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Preliminary Report: Alternative Energy Research and Development in the URC

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Michigan State University
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I. Introduction and Summary of Findings

PURPOSE OF MICHIGAN'S UNIVERSITY RESEARCH CORRIDOR

The University Research Corridor (URC) is an alliance of Michigan's three largest academic institutions: Michigan State University, the University of Michigan, and Wayne State University. The purpose of this alliance is to accelerate economic development in Michigan by educating students, attracting talented workers to Michigan, supporting innovation, and facilitating the transfer of technology to the private sector.

URC ANNUAL ECONOMIC IMPACT REPORTS

Each September, the URC releases an annual report that quantifies the economic impact of the URC's activities on the state of Michigan's economy.[1] This report provides Michigan residents with an assessment of how the URC universities are spending their time and money and allows citizens to track the performance of the URC. The main findings from the 2007 *Annual Economic Impact Report* are presented in "At a Glance...The Economic Contributions of Michigan's Research Corridor" on page A-8.

The URC's *Annual Economic Impact Report* is preceded in May by a *Preliminary Report* that discusses a specific URC initiative or research agenda in greater depth, and may preview some of the annual report's findings. This document is the preliminary report for 2008. In this report we:

1. Evaluate the state of Michigan's potential for growth in the alternative energy industry, and
2. Examine how the University Research Corridor is actively encouraging alternative energy research and development in the state.

WHY THE INTEREST IN ALTERNATIVE ENERGY?

In this report we define alternative energy as energy from non-fossil fuel sources such as agricultural products, water, wind, sun, and nuclear. There are several reasons why a vibrant alternative energy industry can be cultivated in the state of Michigan and will be important to Michigan's economy:

1. *Michigan's Untapped Natural Resources Potential*
   Michigan has the potential to significantly increase the role of alternative energy sources in its electricity production and its development and production of fuels made from alternative energy sources. Michigan has significant untapped natural resources that could provide renewable power in the state, including naturally occurring resources like biomass and wind that need only be harvested. In addition, the strong presence of the auto industry gives Michigan a natural comparative advantage in developing alternative fuels.
2. *Expertise and Research Capacity in the URC*
   Michigan's URC universities are leaders in R&D nationwide. More importantly, the URC has a long history of collaborating with industry to find solutions to real-world

1. See Caroline M. Sallee and Patrick L. Anderson, *Michigan's University Research Corridor: First Annual Economic Impact Report*, commissioned by Michigan's University Research Corridor, September 10, 2007, available at: http://www.urcmich.org and http://www.AndersonEconomicGroup.com.

problems and developing new technologies. In particular, the URC has strong relationships with the automotive industry, a pillar of the Michigan economy.

3. *Michigan's Manufacturing Capabilities and Infrastructure*
   Michigan has a highly-educated and skilled workforce. This, combined with manufacturing facilities, technical know-how, and transportation infrastructure, gives Michigan an advantage in producing new fuels and exporting them to other states.
4. *Regulatory Changes in Michigan and Nationwide*
   By proactively investing in alternative energy technologies today, Michigan can give itself a head start reacting to policy changes and become a leader in a growing area. Federal policies, like new fuel economy regulations, and state policies, like renewable portfolio standards, point to the future growth of the alternative energy industry.

KEY FINDINGS

Michigan has the opportunity to become a leader in alternative energy. The URC will play an important role in making alternative energy a driver of economic growth in the state. We evaluated Michigan's alternative energy assets and the URC's current activities to foster alternative energy research and found:

Michigan Has a Comparative Advantage in Biomass and Wind

- Michigan is rich in natural resources that could be used to produce energy. Based on our evaluation of the energy potential of Michigan's natural resources compared to the energy potential in the other 49 states, Michigan has a comparative advantage in the production of energy from biomass and wind, as shown in Table 1.

TABLE 1. Michigan's State Ranking in Renewable Energy Potential

Energy Source	Potential Ranking[a] (out of 50 states)
Biomass	22
Hydroelectric	37
Wind	14
Solar	44

Source: Anderson Economic Group, LLC

a. State ranking assumes each state has maximized potential output of the resource. A ranking of "1" indicates the state with the most energy potential from that resource.

- While only 3.3% of Michigan's energy currently comes from renewable sources, Michigan has the potential to supply as much as 60% of its power needs through alternative fuels.

The URC is Enabling Michigan to Capitalize on its Comparative Alternative Energy Advantage

- MSU's Biomass Conversion Research Laboratory is working to efficiently transform Michigan's abundant biomass stock resources into fuel.
- Solar researchers at U-M are working to develop a more efficient thin film solar cell that can be applied like spray paint, which will lower the cost of solar energy.

- Researchers at Wayne State are combining the power of wind, solar, and fuel cell technology to create alternative generation systems.
- U-M researchers are developing ways to generate electricity from high-velocity rivers and ocean currents, boosting the potential for hydroelectric power in Michigan and around the world.

The URC Brings in Substantial Funding for Alternative Energy R&D

- Michigan's University Research Corridor is actively enabling alternative energy research in the state. URC universities spent over $79.5 million on research and development related to alternative energy in 2007.
- The URC brings in substantial outside funding for alternative energy R&D. The federal government provided 71% of the URC's alternative energy R&D funding, bringing $56.8 million federal dollars to the state of Michigan in 2007.
- The Great Lakes Bio-energy Research Center (GLBRC), which is a joint effort between MSU and the University of Wisconsin, recently received a five-year $50 million grant from the Department of Energy to research cellulosic ethanol production.

The URC is Working Closely with Private Industry to Develop Commercial Applications

- The URC works closely with industry to develop commercial applications for their alternative energy research. Private sources provided $8.4 million in research in 2007, making up 11% of total funding.
- The URC is working closely with the automotive industry. More than half of alternative energy grants in 2007 were designated toward projects focused on fuels (33% of total) or propulsion and power (25%). In 2007, the automotive industry funded over $2.5 million in alternative energy R&D at URC universities.
- The National Biofuel Energy Lab (NBEL), a consortium that includes WSU, NextEnergy, Bosch, Delphi, DaimlerChrysler, and Biodiesel Industries, is working to establish a sound technical basis for biodiesel and to gain a comprehensive understanding of the relationship between a biofuel's chemical composition and its performance.
- U-M mechanical engineering professor Noboru Kikuchi will serve as the director for the new Toyota Research Institute of North America, soon to be located in Ann Arbor, which will study alternative energy fuels.
- MSU centers, such as the Office of Biobased Technology (OBT), are working to patent and commercialize technologies related to alternative energy. MSU has received over 100 patents for technologies related to renewable fuel sources and energy.

ABOUT ANDERSON ECONOMIC GROUP

Anderson Economic Group is an economic research and consulting firm with expertise in public policy, economics, market research, and business valuation. AEG's past clients include state, city, and county governments, corporations, and nonprofit organizations. AEG has offices in East Lansing and Chicago. For more information visit AEG's website at: http://www.AndersonEconomicGroup.com.

II. Michigan's Alternative Energy Assets

WHY THE INTEREST IN ALTERNATIVE ENERGY?

This report defines alternative energy as coming from non-fossil fuel sources such as agricultural products, wind, water, sun, and nuclear power. Increased electricity demand, regulatory changes motivated in part by environmental concerns, and the potential economic gains from access to this market, have spurred interest in Michigan's alternative energy prospects. Tapping into Michigan's natural resources and existing infrastructure to provide energy could have positive economic benefits to the state by lowering the net cost to Michigan's economy of energy use and providing employment in industries such as the production of biofuels.

MICHIGAN'S CURRENT ENERGY SOURCES AND USES

In 2005, Michigan relied heavily on coal (58% of the total) and nuclear power (27%) for its electricity generation. Compared to the national average, Michigan depends more on coal and nuclear power and less on natural gas, petroleum, and renewable sources,[2] as shown in Table A-1 on page A-2. While coal dominates electricity generation in Michigan, natural gas is the primary energy source for home heating, comprising 33% of energy consumption in Michigan in 2005. See Table A-2 on page A-3.

In 2005, a small percentage (3.3%) of Michigan's energy came from renewable sources, compared to 8.8% nationally. As shown in Table A-3 on page A-4, Michigan generated approximately 3,981,975 megawatt hours, or 0.1% of total U.S. renewable generation power in 2005. Michigan is currently generating electricity from biomass, hydroelectric (power generated from running water), and wind sources. Slightly less than two-thirds (63%) of Michigan's renewable electric generation came from biomass, while 37% came from hydoelectric power and 0.05% came from wind. Similar to other states, the amount Michigan produced from hydroelectric power declined between 2006 and 2007, as shown in Table A-4 on page A-5.

MICHIGAN'S ADVANTAGE IN PRODUCING ENERGY FROM RENEWABLE SOURCES

While not currently producing much energy from renewable sources, opportunity exists for the state to take advantage of its natural resources and existing infrastructure to produce and sell alternative energy. Michigan is rich with diverse natural resources, including forests and agriculture, wind, and water.

We evaluated the energy generation potential of Michigan's natural resources including biomass, wind, water, and sun. By comparing the amount of biomass, water, wind, and sun that each state has available for harvesting, we were able to rank Michigan and the other 49 states on a scale from 1 through 50, with a ranking of "1" indicating the state that has the most obtainable energy from that resource. Energy potential for each resource is based on estimates from the Department of

2. Renewable energy is energy from wind, agricultural products, sun, and water. U.S. Energy Information Administration data does not include nuclear power as a renewable source of power its tables.

Energy, American Wind Energy Association, and the National Renewable Energy Laboratory.

Based on our evaluation, biomass and wind are the most promising resources for Michigan. As shown in Table 2, Michigan's comparative advantage is in producing energy from wind and biomass. However, as shown in the next section, Michigan is a leader in research in all renewable energy resources.

TABLE 2. Michigan's State Ranking in Renewable Energy Potential

Energy Source	Potential Ranking[a] (out of 50 states)
Biomass	22
Hydroelectric	37
Wind	14
Solar	44

Source: Anderson Economic Group, LLC

a. State ranking assumes each state has maximized potential output of the resource. A ranking of "1" indicates the state with the most energy potential from that resource.

In the remainder of this section, we discuss the state's potential to produce more of its energy from renewable resources.

Biomass

Biomass is any organic material made from plants or animals. It can be converted into either electricity (burning to produce steam) or fuels such as ethanol and biodiesel. To convert biomass into biofuel, the feedstock (raw material) must first be turned into starch or cellulose. While Michigan cannot compete with corn producing states to produce starch-and sugar-based ethanol, the state has an advantage in producing cellulosic ethanol, which is made from wood, switch grass, and other raw materials, because relatively less of Michigan's available land is currently under crop cultivation. While the technology must undergo further refinement before it is widely used commercially, cellulosic feedstocks are more energy efficient than other types of raw materials as they require less energy to cultivate and turn into cellulose.

The U.S. Department of Energy (DOE) and Agriculture (USDA) are working to create a large-scale process to produce ethanol from non-food plant materials such as agricultural and forestry residue, grasses, and trees. Last year six commercial biorefineries were selected nationally and funded by the DOE to advance cellulosic ethanol production. While there are currently only four ethanol plants in Michigan, Mascoma Corporation, based in Massachusetts, is partnering with General Motors Corporation and exploring opportunities in Michigan for cellulosic biofuel production and distribution. With the right technology and infrastructure, Michigan's untapped resources have the potential to produce 526 million gallons of ethanol from cellulosic biomass annually.[3]

Michigan's diverse micro-climates and high quality soil allows for an adaptable agricultural base, second in diversity only to California.[4] Table 3 on page 7 shows Michigan's biomass potential based on estimates of land use, climate, soil characteristics, accessibility, and logistics for biomass. According to U.S. DOE's estimates, Michigan's overall biomass potential ranks 22nd in the country, if all states reached their maximum biomass potential. More specifically:

- Michigan ranked 14th for crop residues, including crops such as corn, wheat, soybeans, and other grains.[5]
- Primary mill residues, composed of wood materials and bark generated at manufacturing plants, may be recycled as by-products or left un-utilized. Michigan's forest and primary mill residues both rank 17th in the country.
- Michigan ranked 10th in secondary mill residues, which are generated from wood scraps and sawdust from woodworking shops or manufacturing companies.
- Urban wood residues are collected from wood chips, yard waste, utility tree trimming, and construction. In Michigan there are 1,196,000 dry tonnes of urban wood residues that may be used for energy production, the 8th largest storage in the nation.
- Conservation Reserve Program (CRP) lands may be useful for growing non-conventional crops such as switch grass, willow, or hybrid poplar. These crops grow quickly and produce relatively high yields. CRP is administered by the USDA Farm Service Agency to provide technical and financial assistance to eligible farmers. Michigan ranks 16th and 12th nationally for switch grass and willow or hybrid poplar production on CRP lands, respectively.

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3. Information on Michigan's potential for biomass production can be found at the U.S. Department of Energy, Energy Efficiency and Renewable Energy website: http://www.eere.energy.gov/afdc/sabre/sabre.php
4. Dan Wyant, *The Interrelationship Between Land Use Trends and Michigan Agriculture Policy and Effects of These on Sustainable Agriculture in Michigan*, Michigan Department of Agriculture, March 2003.
5. Residues were estimated by the U.S. Department of Energy based on total crop production, crop to residue ratio, moisture, accounting for the amount of residue that should be left on the field to ensure proper soil protection.

TABLE 3. Michigan's Biomass Potential

Biomass Resources	Thousand Dry Tonnes	National Rank[a]
Crop Residues	3,586	14
Forest Residues	1,275	17
Primary Mill Residues (unused)	1,314 (41)	17
Secondary Mill Residues	86	10
Urban Wood Residues	1,196	8
Switch grass	1,451	16
Willow or Hybrid Poplar	1,410	12
Total Biomass	**10,318**	**22**

Source: U.S. Department of Energy, NREL/TP-560-39181, "A Geographic Perspective on the Current Biomass Resource Availability in the U.S.," Dec. 2005.

Analysis: Anderson Economic Group, LLC

a. National rank of "1" indicates the state with the most biomass resources.

Wind

Wind energy is generated through turning the blades of a turbine connected to a generator. The cost of wind energy varies by several factors, including the amount of available natural resources, the scale and capacity of the wind farm, and how the project is financed. Since wind blows harder and more steadily over water than land, the Great Lakes are a significant asset when it comes to wind power production potential.

Michigan's current wind power capacity ranks 29th in the nation by the American Wind Energy Association. The state's rank increases to number 14 for potential capacity. Energy potential rank is measured by maximized annual energy potential capacity based on wind resources, factoring in environmental and land use exclusions for wind class of 3 and higher. Wind harvesting depends on the speed of the wind and the height of the turbine. For utility-scale turbines, a wind class of 3 or above (on a scale from 1 to 7 with 7 being the highest) is necessary. A wind class of 3 has an average annual wind speed of 6.3 m/s or 14.1 mph at 50 meters. Figure A-1 on page A-6 illustrates the predicted mean wind power density (amount of wind energy) at a 50 meter height.

Table 4 on page 8 shows Michigan's current and potential wind power rankings compared to other Great Lake states. There are currently three utility-scale wind turbines operating in Michigan, two in Mackinac City and one in Traverse City. Three new utility-scale wind farms are under construction in Huron and Misaukee Counties. Among the states with significant lake coastline, Michigan currently has far less wind power capacity and is second to last in the region, surpassing only

Indiana. The potential is there, however, for the state to increase its national ranking to become the second most wind energy producing state in the Great Lakes region.

TABLE 4. Current and Potential Wind Power Ranking of Great Lakes States

State	Current	Potential[a]
Michigan	**29**	**14**
Illinois	8	16
Indiana	37	44
Minnesota	3	9
New York	11	15
Ohio	27	36
Pennsylvania	14	22
Wisconsin	23	18

Source: American Wind Energy Association, http://www.awea.org/projects/

Analysis: Anderson Economic Group, LLC

a. Potential rank if all states maximize their current and potential wind power.

Nevertheless, there are limitations to realizing Michigan's wind energy potential. The available data simply reports the current levels of energy production and estimates the potential based on wind density. Other factors, including variable costs of electricity generated from wind power, transmission and storage costs, and limitations on where turbines can be built are not considered in the data.

Water

Water is converted into hydroelectricity through turbines or generators as the water flows downstream. The Idaho National Laboratory, a project of the U.S. Department of Energy, estimates there is approximately 400 megawatts of potential hydroelectric energy from the state's undeveloped conventional hydropower sites. Table 5 on page 9 compares Michigan's national hydropower ranking to other Great Lakes states. The hydropower potential of the Great Lakes themselves are not taken into consideration, but only the streams and other running water sources.

Comparatively, Michigan has a median ranking, but has less potential to increase hydropower generation than the other states. This data indicates that Michigan is taking advantage of this energy source, but has the potential to increase hydropower generation by 64%. The ranking, however, does not take into account the importance of clean water, abundantly found in Michigan's lakes. Clean water is a necessary component for manufacturing and other renewable energy productions.

TABLE 5. Current and Potential Hydropower Production Ranking of Great Lakes States

State	Current	Potential[a]
Michigan	**23**	**37**
Illinois	44	23
Indiana	39	33
Minnesota	34	43
New York	4	4
Ohio	40	32
Pennsylvania	17	10
Wisconsin	19	27

Source:U.S. Department of Energy, DOE-ID-11263, "Feasibility Assessment of the Water Energy Resources of the U.S. for New Low Power and Small Hydro Classes of Hydroelectric Plants," January 2006

Analysis: Anderson Economic Group, LLC

a. Potential rank if all states maximize their current and potential hydropower.

Solar

Solar power must be generated through either concentrating solar power systems that use reflective materials, a photovoltaic (PV) device that converts light energy into electrical energy, or solar heating systems that absorb the sun's energy.[6] California is the nation's leader in solar energy generation, and southwest states such as New Mexico, Arizona, and Nevada rank highest for PV energy density levels.

As shown in Table 6 on page 10, Michigan is ranked 44th in the nation for PV energy density. Figure A-2 on page A-7 illustrates that the amount of cloud cover and other variables negatively affecting the amount of solar radiation make PV solar energy an unlikely product for Michigan. Yet because of the state's research, manufacturing, and transportation infrastructure, two companies, Dow Chemical and United Solar Ovonic are developing products and building supplies for the solar energy industry in Michigan. Dow Chemical Company, located in Midland, received a 2007 federal grant of $357 million to research and design new solar energy generation materials for commercial and residential buildings. United Solar

6. U.S. Department of Energy, Solar Energy Technologies Program. http://www1.eere.energy.gov/solar/index.html.

Ovonic, located in Detroit, is a world leader in developing, manufacturing, and distributing thin film solar technologies.

TABLE 6. Solar PV Net Density Ranking[a]

State	National Rank
Michigan	**44**
Illinois	29
Indiana	35
Minnesota	36
New York	43
Ohio	47
Pennsylvania	48
Wisconsin	34

Source: NREL Technical Report, NREL/TP-670-42463, "The Regional Per-Capita Solar Electric Footprint for the United States," December 2007.

a. Net PV energy density was calculated using the weighted average of the various power densities and the annual generation values.

Nuclear

Michigan's four reactors located at three nuclear plants generate enough electricity to supply more than one-fourth the state's total generation. In 2007 the state generated 3.1 billion kWh or 4.3% of total nuclear power in the U.S., enough to rank Michigan 10th in nuclear power producing states. Nuclear plants do not emit carbon dioxide or other air pollutants and incur lower average operating expenses.[7]

In recent years nuclear power has been gaining momentum as a viable alternative energy source. The 2005 Energy Policy Act encouraged expansion of nuclear energy in the U.S. through production tax incentives for advanced facilities and funding for research and development that addresses emissions and other innovative technology. Additionally, several federal programs including the Department of Energy's Nuclear Power 2010 program and the Global Nuclear Energy Partnership, pave the way for greater use of nuclear energy in the United States.

Even with emerging technology that increases efficiency and safety, nuclear power has several drawbacks. The Environmental Protection Agency has yet to find a long-term solution for the disposal of nuclear waste. Additionally, nuclear plants incur high initial construction costs and significant business risk. Finished in 1996, Watts Bar 1 was the last plant built in the United States. It cost $6.8 billion and took 23 years to complete.[8] Twenty-two and 29 years after accidents at Chernobyl in

7. Energy Information Administration, "Nuclear Power: 12 Percent of America's Generating Capacity, 20 Percent of the Electricity," available at: http://www.eia.doe.gov/cneaf/nuclear/page/analysis/nuclearpower.html.

Ukraine and Three Mile Island in Pennsylvania, there is still considerable public stigma around nuclear power and the dangers involved.

POTENTIAL ENERGY GENERATION FROM RENEWABLE SOURCES

Using data provided by the Department of Energy, the American Wind Energy Association, and the National Renewable Energy Laboratory, we estimated the current production of biofuels and the potential biofuel production and electricity generation from renewable resources. As shown in Table 7, Michigan is far from realizing its potential to generate energy from renewable sources. If Michigan reaches its maximum wind electricity potential, it could produce 65 billion kWH. To put that figure in context, that is enough energy to generate over 53% of Michigan's electricity generation in 2005.

TABLE 7. Michigan's Renewable Energy Potential from Biomass, Water, and Wind

Resource	Current Production	Ethanol Potential	Biodiesel Potential	Electricity Potential	Electricity Potential as% of Total Net Electricity Generation in 2005
Biomass[a]	314 million gallons of ethanol; 35 million gallons biodiesel	712 million gallons	111 million gallons	2.1 billion kWh	*1.7%*
Water[b]	1.274 billion kWh	--	--	5.4 billion kWh	*4.4%*
Wind[c]	22 million kWh	--	--	65 billion kWh	*53.4%*

memo: By maximizing electricity potential from all three resources, Michigan could have generated almost 60% of its net generation in 2005 from these renewable resources.

Source: U.S. Department of Energy, Energy Efficiency and Renewable Energy, the Energy Information Administration, the American Wind Energy Association, and the National Renewable Energy Laboratory
Analysis: Anderson Economic Group, LLC

a. Biomass assumes 30% crop usage limit for corn production and a 2005 technology ethanol yield that includes 65.3 gal/dry metric ton for agricultural residues using biochemical conversion or 63.2 gal of ethanol per dry metric ton of forestry residue and urban wood waste using thermochemical conversion. Electricity potential assumes 4.4 kWh/gallon ethanol. Data obtained from the US Department of Energy, Energy Efficiency and Renewable Energy.

b. Considers hydropower plants unused, with power, and without power. Electricity potential is annualized based on 613,000 KW and 8760 hours per year. Data obtained from the American Wind Energy Association.

c. Current wind production is based on 2590 KW power capacity of existing wind projects annualized based on 8760 hours per year. Additional power capacity of projects currently under construction is 528,000 KW or 4.6 billion kWh. Electricity potential is based on the annual average amount of generated electricity from average wind density (7.46 million KW) with estimated land-use exclusions annualized based on 8760 hours per year. Data obtained from the National Renewable Energy Laboratory. and Elliott, D.L., Wendell, L.L., Gower, G.L., "An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States. Pacific Northwest Lab, 1991.

INFRASTRUCTURE AND WORK FORCE

Michigan's existing manufacturing infrastructure can help serve a growing alternative energy industry. Industrial facilities, shipping and transportation services, equipment, input suppliers, and other services necessary for feedstock production and processing energy are readily available. Additionally, Michigan is home to a

8. U.S. General Accounting Office, *Tennessee Valley Authority: Financial Problems Raise Questions About Long-term Viability*, GAO/AIMD/RCED-95-134, August 1995.

skilled workforce. MSU Extension has a presence in all counties, and the Michigan Agricultural Experiment Station has 14 field stations that are able to assist with agricultural production for biomass.

RENEWABLE PORTFOLIO STANDARDS

Renewable Portfolio Standards (RPS) require sellers of electricity to generate a percentage of their power from renewable sources. Twenty-four states and the District of Columbia have passed RPS legislation in various forms. Proponents claim that standards encourage greater use of renewable energy and significantly reduce emissions, allowing more competition with fossil fuel energy sources. Opponents note that the technology is not advanced enough for renewable energy to compete with other sources and claim standards will result in higher energy costs. In 2007 the Michigan Chamber of Commerce estimated a 10% RPS using wind energy would result in $6.26 billion of additional cost to the state.[9] To date, Michigan's legislature has considered but not passed energy standards.

9. Doug Roberts Jr., *Memorandum to Members of the House Committee on Energy and Technology*, Michigan Chamber of Commerce, June 20, 2007.

III. Energy Research and Development by the URC

The ability of the URC universities to blend innovative research and education makes them national leaders in advancing technology and workforce development for the alternative energy industry. Below we discuss URC's investment in research, development of a skilled workforce, and collaborative efforts that are transforming Michigan's potential alternative energy sources into commercially viable products.

ALTERNATIVE ENERGY EXPENDITURES

The URC universities were granted more than $79.5 million for research and development in alternative energy in 2007. As shown in Table 8, the research includes a diverse set of topics from wind energy to fuel cells. Not surprising, given the URC's collaboration with the automotive industry in Southeast Michigan, more than half of the grants were designated toward projects that focused on fuels (33%) or propulsion and power (25%).

TABLE 8. URC Alternative Energy Research and Development by Category, 2007

Category	Total Grants	Percentage of Total
Education	$162,727	0.2%
Efficiency	$4,961,986	6.2%
Enabling Technology	$3,245,259	4.1%
Energy Storage	$2,388,162	3.0%
Fuel Cells	$1,472,661	1.9%
Fuels	$26,342,276	33.1%
Hydrogen	$426,373	0.5%
Lighting	$1,691,891	2.1%
Nuclear Power	$4,941,387	6.2%
Policy	$767,362	1.0%
Propulsion & Power	$19,852,568	24.9%
Solar & Thermoelectric	$5,814,863	7.3%
Sustainability	$5,623,436	7.1%
Sustainable Living & Design	$1,046,165	1.3%
Transportation Infrastructure	$274,713	0.4%
Wind & Hydro	$553,447	0.7%
Total	**$79,565,276**	**100%**

Data Source: Michigan State University, University of Michigan, Wayne State University
Analysis: Anderson Economic Group, LLC

Varied university departments conduct research applicable to the alternative energy industry. Many different fields are relevant to alternative energy as the technologies and processes needed to make alternative energy commercially viable are numerous. Research is done in fields such as mechanical, electrical, and computer engineering, geological sciences, physics, natural resources and environment, urban planning, cell and molecular biology, and forestry. Some of the $79.5 million in research and development in the URC in 2007 went towards projects that focused on:

- *Biofuels*—Research included investigating new formulations for enhanced vehicle performance, evaluating Michigan's wood energy availability and supply, and improving oxidative stability of biodiesel fuels.
- *Fuel cells and propulsion and power*—This research has been supported by the auto industry. Projects include modeling water and thermal management in proton exchange membrane (PEM) fuel cells and extending high-efficiency low emission operation of internal combustion engines using high speed imaging and other advanced optical diagnostics.
- *Thermoelectricity*—Research included developing and applying high efficiency thermoelectric materials for power generation and converting waste heat to electricity in an IC engine powered vehicle.
- *Nanotechnology*—This research was undertaken to better understand fuel and solar cells, produce hydrogen, and create greater efficiency overall.
- *Policy*—This included exploring corporate strategies addressing climate change, analyzing how energy producers respond to "Cap and Trade" programs, and identifying small sustainable alternatives to big reform.

URC Research by Renewable Energy Resource

As explained in the previous section "Michigan's Alternative Energy Assets" on page 4, Michigan has untapped natural resources. For each natural resource we provide at lease one example of how the URC universities are helping to develop the alternative energy industry in Michigan through R&D and technology transfers.

Biomass. Researchers at MSU's Biomass Conversion Research Laboratory are developing an integrated process for breaking down cellulosic material, estimating the performance, and defining the costs. Integrating pretreatment of cellulosic material with other operations is a vital step in facilitating improvement in biomass fuel production.

Solar. U-M solar researchers are working to increase the efficiency of thin film solar cells. This technology will lower the cost for clean, renewable solar energy. In addition to being a principal research scientist for Global Photonic Energy Corporation and U-M's Vice President for Research, Dr. Stephen Forrest has secured 155 patents in the area of solar energy. Currently, he is developing solar cells that can be applied like spray paint to generate energy at a low cost.

Wind. Research and industry came together in September 2007 when MSU's Land Policy Institute hosted the first "Manufacturing and Developing Wind Energy Systems in Michigan" conference. In attendance were more than 200 industrialists, industry executives, policy specialists, researchers, and investors. Researchers at U-M are working to develop high-efficiency adaptive blades for wind turbines. The blades will be able to morph in response to wind conditions in order to maximize energy collection.

Water. Researchers at U-M are developing a way to generate hydro-electricity from high velocity rivers. Portable hydro-flow generators will be able to deliver 10KW of power to remote areas.

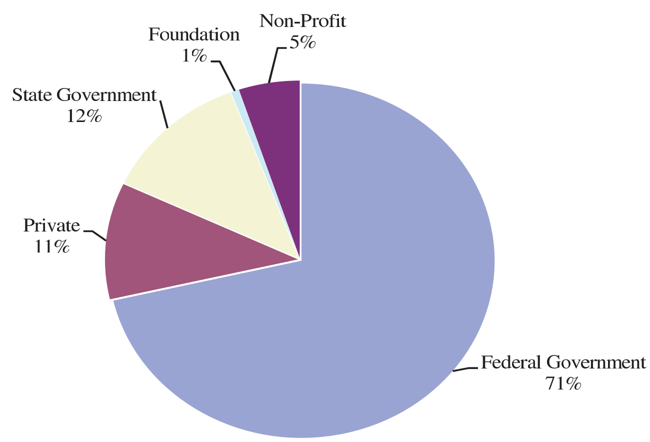
Nuclear. U-M scientists are developing materials that will make nuclear reactors that are more economical, safer, reliable, and produce less waste than reactors currently in use.

FUNDING SOURCES FOR ALTERNATIVE ENERGY RESEARCH

As illustrated in Figure 1 below, the majority of grants received for alternative energy are issued by the federal government (71%). The URC received funding from many federal agencies including the Departments of Energy, Defense, Health and Human Services, and Agriculture. The URC universities brought $56.8 million in federal research dollars on alternative energy topics to the state in 2007. Additional funding stems from 17 separate agencies and institutions including the National Science Foundation, the U.S. Army, and the National Aeronautics and Space Administration.

Private funding from 41 sources, including General Motors, Shell Oil Company, DTE Energy, Ford Motor Company, Toyota, and Battelle Memorial Institute, make up 11% of the awards or $8.4 million. State government (12%), Non-profit organizations (5%), and Foundations (1%) provide the remaining R&D funding.

FIGURE 1. URC Alternative Energy R&D Awards by Source



Data Source: Michigan State University, University of Michigan, Wayne State University
Analysis: Anderson Economic Group, LLC

RESEARCH & TRAINING

The URC universities have many research centers that play several roles in the alternative energy industry. Not only are they on the cutting edge of research and development, but centers serve as a training ground for students who are mentored by experts in their respective field. Additionally, research centers foster collaborative efforts within the public and private sectors to further alternative energy production and use.

Collaborations Among the URC

Researchers from the three URC universities and WWJ News Radio 950 came together on Earth Day 2008 to highlight and discuss the latest ideas and discoveries in alternative energy. Experts discussed the potential opportunities and barriers for biomass, wind, and water power generation and integration.

In order to advance "revolutionary but feasible outcomes" in alternative energy, the URC granted $900,000 in research funding for URC faculty for up to three years. Research projects that address energy materials, clean energy sources, transmission and storage, and/or energy policy were considered. To further emphasize collaborative efforts, preference was given to multi-institutional proposals. Grant winners will be announced at the end of May 2008.

Specific URC Research and Development Initiatives

Great Lakes Bio-energy Research Center. Last year, MSU received a five-year, $50 million grant from the Department of Energy to help establish the Great Lakes Bio-energy Research Center (GLBRC). The GLBRC forms a partnership between MSU and the University of Wisconsin-Madison to accelerate research on the development of cellulosic ethanol production. A MSU Distinguished Professor of plant biology and of biochemistry and molecular biology leads the GLBRC. MSU research at the center focuses on improving plant biomass. Research at the center was also a factor in Mascoma Corporation's decision to build one of the nation's first commercial wood-based bio-refineries in Michigan, which is currently in the planning phase.

Michigan Memorial Phoenix Energy Institute. The mission of the Michigan Memorial Phoenix Energy Institute (MMPEI) at U-M was broadened in 2006 to encompass research on the "development of energy policies that will promote world peace, the responsible use of the environment, and economic prosperity." MMPEI seeks to help implement scientific and technological advancements in sustainable energy. In 2007, MMPEI received a $2 million grant from the US Department of Energy to coordinate efforts among the DOE, General Motors, Ford Motor Company, and DTE Energy to conduct a two-year study on plug-in hybrid vehicles.

Smart Sensors and Integrated Microsystems Laboratory. Through the WSU College of Engineering, researchers are working on ways to efficiently break down fuels into hydrogen to power fuel cells. These researchers are developing a highly energized gas, advanced sensors, and software to improve fuel cell technology. Additionally, researchers are uniting wind, solar, and fuel cell power to generate electricity that is adaptive in diverse weather conditions.

Other URC Centers and Institutes. Other research institutes and centers that focus on alternative energy R&D include:

- The Office of Biobased Technology (OBT), which serves as a clearinghouse for all bioeconomy information and research at MSU. OBT strives to integrate scientific developments and natural resources with public and private sector initiatives in order to enhance the economy, environment, and quality of life locally and globally.
- The MSU Michigan Biotechnology Institute (MBI), which focuses on the development and commercial use of sustainable biobased technologies. The organization also partners with commercial businesses and inventors to help them lower their business risk and move forward with beneficial ideas and technology.
- The U-M Erb Institute for Global Sustainable Enterprise that fosters global enterprise through interdisciplinary research and education initiatives. This includes an interdisciplinary education program through the Ross School of Business and the School of Natural Resources and Environment.
- U-M's DTE Power Electronics and Electric Drive Laboratory, which pursue's power electronics for alternate sources of energy, including fuel cells and hybrid vehicles. The laboratory is funded through grants from DTE Energy and the National Science Foundation.

URC'S COLLABORATION WITH THE AUTOMOTIVE INDUSTRY

The automotive industry is a pillar of Michigan's economy. Michigan produces the most cars and light trucks of any state in the country, producing about 22% of the industry's U.S. production in 2007.[10] Michigan was also home to almost a fifth of the country's automotive workers in 2005.[11]

Michigan is second, only behind California, in the amount of industry-performed research and development at approximately $16.7 billion.[12] More than 330 automotive R&D and technical centers spend approximately $12.4 billion annually and employ 65,000 professionals in the state of Michigan.[13]

The research expertise available at the URC universities encourages numerous collaborative efforts with the auto industry. In 2007, the auto industry collaborated with the URC on $2.5 million in alternative energy research projects, many focusing on fuels, and power and propulsion. General Motors' sponsored several U-M projects in 2007 on various aspects of hybrid vehicles and engine systems and powertrain research, which totaled $1.8 million. GM also funds non-energy related research at U-M in the areas of manufacturing and materials processing. In 2007, the total energy and non-energy related funding by GM was $3.75 million.

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10. Automotive News 2008 Market Data: North American Production
11. U.S. Census Bureau, County Business Patterns, Michigan Automotive Industry Employment, 2005.
12. National Science Foundation, Division of Science Resources Statistics, Survey of Industrial Research and Development, "Top 10 States in Industry R&D performance and share of R&D, by selected industry, 2005. Science and Engineering Indicators, 2008.
13. Michigan Economic Development Corporation.

The U-M Transportation Energy Center provides basic and applied research expertise for the National Automotive Center. The research team is working on producing synthetic fuels and advancing energy storage technology. One project is working to develop an on-board fuel cell generator that converts diesel fuel into hydrogen. Heavy trucks might use this technology to reduce the amount of energy spent when idling. Research at the Automotive Research Center is studying new energy conversion options and propulsion systems, as well as testing hybrid vehicles and the impact of synthetic fuels. The University of Michigan Transportation Research Institute, which is in part supported by the Ford Motor Company, studies alternative fuel infrastructures and estimates the costs associated with various fuels. Additionally, U-M is leading a multi-disciplinary, multi-university study on the optimal greenhouse gas policy from the automotive market perspective. General Motors Corp., Ford Motor Co., and Daimler-Chrysler are part of the 12 member external advisory board.

Another example of the URC working with the automotive industry on alternative energy projects is the National Biofuel Energy Lab (NBEL). The NBEL, which is a consortium that includes WSU, NextEnergy, Bosch, Delphi, DaimlerChrysler, and Biodiesel Industries, is working to establish a sound technical basis for biodiesel fuel and to gain a comprehensive understanding of the relationship between a biofuel's chemical composition and its performance. In conjunction with Titan Energy Development Inc., NextEnergy, and the US Army National Automotive Center, students and faculty from the NBEL are working to develop a power generation product that will supply grid power, clean water, communications, lighting, and HVAC using synthetically produced, biodiesel, and petroleum-based fuels.

Support for MSU's Energy & Automotive Research Laboratories comes in part from the Ford Motor Company and General Motors Corporation. The new research complex, which focuses on engine efficiency and reducing vehicle emissions, features a state-of-the-art powertrain lab and two engine test cells.

As a result of long-standing relationships and URC expertise in energy research, many companies decide to locate near the URC universities. Recently Toyota Motor Corporation announced its plans to spend $100 million to establish a new research center located in the Ann Arbor area. U-M mechanical engineering professor Noboru Kikuchi will serve as the new director.

TECHNOLOGY TRANSFERS

Michigan State, the University of Michigan, and Wayne State University all work with their faculty and students to help them obtain patents and license their new technology through technology transfer offices. If the university decides the innovation is worth patenting, it assumes the costs of obtaining the patent. Technology transfer offices will often conduct patent searches and analyze the invention's commercialization potential, and if the product receives a patent, will help the faculty member market the product to potential licensing partners and investors.

More than 100 patents have been issued or are pending for MSU technologies related to sustainability, energy storage, fuels, and hydrogen production. Examples include methods to produce biodiesel by fermentation, electrochemical methods for generation of a biological proton motive force and pyridine nucleotide cofactor regeneration, and the production of ethanol from transgenic cereal, leaves, and straw. In 2004, the MSU Product Center helped connect Michigan farmers with an MSU Extension educator to launch a biodiesel production facility, Michigan Biodiesel, LLC.

When U-M professor Dr. Michael Bernitsas developed a way to harness the energy from ocean currents, he used the tech transfer office to file a patent, find test sites, locate funding, and start the company. Dr. Bernitsas' VIVACE (Vortex Induced Vibrations Aquatic Clean Energy) Converter uses vortex-induced vibrations created by ocean or river currents to generate electricity, making it possible to create underwater power plants.

Several additional innovations are still in the development stage. In collaboration with the Environmental Protection Agency's National Vehicle and Fuel Emissions Laboratory, professors and students from U-M are testing hydraulic-electric hybrid vehicles. The Xebra, a small electric truck, uses a hydraulic launch system to capture, store, and reuse energy lost used during braking. Researchers estimate they can improve city mileage by 45%, and triple acceleration and hill-climbing ability. Manufacturers of a small gasoline-powered version of the Xebra claim that without regenerative braking the vehicle will reach 72mpg.

Wayne State University co-founded "TechTown," a 47-acre, multi-million dollar research and business technology park. TechTown is a community of entrepreneurs, investors, and corporate partners that empowers entrepreneurs to build successful technology businesses. Among its 39 tenants is NextEnergy, a non-profit corporation founded in 2002 to advance alternative energy technology in Michigan. Three other alternative energy-focused corporations reside there as well. Multiple patents have been issued to Wayne State professors for alternative energy discoveries, including a power booster to increase efficiency and reduce emissions for hybrid vehicles.

EDUCATION INITIATIVES

In 2003, Wayne State University developed Master's, Graduate Certificate (for continuing education), and Undergraduate programs in Alternative Energy Technology. The multi-disciplinary engineering program equips students with the knowledge and skills needed to design and integrate alternative energy systems. Additionally, three leading alternative energy companies, Ballard Power Systems Corporation, Delphi Corporation, and Energy Conversion Devices, collaborated with WSU to develop the university's Alternative Energy Technology degree program.

The University of Michigan offers two degree programs supported by the Michigan Memorial Phoenix Energy Institute: a Master of Engineering in Energy Systems and a Master of Engineering Sustainable Systems. The former is the first in the nation to specifically develop leaders who can design and implement energy systems that respond to expanding environmental and energy needs. The latter confers a dual degree from the School of Natural Resources and Environment and the College of Engineering. In addition to the degree programs specific to alternative energy, U-M is focusing on an interdisciplinary approach to energy. Outside of engineering, 13 departments and 57 faculty members are contributing to the dialogue on alternative energy in fields such as economics, policy, geology, natural resources, architecture and urban planning, and business.

Appendix A: Exhibits

The following exhibits are included in this section:

Table A-1. Net Electricity Generation by Energy Source, 2005

State	Energy Source: All Sources	Coal	Hydroelectric & Other Renewables	Natural Gas	Nuclear	Other & Other Gases	Pumped Storage	Petroleum
Alaska	100.0%	9.5%	22.3%	56.6%	0.0%	0.0%	0.0%	11.6%
Alabama	100.0%	56.6%	10.1%	10.1%	23.0%	0.1%	0.0%	0.2%
Arkansas	100.0%	48.2%	10.1%	12.6%	28.6%	0.0%	0.0%	0.4%
Arizona	100.0%	39.6%	6.4%	28.5%	25.4%	0.0%	0.1%	0.0%
California	100.0%	1.1%	31.6%	46.7%	18.1%	1.2%	0.1%	1.3%
Colorado	100.0%	71.7%	4.5%	24.0%	0.0%	0.0%	-0.2%	0.0%
Conneticut	100.0%	11.9%	3.7%	26.4%	46.4%	2.2%	0.0%	9.4%
District of Columbia	100.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
Delaware	100.0%	59.4%	0.0%	19.6%	0.0%	6.1%	0.0%	15.0%
Florida	100.0%	28.4%	2.1%	38.0%	13.1%	1.6%	0.0%	16.9%
Georgia	100.0%	63.8%	5.3%	7.2%	23.1%	0.0%	-0.2%	0.7%
Hawaii	100.0%	14.2%	5.5%	0.0%	0.0%	1.6%	0.0%	78.8%
Iowa	100.0%	77.6%	6.2%	5.6%	10.3%	0.0%	0.0%	0.3%
Idaho	100.0%	0.9%	84.2%	14.3%	0.0%	0.6%	0.0%	0.0%
Illinois	100.0%	47.5%	0.5%	3.7%	48.0%	0.1%	0.0%	0.2%
Indiana	100.0%	94.2%	0.4%	2.8%	0.0%	2.4%	0.0%	0.2%
Kansas	100.0%	75.2%	1.0%	2.5%	19.2%	0.0%	0.0%	2.2%
Kentucky	100.0%	91.1%	3.5%	1.7%	0.0%	0.0%	0.0%	3.8%
Louisiana	100.0%	24.9%	3.8%	47.0%	16.9%	3.6%	0.0%	3.8%
Massachusetts	100.0%	25.3%	4.8%	42.7%	11.5%	1.6%	-1.0%	15.0%
Maryland	100.0%	55.7%	4.4%	3.6%	27.9%	1.2%	0.0%	7.2%
Maine	100.0%	1.7%	43.3%	44.6%	0.0%	1.8%	0.0%	8.6%
Michigan	100.0%	57.8%	3.3%	11.2%	27.0%	0.8%	-0.9%	0.7%
Minnesota	100.0%	62.1%	6.5%	5.2%	24.2%	0.6%	0.0%	1.5%
Missouri	100.0%	85.3%	1.3%	4.3%	8.8%	0.1%	0.1%	0.2%
Mississippi	100.0%	36.9%	3.4%	34.1%	22.4%	0.1%	0.0%	3.2%
Montana	100.0%	63.8%	34.5%	0.1%	0.0%	0.0%	0.0%	1.5%
North Carolina	100.0%	60.5%	5.6%	2.4%	30.8%	0.2%	0.1%	0.4%
North Dakota	100.0%	94.8%	4.9%	0.0%	0.0%	0.2%	0.0%	0.1%
Nebraska	100.0%	66.2%	3.2%	2.6%	28.0%	0.0%	0.0%	0.1%
New Hampshire	100.0%	16.6%	11.2%	27.7%	38.6%	0.2%	0.0%	5.5%
New Jersey	100.0%	19.2%	1.5%	25.1%	51.8%	1.0%	-0.5%	1.8%
New Mexico	100.0%	85.2%	2.7%	11.9%	0.0%	0.0%	0.0%	0.1%
Nevada	100.0%	45.7%	7.4%	46.6%	0.0%	0.3%	0.0%	0.1%
New York	100.0%	14.0%	18.9%	21.7%	28.9%	0.7%	-0.5%	16.4%
Ohio	100.0%	87.2%	0.6%	1.7%	9.4%	0.2%	0.0%	0.9%
Oklahoma	100.0%	53.0%	5.5%	41.6%	0.0%	0.0%	-0.2%	0.1%
Oregon	100.0%	7.0%	66.1%	26.7%	0.0%	0.1%	0.0%	0.2%
Pennsylvania	100.0%	55.5%	2.1%	5.0%	35.0%	0.6%	-0.3%	2.3%
Rhode Island	100.0%	0.0%	0.1%	99.0%	0.0%	0.0%	0.0%	0.9%
South Carolina	100.0%	38.7%	4.6%	5.3%	51.8%	0.1%	-1.2%	0.7%
South Dakota	100.0%	46.0%	49.6%	4.2%	0.0%	0.0%	0.0%	0.3%
Tennessee	100.0%	61.0%	10.2%	0.6%	28.6%	0.0%	-0.6%	0.2%
Texas	100.0%	37.4%	1.7%	49.4%	9.6%	1.5%	0.0%	0.4%
Utah	100.0%	94.2%	2.6%	3.1%	0.0%	0.0%	0.0%	0.1%
Virginia	100.0%	44.9%	5.0%	10.5%	35.4%	0.6%	-1.8%	5.4%
Vermont	100.0%	0.0%	28.6%	0.0%	71.2%	0.0%	0.0%	0.2%
Washington	100.0%	10.3%	72.8%	8.4%	8.1%	0.4%	0.0%	0.1%
Wisconsin	100.0%	67.4%	4.9%	10.3%	16.0%	0.2%	0.0%	1.2%
West Virginia	100.0%	97.6%	1.7%	0.3%	0.0%	0.1%	0.0%	0.2%
Wyoming	100.0%	95.1%	3.3%	0.7%	0.0%	0.7%	0.0%	0.1%
U.S. Total	**100.0%**	**49.6%**	**8.8%**	**18.7%**	**19.3%**	**0.7%**	**-0.2%**	**3.0%**

Data Source: U.S. Energy Information Administration
Analysis: Anderson Economic Group

Table A-2. Energy Consumption by Source, 2005

(Trillion Btu)

State	Total Energy [b]	Sources: Coal	Natural Gas [c]	Petroleum	Nuclear Electric Power	Hydroelectric Power [d]	Biomass [e]	Other [f]	Net Interstate Flow of Electricity/ Losses [g]
Alabama	2,119.00	890.1	364.1	626.9	330.3	101.4	177	0.1	-371.1
Alaska	799.2	14	433.8	333.3	0	14.6	3.3	0.1	0
Arizona	1,479.70	428.4	327.7	590.8	268.9	64.1	9	3.2	-212.5
Arkansas	1,135.10	247.2	216	383.8	142.7	30.8	76.6	0.4	37.7
California	8,359.80	67.4	2,297.70	3,869.60	376.8	396.3	163.9	346.5	841.6
Colorado	1,425.70	386.7	483.5	493.8	0	14.2	6.9	8.8	32
Connecticut	900.2	42	171.9	452.8	162.2	4.8	37.7	4.6	24.3
Delaware	312.6	56.7	48.6	148.5	0	0	1.3	0.2	57.3
District of Columbia	190.4	0.9	33.8	29	0	0	1	(s)	125.7
Florida	4,563.30	672.3	814	2,163.20	299.7	2.7	180.7	31.7	399
Georgia	3,173.00	901	425.8	1,159.10	328.6	40.3	178.9	0.4	138.9
Hawaii	333.4	18	2.9	295.2	0	1	10.1	6.3	0
Idaho	503.2	11.3	78.2	160.8	0	85.4	25.9	2.1	139.4
Illinois	4,121.50	1,047.50	984.2	1,486.10	971.9	1.3	44.4	2.9	-416.8
Indiana	2,904.70	1,594.40	540.7	879.9	0	4.4	36.7	2	-153.3
Iowa	1,227.80	429.8	242.8	445.7	47.3	9.6	31.5	17.1	4.2
Kansas	1,031.80	379.8	258.7	359.4	91.9	0.1	8.5	4.7	-71.3
Kentucky	1,970.10	986.3	240.9	724.9	0	29.6	26.4	1.2	-39.1
Louisiana	3,613.00	253.5	1,367.30	1,587.40	163.4	8.1	146.2	0.9	86.1
Maine	482.4	7.1	61.1	264.4	0	40.9	119.4	13.9	-24.3
Maryland	1,555.20	329.3	212.2	604.1	153.2	17	34.1	0.3	204.9
Massachusetts	1,561.80	119.3	385.3	754.5	57.1	10.4	53.7	2.7	179
Michigan	3,166.50	799.5	928.4	1,032.90	342.6	14.6	85.5	-6.8	-30.2
Minnesota	1,852.20	379.1	372.2	722.2	133.8	7.7	58.8	42.9	135.4
Mississippi	1,182.30	176.3	310.7	462.8	105	0	60.1	0.5	66.8
Missouri	1,914.70	835.7	273.4	746.7	83.7	11.6	18	0.2	-54.6
Montana	419.4	199.5	71.1	193	0	95.9	11.9	0.4	-152.3
Nebraska	654.9	228.7	120.3	231.9	91.7	8.7	8.9	1.6	-36.8
Nevada	727.8	197.8	236.9	279.6	0	17	3.3	30.1	-36.9
New Hampshire	335.4	44.2	73	191.5	98.5	18	23.6	1.7	-115.1
New Jersey	2,728.60	125.3	626.5	1,331.70	327.1	0.3	33.1	1.7	282.8
New Mexico	675	317.9	227.1	258.8	0	1.6	2.9	9	-142.4
New York	4,179.50	256.9	1,108.30	1,849.40	442.3	257.8	135.8	27.4	101.6
North Carolina	2,732.00	811.9	238.4	999.4	416.6	54	85.1	0.5	126
North Dakota	412.2	431.1	55	138.1	0	13.4	3.8	8.4	-237.7
Ohio	4,081.60	1,481.00	862.3	1,366.50	154.3	5.2	41.4	0.6	170.4
Oklahoma	1,550.70	397.4	605.3	567	0	26.3	27	8.5	-80.6
Oregon	1,095.70	35.6	240.7	392.8	0	309.5	50.9	22.6	43.6
Pennsylvania	4,050.20	1,490.80	719.3	1,535.40	795	22.3	85.4	3.3	-601.3
Rhode Island	227.6	0.1	83.7	98.4	0	0.1	2.6	1.2	41.5
South Carolina	1,694.30	431.1	178.6	571.8	553.7	29.4	77.2	0.3	-147.7
South Dakota	273.5	37	42.9	120.4	0	30.7	1.8	2.3	38.4
Tennessee	2,338.80	657.7	238.4	825.7	289.7	93.1	59.7	0.1	174.4
Texas	11,558.30	1,627.90	3,625.20	5,671.10	398.4	13.3	73	43.3	106.1
Utah	756.7	405.5	168.9	290.8	0	7.8	4.2	4.7	-125.3
Vermont	167	(s)	8.4	90.5	42.4	12.1	9	7.4	-2.9
Virginia	2,610.20	458.5	312.3	1,037.30	290.9	14.8	112.8	1.1	382.4
Washington	2,058.80	112.3	272.7	855.3	85.9	720.7	98.1	-4.6	-81.6
West Virginia	793.9	959.7	125.2	272.8	0	14.5	4.3	1.6	-584.2
Wisconsin	1,861.80	522.5	415.6	624.9	103.4	17.4	78.2	1.3	98.5
Wyoming	461.9	490.9	113	161	0	8.1	0.9	7.9	-319.9
U.S. Total	**100,324.40**	**22,794.90**	**22,645.00**	**40,732.90**	**8,149.00**	**2,702.90**	**2,630.50**	**669.30**	

Data Source: Energy Information Administration
Analysis: Anderson Economic Group, LLC
Notes:

[a]End-use sector data include electricity sales and associated electrical system energy losses.

[b]U.S. total energy and U.S. industrial sector include 44.2 trillion Btu of net imports of coal coke that is not allocated to the States.

[c]Includes supplemental gaseous fuels.

[d]Conventional hydroelectric power. Does not include pumped-storage hydroelectricity.

[e]Wood and waste.

[f]"Other" is geothermal, wind, photovoltaic, solar thermal energy, and net imports of electricity.

[g]A positive number indicates that more electricity (including associated losses) came into the State than went out of the state during the year; conversely a negative number indicates that more electricity (including associated losses) went out of the State than came into the State.

* Where shown, (s) = Value less than 0.05 trillion Btu.

Table A-3. Total Renewable Net Generation by Energy Source and State, 2005

(Megawattthours)

State	Biomass: Waste: Landfill Gas/MSW[d] & Biogenic[a]	Biomass: Waste: Other Biomass[b]	Biomass: Wood & Derived Fuels[c]	% Biomass	Geo-thermal	Hydroelectric Conventional	% Hydro-electric	Solar/ Photovoltaic	Wind	% Wind	Total
Alabama	3,494	17,342	3,738,421	27%	-	10,144,581	73%	-	-	-	13,903,838
Alaska	-	4,873	*	0%	-	1,463,942	100%	-	589	0.04%	1,469,785
Arizona	44,690	3,666	12,058	1%	-	6,410,064	99%	13,581	-	-	6,484,059
Arkansas	-	27,693	1,706,996	36%	-	3,082,516	64%	-	-	-	4,817,205
California	1,587,497	629,236	3,610,097	9%	13,022,639	39,631,867	63%	536,713	4,262,229	7%	63,280,278
Colorado	-	33,879	*	2%	-	1,415,296	64%	-	776,234	35%	2,225,857
Connecticut	746,021	-	7,314	61%	-	478,199	39%	-	-	-	1,231,534
Delaware	-	-	-	-	-	-	-	-	-	-	-
Florida	1,775,272	582,645	2,005,937	94%	-	266,159	6%	-	-	-	4,630,013
Georgia	28,671	48,711	3,148,749	44%	-	4,032,053	56%	-	-	-	7,258,184
Hawaii	163,003	147,715	-	49%	221,597	96,188	15%	-	6,632	1%	635,135
Idaho	-	-	577,040	6%	-	8,542,121	94%	-	-	-	9,119,161
Illinois	593,325	48,452	-	70%	-	129,037	14%	-	141,146	15%	911,960
Indiana	67,779	-	-	13%	-	438,282	87%	-	-	-	506,061
Iowa	81,991	34,852	-	4%	-	959,526	35%	-	1,647,134	60%	2,723,503
Kansas	-	-	-	0%	-	11,337	3%	-	425,823	97%	437,160
Kentucky	62,098	1,222	359,065	12%	-	2,961,193	88%	-	-	-	3,383,578
Louisiana	-	80,507	2,643,987	77%	-	810,948	23%	-	-	-	3,535,442
Maine	233,803	54,554	3,786,633	50%	-	4,090,926	50%	-	-	-	8,165,916
Maryland	417,405	-	195,466	26%	-	1,703,639	74%	-	-	-	2,316,510
Massachusetts	1,113,754	24,510	120,027	55%	-	1,041,950	45%	-	-	-	2,300,240
Michigan	714,068	3,021	1,801,330	63%	-	1,461,708	37%	-	1,848	0.05%	3,981,975
Minnesota	409,254	6,476	649,415	31%	-	774,729	23%	-	1,582,477	46%	3,422,350
Mississippi	-	5,344	1,519,941	100%	-	-	-	-	-	-	1,525,285
Missouri	-	9,249	-	1%	-	1,159,326	99%	-	-	-	1,168,575
Montana	-	-	65,245	1%	-	9,587,349	99%	-	-	-	9,652,594
Nebraska	24,566	18,080	-	4%	-	871,473	86%	-	96,608	10%	1,010,727
Nevada	-	-	-	0%	1,262,707	1,702,380	57%	-	-	-	2,965,087
New Hampshire	156,166	-	785,733	34%	-	1,798,903	66%	-	-	-	2,740,802
New Jersey	872,481	2,425	-	97%	-	31,113	3%	-	-	-	906,018
New Mexico	-	4,644	-	0%	-	164,993	17%	-	794,630	82%	964,267
New York	1,344,149	13,809	537,510	7%	-	25,782,518	93%	-	102,990	0%	27,780,976
North Carolina	87,015	11,770	1,739,583	25%	-	5,396,502	75%	-	-	-	7,234,871
North Dakota	-	9,989	-	1%	-	1,341,824	85%	-	220,345	14%	1,572,158
Ohio	22,526	4,279	359,014	42%	-	515,744	56%	-	13,268	1%	914,831
Oklahoma	-	-	289,217	8%	-	2,630,361	70%	-	847,773	23%	3,767,351
Oregon	70,693	27,350	809,306	3%	-	30,948,345	95%	-	734,274	2%	32,589,968
Pennsylvania	1,352,035	5,695	687,496	45%	-	2,232,179	49%	-	284,241	6%	4,561,646
Rhode Island	-	-	-	0%	-	6,734	100%	-	-	-	6,734
South Carolina	87,751	-	1,697,465	38%	-	2,938,147	62%	-	-	-	4,723,363
South Dakota	-	-	-	0%	-	3,074,566	95%	-	158,104	5%	3,232,670
Tennessee	27,265	-	528,281	6%	-	9,309,541	94%	-	3,339	0%	9,868,426
Texas	206,798	46,614	843,789	16%	-	1,332,560	20%	-	4,237,209	64%	6,666,969
Utah	3,948	-	-	0%	184,802	784,463	81%	-	-	-	973,213
Vermont	-	-	410,491	25%	-	1,210,811	74%	-	11,486	1%	1,632,789
Virginia	676,742	20,820	1,799,862	63%	-	1,484,353	37%	-	-	-	3,981,778
Washington	170,700	27,336	1,419,394	2%	-	72,074,649	97%	-	498,470	1%	74,190,549
West Virginia	-	*	*	0%	-	1,447,566	90%	-	153,892	10%	1,602,171
Wisconsin	325,019	52,018	824,996	40%	-	1,740,219	57%	-	92,544	3%	3,034,797
Wyoming	-	-	-	0%	-	808,375	53%	-	717,264	47%	1,525,639
Total U.S.	**13,469,976**	**2,009,029**	**38,681,147**	**15%**	**14,691,745**	**270,321,255**	**76%**	**550,294**	**17,810,549**	**5%**	**357,533,995**

Source: Energy Information Administration, Form EIA-906,"Power Plant Report," and Form EIA-920, " Combined Heat and Power Plant Report."

Analysis: Anderson Economic Group, LLC

Notes:

(a) Includes landfill gas and MSW biogenic (Paper and paper board, wood, food, leather, textiles and yard trimmings.).

(b) Agriculture byproducts/crops, sludge waste and other biomass solids, liquids and gases.

(c) Black liquor, and wood/woodwaste solids and liquids.

(d) MSW equals Municipal Solid Waste

*=Less than 500 kilowatthours

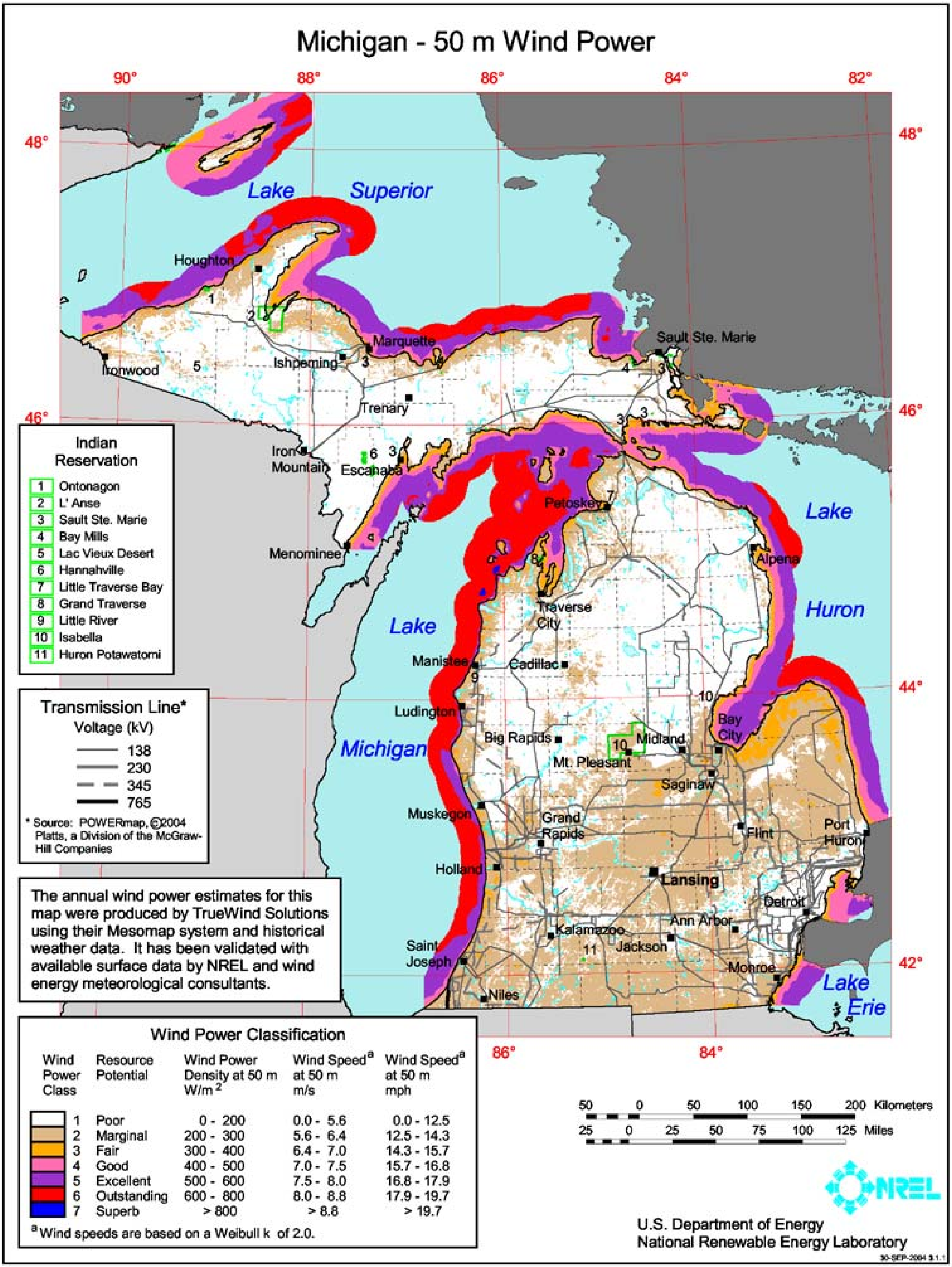
Revisions to biomass removed MSW non-biogenic and tires from renewable waste energy. Dash indicates the state has no data to report for that energy source.

Table A-4. Net Generation from Hydroelectric (Conventional) Power by Sector, December 2007

(Thousand Megawatthours)

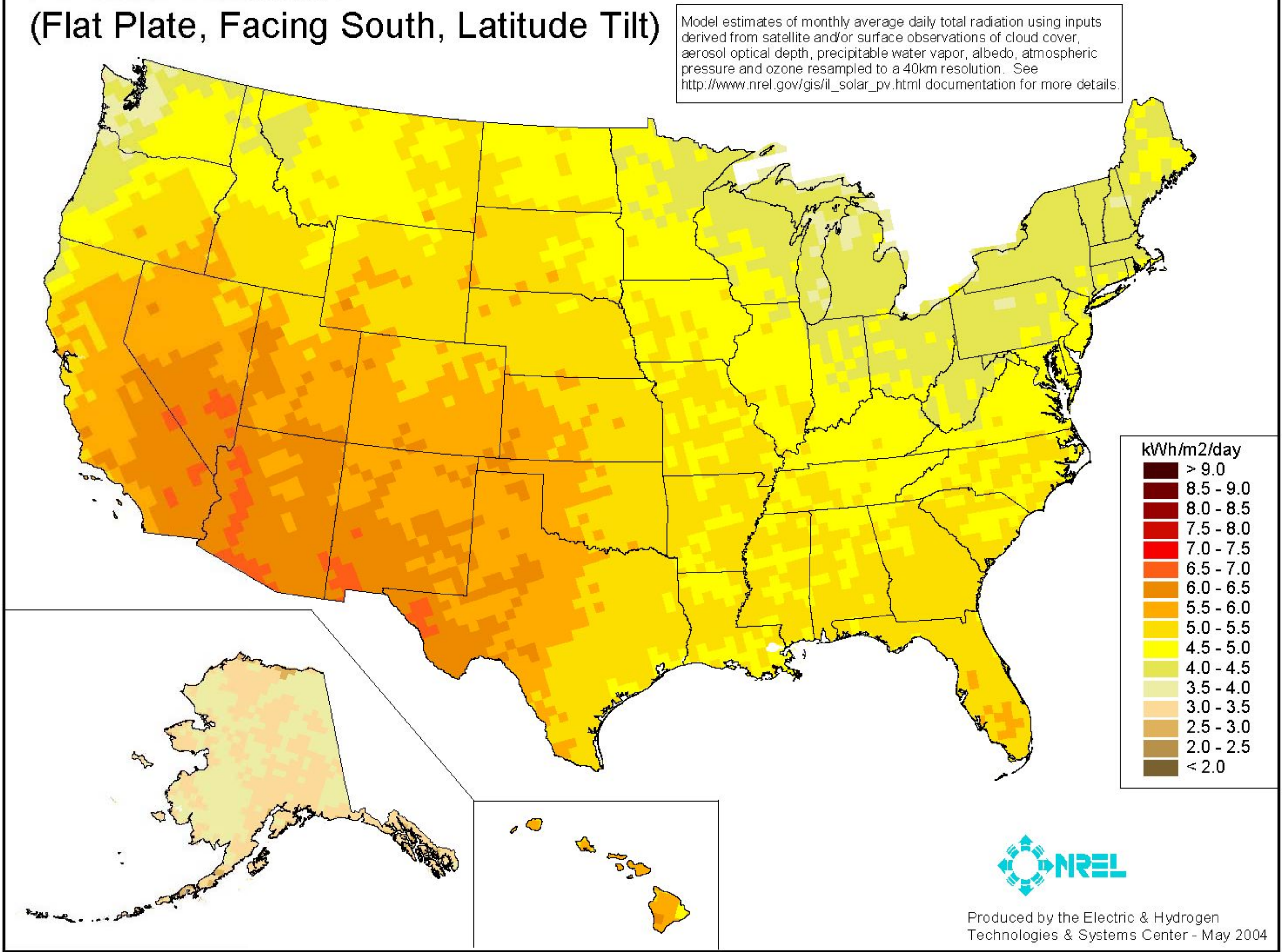
State	Total 2007 (All Sectors)	Total 2006 (All Sectors)	% Change (06-07)	Electric Power Sector: Electric Utilities	Electric Power Sector: Independent Producers	Commercial Sector	Industrial Sector
Alabama	204	574	-64.5	204	--	--	--
Alaska	88	104	-15.4	88	--	--	--
Arizona	556	489	13.7	556	--	--	--
Arkansas	191	216	-11.6	191	--	--	--
California	1,671	2,497	-33.1	1,625	46	NM	--
Colorado	106	143	-25.9	97	NM	--	--
Connecticut	39	44	-11.4	NM	NM	--	--
Delaware	--	--	--	--	--	--	--
District of Columbia	--	--	--	--	--	--	--
Florida	NM	15	--	NM	--	--	--
Georgia	143	200	-28.5	141	NM	--	NM
Hawaii	NM	8	--	NM	NM	--	4
Idaho	521	602	-13.5	492	NM	--	--
Illinois	NM	13	--	NM	NM	--	--
Indiana	30	39	-23.1	30	--	--	--
Iowa	79	85	-7.1	79	NM	--	--
Kansas	*	1	--	--	*	--	--
Kentucky	147	234	-37.2	147	--	--	--
Louisiana	52	74	-29.7	--	52	--	--
Maine	322	347	-7.2	--	263	--	59
Maryland	236	161	46.6	--	236	--	--
Massachusetts	112	122	-8.2	NM	72	--	--
Michigan	105	111	-5.4	94	NM	--	3
Minnesota	39	42	-7.1	NM	NM	--	NM
Mississippi	--	--	--	--	--	--	--
Missouri	26	11	136.4	26	--	--	--
Montana	814	842	-3.3	533	281	--	--
Nebraska	58	58	0.0	58	--	--	--
Nevada	26	181	-85.6	26	--	--	--
New Hampshire	102	124	-17.7	30	72	--	NM
New Jersey	NM	2	--	--	NM	--	--
New Mexico	NM	13	--	NM	--	--	--
New York	2,187	2,195	-0.4	1,803	376	1	7
North Carolina	146	377	-61.3	104	34	1	7
North Dakota	115	115	0.0	115	--	--	--
Ohio	34	56	-39.3	34	--	--	--
Oklahoma	118	44	168.2	118	--	--	--
Oregon	2,878	3,172	-9.3	2,860	NM	--	--
Pennsylvania	280	215	30.2	148	131	--	--
Rhode Island	NM	*	--	--	NM	--	--
South Carolina	97	141	-31.2	94	NM	--	--
South Dakota	216	229	-5.7	216	--	--	--
Tennessee	207	661	-68.7	196	--	--	11
Texas	39	39	0.0	NM	3	--	--
Utah	41	56	-26.8	41	NM	--	--
Vermont	104	111	-6.3	37	66	--	NM
Virginia	75	138	-45.7	70	NM	--	NM
Washington	5,974	6,427	-7.0	5,959	NM	5	NM
West Virginia	128	119	7.6	NM	46	--	45
Wisconsin	114	124	-8.1	99	NM	--	13
Wyoming	23	25	-8.0	23	--	--	--
U.S. Total	**18,443**	**21,596**	**-14.6**	**16,334**	**1,678**	**7**	**149**

Source: Energy Information Administration, Form EIA-906, "Power Plant Report" and Energy Administration, Form EIA-920 "Combined Heat and Power Plant Report."
Analysis: Anderson Economic Group, LLC
Notes:
* Indicates value is less than half of the smallest unit of measure (e.g., for values with no decimals, the smallest unit is "1" and values under 0.5 are shown as "*".)
** NM indicates "Not Meaningful" due to large relative standard error or excessive percentage change.
*** Values for 2007 are preliminary. See Technical Notes for a discussion of the sample design for the Form EIA-906 and Form EIA-920;
Negative generation denotes that electric power consumed for plant use exceeds gross generation.


Michigan - 50 m Wind Power
90°
88°
86°
84°
82°
48°
46°
44°
42°
Lake
Superior
Lake
Huron
Lake
Michigan
Lake
Erie
Houghton
Ironwood
Ishpeming
Marquette
Trenary
Sault Ste. Marie
Iron Mountain
Escanaba
Menominee
Petoskey
Alpena
Traverse City
Manistee
Cadillac
Ludington
Big Rapids
Midland
Bay City
Mt. Pleasant
Saginaw
Muskegon
Grand Rapids
Flint
Port Huron
Holland
Lansing
Detroit
Ann Arbor
Kalamazoo
Jackson
Saint Joseph
Monroe
Niles
Indian Reservation
1 Ontonagon
2 L' Anse
3 Sault Ste. Marie
4 Bay Mills
5 Lac Vieux Desert
6 Hannahville
7 Little Traverse Bay
8 Grand Traverse
9 Little River
10 Isabella
11 Huron Potawatomi
Transmission Line*
Voltage (kV)
138
230
345
765
* Source: POWERmap, ©2004 Platts, a Division of the McGraw-Hill Companies
The annual wind power estimates for this map were produced by TrueWind Solutions using their Mesomap system and historical weather data. It has been validated with available surface data by NREL and wind energy meteorological consultants.
Wind Power Classification
Wind Power Class
Resource Potential
Wind Power Density at 50 m W/m 2
Wind Speed a at 50 m m/s
Wind Speed a at 50 m mph
1 Poor 0 - 200 0.0 - 5.6 0.0 - 12.5
2 Marginal 200 - 300 5.6 - 6.4 12.5 - 14.3
3 Fair 300 - 400 6.4 - 7.0 14.3 - 15.7
4 Good 400 - 500 7.0 - 7.5 15.7 - 16.8
5 Excellent 500 - 600 7.5 - 8.0 16.8 - 17.9
6 Outstanding 600 - 800 8.0 - 8.8 17.9 - 19.7
7 Superb > 800 > 8.8 > 19.7
a Wind speeds are based on a Weibull k of 2.0.
50 0 50 100 150 200 Kilometers
25 0 25 50 75 100 125 Miles
U.S. Department of Energy
National Renewable Energy Laboratory
30-SEP-2004 3.1.1

PV Solar Radiation
(Flat Plate, Facing South, Latitude Tilt)

Annual



Produced by the Electric & Hydrogen Technologies & Systems Center - May 2004

At a Glance...The Economic Contributions of Michigan's University Research Corridor

Summary of 2007 Annual Economic Impact Report

- The University Research Corridor (URC) is an alliance of Michigan's three largest academic research institutions: Michigan State University, University of Michigan, and Wayne State University.
- The URC's mission is to accelerate economic development in Michigan by educating students, attracting talented workers to Michigan, supporting innovation, and encouraging the transfer of technology to the marketplace.
- The URC makes significant economic contributions to the state's economy. Findings from AEG's 2007 *Annual Economic Impact Report* (available at: www.AndersonEconomicGroup.com) show:

1. Enormous Economic Benefits of the University Research Corridor

- URC universities collectively spent $6.5 billion on operations in FY 2006. This is about 2% of all economic activity in the state, as measured by Michigan's gross state product.
- 556,338 URC alumni living in Michigan earned $25 billion in salary and wages in 2006, or 13.4% of all wage and salary income in Michigan.
- The URC employed 46,398 full-time faculty and staff throughout the state of Michigan in FY 2006.
- In FY 2006, Michigan's residents were over $12.8 billion richer due to the URC.

2. URC Contributes Significantly to R&D, Patents, Licenses, and Start-ups in Michigan

- In 2005, the URC spent $1.37 billion on research and development. This is 94% of all R&D spending by universities (public and private) in Michigan.
- On average, the URC filed 437 invention disclosures, 243 new patent applications annually between 2002 and 2006. The URC received on average 126 patents and 118 licenses annually between 2002 and 2006.
- The URC helped cultivate an average of 15 start-up companies annually between 2002 and 2006.

3. URC Brings Millions of Dollars in Federal Investment to Michigan

- The URC brought $832 million in federal research dollars to Michigan in 2005. This is money that paid salaries and bought supplies and equipment, fueling other economic activity in the state.

4. Michigan's URC is Among the Top University Clusters in the U.S.

- The URC spends more on R&D than peer university clusters in Massachusetts (MIT, Harvard, and Tufts) and Pennsylvania (Penn State, University of Pittsburgh, and Carnegie Mellon).
- The URC received more federal dollars for R&D than the North Carolina Research Triangle universities (Duke, University of North Carolina, and North Carolina State University) in 2005.
- The URC received more patent grants on average each year between 2002 and 2006 than the North Carolina and Pennsylvania university clusters.
- Between 2002 and 2006, the URC helped cultivate four more start-up companies on average annually than North Carolina's Research Triangle university cluster.
- The URC was the third most effective cluster of the seven clusters we analyzed in turning research expenditures into licensing revenue.

Appendix B: About Anderson Economic Group

ABOUT ANDERSON ECONOMIC GROUP

Anderson Economic Group, LLC (AEG) was started in 1996 and today has offices in East Lansing, Michigan and Chicago, Illinois. AEG is a research and consulting firm that specializes in economics, public policy, financial valuation, market research, and land use economics. AEG's past clients include:

- *Governments* such as the states of Michigan, North Carolina, and Wisconsin; the cities of Detroit, Cincinnati, Norfolk, and Fort Wayne; counties such as Oakland County, Michigan, and Collier County, Florida; and authorities such as the Detroit-Wayne County Port Authority.
- *Corporations* such as GM, Ford, Delphi, Honda, Taubman Centers, The Detroit Lions, PG&E Generating; SBC, Gambrinus, Labatt USA, and InBev USA; automobile dealers and dealership groups representing Toyota, Honda, Chrysler, Mercedes-Benz, and other brands.
- *Nonprofit organizations* such as Michigan State University, Wayne State University, Van Andel Institute, the Michigan Manufacturers Association, International Mass Retailers Association, American Automobile Manufacturers Association, Automation Alley, and the Michigan Chamber of Commerce.

Visit AEG's website at: http://www.AndersonEconomicGroup.com.

ABOUT THE AUTHORS

Caroline M. Sallee. Ms. Sallee is a Consultant at Anderson Economic Group, working in the Public Policy, Fiscal, and Economic Analysis practice area. Ms. Sallee's background is in applied economics and public finance. Ms. Sallee was a primary author of the *First Annual Economic Impact Report* in 2007 for Michigan's Research Corridor. Her recent work includes fiscal and economic impact studies for Michigan State University, and the benchmarking of Michigan's business taxes with other states in a project for the Michigan House of Representatives.

Ms. Sallee holds a Master of Public Policy degree from the Gerald R. Ford School of Public Policy at the University of Michigan and a Bachelor of Arts degree in economics and history from Augustana College.

Rebecca A. Cohen. Ms. Cohen is an Analyst at Anderson Economic Group, working in the Public Policy, Fiscal, and Economic Analysis practice area. Before working at AEG, she worked at The Center for Community Solutions on early childhood education policy in the state of Ohio. Ms. Cohen is currently pursing a Master of Public Policy degree at the University of Michigan's Gerald R. Ford School of Public Policy. She holds a Bachelor of Arts degree in sociology and psychology from Case Western Reserve University.

Patrick L. Anderson. Mr. Anderson, principal and CEO, founded the consulting firm of Anderson Economic Group in 1996. Since founding the firm, he has successfully directed projects for state governments, cities, counties, nonprofit organizations, and corporations in over half of the United States.

Prior to founding Anderson Economic Group, Mr. Anderson served as the chief of staff of the Michigan Department of State, and as a deputy director of the Michigan Department of Management and Budget. Prior to his involvement in state government, Mr. Anderson was an assistant vice president of Alexander Hamilton Life Insurance, and an economist for Manufacturers National Bank of Detroit.

Mr. Anderson has written over 100 articles published in periodicals such as *The Wall Street Journal*, *The Detroit News*, *The Detroit Free Press*, *Crain's Detroit Business*. His book *Business Economics and Finance* was published by CRC Press in August 2004, and his paper on "Pocketbook Issues and the Presidency" was awarded the Edmund Mennis Award for best contributed paper in 2004 by the National Association for Business Economics.

He is a graduate of the University of Michigan, where he earned a Master of Public Policy degree and a Bachelor of Arts degree in political science.