Advancing the Bioeconomy: Overview of Michigan's Recent Progress

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Michigan State University's Product Center for Agriculture and Natural Resources is offering a series entitled "Status of Michigan's Bioeconomy: Progress & Evolving Potential." The purpose of the series is to better inform decision-makers and bioeconomy stakeholders about a range of issues and opportunities related to the still emerging bioeconomy, especially in Michigan.

The papers in the series include:

- *Advancing the Bioeconomy: Overview of Michigan's Progress*
- *Michigan's Position in the U.S. Biofuel and Bioenergy Market*
- *Potential Future Scenarios of Michigan's Bioeconomy*

The Product Center envisions the series as an ongoing opportunity to track Michigan's bioeconomy progress, identify opportunities for advancing the bioeconomy, and encourage collaboration among the many regional bioeconomy stakeholders.

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As a state that imports almost all of its energy inputs and fuel, Michigan has prioritized growing its bioeconomy to support its own energy needs and to be global supplier. While substantial slowdowns in the state, national, and global economies have limited the growth of the bioeconomy in many parts of the United States, including Michigan, progress in advancing the bioeconomy is being made, entrepreneurialism is happening, and the supply and production chain is active.

The three major sectors of the bioeconomy – biofuels, bioenergy, and biomaterials – have all seen promising advancements in Michigan since Michigan State University (MSU) first published an evaluation of bioeconomy opportunities in the state. The state has five operating ethanol plants and its first commercial-scale cellulosic ethanol plant is underway, one of only seven in the country. In addition to several agriculture and industrial anaerobic digester facilities and 10 current (several more are planned) wood-fired electrical generating facilities, the last few years also have brought a new public-private partnership to develop and operate a biogas facility to provide heat for Flint and methane to fuel the city's bus fleet. Finally, Michigan-based companies such as Dow Chemical, Ford Motor, and KTM industries are all investing in and growing their biomaterials/biochemical businesses in the state.

Michigan has many assets that offer national and global bioeconomy leadership opportunities: a diverse feedstock base, including traditional biofuel crops such as corn and soybeans, timber, waste wood, and animal manure; significant R&D expertise and commitment to bioeconomy sciences within Michigan's universities; access to large, high-quality water resources; and continued efforts by policy-makers to create the regulatory and incentive systems to further build the bioeconomy market. However, like other states, Michigan's bioeconomy is still limited by cost: producing most biobased fuels, energy, and materials still costs significantly more than the fossil fuel counterparts. Consumers have not yet been willing to adopt biobased products. As processes become more efficient and public understanding about the availability and quality of bioproducts expands, Michigan could be well poised to play a strong role in this growing sector.

INTRODUCTION

"Advancing the Bioeconomy: Overview of Michigan's Progress" is the first in the series of white paper reports prepared by the MSU Product Center for Agriculture and Natural Resources on the "Status of Michigan's Bioeconomy: Progress & Evolving Potential." It builds on previous work done in 2006 by MSU and the Centrec Consulting Group[1] to evaluate the emerging bioeconomy in Michigan and identify how MSU could support the advancement of the industry. This report discusses Michigan's progress in capitalizing on the opportunities and addressing the issues identified in the 2006 report as well as those that have arisen in the ensuing years. This white paper is not meant to be a comprehensive or exhaustive evaluation of Michigan's bioeconomy, nor a judgment on Michigan's progress in advancing its bioeconomy. Its purpose is to:

[1] Centrec Consulting Group. "Preparing for the Future of Michigan's Bioeconomy: Recommendations for the Office of Biobased Technologies," and "Linking Knowledge and Resources to Support Michigan's Bioeconomy." 2006.

- Provide a market overview of the various bioeconomy sectors.
- Highlight relevant policy and state leadership efforts over the last five years.
- Provide a sample of some of the key bioeconomy R&D efforts at Michigan State University since 2006.
- Describe some of the economic implications and continuing opportunities for a thriving bioeconomy.

Michigan has prioritized growing its bioeconomy sectors and becoming a leader in the global bioeconomy market. So the key objective of the **"Advancing the Bioeconomy: Overview of Michigan's Progress"** white paper is to provide decision-makers and stakeholders with a reasonably thorough snapshot of Michigan's bioeconomy in 2010.

For the purposes of this report series, the Product Center defines the bioeconomy as *any commercial or industrial effort based on growing renewable bio-materials and converting them into products that replace petrochemical- or fossil fuel-based products.*

To the extent possible, this report draws from publicly available data from a variety of government agencies, trade associations, and published reports and uses the most recent quantitative data and information available.

MICHIGAN'S BIOECONOMY MARKET

Michigan has put a high priority on building and advancing its renewable energy market in terms of both production and consumption, and the bioeconomy has been a significant part of that effort. This focus is based on the recognition that Michigan has several competitive advantages in the evolving bioeconomy, including its automotive manufacturing history, access to vast water resources for bioeconomy product development and transportation, and significant forestry resources.

Michigan is also a net importer of energy, including transportation fuels and electricity/ heating inputs such as coal and natural gas. Michigan produces approximately 30,000 MW of electricity and consumes more than 300 million BTUs per capita (ranking 35th in the United States). The state imports 97 percent of its petroleum, 80 percent of its natural gas, and 100 percent of coal and nuclear fuel from other states and nations. These imports account for about 70 cents of every dollar spent on energy by Michigan's citizens and businesses. Michigan spent a total of $37 billion on all forms of energy in 2007; of that amount $26 billion was for energy resources imported from other states and nations[2]. Advancing the bioeconomy in Michigan not only increases the state's share of the global bioeconomy market, it addresses the need for cost-competitive, Michigan-based energy feedstocks so the percentage of gross state product spent on imported energy can be reduced.

The state's efforts have included policy supports; investments in bioeconomy-related research and development; investment in private sector efforts to construct biofuel, bioenergy, and biomaterials facilities; partnerships with major bioeconomy companies; support of entrepreneurial and pilot-scale efforts; and support for technology commercialization.

[2] Michigan Public Service Commission. *Michigan Energy Overview*. September 2008.

Like most sectors of the U.S. and global economies, the bioeconomy market has been hard hit in the last several years by the substantial economic downturn, tightening credit markets, and lower oil prices. However, in many parts of the U.S., including Michigan, progress in advancing the bioeconomy is being made, entrepreneurialism is happening, and supply and production chains are active.

The state has more than 100 companies operating directly in the bioeconomy (see Appendix A), with dozens more (engineering, research, and consulting firms) supporting the bioeconomy. These companies range in size from entrepreneurial startups to billion-dollar corporations such as Dow Chemical and Dow Corning. Most of the companies are involved in biofuels in some way, but there are many bioenergy companies, including anaerobic digesters, wood or wood products suppliers, and biomass combustion facilities, as well as bioplastic and biobased product companies.

Most market analyses break the bioeconomy down into three sectors:

- biofuels: replacement for gasoline and diesel fuel; generally used as transportation energy
- bioenergy: replacement for coal, natural gas, and (possibly) nuclear energy; generally used to create electricity
- biomaterials: replacement for petroleum and synthetic inputs in products

The biofuels and bioenergy markets have dominated much of the investment in, public dialogue about, and consumer awareness of the bioeconomy. Still, as the fuels sector in particular has struggled in the last few years, there is growing awareness and investment in the biomaterials sector.

Michigan Biofuels Sector

Biofuels tend to be the most recognized sector of the bioeconomy by the general public, particularly as gas prices have fluctuated. For this paper, biofuels are defined as:

- grain ethanol : made from corn and sugar cane, it is blended with petroleum and most commonly sold as an oxygenate blended with gasoline (10% ethanol by content)
- cellulosic ethanol: made from agricultural cellulose feedstocks such as corn stover, wheat straw, switchgrass, and woody biomass
- biodiesel: made from vegetable oils such as soy or palm, waste greases/oils/fats, or from algae; commercially it also can be blended with petroleum diesel in combinations of 5 to 100 percent

The U.S. biofuels market sector has seen growth over the last decade, despite the dropoff in biofuel production facility investment in the last three years because of low oil prices and the substantial economic downturn. U.S. biofuel production capacity was up to 13.9 billion gallons/year (BGY) of ethanol in 2009 (up 688 percent from 2001[3]) and 2.6 BGY of biodiesel by the end of 2009 (up more

[3] U.S. Energy Information Association (EIA). *Short-Term Energy Outlook*. December 9, 2008. http://www.eia.doe.gov/emeu/aer/txt/ptb1003.html

than 4000 percent from 2001)[4]. However, actual production is lower — much lower in the case of biodiesel.

Growing the biofuel market has been a priority for Michigan and significant resources have been focused on attracting the biofuel industry to locate or expand within the state. In 2006, the state created the Michigan Biofuels Commission. Its charge was to make recommendations to allow the state to become a leader in alternative fuel production and use. The governor set an initial target of having 1,000 ethanol or biodiesel pumps across the state by 2008. The state also passed a Renewable Portfolio Standard in 2008, which includes electricity generated from biomass resources. Michigan currently has about 30 operational biofuel-related companies.

Between 2005 and 2010, Michigan, like most of the country, experienced mixed market success in the biofuels industry. Through 2008, the high price of crude oil was stimulating more demand for biofuels and the state saw the continued operation, expansion and/or construction of both ethanol and biodiesel production facilities during that time. As oil prices dropped and the economy and credit markets went into crisis in 2008 and 2009, biofuel production facility growth in Michigan substantially slowed and the investment environment for bioeconomy and other ventures became increasingly tight. One of the largest ethanol producers in Michigan and the nation, VeraSun, filed for Chapter 11 bankruptcy and closed its Woodbury facility. Biodiesel producers were equally hard hit from 2007 to 2009 as the price of soybeans, the primary feedstock for biodiesel, soared to $7 to $15/bushel compared to prices of $4.50 to $8.70/bushel during the previous decade. This increase in soybean prices drastically reduced profit margins and market stability.[5] Many of Michigan's biodiesel plants are currently out of production or only operating at partial capacity.

Frontier Renewable Energy

Frontier Renewable Energy is a partnership between the Mascoma Corporation and J.M. Longyear to develop a commercial-scale cellulosic ethanol plant in Kinross in the Eastern Upper Peninsula. When completed in 2013, the facility will produce up to 40 million gallons of low-cost, low-carbon cellulosic ethanol. It will employ more than 150 people during construction and 50 full-time employees when operational.

The Frontier project was one of the initial Centers of Energy Excellence awards made by the state. Additional partners include the U.S. Department of Energy, Michigan State University, and Michigan Technological University.

Funding for the project includes:

- *$23 million from the state*
- *$26 million from the U.S. Department of Energy*
- *$300 million from Frontier*

[4] U.S. EIA. Short-Term Energy Outlook Supplement: Biodiesel Supply and Consumption. April, 2009. www.eia.doe.gov/emeu/steo/pub/special/2009_sp_01.pdf

[5] Index Mundi. http://www.indexmundi.com/commodities/?commodity=soybeans&months=180

However, progress continued in other areas of the biofuels sector. Ethanol producers such as POET, which operates a 53-million-gallon-per-year ethanol plant in Caro, have been successful by making technological improvements in production processes and increasing sales of byproducts such as distillers grain. Currently the state has five operating ethanol-plants, all using corn as the primary feedstock (see Table 1 for details). In mid-2008, the state signed an agreement with Mascoma Corporation, in partnership with Michigan Technological University and Michigan State University, to provide more than $23 million in Centers of Energy Excellence funding for the development of the state's first production-scale cellulosic ethanol plant in Kinross (Frontier Renewable Resources Project). The plant is expected to be operational by 2013.

TABLE 1 CURRENT AND UNDER DEVELOPMENT ETHANOL FACILITIES IN MICHIGAN

Facility Name	Location	Capacity (mgy)	Feedstock	Operational Status
The Andersons Albion Ethanol	Albion	55	corn	operating
Marysville Ethanol	Marysville	50	corn	operating
Global Ethanol/Midwest Grain	Riga	57	corn	operating
POET Ethanol	Caro	53	corn	operating
Carbon Green Bioenergy	Woodbury	50	corn	operating
Mascoma-Frontier Renewable	Kinross	40	cellulose, wood	under development
American Process Inc. Biorefinery	Alpena	unknown	cellulose	under development - pilot scale

Availability of biofuels and consumer demand also continued to show increases in Michigan in the last decade. Total ethanol consumed includes ethanol used as an oxygenate (a blend of up to 10 percent ethanol with gasoline) and E85 (85 percent ethanol by volume). The vast majority of ethanol is currently used as an oxygenate. Michigan ranks seventh in the nation in total ethanol consumed: more than 300 million gallons of ethanol consumed in 2007. In addition, Michigan has more than 90 E85 stations, with a goal of increasing that number to 1,000.

Michigan's Bioenergy Sector

The term "bioenergy" generally refers to the use of biomass for energy systems that produce heat and/or electricity (versus transportation fuels). The bioenergy sector includes:

- biogas recovery: anaerobic digestion of a variety of waste (animal manure, municipal, and industrial waste water) to create biogas that powers electricity-producing turbines or combined heat and power (CHP) units
- landfill gas recovery: decomposition of solid waste in landfills creates gas that is used to fuel boilers, turbines, or CHP units

- biomass gasification: use of wood or other organic waste to create synthesis gas (syngas) that can be combusted in turbines or used to create methanol and hydrogen
- biomass combustion: direct combustion of biomass (wood chips, pellets, black liquor – a liquid byproduct of pulp and paper manufacturing) in traditional boilers

The bioenergy market has continued to make headway in Michigan across all three types of bioenergy generating facilities. There are currently more than 35 bioenergy-related firms operating in the state (see Appendix A). In 2008, the state signed an agreement with and provided $4 million in Centers of Energy Excellence funding to Swedish Biogas International to develop a biogas plant in Flint, using the city's wastewater as a feedstock source (see inset for project details). The biogas will be used to generate electricity and create biomethane to fuel the city's bus fleet.

Michigan is one of the top 10 U.S. states in terms of megawatt hours produced from biomass such as biogenic municipal solid waste, landfill gas, sludge waste, agricultural byproducts, and other biomass gases (including digester gases and methane)[6]. The state's six farm-based anaerobic digesters generate more than 18,600 megawatt hour equivalents of energy annually[7].

According to the U.S. Department of Energy, Michigan ranks ninth in the country for power production from wood or wood derived products. The state generates more than 1.7 million megawatt hours from combustion of woody biomass at 10 facilities[8]. This capacity is expected to significantly increase in the coming years as Michigan's utilities pursue additional renewable generation opportunities to meet Renewable Energy Standards mandated through Public Act 295, passed in 2009.

Michigan has more than 19 million acres of forests, 65 percent of which are owned privately. Given the growing interest in wood and wood waste as feedstocks for both bioenergy generation and cellulosic biofuel production, the state has partnered with several Michigan universities and other bioeconomy partners to evaluate the extent of existing as well as potentially available wood resources in

Swedish Biogas International

Swedish Biogas International is constructing an $8-$10 million biogas facility in Flint in partnership with Kettering University and the city. The project will:

- *use the city's wastewater sludge to produce biogas fuel to heat city buildings and possibly create biomethane for the city's vehicle fleet*
- *receive $4 million in Michigan Centers of Energy Excellence funding*
- *employ 25 to 45 people*
- *be operational in fall 2010*
- *save Flint an estimated $3.5 million within seven years*

[6] EIA, "State Data for Reserves and Supply," 2008.

[7] U.S. EPA. AgStar Program Accomplishments. April, 2010. http://www.epa.gov/agstar/accomplish.html.

[8] EIA, "State Data for Reserves and Supply," 2008.

the state. In 2009, the Michigan Climate Action Council looked at available biomass resources in the state under a "business as usual" scenario and found that the potentially available resources include[9]:

- more than 20 million dry tons of unharvested biomass growth on timberland acres
- more than 6 million dry tons of energy crops
- approximately 870,000 dry tons of unused logging residue from current timberland harvests
- approximately 1.5 million dry tons of mill and other residue and urban wood waste
- just under 4 million dry tons of agriculture residue
- 1.7 million dry tons of municipal solid waste fiber

These resources will increasingly be looked at for use in the bioenergy sector in Michigan.

Michigan Biomaterials Sector

The biomaterials sector is largely made up of biochemicals, biobased plastics, polymers (e.g., polylactic acid), solvents (e.g., ethyl lactate), biodegradable products, biobased packaging materials, and other platform chemicals such as succinic acid and butanol.

The global polymer market is estimated at $250 billion and is predicted to exceed $450 billion by 2025. Biobased polymers are expected to increase in marketshare from the current 0.1 percent to 10 to 20 percent by 2025. The chemical industry is projected to grow to more than $2 trillion a year, with biobased chemicals representing more than $500 billion by 2025[10].

The state has more than 30 biomaterials firms (see Appendix A), including large multinational companies such as Dow Chemical as well as smaller and startup companies such as Draths Corporation. These companies make a variety of products including biobased plastics, biochemicals, biodegradable products, biobased health and beauty items, biosolvents and cleaning products, biobased packaging materials, biobased automotive materials, beneficial bacteria, and green building supplies. The sector has seen increased activity both in Michigan and nationwide as biofuel producers in particular look for ways to develop integrated biorefineries to create biobased materials as byproducts of biofuel development. Some existing biofuel producers are also beginning to shift current feedstocks (soybeans for example) to biochemical production because it offers more opportunity for economic viability. While the Michigan market as whole has not seen substantial growth in commercial operations over the past five years, there have been several key advancements during this time.

To help support the biomaterials market, the state granted one of six Phase I Centers of Energy Excellence awards to Working Bugs LLC to establish a biorefinery that will produce high-value specialty and fine biochemicals and biofuels from natural feedstocks. Technology developed at this

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[9] Michigan Climate Action Council. *Climate Action Plan.* March, 2009. Defined as: "the amount available if the resource were managed according to its current demonstrated productive capacity, and if social, ecological, administrative, and technical constraints were managed to minimize their impact on utilization." P. J-3.

[10] U.S. Department of Agriculture (USDA). *US Biobased Products*. 2008.

center can be applied to existing biomaterial processing facilities across the state, including corn ethanol plants, beet sugar refineries, and pulp mills, to produce new, higher value bioproducts.

Several other Michigan biomaterials companies have seen notable growth and expansion in recent years, including:

- Dow Chemical: industry-leading manufacturer of specialty chemicals, advanced materials, agrosciences and plastics products.
- KTM Industries: developer and manufacturer of Green Cell biodegradable engineered foam for cushioning and insulation applications. The company is located in Lansing and has more than $2.5 million in annual sales.
- Ford Motor Company: leading U.S. auto manufacturer working to develop advanced, low-temperature combustion diesel engines that use biofuel blends optimized for engine performance. Ford has been partnering with MSU researchers on a $4.7 million U.S. Department of Energy grant to integrate the development of advanced engines with the development of next generation biofuels. Additionally, Ford currently uses biobased materials in some vehicles, including a wheat straw-reinforced plastic and soy-based polyurethane seat cushions, seat backs and head rests.
- Draths Corporation: next generation chemical company that combines microbiological and chemical processes to produce chemical intermediates such as nylon precursors from biobased materials. Draths recently received more than $5 million in Michigan state tax credits to construct headquarters, research, and multiple pilot facilities in Delhi Township.
- Bio-Kleen: manufacturer of high performance, biodegradable cleaning products for the marine, RV, snowmobile, motorcycle, automotive, household, and commercial industries.

KTM Industries

KTM Industries was founded in 1997 by four Michigan State University researchers who wanted to make products from biomaterials. It started out as a small home office and now is a multimillion dollar company that occupies a 42,000-square-foot building in Lansing. The company manufactures and sells biobased:

- *green cell foam used for cushioning and shock absorption*
- *compostable/recyclable thermal cooler*
- *Magic Noodles biodegradeable building blocks for kids*

POLICY SUPPORT FOR MICHIGAN'S BIOECONOMY

Two pieces of federal legislation, the 2005 Energy Policy Act and the 2007 Energy Independence and Security Act, created renewable fuel standards for the United States that mandated production and use of 36 billion gallons of biofuels by the year 2022. The standard requires that this must be made up of 21 billion gallons of advanced biofuels (renewable fuels other than ethanol derived from corn starch) and specified that at least 16 billion gallons be from cellulosic biofuel and at least 1 billion gallons must be diesel made from biomass. The remaining 15 billion gallons may be either advanced biofuels or conventional biofuels such as corn ethanol. The renewable fuel standards have been driving growth in the biofuels sector across the country, including Michigan.

In addition to the federal renewable fuel standards, Michigan has implemented numerous other policies, incentive programs, and regulatory requirements to advance its growing bioeconomy. These efforts have been particularly focused on attracting new bioeconomy-related businesses to the state, creating public-private partnerships, and helping existing Michigan companies diversify into and expand bioenergy and other renewable energy manufacturing and production facilities. Table 2 highlights some of the state's key policy support efforts for the bioeconomy.

TABLE 2. STATE POLICIES AND INCENTIVES PROGRAMS

Incentive Programs	Program Description
Centers of Energy Excellence	The Centers of Energy Excellence (COEE) program was created to promote the development, acceleration and sustainability of energy excellence sectors in this state. In 2008, the Michigan Strategic Fund Board awarded $43 million to six Centers of Energy Excellence in the first phase of the program (four of which are bioeconomy projects). The 2009 Phase II of the program authorized an additional $30 million. The initiative provides grants to for-profit companies that are commercializing innovative energy technologies with support from a university.
Renewable Energy Renaissance Zones	Allows companies operating within the zone to operate free of virtually all state and local taxes for 15 years. Facilities within a renaissance zone do not pay the Michigan Business Tax, state education tax, personal and real property taxes, or local income taxes (where applicable). The program allows for 15 RERZs, with a requirement that at least five be focused on the production of cellulosic biofuels
Nonrefundable Business Activity Tax Credit	Businesses engaged in alternative energy research, development, and manufacturing may claim a nonrefundable credit from the Michigan business tax. Qualified business activity is defined broadly to include research, development, or manufacturing of an alternative energy marine propulsion system, an alternative energy system, an alternative energy vehicle, alternative energy technology, or renewable fuel.
Biomass Gasification and Methane Digester Property Tax Digester	Provides 100 percent exemption from real and personal property taxes for certain methane digesters, biomass gasification equipment, and equipment used to harvest crop residues or dedicated crops percent used for energy production.
Biomass Energy Grant Program	Provides funding for state bioenergy and biofuels projects on a regular basis. Funding categories typically include biofuels and bioenergy education, biofuels infrastructure, and biomass technology development and demonstrations.
Refundable Payroll Tax Credit	Businesses certified by the NextEnergy Authority that locate in the NextEnergy Zone to research, develop, or manufacture "alternative energy technologies," as defined by the Michigan Next Energy Authority Act, may claim a credit equal to their qualified payroll amount multiplied by their income tax rate for that year.
Policies/Mandates	**Policy Description**
Renewable Energy Standard	Public Act 295, requiring the state's investor-owned utilities, alternative retail suppliers, electric cooperatives and municipal electric utilities to generate 10 percent of their retail electricity sales from renewable energy resources by 2015. Under the standard, eligible renewables include biomass, solar and solar thermal, wind, geothermal, municipal solid waste (MSW)*, landfill gas, existing traditional hydroelectric (i.e., water passed through a dam), tidal, wave, and water current (e.g., run of river hydroelectric) resources. Biomass is broadly defined as organic matter that is not derived from fossil fuels and which replenishes over a human time frame
Renewable Fuels Commission	In 2006 the state created the RFC, made up of stakeholders from across Michigan's bioeconomy sectors, to make recommendations about how the state could encourage and accelerate the the production and deployment of biodiesel and ethanol. The RFC issued its report in 2007, which included more than 40 recommendations. Several of the key recommendations have been implemented already, including the designation of Renewable Energy Renaissance Zones for cellulosic ethanol materials.

The Michigan Economic Development Corporation also offers technical and market assistance to bioeconomy companies and has included bioenergy as one of its four key growth areas for the state.

BIOECONOMY RESEARCH AND DEVELOPMENT AT MICHIGAN STATE UNIVERSITY

Michigan's public universities, like most across the United States, are increasingly facing reduced state and federal funding for research across disciplines. Michigan's investment in its higher education institutions (two- and four-year) dropped by about 6 percent from 2005 to 2009[11]. Federal R&D funding during the decade was also volatile, but saw some positive opportunities. Research funding by the National Science Foundation's (NSF) Directorates for Biological Sciences, Math and Physical Sciences and Engineering, increased overall by more than 50 percent from 2000 to 2009[12]. U.S. Department of Energy (DOE) funding for the Energy Efficiency and Renewable Energy (EERE) Program (which includes bioeconomy-related research) was up and down during this period, ranging from a high of $851 million to a low of $456 million[13]. The state of Michigan has been a beneficiary of funding from both agencies. In FY 2007, Michigan institutions received more than $125 million in NSF funding and more than $31 million in DOE R&D funding.[14] While this is total agency funding, not specific to the bioeconomy, it does give a picture of the overall federal R&D funding for science and technology. In FY 2008, Michigan received a DOE award of more than $50 million in partnership with the University of Wisconsin-Madison to form the Great Lakes Bioenergy Research Center, one of three DOE bioenergy research centers.

Most of Michigan's major research institutions are doing at least some bioeconomy research and several have become national leaders in terms of expertise, funding received, patents and/or commercial venture spin-offs. While the full scope of all the university research cannot be captured in this briefing paper, some notable examples of research and initiatives at MSU that have helped advance the bioeconomy in Michigan and globally are highlighted below. Later papers in this series will provide more in-depth case studies on bioeconomy research at MSU and other Michigan universities.

- Great Lakes Bioenergy Research Center: a five-year, $250 million partnership with the University of Wisconsin-Madison to research and develop technologies and processes to produce biofuels, bioenergy, and high value biobased products.

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[11] State Higher Education Executive Officers. 2009. *State Higher Education Finance FY 2009*. "Grapevine Table 2." (two and four-year institutions included) **http://www.sheeo.org/finance/shef/SHEF_FY_2009.pdf**

[12] American Association for the Advancement of Sciences. *AAAS Analysis of R&D in the FY 2009 Budget*. March, 2008 (revised) **http://www.aaas.org/spp/rd/prev09p.htm**.

[13] AAAS. *AAAS Report XXXIV: Research and Development FY 2010*
http://www.aaas.org/spp/rd/rdreport2010/tblii11.pdf

[14] National Science Foundation, Division of Science Resources Statistics. 2010. *Federal Funds for Research and Development: Fiscal Years 2007 – 2009.* Detailed Statistical Tables NSF 10-305. Arlington, VA. Available at **http://www.nsf.gov/statistics/nsf10305/**.

- MSU BioEconomy Network: universitywide organization designed to marshal MSU research and resources to help foster connections with public and private sector initiatives aimed at expanding Michigan's bioeconomic sector, as well as identify, encourage and support research programs that position MSU as a world leader in developing the bioeconomy.
- Biomass Conversion Lab: focused on developing pretreatment, enzymatic and fermentation technologies to break down cellulose and hemicellulose more economically and efficiently.
- MSU-DOE Plant Research Lab: research focuses on manipulating plants at the molecular level to create more efficient and economical biofuels and biochemicals.
- Working Bugs LLC: in partnership with Luleå University of Technology in Sweden, Working Bugs is identifying potentially useful microbes that could be used in fermentation processes to make products from renewable resources, as well as intermediate chemicals that are then used to make other biobased products.
- Biostarch: using biomass from soybeans and corn, researchers are creating bioplastic bags and biofoam sheets to protect cargo during shipping and for use as insulation.
- MSU Bioeconomy Institute: opened in spring 2009 at the former Pfizer facility in Holland, the 138,000-square-foot facility complements and extends campus research supporting the bioeconomy, including research on biofuels, biobased chemicals and biomaterials.
- MBI: a wholly-owned subsidiary of the MSU Foundation, MBI's mission is to develop and commercialize sustainable biobased technologies. MBI partners with bioeconomy inventors and startups to de-risk, develop, and scale up discoveries into commercially viable technology packages.

ECONOMIC IMPLICATIONS AND BIOECONOMY POTENTIAL IN MICHIGAN

The bioeconomy offers substantial opportunities for Michigan to improve the state's economy by reducing reliance on imported energy, creating local and regional jobs, helping create markets for advanced automobiles, and expanding the global export of agriculture- and forestry-based products. The supply and buy chains for the bioeconomy include significant opportunities for energy consumers, component suppliers, energy service suppliers, manufacturers and distributors, service providers, developers, fuel retailers, fuel distributors, blenders, biofuel refiners, and feedstock suppliers.

In addition to the bioeconomy progress highlighted above, Michigan has numerous planned efforts or programs and projects that are underway, but not fully-realized. There are several factors that could shape Michigan's ability to continue building its bioeconomy and become a market leader, including:

<u>Continued policy support, such as renewable energy standards, tax credits, and grant programs</u>

- Michigan continues to implement and possibly augment Public Act 295 that created the state's renewable energy standards. The state also is working with investor-, municipal-, and cooperative-owned utilities to develop programs to meet their renewable energy targets.

- Michigan is in the second phase of Centers of Energy Excellence funding, a program that has significantly attracted global bioeconomy companies to the state to develop and commercialize biobased fuels, energy, and products.

- The state also is considering several other pieces of legislation specifically aimed at advancing the bioeconomy including:[15]

    - House Bill 4137 that would offer 20-year biofuel contracts at feed in tariff rates of $0.105 to $0.145/kWh (compared to new coal price estimates of $0.133/kWh)

    - House Bill 4107 to provide tax credits for the purchase of biomass stoves

    - House Bill 4170 to provide tax credits for biomass gathering and handling

    - House Bill 4241 to provide tax credits for amounts expended on biomass fuel

  As of July 1, 2010 there has been no action on these bills.

However, until the development and production of biofuels, bioenergy, and biomaterials are more efficient, there will continue to be a significant cost differential between bioproducts their fossil-fuel counterparts. Michigan's policy-makers must have the political will to support the necessary systems that will speed adoption and help increase consumer acceptance of these products.

<u>Investment in research and product development at Michigan's universities and facilitation of the commercialization process</u>

Michigan's public universities, like most across the United States, are facing long-term reductions in research funding across disciplines. For Michigan to advance its growing bioeconomy, the state must continue to partner with its research institutes to provide funding and facilitate industry collaboration. The Michigan Centers of Energy Excellence program has been a valuable tool for creating opportunities for the state's universities to collaborate with industry on the development and commercialization of clean energy technologies. Phase II of that effort (targeted at $30 million) will continue that investment.

As indicated in the "Bioeconomy Research and Development at Michigan State University" section above, Michigan's funding for its higher education institutions has declined in recent years. In fiscal year 2008, Michigan's per capita investment in higher education was $258, approximately 88 percent of the U.S. average. This funding represented just less than 7 percent of the state's tax and lottery revenues and included all higher education funding, not just research.[16]

State support for research funding at higher education institutions likely will continue to decline in the coming years, as the state struggles to boost its sagging economy. Michigan has been particularly hard hit by the global economic crisis and continued efforts to balance competing budget priorities means

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[15] Michigan Public Service Commission. *Growing Green Energy in Michigan*. Presentation by Tom Stanton, February, 2010.

[16] State Higher Education Executive Officers. *State Higher Education Finance FY 2009*.

higher education funding has suffered. State investment, however, is a critical component for developing the technologies, processes, and feedstocks for the next generation of the bioeconomy. The innovation to make biofuels, bioenergy, and biomaterials more efficient and cost comparable to their fossil-fuel counterparts comes from basic and applied university research; if Michigan hopes to be a bioeconomy leader, as its priorities suggest, support for this research at the state's universities must take precedence.

Investment in biomass availability and biomass transportation infrastructure

Michigan has more than 19 million acres of forest land and forest land has increased more than 6 percent since 1980. The state's forest resources currently are being underutilized and this is a significant area of bioeconomy growth potential. In 2009, the Michigan Climate Action Council released a report making several recommendations for advancing energy and biofuels production in the state including:

- Expanded use of biomass feedstocks for electricity, heat, or steam production: produce 10 percent of total in-state electric generation from sustainable biomass feedstock by 2025.
- In-state liquid biofuels production: achieve 10 percent use of renewable fuels by 2012 and 25 percent by 2025.
- Methane capture and utilization from manure and other biological waste: reduce greenhouse gas emissions from handing, treating, and storing livestock manure and organic waste by 15 percent by 2015 and 25 percent by 2025 through improved manure management practices and methane use.
- Expanded use of biobased materials: use 100,000 metric tons of biobased products annually by 2025 and reclaim 150,000 metric tons of solid wood residues from manufacturing processes, deconstruction sites, and urban/suburban trees annually by 2025.

The council evaluated the potential availability of biomass feedstocks to meet the above recommendations (based largely on a "business as usual" scenario) and estimated that 8.4 million dry tons/year are available for cellulosic biofuel production and 14.1 million dry tons/year are available for use in electricity or heat/steam production. The overall biomass demand of the council's recommendations is estimated to be about 78 percent of the available sustainable supply for the state[17].

The council's recommendations are being considered by the state and many have been adopted in Michigan's recent energy legislation, Public Act 295. Implementing the Climate Action Council's recommended goals not only achieves climate reduction goals, it facilitates the development of a thriving bioeconomy by promoting investment in biomass feedstock production and infrastructure to improve its accessibility.

There are numerous challenges to addressing some of these recommendations and increasing the availability of biomass, including:

[17] Michigan Climate Action Council. Climate Action Plan. March, 2009. Appendix J-3.

- political leadership and state budget support is needed to create requirements and incentives for producing energy from renewable sources such as biomass
- developing ways to access the substantial amount of forest resources on widely distributed private lands
- ensuring that increased use of biomass resources is done sustainably
- private sector investment in technology and infrastructure is needed
- identifying and evaluating available lands for energy crop plantations
- prioritizing and investing in biomass/biofuel transportation infrastructure (rail, road/highway upgrades, trucking efficiencies)

Capitalizing on Michigan's access to substantial water resources for both biofuel and biomaterials production processes and transport of biomaterials via Great Lakes shipping

All agricultural crops, including biomass feedstocks, are watered by either rainfall and/or irrigation (which uses either ground or surface water). Water and irrigation needs vary significantly between crops and regions. In general, common biomass crops such as corn, soybeans, and wheat need more water than cellulosic biomass crops such as switchgrass, but there is a lack of historical data and knowledge about the water implications of growing more cellulosic crops. Figure 1 shows the state-by-state water requirements in 2003 of irrigated corn (gallons of irrigation water per bushel)[18] as a proxy variable of some of the regional differences in water needs for biofuel/bioenergy crops. There will obviously be geographic limitations on the types of biomass feedstocks that can be grown. If biofuels, bioenergy, and biomaterials feedstock markets expand beyond current irrigated cropland, there could be significant pressure on water resources in some areas of the country, especially dry western areas.

[18] National Academy of Sciences. *Water Implications of Biofuels Production in the United States.* 2008. (NAS cited source: N.Gollehon, USDA ERS, written commun., July 12, 2007. Based on data from 2003 Farm and Ranch Irrigation Survey (USDA, 2003).

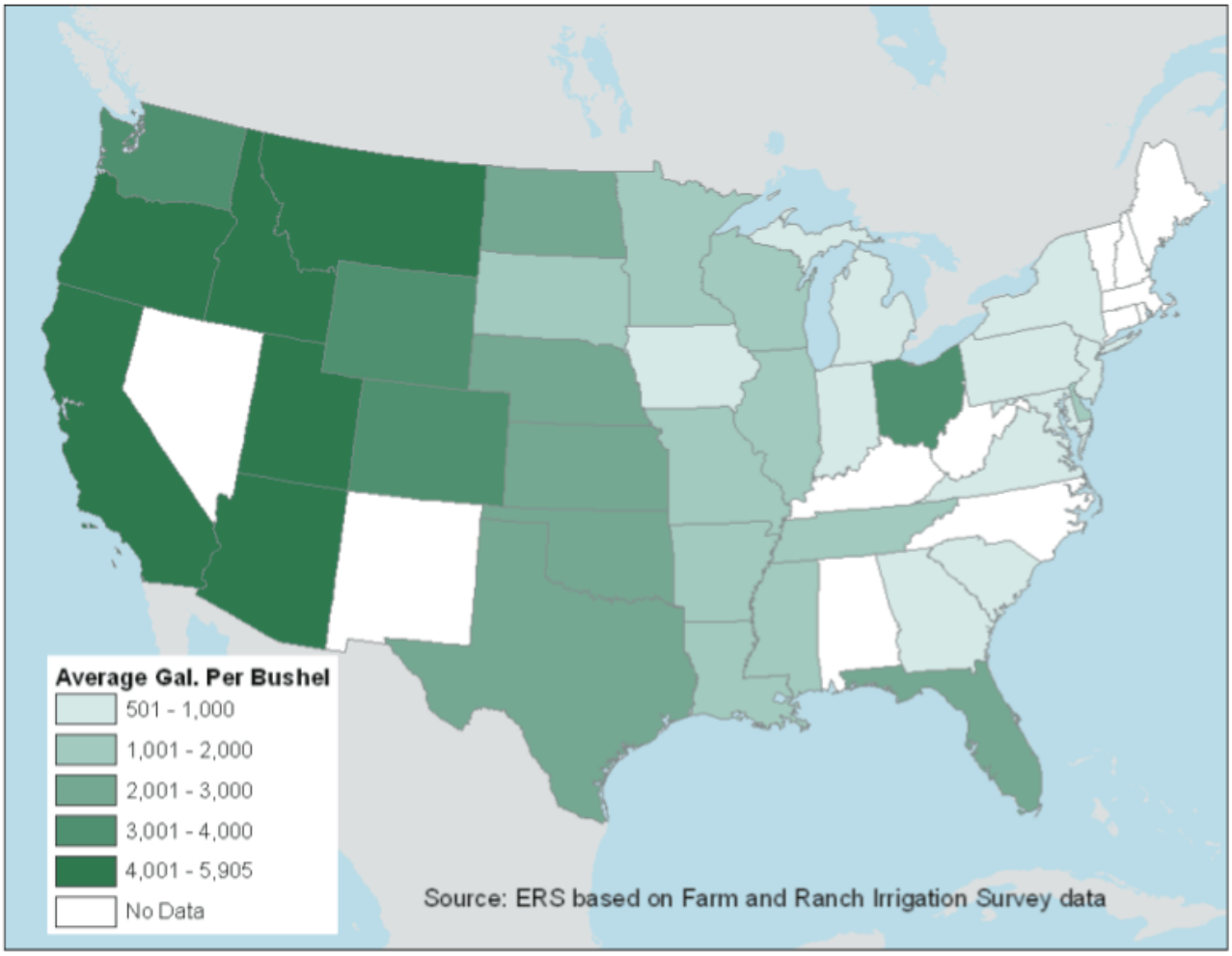

FIGURE 1 STATE-BY-STATE WATER REQUIREMENTS FOR IRRIGATED CORN IN 2003

In addition to the water required to grow biofuel, bioenergy, and biomaterials crops, processing these goods requires water. The process of creating ethanol, for example, is similar to brewing processes and uses water for conversion and for heating and cooling the products. Current estimates of consumptive water use at corn ethanol facilities are about 4 gallons of water per gallon of ethanol produced. So an ethanol plant that produces 100 million gallons per year would withdraw slightly more than 400 million gallons of water per year from either groundwater or surface water sources. While there are not a lot of commercial cellulosic ethanol plants, their water use is estimated to about 9 gallons of water per gallon of ethanol produced, though this is projected to decrease to about 2 to 6 gallons of water per gallon of ethanol produced as efficiencies improve. These ethanol production water requirements compare to about 1.5 gallons of water used per gallon of petroleum refined.[19]

Compared to most of the West, High Plains, and South, Michigan has a relatively large amount of accessible water. The state's climate provides significant precipitation, which reduces the overall need for irrigating crops, as Figure 2 demonstrates. As a result, growing biomass crops in Michigan will not

[19] NAS, 2008.

put as much pressure on groundwater supplies compared to other states. While protection of water resources from overuse or contamination is a very high priority for the state, Michigan is blessed with substantial groundwater resources, 36,000 miles of streams, 11,000 inland lakes and ponds, and is almost completely surrounded by the Great Lakes. These resources provide vast supplies of clean and affordable water for Michigan's residential, commercial, and industrial sectors.

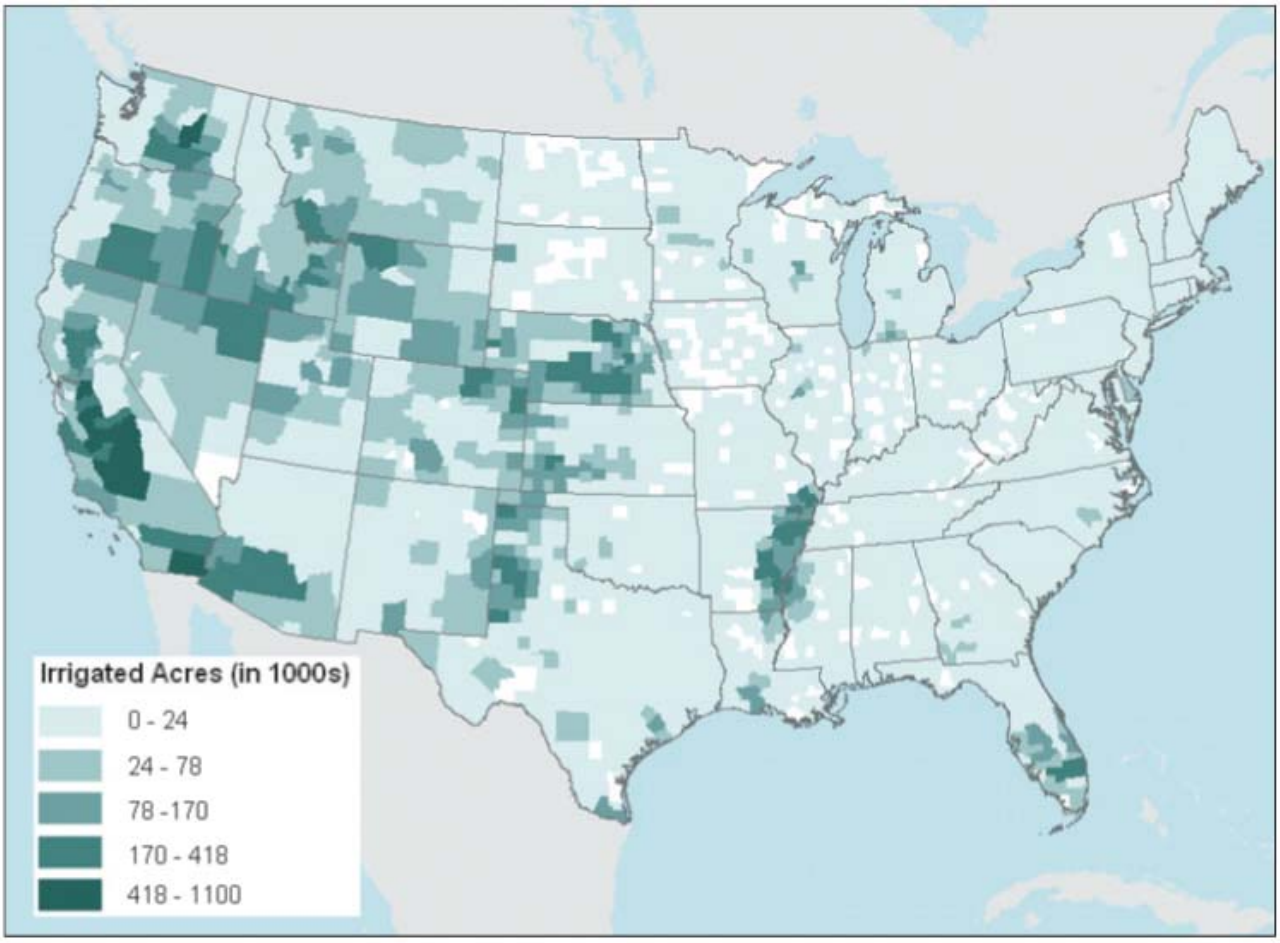

FIGURE 2 IRRIGATED LAND IN THE UNITED STATES[20]

In addition, Michigan's position at the center of the Great Lakes offers significant opportunities to ship biomass feedstocks, biofuels, and other biobased products to other regions of the country and world via the Atlantic Ocean. Combined with the state's other product shipping infrastructure, this access diversifies Michigan's ability to have a strong supply chain and be an exporter of biobased products.

[20] NAS, 2008.

Increasing the use of Michigan's agricultural and municipal wastes to create bioenergy

In addition to those facilities already operating, the Michigan Department of Agriculture has been working with several other farms and industrial agriculture producers to develop and receive permits for anaerobic digestion facilities.

The Product Center and Shepherd Advisors also evaluated Michigan's overall potential for energy generation from anaerobic digestion. Michigan has more than 175 large confined animal feeding operations (CAFOs),[21] and more than 200 food processing companies.[22] This presents a significant opportunity to convert animal manure and food processing waste to energy using anaerobic digestion. Animal waste in the state, for example, offers the opportunity for as much as 493,037 kWh/day or 2.2 million MJ/day as Table 3 demonstrates.

TABLE 3. POTENTIAL BIOGAS YIELD FROM MICHIGAN'S CATTLE AND SWINE FARMS

Animal Type	Number of Animals in Entire State	Manure Production (lbs manure/ animal * day)	Tons of Manure (per day) in Michigan	Biogas Yield (m^3/ton)	Biogas Yield (m^3 per day)	Electrical Yield (kWh/day)	Heat Yield (MJ/day)
Dairy Cattle	150,928	115	8,678	25	216,959	368,830	1,670,584
Beef Cattle	34,341	92	1,580	25	39,492	67,137	304,090
Swine	186,505	10	933	36	33,571	57,071	258,496
Total	371,774	-	11,191	86	290,022	493,037	2,233,170

CONCLUSIONS

As a state that imports almost all of its energy inputs and fuel, Michigan has put a priority on growing its bioeconomy to support its own energy needs and to be global supplier. While substantial slowdowns in the state, national, and global economies have limited the growth of the bioeconomy, in many parts of the United States, including Michigan, progress in advancing the bioeconomy is being made, entrepreneurialism is happening, and the supply and production chain is active.

In cultivating its bioeconomy, Michigan has avoided some of the pitfalls that have plagued other states by not overinvesting in traditional corn-based ethanol and biodiesel plants. As a result, while our bioeconomy has struggled during the economic downturn of the last few years, the state is not hurting in this sector as much as other regions.

The ongoing and potential bioeconomy efforts described in this paper, combined with the state's geographic advantages in terms of diverse feedstocks, underutilized forestry resources, and vast water

[21] Michigan Department of Agriculture. The EPA defines a large CAFO as an operation with 1,000 or more cattle or cow/calf pairs, or 700 mature dairy cattle, or 2,500 swine weighing more than 55 pounds. The analysis uses CAFOs because they are larger operations, generally making bioenergy production more cost effective.

[22] U.S. Census, 2007. Food Processors with over 20 employees.

resources, offer significant opportunities for Michigan to expand its bioeconomy and advance its position in the global bioeconomy market going forward. In doing so, the state can:

- continue to diversify its economy and create more local jobs and wealth across the broad spectrum of the bioeconomy supply chain, positioning Michigan companies to be more competitive in a world that increasingly values sustainability
- gain greater fuel security
- contribute to global reductions in climate change emissions

Achieving these objectives will require commitment on the part of decision-makers and industry to make key investments and address some of the remaining but significant barriers including:

- sustainably increasing the use of state forestry resources to boost availability of biomass feedstocks
- improving the infrastructure to access, harvest, and transport biomass resources
- continuing existing public-private-university partnerships and increasing investment in bioeconomy research to develop the technologies, processes, and feedstocks for the next generation bioeconomy
- providing continued policy support for growing the state's renewable energy sector by implementing existing and creating new legislation that requires renewable energy targets, provides investment and research incentives, and facilitates the siting and development of bioeconomy facilities
- educating consumers about the value and quality of biobased energy and products

As Michigan addresses these remaining hurdles, it could be well poised to play a strong role in the growing, global bioeconomy sector.

APPENDIX A – WORKING LIST OF MICHIGAN BIOECONOMY-RELATED COMPANIES

The following is a list of most the bioeconomy-related companies operating in the state, drawn from publicly available information, such as news articles and press releases. With two exceptions, these firms are headquartered in Michigan. The Product Center and Shepherd Advisors recognize that it is not a comprehensive list and that the bioeconomy is constantly evolving. The Product Center welcomes information on any other firms operating in the bioeconomy but not represented here.

These companies are in various stages of commercial operations. In addition to these, there are dozens of other emerging and start-up companies that are contributing to the growth of this industry.

Company	City	Type of Bioeconomy Company
Carl Meyer Farms[23]		Anaerobic Digester
Den Dulk Dairy Farm[24]	Ravenna	Anaerobic Digester
Geerlings Hillside Farm[25]	Overisel	Anaerobic Digester
Green Meadow Farms, Inc.[26]	Elsie	Anaerobic Digester
Meadowbrook Farms[27]	Hamilton	Anaerobic Digester
Scenic View Dairy[28]	Freeport	Anaerobic Digester
Scenic View Dairy[29]	Fennville	Anaerobic Digester
Sietsema Farms[30]	Allendale	Anaerobic Digester
Consumers Energy Green Generation	Jackson	Bioenergy
DTE Energy Green Currents	Detroit	Bioenergy
Fiber By-Products	White Pigeon	Bioenergy
Granger	Lansing	Bioenergy
Heat Transfer International	Caledonia	Bioenergy
HESCO Sustainable Energy	Warren	Bioenergy
Hogquest, LLC	Hamilton	Bioenergy
Kirtland Products, LLC	Boyne City	Bioenergy
Landfill Energy Systems	Wixom	Bioenergy
Lansing Board of Water and Light GreenWise	Lansing	Bioenergy
Maeder Brothers Quality Wood Pellets, Inc.	Weidman	Bioenergy
Michigan Biomass	Ithaca	Bioenergy
Michigan Wood Pellet Fuel, LLC	Holland, Grayling	Bioenergy
Mid-Michigan Liquidators	Ithaca	Bioenergy
Morbark	Winn	Bioenergy
MSR Sales	Brighton	Bioenergy

[23, 24, 25, 26, 27, 28, 29, 30] These farms are all operating anaerobic digestion bio-energy equipment for self-contained heating and power use, but are not operating in the wider bioeconomy market. As net metering becomes more prevalent, these farms may become energy providers to the grid.

Company	City	Type of Bioeconomy Company
PelletSales.com	Manchester	Bioenergy
Phase 3 Development & Investments, LLC	Fennville	Bioenergy
Re Gen Bio Fuels	Whitmore Lake	Bioenergy
RenewaFuel	Kalamazoo	Bioenergy
Renovare Energy Inc.	Farmington Hills	Bioenergy
Upper Peninsula Power Company Nature Wise	Green Bay, Wisconsin	Bioenergy
Vulcan Wood Products, Inc.	Kingsford	Bioenergy
We Energies - Energy for Tomorrow	Milwaukee, Wisconsin	Bioenergy
Advanced Biodiesel Partners	Ann Arbor	Biofuels
Ag Solutions, Inc.	Gladstone	Biofuels
Albion Ethanol - The Andersons	Albion	Biofuels
Alternative Fuel Technology	Redford Township	Biofuels
American Process, Inc.	Alpena	Biofuels
Biodiesel Industries	Detroit	Biofuels
Blue Green Energy, LLC	Ann Arbor	Biofuels
Center for Alternative Fuels - Macomb Community College	Warren	Biofuels
Corn Energy Products	Newaygo	Biofuels
Crorey Biomass Gasifier Systems LLC	Beverly Hills	Biofuels
eFarms	Holland	Biofuels
Ender LLC, Inc.	Detroit	Biofuels
Grayling Generating Station	Grayling	Biofuels
Great Lakes Ethanol - Global Ethanol	Riga	Biofuels
Liberty Renewable Fuels LLC	Owosso	Biofuels
Marysville Ethanol, LLC	Marysville	Biofuels
Michigan Biodiesel	Bangor	Biofuels
Michigan Ethanol - Poet Biorefining	Caro	Biofuels
Midland Energy LLC	Midland	Biofuels
Milan Biodiesel, LLC	Milan	Biofuels
NextDiesel	Adrian	Biofuels
NextGen Energy LLC	Livonia	Biofuels
NextGen Energy Ethanol Plants	McBain, Watervliet	Biofuels
Northwest Michigan Biofuels LLC	South Boardman	Biofuels
RKA Petroleum Companies	Romulus	Biofuels
The Andersons - Ethanol Division	Albion	Biofuels
US Bio Woodbury - Verasun	Woodbury	Biofuels
A. R. B. Distributing, LLC	Grand Rapids	Biomaterial

Company	City	Type of Bioeconomy Company
Advanced Advertising Products	Jackson	Biomaterial
Alines Soy Candles & Products	Burton	Biomaterial
B Green Today.com	Ann Arbor	Biomaterial
Bio-Kleen	Kalamazoo	Biomaterial
BioPlastic Polymers & Composites, LLC	Okemos	Biomaterial
Biosolutions LLC	Grand Haven	Biomaterial
Bliss Soybean Candles and Gifts	Grand Haven	Biomaterial
Candles Made from Soy	Westland	Biomaterial
Changing Poses	Bloomfield Hills	Biomaterial
Diversified Natural Products, Inc.	Scottsville	Biomaterial
Dow Chemical	Midland	Biomaterial
Draths Corporation	East Lansing	Biomaterial
Eco Roofs LLC	Berrien Springs	Biomaterial
Eco-Logic Lawn and Landscape	Gross Pointe Park	Biomaterial
Global Green Roofs	Grand Rapids	Biomaterial
Hydro Safe Oil	DeWitt	Biomaterial
KelseyPromo, LLC	Livonia	Biomaterial
KTM Industries	Lansing	Biomaterial
L & L Packaging	Livonia	Biomaterial
Live Roof	Spring Lake	Biomaterial
Michigan Green Safe Products	Detroit	Biomaterial
Mystic Flames, LLC	Redford	Biomaterial
OmniTech International, Ltd.	Midland	Biomaterial
Organic Ponds	Sterling Heights	Biomaterial
Permaloc Corporation	Holland	Biomaterial
Pine Ridge Soy Candles	Norway	Biomaterial
Royal Roofing Company, Inc.	Orion	Biomaterial
Schena Roofing	New Baltimore	Biomaterial
Selestial Soap	Traverse City	Biomaterial
Southern Scentsations	Flat Rock	Biomaterial
Strong Products LLC	Battle Creek	Biomaterial
Superior Ground Cover Inc.	Hudsonville	Biomaterial
The Greener Cleaner Carpet and Upholstery	Detroit	Biomaterial
True Artesian	Alanson	Biomaterial
Working Bugs, LLC	East Lansing	Biomaterial
Xeroflora	East Lansing	Biomaterial