were selected to represent the range of issues that have surfaced during our research. The three cases include:

[7] While current technology uncertainty may be relatively low, further advances in technological capabilities certainly can provide important benefits, especially with respect to more effective means to deal with byproducts.

1. Grass and Ag Residues Biorefinery – considered the issues related to bringing a 90 million gallons per year (MMgpy) ethanol and chemical co-products biorefinery on line in 2011.
2. Forest-based Biorefinery – considered the issues related to bringing a 100 MMgpy ethanol and chemical co-products biorefinery on line in 2015.
3. Grain-based Biofuels – considered shorter-term opportunities in the areas of corn ethanol and biodiesel production.

It is important to note that the location, timing of construction, and other specifics of the biorefineries in these case studies should not be interpreted literally. The intent of depicting these examples is not to imply feasibility for a particular kind of plant in a particular location. Nor is the selection of case studies intended to represent the full range of possibilities for biobased value chains. Rather, the purpose is to provide a foundation for identifying the complex range of issues that will need to be addressed should a plant of the general size and type be built in different regions of the state.

The following discussion contains two sections for each of the cases. First is a general description of the parameters to characterize the scenario. Second is a discussion of findings that have emerged in the course of discussions with industry experts and review of literature. These findings describe various issues that will need to be addressed in some fashion should the scenario become reality and provide the foundation for the recommendations of this report. Historical values used to construct these scenarios were derived from various USDA-ERS publications.

## 3.2. Grass and Ag Residues Biorefinery

### 3.2.1. Description

This case depicts a biorefinery located in lower central Michigan that utilizes switchgrass grown on CRP and crop acres. The plant will be announced in 2007 and will begin production in 2011. It will produce 90 million gallons of ethanol per year plus a variety of co-product chemicals and other industrial products. Note that while the plant is characterized in terms of its ethanol production capacity, the value of the chemicals and industrial products produced are expected to be very significant as well. However, these are not discussed in specific terms since the possible portfolio of these products is very diverse and will be driven by emerging market conditions.

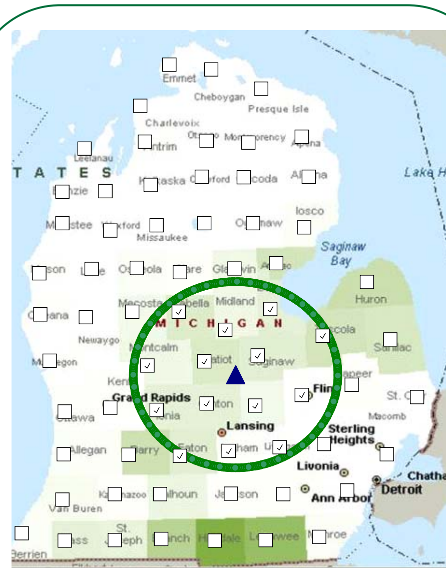



Figure 13. Catchment Area for Grass and Ag Residues Biorefinery

*Assumptions – Production*

- The feedstock would come from a 14 county catchment area as indicated in Figure 13.
- Farmers can ramp up to fulfill feedstock needs by 2011/2012. (As a point of reference, the current hay production in the catchment area is about 600,000 tons and additional production for the biorefinery will need to be about 1,100,000 tons.)
- 50% of the CRP acres would have to be used for switchgrass production.
- Farmers who plant on CRP acres would likely lose part of their payments.

- Production of switchgrass on crop acres would need to be competitive with lower-end traditional crop returns.  It is presumed that Michigan does not have significant competitive advantages in switchgrass production.
- Cost to produce crops during ramp-up period would be in excess of $50 million.
- The breakdown of the land in the 14 county area and the utilization of CRP and crop acres are depicted in the Figure 14.

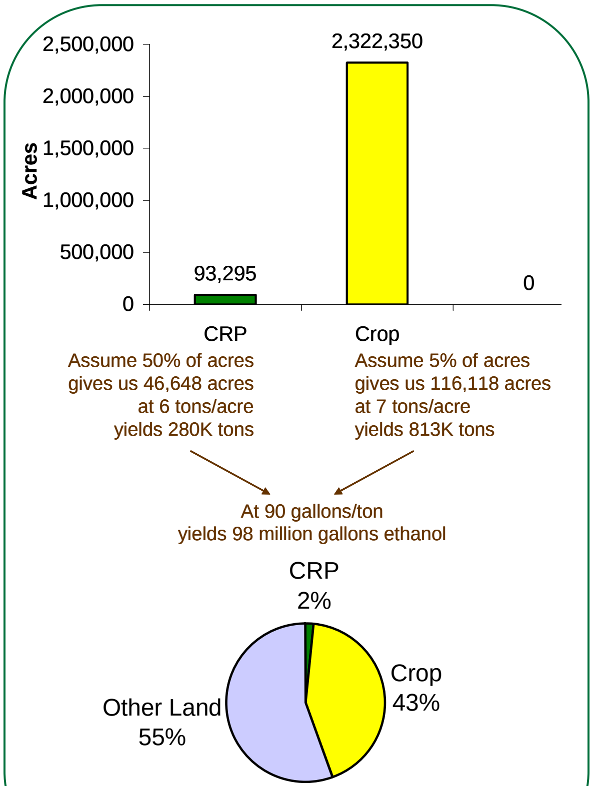


**Figure 14.  County Area Utilization of CRP and Crop Acres**

*Assumptions – Storage and Transportation*

- Storage and transportation infrastructure would need to be in place by 2011.
- Loading and unloading 182 semi-loads per day 360 days per year would be required (7.6/hour for 24 hour shifts, or 11.3/hour for 16 hour shifts).
- Creates around 75 jobs (direct)

*Assumptions – Biorefinery*

- Assume it is ready to begin processing by the end of 2011
- Capital investment of around $350 million
- Primary product would be ethanol, but also produces chemicals as dictated by market demand
- 10-20% of output value from co-products
- Initial ethanol yield is 89 gallons/ton, but ramps up to 100 by 2022
- Creates around 45 jobs (direct)

*Assumptions – Output Supply Chain*

- Ethanol
- Ethanol demand will be sufficient to utilize all of production
- Distribution systems are re-tooled as needed
- Chemicals
- Products will need to be equal to or superior to the products they are replacing
- End-users will need to accept these products as viable alternatives
- Retooling of marketing distribution systems will be needed
- Will likely rely on discovery of new applications for output products

### 3.2.2. Findings

*Competing with Traditional Crop Acres has Many Hurdles*

From an agronomic and ecological perspective, growing biomass on crop lands is very logical. This likely would provide the greatest yields since it is on land that has proven productivity and would cause the least disruption of ecosystems. With over 6 million acres in major field crops, Michigan could produce significant biomass. However, economically, there are a number of significant hurdles.

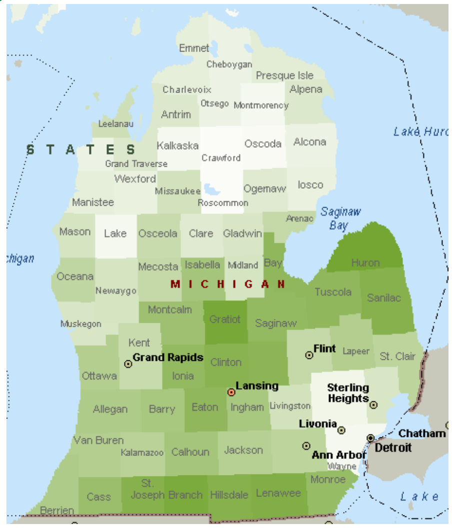



**Figure 15. Relative Density of Crop Acres in Michigan's Lower Peninsula**

Traditional Crops Set the Economic Standard

The economic value of raw biomass will continue to change as supply and demand evolves over time. Today, the value of raw biomass in Michigan is very low (or perhaps even nonexistent) since there are no processing facilities demanding it. But that will change quickly whenever a processing facility comes on line. However, the long run prices will eventually be established and will be a function of the difference between the value of end use products and the costs to process and produce those products (Table 1).

**Table 1. Biomass Value Computation**

| | Computation | Influencers |
|---|---|---|
| | End use value | Energy prices, cost of petro alternatives, demand for product |
| Minus | Processing costs | Investment required, technological efficiency, input costs, labor |
| Minus | Storage and handling cost | Equipment and infrastructure costs, fuel, labor |
| Equals | Biomass value | All of the above |

At the same time, the economics of growing biomass on traditional crop land will always be pressured by the value of the traditional crops. Farmers will not switch from traditional crops to grow biomass crops unless the returns and risks are better for the biomass crops. In today's price environment, it is difficult to justify replacing traditional crops such as corn, soybeans, or wheat with a dedicated biomass crop such as switchgrass. Further, the mid to long-term outlook for corn and soybean prices is currently very positive, due in large part to expected sustained demand for biofuels. If this holds true, prices for biomass will have to be quite high in order to displace those acres.

Table 2 indicates the value per ton that biomass would need to command in the market in order to be competitive with corn at various price levels.

**Table 2. Corn to Biomass Price Comparison**

| | Equivalent Range Biomass Price/Ton | |
|---|---|---|
| Corn Price | Low | High |
| $2.00 | $25 | $30 |
| $2.25 | $30 | $34 |
| $2.50 | $34 | $38 |
| $2.75 | $38 | $43 |
| $3.00 | $43 | $47 |
| $3.25 | $47 | $42 |
| $3.50 | $52 | $57 |
| $3.75 | $57 | $62 |
| $4.00 | $62 | $66 |

Switching Costs are Significant

Another challenge to increasing the amount of biomass grown relates to the costs of switching from traditional crops to biomass crops. This includes both hard and soft costs.

Hard costs include:

- Investment in new equipment (tillage, planting, and harvesting)
- Annual variable costs of production
- Initial establishment costs (especially if multi-year crop)

Soft costs include:

- Perceived risk of entering unknown territory
- Building agronomic experience
- Learning new crop operations
- Establishing new relationships with business partners

Establishment time is also an issue with certain biomass crops. For example, switchgrass does not reach full production until the third year after planting. There is no harvestable yield in the first year, roughly 50% of potential yield can be harvested in the second year, and usually full production in the third year. Even if the long-term economics are equal or better than traditional crops, the change requires a significant commitment on the part of the farmers to move from a known crop with returns each year to one that will require them to forgo full returns for two years.

In summary, replacing existing field crops with biomass crops could generate significant volumes of biomass in fairly concentrated areas. However, given expected price relationships between traditional crops and biomass, it is unlikely that significant acres will be converted exclusively to biomass production.

*Growing Biomass on CRP Land Appears Viable, but has Practical Limits*

CRP (Conservation Reserve Program) acres have been identified as a potential source of land for producing biomass. The logic is that this is potentially productive land that can be converted to biomass crops such as switchgrass with a fairly low opportunity cost (note that this assumes a relaxing of federal government policies that would allow CRP acres to go back into production – with or without partial continued rent payments). This makes intuitive sense, but there are certainly limits to the productive capacity of CRP land.

In February 2006, there were roughly 271,000 acres of CRP land in Michigan (not counting wetland reserve acres). If all of these acres could be converted to switchgrass production, it could yield 1.6 to 1.9 million tons of switchgrass annually assuming yields of six to seven tons per acre respectively. This could be used as feedstock to produce approximately 150 to 190 MMgpy of ethanol per year. Assuming that the economical size of a cellulosic biorefinery is in the range of 50 to 150 MMgpy, this would be sufficient to support two or three plants.

However, these estimates grossly overestimate the productive capacity of Michigan's CRP acres collectively. Not all CRP acres are conducive to planting to switchgrass, due to:

Production issues

- Some ground is too hilly
- Some individual plots or strips are too small to plant and harvest
- Some are in remote areas that do not make it feasible to access
- Some have trees and other natural barriers

Social concerns

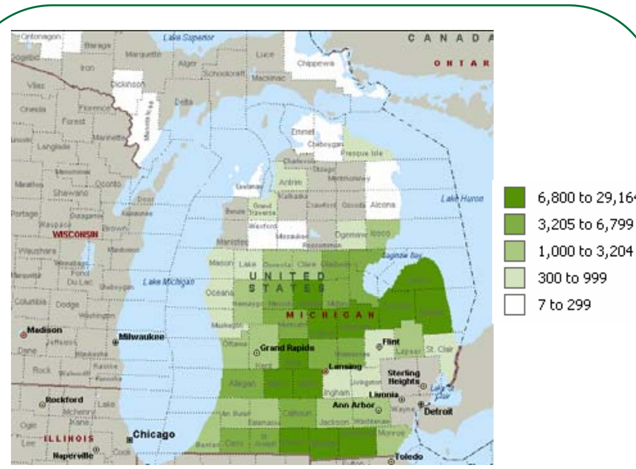
- Valued by many as a habitat for natural species
- Possible increased erosion from planting crops on sensitive areas

Other

- Not all farmers will be willing to participate
- Few farmers own enough CRP land individually, so planting and harvesting would likely need to be done on a cooperative basis (not a deal killer, but certainly a bump in the road)

Conversations with a number of industry experts suggest that after accounting for all of the above factors, the percentage of CRP acres that actually would be available and viable for switchgrass production would be somewhere between 20% and 50% of the total. This suggests that CRP land could, in total, provide enough biomass to support a single modest-sized biorefinery.

As shown in Figure 16, the counties with CRP acres are broadly distributed. For each county that has any CRP-enrolled acres, there is an average of 4,200 acres in CRP. This leads to challenges with the "local biomass utilization" rule. And, this challenge is exacerbated as acres are eliminated for the reasons cited above.




Source: USDA

**Figure 16. CRP Acres by County**

To put this in perspective, assume that a 55 MMgpy biorefinery was built in the middle of the state. Further assume that it was to operate only using switchgrass from CRP acres, and that 33% of all CRP acres were available to be planted to switchgrass. In this case, the feedstock would need to be hauled from all corners of the state to meet the demand. Obviously, this is not feasible, but it sets forth an important illustration of the role that CRP acres can play in meeting feedstock demands.

In summary, CRP acres can provide some feedstock production capacity. However, its contribution will be on the margin and will serve to augment more significant volumes of feedstocks grown on other types of land.

*Extracting Unused Biomass from Existing Crops*

Another potential for utilizing existing crop land for biomass production is to collect currently unused crop residues. The most common example here is corn stover which consists of the stalks, stems, leaves, and cobs left after harvesting the corn for grain. This is appealing because many of the impediments described earlier for growing biomass on crop land are no longer factors. For example, there is no establishment cost or non-productive period while the crop matures over multiple years.

Studies suggest that 50-66% of the residues can be removed from corn fields without adversely impacting the productivity of the field. For Michigan corn, this would translate into roughly 2 tons of biomass per acre. Farm gate prices for corn stover will vary depending on the transportation distance. However, even prices of between \$5 and \$15 per ton would provide returns to farmers equivalent to an additional 4-12 bushels of corn per acre (assuming \$2.50 corn). As long as there are no perceived or actual downsides to the gathering process from the farmer's perspective, this could be a way to begin producing biomass fairly quickly.

However, as discussed earlier, it is not economically feasible to ship low value biomass very far before the transportation costs become prohibitive. This is an issue due to the relatively low yields per acre and the fact that corn acres are interspersed with other crops. To put this in perspective, assume a 100 MMgpy plant in lower central Michigan. Further assume that two tons per acre are removed each year from 50% of the corn acres. In order to obtain sufficient feedstock for this plant, corn stover from all of the counties within the circle in Figure 17. The catchment area circle requires a 69 mile radius around the plant, which is beyond what is considered to be an economical transportation range.

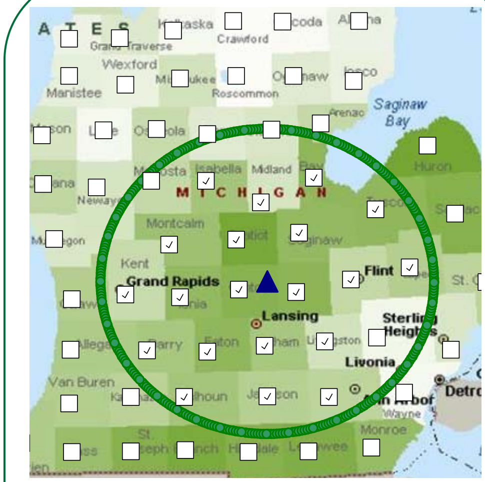



**Figure 17. Catchment Area Assuming Corn Stover is Collected from 50% of the Acres (69 mile radius)**

If corn stover could be collected from 100% of the corn acres, then the radius of the catchment area circle drops to 45 miles as shown in Figure 18. While gathering corn from 100% of the acres is probably not achievable, this does provide some perspective as to the relative amounts of corn stover that can be provided.

Collection of 2 tons per acre of corn stover from all corn acres in the entire state would support a total production of 446 MMgpy. This is sufficient to support somewhere between three to four large scale cellulosic ethanol plants.

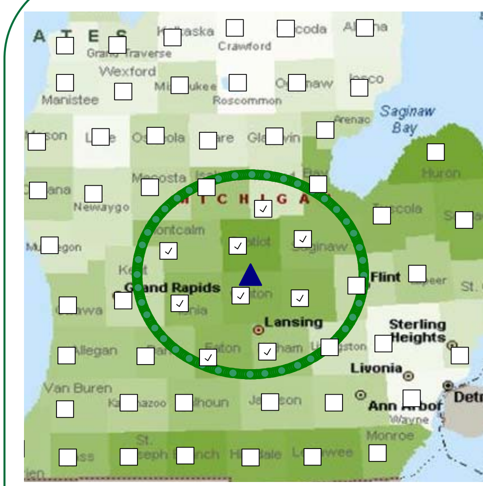



**Figure 18. Catchment Area Assuming Corn Stover is Collected from 100% of the Acres (45 mile radius)**

This suggests that a biorefinery utilizing stover as a feedstock would need to be able to accommodate multiple types of feedstocks since it is unlikely that localized sources of stover would be sufficient to supply a large scale plant.

In summary, utilizing unused corn and wheat stover could provide significant amounts of biomass. However, because of its relatively low yield and dispersion of corn acres, it will be difficult to supply an entire large-scale plant from just this source.

*Cost of Feedstock Production Ramp-Up*

The Challenge

Economics will likely dictate that biorefineries need to be very large to achieve efficiency. This quest for size efficiency is not novel or unique to biorefineries. For example, consider the situation where one large furniture manufacturer merges with another to form a mega manufacturing company. This will most certainly have some impacts up and down the value chain, but it will not require the creation of a totally new supply chain, or a totally new distribution chain on the downstream side. Existing suppliers will continue to supply, albeit to a different entity, and there will likely be some changes in terms. However, the supply chain was in place before, providing wood, glue, screws, paint, etc. so it is not necessary to build the supply chain from the ground up.

Contrast this with the 100 MMgpy biorefinery which comes on line and from the day it opens it needs over 3,000 tons of feedstock per day (365 days per year) to keep it running at capacity. This is demand for a stream of feedstock that did not exist the day before or the year before the plant opened. Unlike the mega furniture manufacturer, the biorefinery will require that an entirely new supply chain is put into place. In this case, a key part of that supply chain is the production of biomass.

This challenge can be illustrated in Figure 19. The processing needs of the plant move from zero to full capacity almost overnight. However, building the capacity to produce and deliver the needed feedstocks will take a number of years.

The gradual progression in capacity ramp-up is due to a number of factors including agronomic, economic, political, and social constraints.

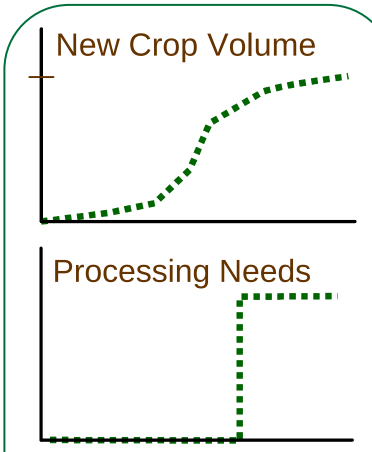


**Figure 19. Difference in Volume Capacities**

Getting Up the Curve

The BVCA model was used to help understand the challenges of ramping up production to meet this level of demand. We will again use switchgrass as the feedstock for this illustration and will focus only on the challenge of getting production up to capacity.

Consider the following assumptions:

- Provide biomass for a biorefinery that produces 100 MMgpy of ethanol plus co-product chemicals. On average, this would require switchgrass from over 163,000 acres of crop and CRP land once in steady-state production (roughly 70% from crop and 30% from CRP).
- Switchgrass takes three years to reach full production with no usable production in the first year and 50% production in the second year. Also, switchgrass has to be re-established every 10 years on average. This means that in order to be to have sufficient feedstock to open the plant at capacity, all 163,000 acres will need to be planted three full years prior to startup.

The challenges to accomplishing this in a short time frame are many.

**Farmer participation rates** – History has shown that farmers are fairly conservative in taking on new crops or cultural practices. The typical adoption process proceeds as follows. First, a group of “early adopter” farmers (usually just a few percent of the total) will try the new concept while others look on. During the first couple of years, even the early adopters are only willing to commit a small portion of their acres to the new concept until they feel more comfortable with the performance and risk. Slowly, other producers begin experimenting, and the number of producers who are participating increases. However, there is a group of laggards who will hold off for a long time, or may never adopt until they are forced to because the market for the old concept goes away.

Reverting back to the “local biomass utilization” principle, it is important that the production of biomass around the biorefinery is at a fairly high concentration level. If historical patterns hold true, it will take a long time before there is a high concentration of farmers within a 40-50 mile radius of a biorefinery that convert over to switchgrass. Strong financial incentives will help here, but remember that the farmers are making long-term commitments and they need assurance that they will have a market for their crop in the future.

**Cost of production in early years** – Because there are no established markets for biomass prior to the new plant coming on line, the farmers will not have anyone to sell their crop to in the early years. Using the BVCA model, it is estimated that the collective cost of producing feedstock in the ramp-up years prior to the 100 MMgpy plant actually opening will be somewhere between $50 and $100 million. This raises the question of who is going to cover those costs. It is unlikely that farmers will be willing to take the risk of planting a crop that will not have a market for three to five years in the future. Thus, it may be necessary for the entity building the biorefinery to offer pre-purchase agreements to essentially fund the planting and maintenance of switchgrass in the years prior to the plant actually opening.

**Harvesting capacity and logistics** – For traditional crops, most farmers own their own harvesting equipment and have built up years of experience in efficiently harvesting their crops and getting them to storage. Biomass harvest will require both new equipment and new skills that will take a while to learn. Significant amounts of machinery for harvesting will need to be employed. In a rapid ramp-up situation as suggested here, novel strategies will be needed to build and deploy the harvesting capacity most efficiently. This may involve cooperative ownership of machinery, coordinated custom harvesting of biomass, or other arrangements.

## Providing Steady Supplies of Feedstock

We just examined the challenge of getting production up to the levels needed to support the biorefinery. In addition, there are challenges once the production sector is up to scale.

In the near-term, there are no established secondary markets for biomass. This means that whatever is produced within the catchment area for the biorefinery will only have value if used at that biorefinery. Any overproduction will be of limited value due to the fact that the storage life of biomass is limited. Conversely, any production shortfalls in a given year will result in running the biorefinery at less than capacity. This is quite different than a corn ethanol plant that is located in the middle of an area where an abundance of corn is produced. In that case, the excess production can be absorbed by other markets, and shortfalls lead to modest price increases.

Figure 20 illustrates the variability that could be expected in switchgrass yield based on historical yield variability of hay crops in Michigan. It is not unusual for actual yields to vary by 15-20% of the average.

This presents some significant challenges of inventory management.

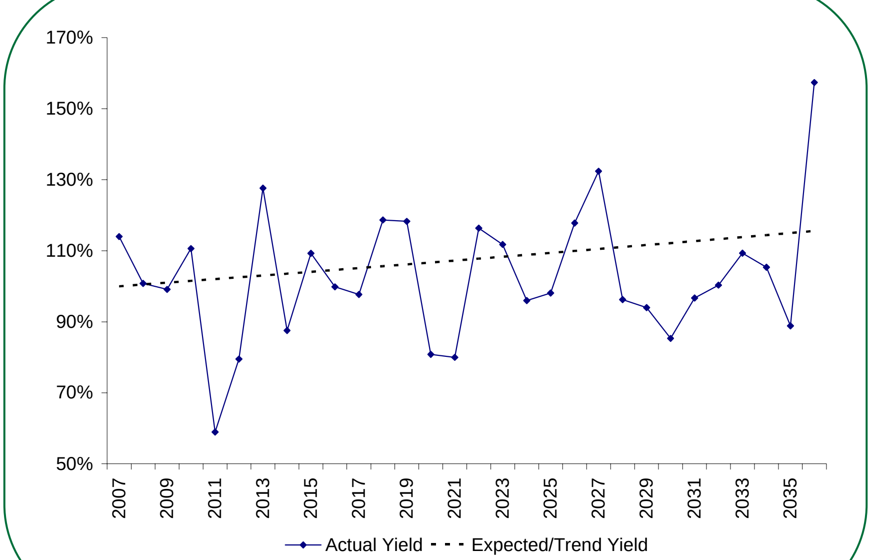


Figure 20. Switchgrass Yield

Another issue relates to the three year establishment period for switchgrass combined with a rapid ramp-up in production. Since switchgrass must be re-established every ten years (on average), there will be a dip in production ten years out that will result from re-establishing the fields across the region. Figure 21 illustrates this phenomenon.

Each band of colors represents the share of acres that are within a given year of maturity. The green bands are the "youngest" acres and it progresses through yellow to the red bands indicating the "oldest" acres. Note that while the average re-establishment period is ten years, the model assumed that a certain portion was actually re-established prior to ten years and some after ten years.

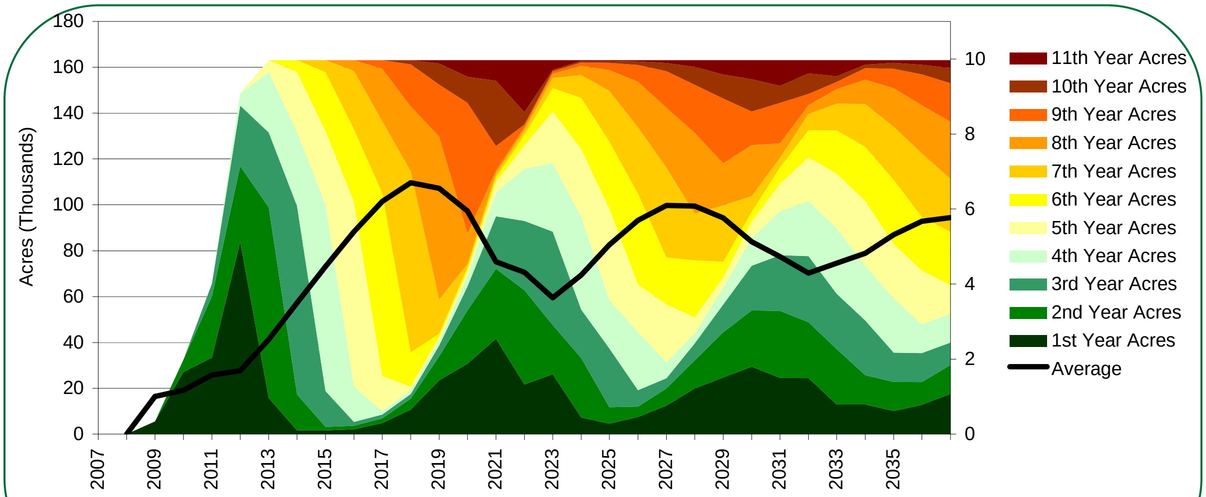



**Figure 21. Acres by Age of Switchgrass**

The black line is an indication of the average age of all acres in production in any given year. It follows that in years when there is a lot of re-establishment activity (for example, 2019 through 2025), the total yields will be lower due to the fact that no production comes from first year crop and only half from the second year crop. Figure 23 illustrates the volume of production that would result from the previous example assuming no weather variability.

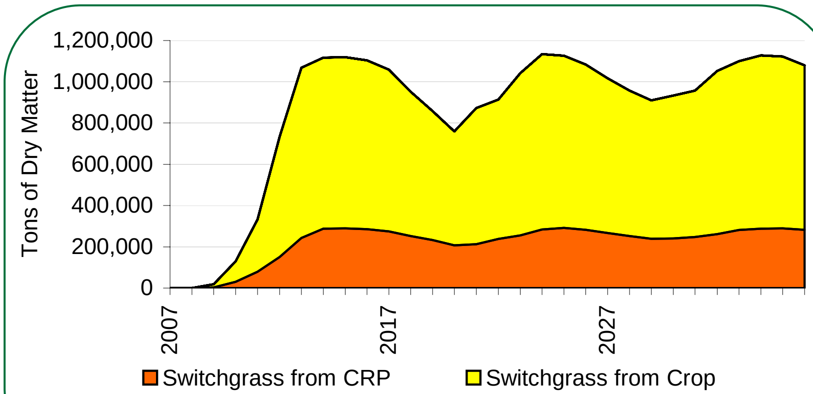



**Figure 23. Feedstock Volumes Produced with No Weather Variability**

Note the dips in production in those years corresponding to the points where the total yield is decreased as a result of the re-establishment.

If we introduce the variability from weather and environment as illustrated in Figure 22, the overall difference in total yields becomes even more erratic.

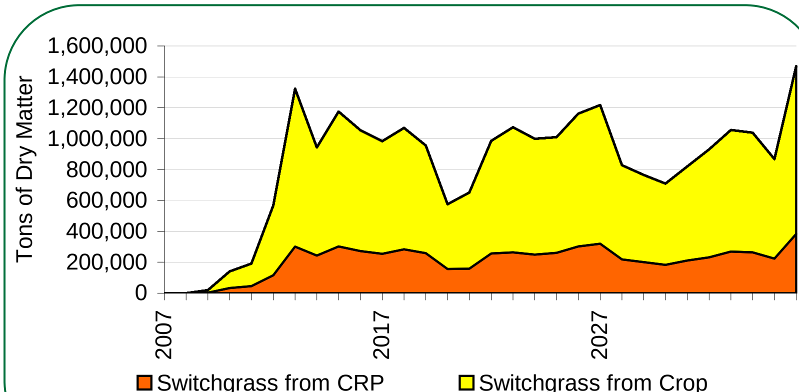



**Figure 22. Feedstock Volumes Produced with Weather Variability**

Figure 24 shows the difference between the needs of the plant and the volume of feedstock produced each year. Area above the zero line indicates a surplus of biomass in a given year, while area below the zero line indicates a deficit.

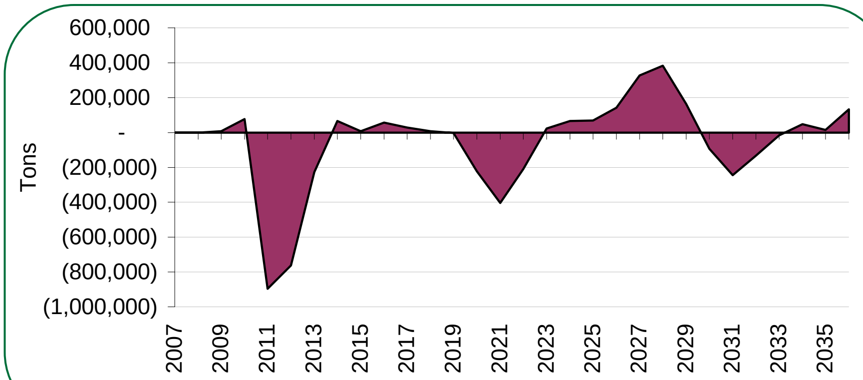


**Figure 24. Excess (Deficit) Feedstock Volume**

This chart depicts a significant deficit in the early years due to lower yields during ramp-up, and then fairly significant deficits and surpluses over time. There are costs involved of underproduction and overproduction.

This suggests that strategies are needed to protect against the shortfalls and to deal with surplus years as well. Many important questions need to be addressed, such as:

- What new business models are needed?
- Is the farmer contracted to grow acres of biomass and the biorefinery simply takes the yield risk?
- How are prices set? If left to supply and demand, there would be wide swings in prices from year to year.
- Can institutions, such as new futures market contracts, provide effective risk management tools for suppliers and customers?
- Can shortfalls be filled by supplementing with corn or wheat stover?
- How much of the biomass from a surplus production year can be stored to protect against future shortfalls (technical issue of storage life and conditions)?
- Can biomass be preprocessed and held in storage in that form for longer periods of time providing insurance for short years?

In summary, the biorefinery needs to have a steady year-round flow of feedstock from the start. These are feedstocks that are not being produced at any commercial scale in Michigan. Due to the feedstock volume requirements of even a single biorefinery, it is a significant challenge to build the supply chain in a short amount of time. Since there are no secondary markets for biomass (at least in the short-run), the co-dependency of the feedstock supply chain and the biorefinery is significant.

### *Ability to Process a Variety of Different Feedstocks is Key*

Michigan does not have any single crop that will dominate cellulosic ethanol production. However, if crop residues such as corn stover can be combined with dedicated energy crops planted to acres not currently in crop production, the amounts of feedstock available begin to reach sufficient levels to support a handful of biorefineries.

This will require large biorefineries to have flexible feedstock handling capacities allowing them to change feedstock types throughout the year. This will also require that feedstock supply chains be coordinated to queue different feedstock types and provide them in a manner that maximizes the efficiency of the processing at the biorefinery.

## 3.3. Forest Products Biorefinery

### 3.3.1. Description

This case depicts a biorefinery located in the Upper Peninsula of Michigan that utilizes biomass primarily from residuals, and pulpwood on federal, state and privately owned timberland. It draws forest biomass feedstocks from an 8 county catchment area as indicated in Figure 25. The plant is announced in 2012 and production begins in 2015 and it has a capacity of 100 million gallons per year (MMgpy) plus production of co-product chemicals. Note that while the plant is characterized in terms of its ethanol production capacity, the value of the chemicals and industrial products produced are expected to be very significant as well. However, these are not discussed in specific terms since the possible portfolio of these products is very diverse and will be driven by emerging market conditions.

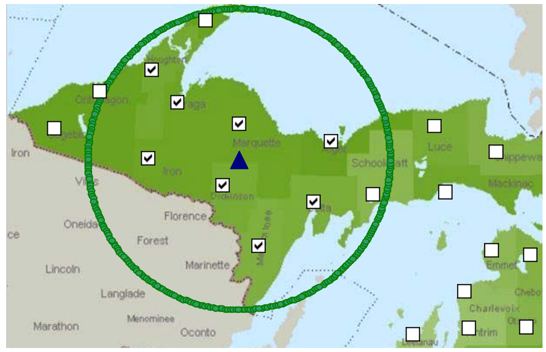


**Figure 25. Catchment Area for Hypothetical Forest Products Biorefinery**

*Assumptions – Feedstock Sources*

- From existing removals currently being sold as pulpwood. Pulpwood from this forest basket is currently estimated to consist of 75% of forest product volume.
- Assumption is made that there will be continued reduction in pulpwood demand in this region as pulp mills continue to close, therefore, providing an opportunity for diversion of pulpwood to other sources such as bioenergy
- Additional net growth to timberland that is not currently being harvested. Accessibility to the timberland is the biggest constraint

The assumed biomass output from diverted pulpwood and increased harvest is summarized in Figure 26.

| Ownership | Estimated Current Pulpwood Product Share | Assumed Pulpwood Product Share | Product Diversion to Bioenergy | Resulting Biomass (Thou ODT) |
|---|---|---|---|---|
| Federal | 75% | 45% | 30% | 29.7 |
| State | 75% | 45% | 30% | 89.3 |
| Private | 75% | 45% | 30% | 314.4 |

| Ownership | Current Growth-harvest Ratio | Assumed Growth-harvest Ratio | Percent Increase in Harvest | Resulting Biomass (Thou ODT) |
|---|---|---|---|---|
| Federal | 5.9 | 5.5 | 8.1% | 8.0 |
| State | 2.5 | 2.0 | 26.1% | 77.7 |
| Private | 2.2 | 1.49 | 45.6% | 481.0 |

| | Biomass (Thou Oven Dry Ton) | | |
|---|---|---|---|
| Ownership | Diverted Pulpwood | Increased Harvest | Total |
| Federal | 29.7 | 8.0 | 37.8 |
| State | 89.3 | 77.7 | 167.0 |
| Private | 314.4 | 481.0 | 795.4 |
| Total | 433.3 | 566.7 | 1,000.0 |

100 gallons/1 ODT ethanol yield yields 100 million gallons ethanol annually

**Figure 26. Assumed Biomass Output from Diverted Pulpwood and Increased Harvest**

*Assumptions – Harvest, Storage and Transport*

- Harvest occurs approximately 11 months of the year
- Delivered prices must be competitive with competing uses of pulpwood and cost-effective for residual material
- Expected to increase current logging industry employment in area
- Storage and transportation will look similar to current logging and pulping operations
- Much of the existing infrastructure will be converted and enhanced

*Assumptions – Biorefinery*

- Assume it is ready to begin processing by the end of 2015
- Capital investment of around $400 million
- Primary product would be ethanol, but also produces chemicals as dictated by market demand
- 10-20% of output value from co-products
- Creates around 45 jobs (direct)

*Assumptions – Output Supply Chain*

- Ethanol
- Ethanol demand will be sufficient to utilize all of production
- Distribution systems are re-tooled as needed
- Chemicals
- Products will need to be equal to or superior to the products they are replacing
- End-users will need to accept these products as viable alternatives
- Retooling of marketing distribution systems will be needed
- Will likely rely on discovery of new applications for output products

### 3.3.2. Findings

*Michigan Has Resource Base to Be a Top Contender in Forest Bio-Products*

With over 18.6 million acres, Michigan is the fifth largest state in the country in terms of timberland acreage. This says that if forest-based bio-products are viable, Michigan is in a strong position to be a significant player. This relative scale is important because it will attract the attention of companies willing to invest in forest-based bioproducts. Also, the existing timber industry resources provide a foundational infrastructure for the harvesting and material handling challenges that will need to be addressed.

*Diversity is Key Strength of Forest Resources*

The range of potential products from forest resources is broad. These include:

- Woody biomass from the forest
- Logging residues (tops, branches, bark)
- Short rotation plantations
- Sawmill residues
- Municipal waste wood and paper
- Paper mill sludge

In addition, the woody biomass comes from a wide variety of different species of hardwoods and softwoods. This diversity not only provides opportunities to derive unique products from selected species, but it also provides a resilient supply of feedstocks over time. For example, if a particular species or source of feedstock is interrupted for some reason, other sources will be available to fill in providing that the facility is designed to process a range of species.

*Forests Have Unique Inventory Management Advantages*

Managing year-round supplies of grassy biomass materials is very challenging due to the fact that they are harvested once each year and used throughout the year. In contrast, biomass from forest resources can remain standing until it is needed for processing. This eliminates the need for costly storage facilities and extra handling steps.

Likewise, the annual variations in yield for forest products are much more stable than for grassy biomass. A poor growing year can impact the yields of a grassy biomass crop significantly in any given year. However, the impact on inventory of the forest biomass will be much less severe in any given year since the impact of the single year of poor growing conditions will be spread over multiple years of harvest.

*Plans Needed to Protect Delicate Ecosystems*

Forests represent diverse ecosystems that are in a constant state of evolution. The harvesting of trees for saw timber and pulping has been going on for years. However, new management practices such as removing biomass, introducing new species, or changing the mix of existing species of plants will most certainly impact the balance of the local ecosystems. It will be important to understand these impacts early on so that negative unintended consequences are avoided.

For example, after harvesting trees from an area, it is common to leave small branches, leaves, bark, and other residues behind. These serve to maintain and build organic matter as well as provide protection against erosion. If the system is changed and these materials are removed for use as biomass, there will be changes in the ecosystem (some good and some bad).

Many different management approaches ranging from the removal of existing excess growth to agroforestry systems to high growth plantations are possible. Each of these will have their own set of consequences that will need to be studied and better understood.

Finally, special interest groups will be watching. However, with proper policies and practices, their needs can be met since more intensive harvesting can be done in a manner that actually improves the health of the forest ecosystems. It will be important to keep these people at the table as policies and industry strategies are being developed.

*Long Haul Strategies*

While breeding and genetic enhancements can lead to the production of more efficient feedstocks, the length of time required to make changes to the makeup of forests is significantly longer than changing crop rotations or establishing biomass grasses. Even with fast growing species, the time to establish new stands can be three to five years.

This is in sharp contrast to the type of decision making that crop producers make on an annual basis. For example, a crop farmer can elect to plant more of a certain type of crop this year because demand is strong and they can lock in good returns for next year's crop. Owners of forest lands must have confidence that there will be a viable market for their products for years to come. Thus, any strategies that involve agroforestry practices will require that the forest owners are convinced of the long term opportunities.

*Conversion of Pulp Mills to Integrated Forest Biorefineries (IFBR)*

The forest-based biorefinery's processing approach and product portfolio will significantly impact how its technology and economic risks are mitigated.

A forest-based biorefinery can produce an array of products, depending on the processing approach employed. This product array includes ethanol, power, fuel and chemicals (Figure 27).

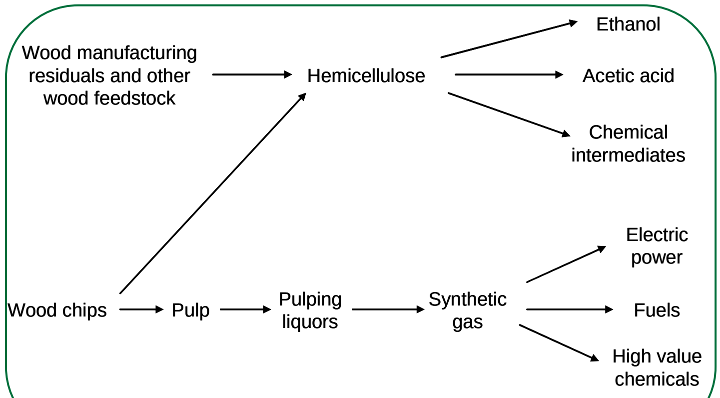



**Figure 27. Forest-based Biorefinery Products**

Two different approaches can be taken to processing ethanol from cellulose. The first is a focused approach where the main objective of the process is the production of ethanol along with the resulting co-products of acetic acid and chemical intermediates. This is the approach outlined in the case study.

The second approach is an integrated forest biorefinery (IFBR) where ethanol is co-produced with pulp and its co-products. This concept has received a lot of publicity with the most promoted processing platform being a converted kraft pulp mill[8]. One vision of an IFBR is based on:

- A sulfur-free, alkaline pulping of hardwood
- Alkaline hemicellulose extraction step prior to pulping
- Spent pulping liquor gasification and lignin precipitation after pulping
- Product portfolio would include pulp, ethanol, polymers, and carbon fibers
- Additional energy requirements met by gasification/combustion of waste biomass

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[8] Van Heiningen, A. Converting a Kraft Pulp Mill into an Integrated Forest Biorefinery. Pulp & Paper Canada. 2006. 107:6. 38.

New IFBRs can be constructed or existing pulp mills can be converted to an IFBR. A lot of interest has been expressed in converting existing or moth-balled pulp mills to IFBRs. However, many of the existing mills are not locally owned, and the executive management team of the mills might only be interested in maximizing output from an aging operating facility and not interested in re-thinking the role the mill plays in the company's overall portfolio of production facilities.

The processing technologies for either approach are not yet fully developed, and this presents technological risks for the investors. In addition, these approaches can generate different co-products, and the resulting product portfolio significantly influences the financial viability of a biorefinery. One way to mitigate economic risk is to incorporate process flexibility into the biorefinery. This would provide the firm the flexibility to adjust its processing under a range of market and economic conditions.

Deciding the production platform on which to base the biorefinery is an important consideration. Our research indicates that there are people who firmly believe that converting pulp mills to an IFBR is an attractive and viable option. On the other hand, interviews with industry experts suggest that the business case does not exist given the current ownership structure of the pulp and paper mills in Michigan. It is important strategically for Michigan to figure out if the conversion option is feasible. If it is feasible, Michigan has considerable assets on the ground that should be leveraged – an opportunity that should not be missed. If it is not feasible, then efforts can be focused on other approaches to securing an IFBR.

*Forest Growth ≠ Access*

The most likely forest-based biomass would come from logging residuals (the tree tops and limbs), diverted pulpwood, and increased harvest rates in existing forests. Issues accompany each of these sources. Economics dictates what is done with the residual material. If logging companies receive sufficient compensation for the residual material to cover removal costs (likely including a chipper to maximize removal efficiency), they will market the residual material.

The pulp industry has been and is currently undergoing significant transformation, and Michigan is part of that change. Local demand for pulpwood has declined in recent years as production of pulp has become a global industry and pulp mills have closed in the region. This has left behind a logging industry with an insufficient market for its product, and as a result, often unpurchased logging contracts. This surplus supply could provide an opportunity for pulpwood to be diverted to biorefinery use either solely to produce ethanol or in an IFBR setting. However, the challenge will be capturing that supply before it is lost due to a shrinking logging industry.

Increasing harvest rates is another option for forest-based biomass. The current growth-harvest ratios on the major ownership tracts (federal, state and private) of land indicate that additional trees could be harvested while still maintaining a sustainable, healthy forest. However, several barriers exist to this strategy. The current ownership of land in the eight county catchment area for the case study is shown in Figure 28. Numerous barriers exist in retrieving additional timber off of state and national forests for reasons including concerns about potential litigation, environmental concerns and bureaucracy. Increased timber harvest on state and national forests is not anticipated to be significant if current policies remain in place.

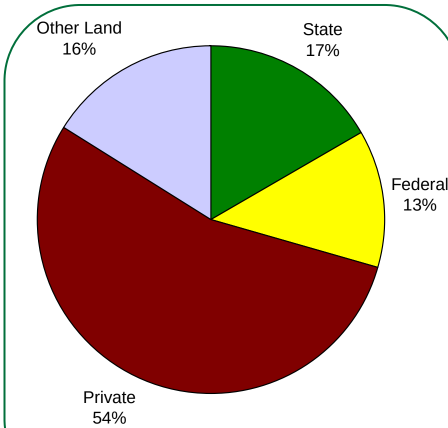

**Figure 28. Current Ownership of Land**

Private forests fall into two categories. The large tracts of privately owned land are often owned and managed by Timber Investment Management Organizations (TIMOs), most commonly found in the Upper Peninsula. These forests are actively managed for timber harvest and often have the most aggressive harvesting rates. Their resident forestry expertise would be very beneficial in making the most effective use of available biomass on their land. The second category of private forests is the small tracts of land owned by individuals. These tracts are often only a few acres, and the owners' attitudes towards harvesting timber are often negative. In addition to overcoming the hurdle of owners' attitudes, the logistics of harvesting on small acreage and managing multiple contracts is a significant challenge and might make it cost prohibitive to consider as a feedstock source. One option for addressing owners' concerns about timber harvest is for a forestry expert to work with the individual land owners to help them meet their objectives of owning the acreage while permitting timber harvest.

While the loggers are faced directly with the challenges of accessing the forests, their customers are indirectly impacted by the issues. Therefore, these challenges must be considered when analyzing the viability of a biorefinery in a specific area.

Another option for forest-based biomass is fast growing tree species such as hybrid poplars and willows. Their production process would be similar to an actively managed crop, and thus the most likely short-term options for growing them would be on either existing crop acreage or CRP ground. In the longer run, these species could be grown on lands where existing forests have been clear cut and replanted.

*Keeping the Biomass Collection Infrastructure in Place*

A significant infrastructure exists for the logging industry throughout the Upper Peninsula and upper Lower Peninsula. This includes logging, hauling, and staging. However, as the milling industry has contracted, the logging component has also responded by reducing its capacity. The ideal situation for a biorefinery would be to capture the existing infrastructure before it disappears. As previously mentioned, the viability of a new enterprise is increased if it can rely on an existing supply chain instead of having to create a new one. However, the time lag between the current state of the industry and when a biorefinery might be online adds uncertainty to the scenario. If the logging industry has contracted to the extent that it needs to be re-created, this might create additional hurdles or risk. This needs to be examined and strategies need to be identified to minimize the rate of erosion and to protect this potentially valuable asset.

## 3.4. Grain-Based Biofuels

### 3.4.1. Description

This case scenario focuses more generally on both ethanol from corn and biodiesel production in the state.

*Ethanol*

Currently at least seven corn ethanol plants are planned for construction in Michigan within the next couple of years with total production capacity of 290 MMgpy. More ethanol plants are in the pre-planning stages. At this time, it is believed that all of the planned facilities will utilize traditional dry-grind technology.

The starred circles Figure 29 represent the general location of the seven ethanol plants. For this illustration, we assumed that 50% of the corn produced in each county went to fulfill the needs of these plants. Given this assumption, the corresponding colored squares indicate the counties necessary to meet the needs of each plant.

In total, these plants will utilize roughly 44% of all corn produced in the state and generate 986,000 tons of distiller's dried grains (DDG). The following pie charts illustrate the impact that this change would have on the use of corn in Michigan. Figure 30 indicates the share of corn that has been used in-state in recent years compared to that which is exported out of the state. Figure 31 indicates how much of the previously exported corn would be consumed by the proposed ethanol plants.

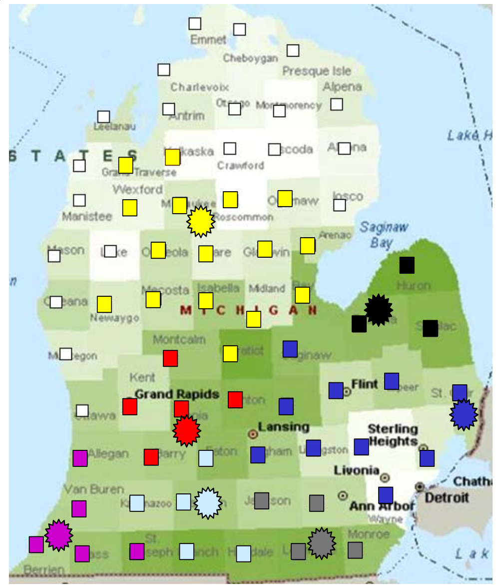


**Figure 29. Location and Catchment area of Proposed Corn-based Ethanol Plants**

*Biodiesel*

At least 3 biodiesel plants are planned for construction in Michigan within the next couple of years with total production of less than 20 MMgpy. The details of intended feedstocks are not available at this time, but the impact on utilization is expected to be similar as the situation just illustrated for corn.

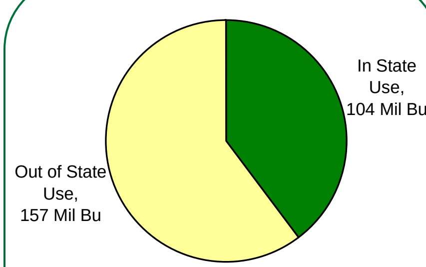


**Figure 30. Michigan Corn Crop Recent in-State Use versus Out-of-State Use**

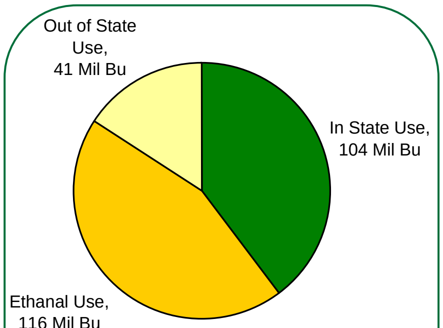


**Figure 31. Michigan Corn Crop Use Assuming Proposed Plants**

### 3.4.2. Findings

*Feedstock Capacity is Limited*

Some believe that the U.S. is headed towards a situation where the capacity of corn-based ethanol and biodiesel plants will be higher than sustainable in the short to intermediate term. The concern is that too much biofuel production will lead to shocks in the price of feedstocks that will disrupt those markets.

For example, a biodiesel plant in today's environment (given crude oil prices of $50-$60 per barrel, soybean oil around 24-26 cents per pound, and a $1 federal tax credit) can be profitable.

They were even more profitable just a short while ago when the price of crude oil was higher and the price of soybean oil[9] was lower. It was during this period of time that many expansion decisions were made. However, like any manufacturing process, the margins are fragile and will change dramatically with relatively small changes in the price of inputs or of the final product.

There are two key factors that impact these margins. First is the price of diesel fuel, which is a direct derivative of crude oil prices. It is important to note that the price of crude oil will not be impacted by the production of biodiesel. The volume of biodiesel production potential (from current feedstocks) is insignificant relative to the total consumption of diesel, so supply shocks will not occur. Thus, if the price of crude oil drops much below current levels, the profitability of biodiesel declines or become negative.

The other factor is the price (as well as availability) of biodiesel feedstock. Since feedstock oil cost represents 60% to 70% of the total cost of biodiesel production, small changes will have large impacts on the margin. Unlike crude oil prices, increases in demand for biodiesel feedstocks can have a significant impact on the price of the feedstock. Table 3 illustrates the relative volume impacts of diesel and biodiesel from soybean oil.

**Table 3. Relative Volumes of Biodiesel Production Potential and U.S. Diesel Use**

| | Typical Year | |
|---|---|---|
| Total U.S. Soybean Oil Utilization | 18,000,000,000 | lbs |
| Share of Soybean Oil to Biodiesel | 20% | |
| Soybean Oil Used for Biodiesel | 3,600,000,000 | lbs |
| Biodiesel Produced from Soybean Oil | 459,116,883 | Gallons |
| Total Gallons of Diesel Used in U.S. | 58,000,000,000 | Gallons |
| Share of Diesel from Biodiesel | 0.79% | |

If we assume that 20% of current levels of U.S. soybean oil utilization is diverted to biodiesel production, that would generate 459 million gallons of biodiesel. (As a point of reference, less than 4% of soybean oil is currently used for biodiesel.) However, 459 million gallons only represents 0.79% of the total diesel use in the U.S. This illustrates the tremendous mismatch of scale between soybean oil and diesel.

Studies by Centrec suggest that even slight increases in the demand for soybean oil will cause its price to increase above levels that are economically viable for biodiesel production. While not as extreme, similar relationships exist for the price of corn and ethanol production.

The point here is that there could be volatile times ahead for some of these first generation biofuel facilities. This has strategic implications to the State of Michigan from a couple of perspectives. First is that the facilities in Michigan could be impacted more severely than facilities located in states where grain-based feedstocks are more abundant.

The second strategic issue is related to the potential for a negative image of biofuels and bioprocessing that could emerge within the next couple of years if they experience a period of difficulty. This is especially important since the negative press around these facilities could come at a time when leaders in Michigan are trying to rally support for building second or third generation biorefineries. Regardless of the fact that the second and third generation plants are substantially different, the press and public will most likely paint them all with the same broad brush.

### *Smaller Scale Opportunities with Biodiesel*

Due to the relatively simple technology involved, biodiesel production is scaleable. Further, biodiesel can be made from a variety of feedstocks including waste greases from food processing and retail operations. On one hand, the volume of these feedstock sources is

[9] While biodiesel can be produced from many different feedstocks, soybean oil price is used here as a proxy since other feedstock oil prices tend to follow similar price patterns.

relatively limited and very small in scale when compared to diesel utilization. (Those who suggest that we can achieve energy independence by recycling restaurant grease have misconceptions about the relative volume issues.) On the other hand, a number of small biodiesel plants can provide an economic opportunity for the entrepreneurs who can find and exploit these niche opportunities. Perhaps the biggest challenge these types of producers will face is that of quality control. As with the entire biodiesel industry, quality control will be a critical element to gaining acceptance (especially in colder environments). It will be important to understand the needs of these smaller opportunities and provide a supportive business environment. This same holds true for other types of small biobased ventures.

*Unintended Consequences of Moving Too Fast With Corn-Based Ethanol and Biodiesel*

The production of ethanol from corn and biodiesel from various feedstocks in the U.S. is in the midst of what is being called a gold rush mentality. This has both positive and potentially negative consequences.

Michigan is getting its fair share of attention when it comes to interest in ethanol and biodiesel production facilities. Recent work by MSU's Product Center suggests that Michigan could become a "corn-deficit" state if all of the currently planned corn-ethanol plants are built. This means that Michigan would use all of the corn produced in Michigan for locally produced livestock and ethanol, plus they would need to import corn to meet demands. Corn producers will view this as a positive, because the demand for corn will undoubtedly result in higher prices for corn. On the other hand, livestock producers will end up paying more for feed rations made from corn. The shortfall of corn will be mitigated somewhat by the availability of DDGs which can be fed to some types of livestock.

It is also important to understand the consequences of changing the overall flow of corn out of the state. In recent years, nearly 160 million bushels of corn were shipped out of state. In just a couple of short years, that could drop to zero. This will have an economic impact on those companies who transported the grain across state lines.

All in all, corn-based ethanol and biodiesel production can provide positive contributions to Michigan's economy. However, it will be very important to understand the total system impacts of different levels of production and to set appropriate policies that will encourage the "right-sizing" of the industry.

*Opportunities may be in Co-Location of Cellulosic with Corn*

The investment required for corn-based ethanol plants is significant. These 1st generation biorefinery facilities are generally fairly specific in terms of the processes that they support. However, their physical infrastructure does include some of the key elements that would support activities for next generation biorefineries. These include a handling infrastructure for large volumes of biomass, access to downstream product channels, and transportation infrastructure.

There are varying degrees of enhancements that could be "bolted on" to a standard dry-mill operation. These range from augmentations to the current processes such as dry fractionation technologies, to co-location of a cellulosic processing facility.

These options may provide Michigan with an opportunity to maximize value from these facilities

## 4. Findings

Conduct of this effort, and the Phase 1 project which preceded it, has led to identification of a number of important conclusions relative to the potential for bioeconomy development in Michigan. These conclusions have corresponding implications for actions of decision makers in both the public and private sectors to most effectively move that development forward. In this section, these conclusions are presented as two categories of findings. One section refers to insights gained from throughout the effort while the second section discusses the four themes defined at the October roundtable discussion meeting held as part of the effort. These two categorizations are used primarily to allow the roundtable themes to be presented as a separately identifiable set of concepts.

### 4.1. Findings from Analysis

A state or region's success within the emerging bioeconomy will be affected by key factors such as its physical resources, industrial infrastructure, intellectual capabilities, and leadership commitment.

- The State of Michigan scores well on many of those factors. However, the scale of its physical resources, especially with respect to grain-based biofuels, limits its ability to achieve competitive advantage based upon scale of operations.
- Relative to intellectual capabilities, industrial infrastructure (particularly related to potential non-fuel bioproducts), and leadership commitment, Michigan has the potential to be differentially competitive.
- Michigan's forest resources are extensive and, although development is likely to occur only in the longer run, could provide scale advantages.

Job creation will be significant, but not at the same scale as the auto industry. Today, an efficient ethanol producing plant is expected to require fewer than 75 full-time employees. And, as indicated elsewhere, the prospects for a large number of plants to be built in the near term in Michigan are low.

Establishment of successful bioeconomy value chains will occur within the context of a set of complex, interrelated actions that will involve private and public sector decision making. A number of key implications result from that realization:

- The economic, social, and environmental benefits of moving to a biobased economy will accrue over a long period of time.
- Markedly different time patterns need to be expected relative to feedstocks (grain, cellulosic, and forest product based) and products (fuel versus plastics or chemical replacements).
- The patterns of growth and of success will not be smooth, with the public and the media tending to focus on the inevitable conditions of capacity "overshoot" and "undershoot" that occur in commodity-oriented markets.

For cellulosic and forest product-based value chains, lack of pre-startup investment in supply chain infrastructure could be a key impediment to rapid investment and development.

- In contrast to grain-based ethanol, where the feedstock could easily be diverted from an existing large stream of materials, existing input streams are not available for cellulosic and forest production applications. Yet when a large scale biorefinery comes online, it will need to consume vast quantities of inputs immediately if it is to achieve operational efficiency.
- Overcoming this impediment will require considerable capital investment. Public perceptions, both positive and negative, also will affect the time and resources required to build the needed supply chain infrastructure.
- Effectively managing these constraints could make a specific locale differentially attractive as a site for development.

The makeup of the bioeconomy can be very diversified and distributed. There may be no single dominant type of biobased business, especially if non-fuel products emerge as important. Large ethanol processing plants and biorefineries will be components of the bioeconomy, but small or mid sized operations also are likely to be key components to drive innovation and capture niche opportunities.

Diversion of grain and other livestock feed products to satisfy bioprocessing needs will be very disruptive to the livestock sector. This will have an impact on both the availability and price of livestock feed. While this may be moderated somewhat by the production of co-products that can be used to partially substitute the lost feed sources, it will still have an impact. It will be very important to understand these impacts and not create a situation where bioprocessing expands at the expense of an otherwise viable livestock sector.

The appropriate downstream infrastructure, that can accept products from many different kinds of biobased businesses, will be important. The electrical energy grid and the liquid fuel infrastructure system are examples that come immediately to mind. In the longer run, a downstream infrastructure that can participate in developing, as well as utilizing, innovative biobased industrial products is likely to be important. The capacity for downstream product applications can be expected to be a critical feature of the successful bioeconomy innovation ecosystem.

While technological innovation is expected, the need for business system innovation may be just as much a feature of the bioeconomy's future.

- Arguments can be made to support the notion that vertical ownership integration should be expected. Others can assert valid reasons that market-based exchange will dominate.
- Important research and outreach opportunities exist relative to fostering innovative business system arrangements that can facilitate supply chain development.
- From the perspective of local and state public decision making, it probably is most important that there be an understanding that these business systems will be dynamic and that there be a capacity to understand and communicate changing business systems relative to the public interests of effected communities.

## 4.2. Findings from the Roundtable

As discussed earlier, four summary themes emerged from the considerable dialogue and debate that occurred throughout the roundtable meeting. Further all of the themes are shaped by the considerable expertise of the roundtable participants. While it is not possible to capture and describe the entire scope of the group's analysis, the following paragraphs provide several of the concepts identified by the participants as being of central importance.

*Theme 1: Inform and enhance public understanding and public policy decision processes regarding the pace and nature of growth within the Michigan bioeconomy.*

Growth of the bioeconomy to be a significant contributor to economic development requires more than research and development. Important societal issues will arise and need to be addressed through public policy. Further, if a region aspires to a leadership position, public policy initiatives at the state, regional and local levels can facilitate those aspirations.

Although the prospects for the bioeconomy are in general attractive, every initiative will not have positive economic prospects. Further, prospects which are economically attractive in an overall sense are likely to have secondary consequences that may be negative for some. The land grant university has a unique position from which to evaluate and inform both public and private decision makers of the opportunities and drawbacks in such circumstances. These efforts should encompass discovery and documentation of both general frameworks for evaluation and specific applications of those frameworks.

Operating as an "honest broker" to rigorously evaluate and to communicate the opportunities and challenges associated with the emerging bioeconomy, MSU is uniquely positioned to foster an innovation focused environment. Examples of the types of activities that could be accomplished within this theme include:

- Examination and enhancement of state and local government regulations to insure that the bioeconomy advances harmoniously with other interests of Michigan's citizens.
- Communicating value stories, which describe both the potentials and the needs to the public and within educational offerings.
- Providing forums to engage and inform the public and industry.
- Identification of cost effective, bio-favorable procurement policies for state and local governments.

*Theme 2. Foster interdisciplinary scholarship which acts as an innovation catalyst for Michigan's bioeconomy.*

The complexity of the emerging bioeconomy requires an interdisciplinary approach to address current and future challenges and opportunities. Those issues must incorporate science, technological and societal uncertainties. Therefore efforts from across the university, from the basic biosciences to marketing, public policy and sociology, can meaningfully contribute to their resolution. While some types of invention and advances in science can result from disciplinary scholarship, aggressive leadership focused on innovation will demand interdisciplinary collaboration.

Effective scholarship will necessarily be future oriented. For example, tomorrow's bioeconomy innovation ecosystem likely will require a perspective that moves:

- Beyond corn — to cellulose and to wood as feedstocks and
- Beyond ethanol — to biobased replacements for a broad range of fuel sources, chemicals, and materials.

As a catalyst for the Michigan bioeconomy, knowledge discovery, education and communication must be recognized as necessary, but not sufficient, elements of success. Engagement with existing and emerging private sector firms, with results that can be measured in terms of enhanced Michigan-based economic development, is required.

Theme 3. Insure that the necessary research and development facilities, including commercialization and business development support infrastructure, are available to match the current and future needs of Michigan's bioeconomy.

*In addition to extensive laboratory and computational capabilities, critical aspects of bioeconomy-oriented innovation require specialized and sophisticated infrastructure for both research and development activities to be effective. Illustrative examples of these types of infrastructure include:*

- Pilot biorefinery capabilities
- Feedstock "farms"
- Logistics testing "grounds"

Access to such facilities and proximity to the expertise required to optimally employ them typically is a necessary component of an innovation ecosystem. Innovative organizational structures, including alliances with non-university entities, likely will be needed to facilitate access to these bioeconomy specific assets.

New and emerging businesses in the bioeconomy will need continuing support to determine the likely feasibility of products and business plans relative to both technological and market factors.

Such support will be particularly important where innovations in supply chain linkages and performance are critical to business success. The capability to provide business development and commercialization support should be included as an important component of needed facilities.

While MSU has a strong base of scientific infrastructure, it will be important to strive to continually enhance and upgrade capabilities as science and development needs evolve. Because the presence of such infrastructure and its supporting expertise often attracts development activity, aggressive actions can have a cascading impact. Forward looking investment plans, therefore, can provide important signals to the broader innovation community that the will exists to establish and maintain a vibrant innovation ecosystem.

*Theme 4. Aggressively strive to ensure MSU's leadership role within the innovation ecosystem of the Michigan bioeconomy*

Leadership through scholarly advances must be the preeminent aspiration of the land grant university. Relative to the bioeconomy, however, the large state university also can demonstrate the tangible contributions of biobased innovations within the structure of its own internal operations. Exploiting both the scholarly and the operational perspectives can contribute to the attainment of a sustainable leadership position.

Scholarly leadership is the province and responsibility of the faculty within the successful land grant university. Over time, scholarly success will result primarily from the innovative efforts of what is a large and diverse set of skills and expertise operating in a decentralized fashion. Administrative support of these scholarly entrepreneurs is essential, even if the overall system is decentralized in nature. If a highly supportive innovation ecosystem is to develop, the processes by which the university's internal resources are monitored, managed and redirected need to aggressively support innovation which will fuel growth in Michigan's bioeconomy. Management of intellectual property and the associated commercialization strategy is a key internal process relative to biobased innovation. Tactics which strive to insure that MSU intellectual property and innovation foster development within Michigan can foster growth of its innovation ecosystem.

The operations of large land grant universities, such as MSU, are themselves significant resource-consuming activities. Operational policies, for example, are routinely made relative to procurement of fuel for vehicles, selection of energy sources for building heating and cooling, and acquisition of construction materials. Aggressive efforts could be undertaken to identify and employ specific biobased opportunities within the MSU community and its operations. These actions would serve as tangible evidence of MSU's commitment to the bioeconomy as well as present opportunities for further scholarship that could be leveraged more broadly.

The university's undergraduate community represents both a responsibility and an opportunity. As future citizens and leaders, MSU's undergraduates will be engaged in decisions that affect the future evolution of the bioeconomy. Educational efforts which allow them to effectively evaluate future resource choices will provide societal benefits whether those choices are acted upon in private or public settings. In addition, the undergraduate community can serve as an active laboratory relative to the social dimensions by which the bioeconomy's potential are understood. Interested undergraduates also can serve as effective agents to catalyze change.

## 5. Recommendations

A roundtable discussion meeting, held in early October, 2006, was a key activity within this project. The meeting was attended by individuals representing a cross section of interests from the private sector, non-governmental and public interest groups, and from the university community. As noted previously, one output of that meeting was specification of four themes which summarized directions that the Office of Biobased Technologies should pursue. In this section, those themes provide the organizing structure for the project's recommendations. These recommendations are not limited, however, to actions suggested at the roundtable discussion meeting. Rather, they reflect insights gained throughout the project.

### 5.1. Theme 1

*Inform and enhance public understanding and public policy decision processes regarding the pace and nature of potential growth within the Michigan bioeconomy.*

Growth of the bioeconomy to be a significant contributor to economic development will require more than research and development. Important societal issues will arise and need to be addressed through public policy. Further, if a region aspires to a leadership position, public policy initiatives at the state, regional and local levels can facilitate those aspirations.

*Theme 1 Recommendations*

Create the capacity to conduct focused policy research which investigates and suggests preferred means by which state and local governments can best support and enhance bioeconomy initiatives within Michigan. A comprehensive perspective would include considerations such as:

- Examination and enhancement of state and local government regulations to insure that the bioeconomy advances harmoniously with other interests of Michigan's citizens.
- Identification of cost effective, bio-favorable procurement policies for state and local governments and of workable implementation procedures for those policies.
- Rigorous analysis of alternative incentive mechanisms (property tax relief, training grants, etc.) and specification of preferred mechanisms in various settings.

Develop the capability to effectively inform and educate Michigan decision makers regarding the bioeconomy and Michigan's actual and potential roles within it.

- Mass media would be only one of the targeted audiences for these efforts. Content development and communication methods also should target means to effectively inform local and state public officials and to support education at the K-12 levels.
- Examples of message topics include:
  - ✓ Examination of the "right size" scenario for corn-based ethanol in terms of both the potential positives and negatives,
  - ✓ Analysis of the "right size" scenario for cellulosic ethanol from corn stover and grasses to identify,
  - ✓ Realistic returns to growing dedicated energy crops compared to traditional crop production, and
  - ✓ Realistic estimates of dedicated energy crops that can be grown on CRP.

Conduct research and outreach efforts which identify actions that will assist in building the forestry bioproducts value chain. Such as the need for:

- Changes in state forest management policies,

- Analysis of the impacts of various forestry management systems,
- Specification of practices that maintain forest health while enhancing productivity, and
- Educational programs for private land owners.

Sponsor Office of Biobased Technologies forums, which explicitly include participation from a wide range of stakeholders, on various topics as a way to communicate issues and gather information about the current status of relevant developments.

## 5.2. Theme 2

*Foster interdisciplinary scholarship which acts as an innovation catalyst for Michigan's bioeconomy.*

The complexity of the emerging bioeconomy requires an interdisciplinary approach to address current and future challenges and opportunities. Those issues must incorporate science, technological and societal uncertainties. Therefore efforts from across the university, from the basic biosciences to marketing, public policy and sociology, can meaningfully contribute to their resolution. While some types of invention and advances in science can result from disciplinary scholarship, aggressive leadership focused on innovation will require interdisciplinary collaboration.

### *Theme 2 Recommendations*

Identify and support initiation of high priority research ventures.

- Development of an Office of Biobased Technologies statement of strategic intent can provide the fundamental basis for specification of priorities (see Theme 4 recommendations).
- Inventory of current research provides benchmark relative to future desired outcomes.
- Office of Biobased Technologies crafts processes whereby interdisciplinary groups are provided the opportunity to form functioning research teams to pursue high priority efforts.
  - ✓ Solicit input and, potentially, participation of relevant Michigan private sector interests.
  - ✓ Include "triple bottom line" (economic, environmental, and societal) assessment capabilities within the interdisciplinary group structures.
- Office of Biobased Technologies employs discretionary dollars, from redirection of current resources as well as attraction of additional support, to support initial and early stage research efforts within the priority areas. OBT can work more closely with entities such as the MSU Foundation to ensure that use of discretionary resources is aligned with key priorities.

Actual specification of high priority research topics should be the result of considerable analysis and dialogue among MSU faculty and with stakeholder interest through OBT. However, some example topics that seem to have considerable current interest include:

- Determining the viability of converting existing pulp mill operations to integrated forest biorefineries.
- Determining the "right size" for corn-based ethanol in Michigan. This is inherently an interdisciplinary question since dramatic shifts in corn utilization will impact many aspects of the economy and the rural environment.
  - ✓ What are the tipping points at which the benefits of corn-based ethanol production are overcome by negative impacts? For example, what is the impact of higher local corn prices on livestock producers?

- ✓ What research and/or outreach efforts can reduce the effect of those negative consequences?
- ✓ What are the most promising, high value bioproducts that should be pursued in conjunction with or in isolation of ethanol production initiatives?

Aggressively pursue research efforts to foster innovation in potential biobased supply chains where strong opportunities appear to exist for Michigan. Attractive targets include:

- ✓ Novel downstream uses of bioproducts,
- ✓ Crop residue and perennial grasses as feedstocks, or
- ✓ Use of high growth forest technologies to support biofuel and bioproduct supply chains.

The interdisciplinary teams formed need to stretch the boundaries of disciplinary perspectives. While contributions of scientists, engineers, and economists are essential, input from legal, environmental, social, and business disciplines also is needed.

## 5.3. Theme 3

Insure that the necessary research and development facilities, including commercialization and business development support infrastructure, are available to match the current and future needs of Michigan's bioeconomy.

In addition to extensive laboratory and computational capabilities, critical aspects of bioeconomy-oriented innovation require specialized and sophisticated infrastructure for research and development activities to be effective. Illustrative examples of these types of infrastructure include:

- Pilot biorefinery capabilities
- Feedstock "farms"
- Logistics testing "grounds"

Access to such facilities and proximity to the expertise required to optimally employ them typically is a necessary component of an innovation ecosystem. Innovative organizational structures, including alliances with non-university entities, likely will be needed to facilitate access to these bioeconomy specific assets.

### *Theme 3 Recommendations*

Specify facility needs associated with the high priority ventures identified within the Theme 2 recommendations.

- A comprehensive, innovation ecosystem perspective should be adopted. This perspective should include both on and off-campus requirements.
- The facility needs for the ecosystem are likely to extend beyond university owned/controlled facilities. Aggressive collaboration with public and private sector ventures can enhance the timely access to key facilities.
- Public-private facility collaboration may require innovation relative to organizational interrelationships as well as foster alliance-based pursuit of additional resources. For example,
    - ✓ Novel partnering arrangements may need to be defined and made routine, whereby university researchers are engaged extensively in private sector research.
    - ✓ It may be desirable to pursue new sources of support from programs such as the Department of Energy's EPACT Section 932 funding for biorefinery demonstration projects.

Even with effective and extensive collaboration, significant new resources are likely to be required to support leading edge research and outreach in support of Michigan's aspirations to excel as a leader in the emerging bioeconomy. Targeted public support for facility development likely is required. A significant public initiative is critically important as a signal that Michigan's leadership aspirations warrant investment from both public and private sources outside of Michigan. Key factors within such an initiative would include:

- A major component focused on campus infrastructure. This fund would support targeted improvements to on-campus research and computational facilities.
- "In the field" infrastructure enhancements are needed to support those parts of the innovation ecosystem that extend beyond basic research. Such enhancements would fuel development of the broader bioeconomy value chain, including bioprocessing, feedstock production, and the associated logistics capabilities. For example to:
  - ✓ Develop a demonstration scale (1/10) plant to begin testing processes for a forest biorefinery,
  - ✓ Develop a demonstration scale (1/10) enzyme production facility,
  - ✓ Support test plots for growing new varieties of biomass across the state (for both crops and forest products), or
  - ✓ Co-locate a pilot biorefinery with an existing pulp mill.
- Although new public funds are essential, it is equally important that the facilities development initiative include efforts to aggressively identify and pursue private and public sector partners, including collaborative efforts with MBI.

Establish the capability to provide business development and commercialization support for biobased products and business ventures as a key component of the enabling infrastructure available through the OBT.

Establish and maintain a comprehensive internet web resource center to support collaboration and outreach efforts. While the physical resources referred to above are essential, a virtual infrastructure focused on the bioeconomy of Michigan and its innovation ecosystems will allow those physical resources to be leveraged more effectively.

## 5.4. Theme 4

*Aggressively strive to ensure MSU's leadership role within the innovation ecosystem of the Michigan bioeconomy.*

Leadership through scholarly advances must be the preeminent aspiration of the land grant university. Relative to the bioeconomy, however, the large state university also can demonstrate the tangible contributions of biobased innovations within the structure of its own internal operations and in accomplishing its undergraduate education responsibilities. Exploiting both the scholarly and the operational perspectives can contribute to the attainment of a sustainable leadership position.

### *Theme 4 Recommendations*

Establish an Office of Biobased Technologies Advisory Council

- Include participants of the roundtable session as initial members of the Council,
- Over time expand participation to ensure active involvement from a broad cross section of stakeholder groups,
- Although presumably more active in its initial stages, this group would meet at least semi-annually to monitor and enhance collaboration with the private sector, to evaluate emerging issues, and provide recommendations for activities of the Office of Biobased Technologies

With input from both the Office of Biobased Technologies Advisory Council and other stakeholders, establish an Office of Biobased Technologies statement of strategic intent which identifies:

- An aggressive set of long-run desired objectives,
- The specific collection of measures by which progress to attaining the desired objectives will be assessed on an ongoing basis, and
- The individuals responsible for ensuring that the process operates on a continuing basis.

Inventory current university activities relating to bioeconomy-related topics, especially those which include interdisciplinary perspectives. Activities across the research, education and outreach functions should be included. The assessment should ascertain information relative to:

- Who is engaged?
- What are they doing?
- What components of the bioeconomy value chain are being addressed (where are holes)?
- What is the current effectiveness level?
- What funding tactics have been most fruitful?

Assess, on an on-going basis, the effectiveness of campus policies, procedures, and practices relative to the protection, transfer and commercialization of bio-related intellectual property.

- Establish means to score campus efforts so that economic development within Michigan is included as a relevant factor.
- Recognize that early and strong research linkages with the private sector will require timely IP processes and a dynamic intellectual property regime.

Assemble a group of campus representatives and students to examine campus operations and to develop recommendations for policies that will encourage the use of biobased products and methods.

- Assign responsibility within the campus administrative structure for specification of plans to aggressively move the campus towards greater use of biobased resources.
- Sponsor research and assessment efforts relative to the expected and actual impact of recommended actions (economic, environmental, and awareness generating potential).

Proactively accept the responsibility to ensure that current and future undergraduates are extremely well positioned to appreciate, to be able to evaluate and to provide public and private sector leadership as the bioeconomy evolves.

- Incorporate bioeconomy perspectives within appropriate curricula, encompassing both the biological and social sciences, by providing small, targeted curricula enhancement grants to interested faculty.
- Energize relevant student activity groups to investigate and to champion bioeconomy opportunities.
- Establish an on-going competition to solicit proposals for student led evaluation and action to advance the bioeconomy:
  - ✓ Provide seed funding for proposals which most effectively meet program goals.
  - ✓ Include participation from student activity groups and from efforts that occur within academic courses
  - ✓ Provide separate evaluation/funding tracks for efforts focused on local (campus and the Lansing area) projects versus those proposing to conduct activities beyond the local area.