Charting Michigan's Renewable Energy Future

Accelerating the transition to clean, affordable, and reliable power

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Michigan took an important first step toward a clean energy future when the state legislature passed Public Act 295 in 2008. The law, known as the Clean, Renewable, and Efficient Energy Act, established a renewable electricity standard (RES) that requires electricity providers in Michigan to supply 10 percent of the state's electricity with renewable energy sources like wind, solar, and bioenergy by 2015.

More than five years later, the RES has been a success. Michigan utilities are ahead of schedule in bringing clean energy resources online to meet the 10 percent standard, and they are doing it at a lower cost and with better-performing technologies than originally expected. These investments in renewable energy are creating jobs, boosting local economies, and delivering clean electricity to homes and businesses throughout the state (Quackenbush, Isiogu, and White 2013). But with the RES set to level off in 2015, momentum in renewable energy development is already being lost. Stronger policies are needed to help Michigan take the next steps toward a clean energy future.

At the end of 2012, Governor Rick Snyder launched a year-long initiative to analyze the condition of Michigan's electricity sector, collect information from stakeholders, and explore potential paths forward for the state (Snyder 2012). In November 2013, the governor's final report concluded that Michigan can cost-effectively and reliably achieve at least 30 percent renewable energy with in-state resources (Quackenbush and Bakkal 2013a).

Following the report's release, Governor Snyder announced four energy goals for the state: affordability, reliability, protection of the environment, and adaptability. He acknowledged that increasing Michigan's commitment to renewable energy would be an important component of achieving these goals. While the governor has not discussed specific policy recommendations, the process has laid the groundwork to strengthen and expand Michigan's RES.

This report explores Michigan's energy future and the role that renewable energy policy can play in transitioning to a clean energy economy. We first look at Michigan's current shift away from its historical overreliance on coal-fired generation and the state's experience in meeting its current 10 percent RES. Next, we describe Michigan's potential to meet more of its electricity demand with in-state renewable energy resources. Then, using the Regional Energy Deployment System model developed by the National Renewable Energy Laboratory, we examine the impacts on consumers, the economy, and the environment of three potential pathways for meeting Michigan's future electricity demand:

1. Continuing with the current law that maintains Michigan's RES level at 10 percent from 2015 onward, with no new policies in place that would further increase renewable electricity generation
2. Increasing Michigan's RES to 17.5 percent in 2020
3. Increasing Michigan's RES to 32.5 percent in 2030—a 1.5 percent rate of growth in the annual requirements that would keep Michigan utilities on about the same pace as the current RES for the next 15 years

Our findings show that Michigan can affordably meet 32.5 percent of its electricity needs with in-state renewable energy resources by 2030 while maintaining reliability in the electricity system. Doing so will spur billions of dollars of investment in Michigan, cut power plant carbon emissions, and reduce the risks of an overreliance on coal or natural gas by further diversifying Michigan's mix of electricity sources. Pursuing a less robust RES—17.5 percent by 2020—significantly reduces the benefits that accrue to Michigan from developing its renewable energy resources without reducing the costs to consumers.

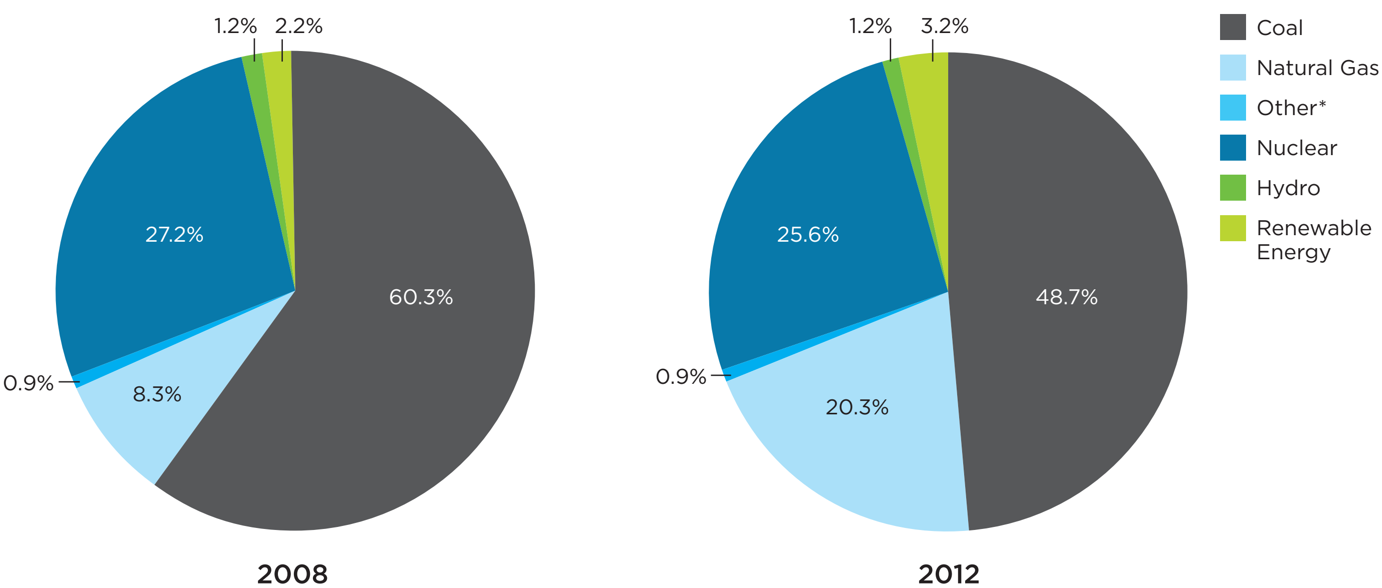
According to our analysis, establishing a 32.5 percent by 2030 RES in Michigan means:

- **Sustained and robust development of Michigan's renewable energy resources.** Michigan's renewable energy industries would add an average of more than 550 megawatts (MW) of new renewable energy capacity per year, totaling more than 11,000 MW by 2030.[1] Without policy support beyond 2015, renewable energy development in Michigan would remain largely stagnant from 2014 to 2030.
- **Significant economic benefits.** The development of Michigan's renewable energy resources would drive more than $9.5 billion in new capital investments from 2016 to 2030. By 2030, renewable energy facilities would also add nearly $570 million in operation and maintenance payments and more than $21 million in land lease payments annually.
- **Minimal impact on consumers.** Electricity sector costs would increase by just 0.3 percent between 2014 and 2030 under a 32.5 percent by 2030 RES compared with the scenario that includes no policy changes. In some years, average retail electricity prices would be lower under the 32.5 percent RES scenario than they are under the other scenarios.
- **Reduced carbon dioxide (CO_2) emissions.** Reduced dependence on coal and natural gas would lower CO_2 emissions by more than 65 million tons from 2014 to 2030—equivalent to the annual emissions of 15 typical-size (600 MW) coal plants.
- **A more diverse electricity supply for Michigan.** Renewable energy development, led primarily by wind energy, would displace both coal and natural gas in Michigan's electricity generation mix, leading to lower risks to consumers resulting from an overreliance on fossil fuels to meet electricity demand.

Michigan's Current Shift Away from Coal-fired Generation

Like many states in the Midwest and throughout the country, Michigan's electricity sector is going through a historic transformation. While coal plants are still the largest source of the state's electricity, coal's economic competitiveness has been eroding for years. From 2008 to 2012, coal-fired generation in Michigan declined from 60 percent to 49 percent as lower-cost resources such as natural gas and wind have replaced higher-cost electricity from Michigan's old, inefficient coal plants (Figure 1) (EIA 2013a).

FIGURE 1. Michigan's Electricity Generation Mix, 2008 vs. 2012



Michigan's electricity sector is going through a major transformation. While the sector is still heavily reliant on generation from coal-fired power plants, coal's economic competitiveness has declined since 2008, leading to a significant increase in generation from natural gas. The contribution of renewable energy to the state's power supply also increased from 2008 to 2012.

* Includes petroleum, non-biogenic municipal solid waste, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, tire-derived fuels, and other manufactured and waste gases derived from fossil fuels.

SOURCE: EIA 2013A.

There are several reasons why the use of coal is declining in Michigan. The state is home to one of the oldest coal power plant fleets in the nation: 87 percent of the state's coal capacity is more than 30 years old, while nearly a third of the state's coal capacity began operation more than 50 years ago. Most of the state's old coal plants lack essential modern pollution controls, and utilities face important near-term decisions about whether to invest hundreds of millions of dollars in upgrades or to retire the plants. Our recent assessment of the viability of the U.S. coal fleet determined that more than half of Michigan's total coal power capacity (6,719 MW) is economically vulnerable—meaning it will have a difficult time competing with other resource options—and should be considered for closure. This is a greater amount than for any other state (Fleischman et al. 2013).

Coal prices also continue to increase in Michigan, adding to coal's economic vulnerability going forward. The average price that Michigan utilities pay for coal has increased by nearly 50 percent from 2008 to 2012, from $37.67 to $55.22 per ton. Because Michigan does not have any in-state coal resources, it must import 100 percent of its coal from other states—sending $1.2 billion out of state in 2012 alone (UCS 2014).

While switching from coal to natural gas offers some benefits of near-term air quality and cost, there is growing evidence that an overreliance on natural gas poses significant and complex risks to consumers and the economy, public health and safety, land and water resources, and the climate.

To date, much of the decline in coal use has been replaced with natural gas (Figure 1). Because of the current low costs of natural gas and its abundant supplies nationally, natural gas generation in Michigan more than doubled from 8 percent in 2008 to 20 percent in 2012 (EIA 2013a). While switching from coal to natural gas offers some benefits of near-term air quality and cost, there is growing evidence that an overreliance on natural gas poses significant and complex risks to consumers and the economy, public health and safety, land and water resources, and the climate (Fleischman, Sattler, and Clemmer 2013). For example, a recent cold snap across the nation led to spiking electricity and natural gas prices in the Northeast as natural gas demand for heating and electricity generation exceeded supplies (Jacobs 2014). In addition, as with any fossil fuel, burning natural gas for electricity generation results in the release of CO_2 and thus contributes to global warming. While natural gas emits considerably less CO_2 than a coal-fired power plant at the smokestack, a natural gas–dominated electricity system would not cut emissions sufficiently to meet U.S. climate goals (Fleischman, Sattler, and Clemmer 2013).

Renewable Energy Is Working for Michigan

Most of the recent growth in Michigan's renewable energy industry is attributable to the state's successful RES policy.[2] The 2008 Clean, Renewable, and Efficient Energy Act requires all of Michigan's electricity suppliers to gradually increase the contribution of renewable energy sources to 10 percent of the state's electricity supply by 2015 (up from about 1 percent in 2008). The state's two largest power providers—DTE and Consumers Energy—have an additional renewable energy capacity requirement of 500 and 600 MW by 2015, respectively.

Renewable energy technologies that are eligible to meet the RES include wind, solar photovoltaic (PV) and solar thermal, bioenergy, geothermal, hydroelectric, municipal solid waste (at facilities in operation before October 2008), and landfill gas. Renewable energy systems must be located either within Michigan or in the service territory of a power provider that serves Michigan.

Compliance with the RES is mandatory, and utilities must meet the annual requirements or else pay penalties. Utilities are permitted to levy a surcharge on their ratepayers to cover any new costs associated with compliance, and the surcharge for a home owner is capped at three dollars per customer per month.[3] The Michigan Public Service Commission (MPSC) is tasked with implementing, enforcing, and reporting on the progress toward achieving the state's RES.

Michigan's utilities are well on their way to meeting the 10 percent requirement. In 2012, renewable energy accounted for 5.4 percent of the state's retail electricity sales. In 2012 and 2013, more than 1,100 MW of renewable energy capacity were added to the Michigan power supply, and another 280 MW are planned for 2014 and 2015 (Quackenbush, White, and Talberg 2014). This additional capacity is expected to provide enough electricity for Michigan utilities to fully comply with the current 10 percent RES (Quackenbush, White, and Talberg 2014).

The RES is being achieved affordably, and the cost of deploying renewable energy technologies has declined in every year since the policy was adopted. The average cost of all new renewable electricity facilities used to meet the standard is $78.39 per megawatt-hour (MWh)—less than what was forecasted by utilities and well below the cost of building a new coal power plant (estimated by the MPSC at $133 per MWh) (Quackenbush, White, and Talberg 2014).

Wind technology, in particular, has seen a significant decline in cost. Improvements in wind technology combined with reductions in capital costs have resulted in a significant decline in the cost of wind-powered electricity generation in Michigan. Contracts approved by the MPSC to develop new wind projects in 2013 and 2014 will provide electricity at a cost of approximately $52 per MWh, 35 percent lower than wind projects developed between 2008 and 2012 (at $80.32 per MWh) and nearly 20 percent lower than Michigan's estimated average cost of electricity generation overall (at $64 per MWh) (Quackenbush, White, and Talberg 2014).

The lower costs of developing renewable energy projects are translating into savings for consumers as well. In 2013, DTE and Consumers Energy lowered their residential surcharges for RES compliance due to the declining costs of renewable energy. In June, DTE dropped its monthly surcharge from $3.00 to $0.43, and in August, Consumers Energy announced that it would eliminate its monthly surcharge of $2.50 altogether (Haugen 2013). In doing so, Consumers Energy joins 46 other electricity providers in Michigan (out of 59) that are meeting RES requirements without the need for a residential customer surcharge (Quackenbush, White, and Talberg 2014).

Michigan's RES is also driving investment and economic development opportunities in local communities. The MPSC estimates that through 2013, $2.2 billion has been invested in Michigan to bring new renewable energy projects online to meet Michigan's RES requirements (Quackenbush, White, and Talberg 2014). These investments support jobs in construction, clean energy manufacturing, and the installation, administration, and operation of the new energy infrastructure, as well as deliver new tax revenues and land lease payments for rural landowners (UCS 2013a). For example, the American Wind Energy Association estimates that in 2012 Michigan's wind industry supported 4,000 jobs either directly tied to wind technology or new jobs in local communities, and made more than $2.8 million in land lease payments to local landowners who host wind turbines (AWEA 2013).

Michigan is one of 29 states that have adopted an RES (along with the District of Columbia). For the last 15 years,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The Harvest Wind Farm near Elkton, MI, is one of several that have been developed to help meet the state's renewable energy requirements. The wind farm represents a $94 million investment and provides enough clean electricity annually to power 15,000 homes (WPC n.d.).

these policies have been a primary driver of new renewable energy development nationwide. Michigan's RES requirement of 10 percent is one of the four lowest in the country. Seventeen states have renewable electricity requirements of at least 20 percent, and several leading states—California, Colorado, Hawaii, Maine, Minnesota,[4] and New York—have requirements of 30 percent or higher. However, even though Michigan's existing RES ranks low in terms of the required percentage, the state ranks in the middle of the pack with respect to the amount of new renewable energy generation supported by the policy. That is because the 10 percent requirement applies to one of the larger electricity loads in the United States and because Michigan applies its 10 percent requirement to all of the state's electricity providers.

Michigan's Robust Renewable Energy Resources

Michigan has vast in-state renewable energy resources, enough to generate annually several times the state's total 2012 electricity demand (Table 1). Not all of Michigan's renewable energy potential can or should be tapped due to conflicting land use needs, cost considerations, transmission constraints, and other hurdles, but the magnitude of the resource gives the state a high degree of latitude in selecting the optimal technologies and locations for development. Even after accounting for these constraints, Michigan has a strong and diverse pool of renewable energy resources to support the state's continued transition to a clean energy future.

Onshore wind. Even after a variety of competing land uses are accounted for, such as developed lands, parks, and environmentally sensitive areas, onshore wind resources in Michigan have the potential to generate more than 1.6 times Michigan's 2012 electricity demand—approximately 170,000 gigawatt-hours (GWh)[5] of electricity annually (WPA 2010). However, this estimate, while commonly used by the MPSC and others to estimate wind resources in Michigan, represents the low end of the resource's potential, as its calculations assume the energy output of turbines 80 meters tall. In Michigan, the wind industry is rapidly moving toward next-generation 100-meter-tall turbines that are able to capture significantly more wind energy.[6] This industry shift, combined with other technological improvements that are increasing the efficiency of wind turbines, greatly increases the potential wind resource in Michigan. Using modern 100-meter turbines, Michigan's wind resource has the potential to produce more than 500,000 GWh of electricity annually, more than three times that at 80 meters and nearly five times Michigan's 2012 electricity demand (WPA 2010).

Solar. Michigan has vast solar power potential, in the development of both large, utility-scale PV systems on undeveloped lands and smaller rooftop systems on residential and commercial buildings (Lopez et al. 2012). Michigan has the potential to satisfy approximately 71 percent of its annual demand—more than 74,000 GWh—using only rooftop PV systems and ground-mounted utility-scale PV systems in urban areas (Lopez et al. 2012). When Michigan's rural areas are included, solar PV potential increases more than 70-fold—to an estimated 5.2 million GWh annually (Lopez et al. 2012).

Bioenergy. Michigan has a large supply of sustainable[7] cellulosic biomass resources, which includes energy crops, agriculture and forest residues, wood waste from the forest products industries, and wood wastes from urban areas. These resources can be used to produce electricity in dedicated biomass facilities or can be co-fired at existing coal plants (blended with coal, with biomass constituting up to 10 or 15 percent of the mix). Captured methane emissions from such sources as animal waste, wastewater treatment plants, and landfills are also a potential resource for renewable electricity generation. In total, Michigan's bioenergy resource has an estimated potential to generate 11 percent of Michigan's 2012 electricity demand (Lopez et al. 2012).

Offshore wind. Michigan has the potential to generate large quantities of electricity by tapping into the offshore wind resources of the Great Lakes. Offshore wind has the potential to provide more than 16 times Michigan's annual electricity demand (1.7 million GWh) (Lopez et al. 2012). The Great Lakes wind resource and the feasibility of developing it is currently being researched by Grand Valley State University in partnership with the University of Michigan, Michigan State University, and others (GVSU n.d.).

Other renewable energy resources. In addition to wind, solar, and biomass, a variety of other renewable energy resources are available in Michigan. For example, many existing hydropower facilities can be updated, electricity generation equipment can be added to existing dams, and new small-scale hydropower resources can be developed. A U.S. Department of Energy (DOE) study identified 133 MW of potential small-scale hydropower capacity that could be developed in Michigan after evaluating the resources under a set of criteria that included land use and environmental sensitivities (Hall et al. 2006). There is also the future potential to generate electricity from emerging technologies such as enhanced geothermal systems that extract energy from deep within the earth's crust. One estimate found that geothermal systems in Michigan could generate more than 450,000 GWh of electricity annually (Lopez et al. 2012).

TABLE 1. Michigan's Renewable Electricity Resource Potential

Resources	Electricity Generation in 2012	Potential
Solar PV in Urban Areas (utility-scale and residential/commercial rooftops)	33 GWh	74,373 GWh/year
Onshore Wind Power (at 100 meters)	1,108 GWh	523,374 GWh/year
Sustainable Bioenergy	3,326 GWh	11,897 GWh/year
Total	4,467 GWh	609,644 GWh/year
2012 State-wide Electricity Demand		**106,609 GWh/year**

Michigan has a vast and diverse supply of renewable energy resources—the potential to supply all of the power demand in the state several times over. However, this potential remains largely untapped today. (Resource estimates are technical potential that consider physical constraints such as system performance, competing land uses, or unsuitable lands. They do not consider regulatory, market, or economic constraints.)

SOURCES: EIA 2013B; LOPEZ ET AL. 2012; WPA 2010.

Renewable Energy's Role in an Affordable, Clean, and Reliable Energy Future

A commitment to greater investments in renewable energy, particularly when paired with strong energy efficiency programs (see the box, p. 8), will help put Michigan on a path toward achieving each of Governor Snyder's goals for the state's electricity sector: affordability, reliability, protection of the environment, and adaptability.

RENEWABLE ENERGY CAN IMPROVE AND MAINTAIN AFFORDABILITY

One of the benefits of an electricity portfolio that includes significant levels of renewable energy is that it protects against the price volatility of fossil fuels. Coal prices have risen steadily in recent years and are projected to continue increasing (EIA 2013d). Natural gas prices have historically been volatile, and they face future uncertainty over both supply and demand that could send prices upward (EIA 2013d). In contrast, for wind and solar resources the "fuel" is free, providing a valuable hedge against the risk of rising fuel costs for Michigan's coal and natural gas fleets.

Renewable energy prices for electricity generation can be locked in for 20 years or more through power purchase agreements between renewable energy developers and utilities. In Michigan, utilities have recently signed 20-year contracts for wind power at prices that average below five cents per kilowatt-hour (kWh)—more than 20 percent lower than the current average overall cost of providing Michigan's electricity (Doty 2013; Vela 2013). By providing electricity at affordable and stable rates over a long period of time, renewable energy helps to keep electricity rates affordable for Michigan residents and businesses.

Renewable energy also helps keep electricity affordable in the regional wholesale markets in which Michigan utilities participate. Utilities are constantly buying or selling electricity in these regional markets to ensure that enough electricity is available to meet demand at all times. Because wind and solar resources are not dependent on fuel to generate electricity, they have very low marginal costs—the ongoing costs of producing electricity beyond the cost to build the power plant. This allows renewable energy to be bid into regional wholesale markets at very low prices, thereby forcing other, more expensive resources out of the market and lowering overall market rates (PE 2013). Analysis shows that the continued addition of wind power into the regional market that serves about 90 percent of Michigan's electricity demand will continue to reduce the overall price of energy in the market (Fagan et al. 2012).

RENEWABLE ENERGY CAN IMPROVE SYSTEM RELIABILITY

Transitioning to a system that relies on significant levels of renewable energy can be done while maintaining and even improving the overall reliability of Michigan's electricity supply system. The wind does not always blow and the sun does not always shine, but for grid operators, meeting electricity demand in the face of variability and uncertainty is routine. They already make adjustments for constantly changing demand, planned and unplanned power plant outages, and other unexpected events such as transmission line failures, fuel shortages, and weather events.

Today, reliability is managed by regional grid operators, such as the Midcontinent Independent System Operator (MISO), which serves the majority of Michigan as well as part or all of 15 other states. Grid operators maintain reliability while providing consumers with high levels of renewable

Renewables and Efficiency: An Effective Combination for Achieving a Clean Energy Future

Energy efficiency is one of the quickest and most affordable ways to reduce dependence on fossil fuels. The combination of energy efficiency with greater investments in renewable energy makes a powerful and sensible one-two punch as Michigan transitions toward a clean energy economy. When the Clean, Renewable, and Efficient Energy Act passed in 2008 (the same legislation that included the RES), Michigan made an important commitment to tap into its tremendous energy efficiency potential. The law included an energy efficiency resource standard, which requires electricity providers to implement efficiency programs for residents and businesses that reduce electricity demand each year; the efficiency target ramped up to 1 percent in 2012 and continues at that rate through 2015 (Quackenbush, White, and Talberg 2013).

Michigan's energy efficiency resource standard has been a resounding success. For every dollar spent on utility energy efficiency programs, consumers will receive more than four dollars in benefits through reduced electricity costs over time. Energy efficiency also delays the need for new power plants and new transmission lines, and provides substantial environmental and public health benefits by directly reducing the use of coal and natural gas (Quackenbush and Bakkal 2013b; Stanfield and Neme 2013). Grid reliability is improved as well, as energy efficiency can reduce the strain on the grid by cutting power demand, especially important during times of peak demand.

Michigan's energy efficiency commitments, however, have only scratched the surface. A recent report from the MPSC determined that Michigan could cost-effectively reduce electricity demand 31 to 35 percent below forecasted demand by 2023 (Quackenbush and Bakkal 2013b). Another study estimated that doubling Michigan's standard to 2 percent annually could increase the annual net economic benefits to more than $1.6 billion per year (Stanfield and Neme 2013). These benefits include reduced electricity costs as well as avoided transmission and distribution infrastructure and reduced CO_2 and pollutant emissions (Stanfield and Neme 2013).

Renewable energy and energy efficiency complement each other by providing a clean, affordable, and reliable electricity resource supply that can move Michigan away from overdependence on fossil fuels. By combining a strong RES with an equally strong energy efficiency resource standard, Michigan will be well on its way toward a clean, reliable, and affordable energy future.

Energy efficiency complements renewable energy investments by further reducing Michigan's dependence on fossil fuels.

energy by using operational adjustments and sophisticated forecasting of both supply and demand.[8] They use scheduling practices that allow greater flexibility, transfers of electricity between neighboring areas to improve system durability, and active forecasting and management of renewable energy resources. With these tools, grid operators provide the necessary flexibility for the system to reliably accommodate high levels of renewable energy (Exeter Associates and GE Energy 2012).

Several parts of the country have integrated significant amounts of variable renewable resources into their electricity systems while maintaining reliability (UCS 2013b). In 2012, wind power provided 24 percent of the electricity generated in Iowa and South Dakota, and more than 10 percent in seven other states (EIA 2013b). In addition, on November 23, 2012, the Midwest set a record when wind power supplied 25 percent of the region's electricity (Reuters 2012).

Renewable energy can also help to improve the overall reliability of the grid. Having a diverse mix of resources increases the likelihood that sufficient electricity will be available to meet demand at any given moment. Therefore, the diversification of Michigan's electricity portfolio with renewable energy resources helps to protect against some of the reliability risks of fossil fuel and nuclear power plants. Renewable resources (other than bioenergy) do not depend on fuel distribution systems that can break down or become overcrowded. They are also less vulnerable to prolonged interruptions in operation stemming from transportation bottlenecks, system failures, or accidents (UCS 2013b).

Renewable energy also often fares better in the face of extreme weather and other natural disasters. For example, wind and solar facilities in the Northeast experienced few operational problems compared with coal, natural gas, and nuclear plants during Hurricane Sandy (Wood 2012). In Texas, wind power played a critical role in mitigating power crises during a winter freeze, a summer heat wave, and ongoing drought, all of which caused outages at some conventional power plants (Bode 2011; Galbraith 2011).

RENEWABLE ENERGY BENEFITS PUBLIC HEALTH AND THE ENVIRONMENT

Fossil fuel resources come with myriad environmental and public health risks that impose significant costs, either through their impact on communities and public health or through the costs incurred by utilities in complying with increasingly stringent regulations (MEC 2011). Coal-fired power plants, for example, emit nitrous oxides, sulfur dioxide, particulate matter, and mercury pollution—all of which are regulated by the Environmental Protection Agency (EPA) and are proven to be damaging to public health and the environment. In contrast, wind and solar resources emit none of these pollutants.

Fossil fuel–based resources and renewables also differ with regard to their contributions to climate change, an increasing threat to Michigan and the Great Lakes region (UCS 2009). The use of both coal and natural gas significantly increases humans' vulnerability to climate change. Coal plants remain one of the nation's largest sources of CO_2, and, although an efficient natural gas–fired power plant emits 50 to 60 percent less CO_2 than does a typical coal plant, burning natural gas nonetheless contributes significant levels of CO_2 to the atmosphere.[9] Simply transitioning from coal to natural gas and stopping there will not achieve the long-term reductions in CO_2 emissions necessary to minimize the most dangerous environmental and economic consequences of climate change (Fleischman, Sattler, and Clemmer 2013).

[An effective strategy for improving the reliability and adaptability of Michigan's electricity system is to diversify the state's electricity portfolio with renewable energy resources.]

RENEWABLE ENERGY IS ADAPTABLE

An effective strategy for increasing the adaptability of Michigan's electricity sector is to diversify Michigan's electricity portfolio with renewable energy. Because renewable energy resources have very different operating characteristics and risk profiles than traditional resources such as coal and natural gas, they can increase the adaptability of the electricity sector. Adaptability is increased by utilities' operating wind turbines and solar panels at times when relying on fossil fuel or nuclear resources is not optimal—such as when fuel prices spike, when environmental or safety concerns arise, or when power plants go off-line due to extreme weather events.

Renewable resources can also be developed relatively quickly and are more modular in nature than coal, natural gas, or nuclear power. They can be deployed in capacities ranging from very small, such as a few kilowatts for a rooftop solar PV system, up to hundreds of megawatts for a utility-scale wind farm. Renewable energy capacity can also be developed incrementally, with capacity added according to what is needed at a given time. Utilities' ability to rapidly deploy renewable energy technologies at capacities based on what is necessary just in the near term increases the electricity sector's ability to adjust to changing or unforeseen circumstances, as opposed to the traditional method of building large, centralized power plants that take many years to plan and build.

Given the myriad benefits that renewable energy provides to utilities and consumers, and recognizing that Michigan has only begun to tap its robust renewable energy resources, Governor Snyder and the state legislature should be pursuing an energy policy agenda that expands the state's long-term commitment to renewable energy. One of the most effective ways to achieve that is to increase and extend Michigan's RES.

Methodology of Our Analysis

THE MODEL

In order to analyze the impact of continuing and increasing Michigan's commitment to renewable energy on consumers, Michigan's economy, and the environment, we utilized the Regional Energy Deployment System (ReEDS) model developed by the National Renewable Energy Laboratory. The ReEDS model is a long-term capacity-expansion model that projects future deployment of all major electric

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Transitioning to an electricity portfolio that includes significant contributions from renewable energy resources reduces the myriad risks associated with an electricity sector that is overly dependent on fossil fuels.

power generation technologies and provides a detailed representation of the accompanying transmission systems. It is designed to analyze critical energy issues related to the operation of power systems and the expansion of infrastructure, and can model the outcomes of specific energy policies such as clean energy standards.[10]

ReEDS specifically addresses a variety of issues related to the integration of renewable energy onto the grid, including the regional quality of renewable energy resources, their accessibility and the cost of transmission, the variability of wind and solar power, and the impact of this variability on the reliability of the grid. The model allows users to understand the interplay of policy decisions, energy use, energy prices, energy infrastructure investments, the protection of the environment, and the economy under different future scenarios.

When the modeling exercise is carried out, the ReEDS model is given a set of inputs—such as details about a power system and how they change over time, grid reliability requirements, technology constraints, and policy constraints. Based on these inputs, the model forecasts the lowest-cost mix of technologies needed to meet all regional electric power demand. The major outputs of the model include:

- Amount of capacity and generation for each energy technology every two years through 2050
- Average retail electricity prices
- Investments made in renewable energy technologies
- Electricity-sector CO_2 emissions

CUSTOMIZATION OF MODEL INPUTS TO BETTER REFLECT MICHIGAN'S ELECTRICITY SECTOR

We customized several inputs to the model to reflect our current understanding of key issues facing the electricity sector, especially within Michigan. Our starting point was the data provided by the U.S. Energy Information Administration in its *Annual Energy Outlook 2011* (EIA 2011). We then evaluated the cost and performance assumptions for technologies in the electricity sector with other independent analyses, data from actual projects, input from experts, and filings before the MPSC.[11]

The primary ways that we customized the model for Michigan included using the most up-to-date information on:

- Costs, performance, and availability of energy technologies (as of October 2013)[12]
- Fuel costs for coal and natural gas (EIA 2013d)
- The latest state and federal policies that were enacted into legislation (as of October 2013)
- Planned and recently installed wind power facilities, recent or announced coal plant retirements, and recent transmission builds in Michigan (as of October 2013)

We also customized the model to account for the design elements of Michigan's RES. We made adjustments to the scale and geographic limitations of renewable energy to account for two key Michigan RES design elements: the availability of "incentive" renewable energy credits[13] (RECs) to meet part of a utility's obligation to comply with the standard, and the geographic limitations on where renewable energy facilities can be built in order to count toward meeting utilities' annual requirements.

Under the Michigan RES, a series of incentive RECs are granted for such things as producing electricity during peak demand hours throughout the year, using Michigan-based labor in the construction of a facility, or using equipment manufactured in-state. (The latter two incentives are available only for the first three years of a renewable energy project's operation.) These incentive RECs do not actually represent renewable energy generation, but can count toward utilities' efforts to comply with the RES. Their use, therefore, lowers the overall amount of renewable electricity that is actually added to the system in the course of utilities' compliance with Michigan's RES. To account for the use of incentive RECs in our two scenarios representing strengthened RES policies, we reduced the amount of renewable electricity necessary to comply with each annual requirement by 10 percent over a three-year period. This adjustment is based on the historical use of incentive RECs to date (Quackenbush, Isiogu, and White 2013). As a result, the adjusted 32.5 percent by 2030 RES requirement resulted in an actual modeled requirement of 32 percent in 2030.

Michigan's RES also grants triple RECs for solar PV generation. While ReEDS cannot explicitly model this, we adjusted the model so that solar PV generation counts three times toward compliance with Michigan's annual requirements. This adjustment allows the model to properly value solar PV as a resource toward compliance with Michigan's RES.

Finally, Michigan's current RES requires utilities to comply by using renewable resources located within the service territories of utilities serving Michigan, some of which extend beyond the state's boundaries. Because the model does not identify utility service territories specifically, as a substitute for this aspect of Michigan's RES we assumed that all renewable projects installed to meet Michigan's extended and strengthened RES policy would be installed in-state.

MODELING LIMITATIONS AND UNCERTAINTIES

Projections of long-term changes in the supply, use, and price of energy are subject to uncertainty. Modeling the impacts of energy policies that involve significant changes in the way we produce and use energy adds to this uncertainty. Our model results are therefore not statements of what will happen but of what could happen, given the assumptions and methodologies used in the model.

We studied just two potential scenarios for extending and strengthening Michigan's RES policy. Other scenarios with different policies in place could achieve similar levels of renewable energy, but with different effects. Further, while our assumptions about energy prices and the cost, benefits, and performance of technologies are informed by data from recent projects and historical trends, these factors have not always followed historical trends. They have some inherent volatility. Natural gas prices, for example, have proven particularly challenging to forecast, spiking to near-record levels in 2008, only to decline dramatically by 2010 owing to increased supplies and lower energy demand (Bolinger and Wiser 2010).

Also, ReEDS does not dynamically account for customer-driven changes to the electricity sector, such as energy efficiency or the installation of rooftop solar, or consider these resource options when determining the lowest-cost mix of resources to meet future electricity demand. Energy efficiency driven by Michigan's current energy efficiency resource standard is, however, built into our demand forecasts. To account for the future development of Michigan's rooftop solar resources, we input into the model 90 MW of rooftop solar through 2030 to reflect a conservative level of deployment over the forecast period. The cost of this development and the energy production of rooftop solar facilities are taken into account by the ReEDS model in its electricity sector projections.

> ***The 2030 Case models a ramp-up in Michigan's renewable energy requirements—from 10 percent in 2015 to 32.5 percent in 2030.***

While any forward-looking analysis comes with some inherent uncertainty, the ReEDS model is a robust and widely respected analytic tool for understanding how different decisions might impact the costs, benefits, and reliability of the electricity system under different circumstances. It is in this context that we conducted this analysis—to inform the decision-making process with the best available data.

DESCRIPTIONS OF THE SCENARIOS

We analyzed three scenarios to understand the impacts of different RES policies on Michigan's electricity sector, examining the resulting fuel mixes in Michigan's electricity generation, as well as renewable energy investments, CO_2 emissions, and average retail electricity rates in Michigan.

Our **Baseline Case** assumes no extension of Michigan's current RES (10 percent by 2015) or any other legislative or policy changes. Under the current RES, in each year after 2015, utilities are required to maintain the level of renewable electricity generation equal to 10 percent of the demand in 2015.

The **2030 Case** models an ongoing ramp-up in Michigan's annual renewable energy requirements at about the same pace established by the 2008 RES law: 1.5 percent each year. It assumes an increase from 10 percent in 2015 to 32.5 percent in 2030 (then remaining at 32.5 percent thereafter).[14] We assume that the extended and strengthened RES is implemented under the same structure and policy elements as Michigan's current RES.

For the **2020 Case**, we modeled a more modest RES that continues to ramp up Michigan's annual renewable energy requirements at 1.5 percent per year but over a shorter term, from 10 percent in 2015 to 17.5 percent in 2020 (and each year thereafter).

Results of the Modeling

In brief, our analysis comparing the three scenarios finds that Michigan can affordably strengthen its investment in renewable energy and that doing so creates a more diverse electricity portfolio for Michigan. We find that a longer-term, more ambitious policy maximizes the benefits to Michiganders. Meeting a 32.5 percent-by-2030 RES requirement increases the economic benefits of renewable energy investments in Michigan and reduces power-sector CO_2 emissions more substantially than the other cases modeled, and these benefits accrue to Michigan with little to no increase in average retail electricity prices.

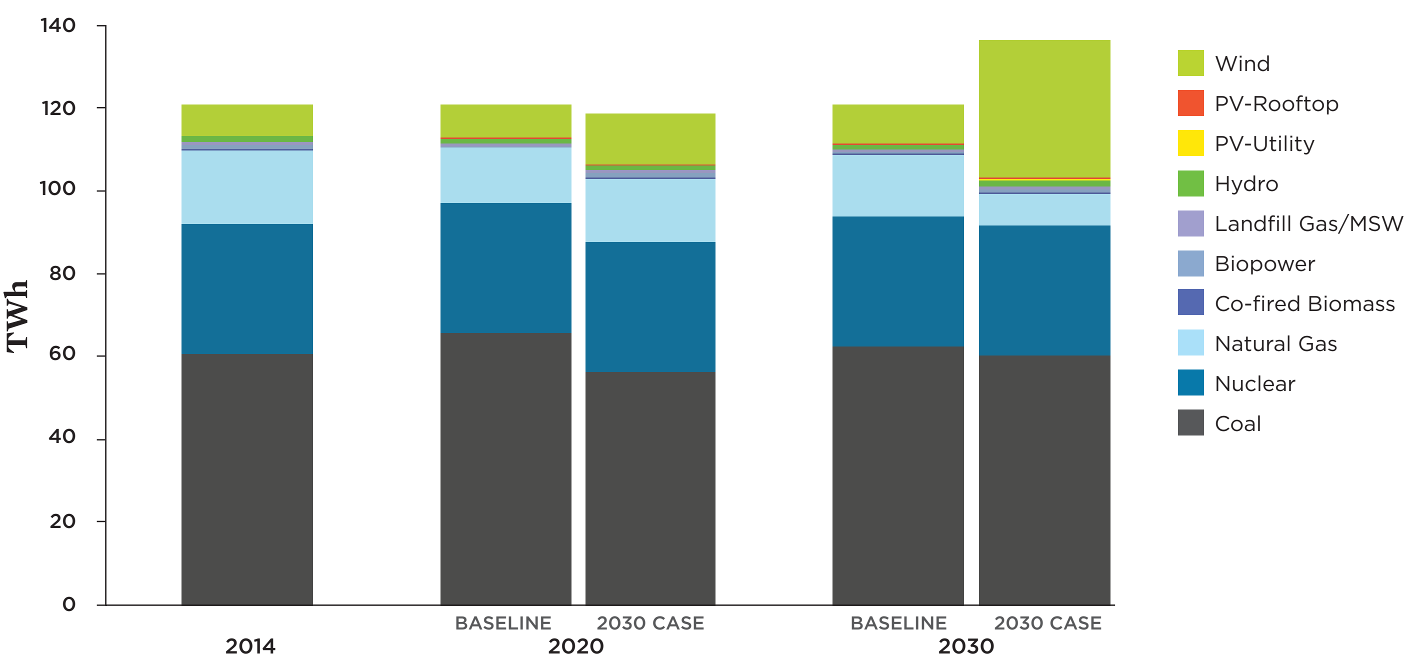
THE 2030 CASE: ACHIEVING 32.5 PERCENT RENEWABLE ENERGY BY 2030

MICHIGAN'S FUEL MIX FOR ELECTRICITY GENERATION

The model's results for the Baseline Case indicate that Michigan will remain heavily dependent on fossil fuels and nuclear power for electricity generation; in fact, Michigan's generation mix remains largely unchanged from 2014 to 2030 (Figure 2). Coal continues to dominate, accounting for more than 50 percent of the generation mix throughout the forecast period. Renewable electricity generation, after ramping up to 10 percent of the state's demand in 2015, remains flat through 2026, and increases only slightly in the later years of the modeling forecast.

Under the 2030 Case, Michigan's electricity generation mix begins to move away from being dominated by fossil fuels and toward a more diversified portfolio that includes a significant increase in renewable energy's contribution to meeting electricity demand. Renewable energy displaces some coal generation in the earlier years (through about 2020) and then begins displacing natural gas generation in the later years.[15] This shift in the generation mix helps to lower the state's exposure to the potential economic, consumer, and environmental risks associated with an overreliance on fossil fuels. While coal, and to a lesser extent natural gas, continues to play a significant role in meeting

FIGURE 2. Electricity Generation Mix, Baseline Case and 2030 Case



If Michigan stays on its current path (the Baseline Case), the state will remain heavily dependent on fossil fuels and nuclear power for electricity generation through 2030. By strengthening its commitment to renewable energy, Michigan can continue to diversify its energy supply and reduce its dependence on coal and natural gas. Under the 2030 Case, renewable energy supplies 32 percent of the state's electricity demand while maintaining grid reliability for consumers.

Michigan's electricity demand, Michigan achieves the integration of 32.5 percent renewable energy in 2030 while maintaining the reliability requirements that are factored into the model.

Under the 2030 Case, both renewable energy and natural gas ramp up to displace some of the coal-fired generation, which is reduced by nearly 15 percent in 2020 compared with the Baseline Case. By 2030, the increase in renewable electricity generation helps to displace electricity generation from both coal and natural gas, which are 3.4 percent and 50.4 percent lower, respectively, than in the Baseline Case. The 2030 Case shows an increase in overall electricity generation, likely reflecting the regional competitiveness of Michigan's coal and nuclear fleets, which are exporting electricity to other states.

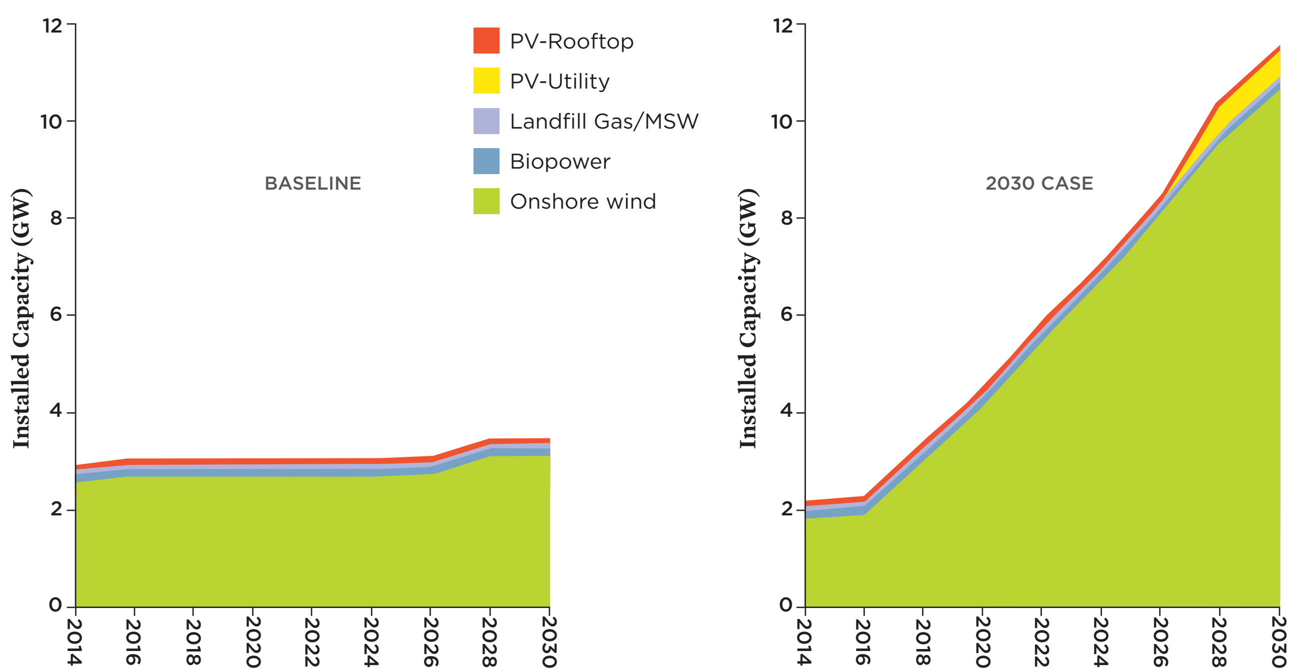
Under the 2030 Case, wind energy is the dominant technology deployed to meet Michigan's expanded renewable electricity policy. Wind generation increases in Michigan more than 65 percent over 2014 levels by 2020 and more than 440 percent by 2030. By comparison, under the Baseline Case the increase is only 5 and 23 percent by 2020 and 2030, respectively. The strong buildup in wind power is primarily due to the technology's low costs combined with Michigan's abundant supply.

RENEWABLE ENERGY DEVELOPMENT IN MICHIGAN

Under the 2030 Case, sustained development of Michigan's renewable energy resources takes place compared with its nearly leveling off under the Baseline Case (Figure 3). Total wind power capacity in Michigan increases to nearly 10,700 MW by 2030, growing at an average of more than 550 MW per year. Utility-scale solar PV also benefits from the expanded RES, although not until later in the forecast period. By 2030, utility-scale solar PV capacity reaches nearly 530 MW.

This expansion represents a significant opportunity for Michigan to continue bolstering local economies. Given the current and projected capital costs to build renewable energy capacity in Michigan, the deployment of Michigan's renewable energy resources under the 2030 Case represents

FIGURE 3. Renewable Energy Development, Baseline Case and 2030 Case



Without policy support beyond 2015, renewable energy development in Michigan remains largely stagnant from 2014 to 2030. However, under the 2030 Case, the sustained deployment of renewable energy in Michigan averages more than 550 MW of renewable energy capacity additions per year. Due to the cost-competitiveness of wind power and Michigan's strong resources, wind development dominates the renewable energy capacity additions throughout the period, and utility-scale solar PV gains traction after 2026.

TABLE 2. Renewable Energy Investments under the 2030 Case

Technology	Total Capacity Additions 2015–2030	Capital Investment 2014–2030[17]	Annual Operation and Maintenance Payments in 2030[18]
Onshore Wind	8,840 MW	$9,120 million	$555 million
Utility-scale Solar PV	527 MW	$430 million	$12 million
Total	**9,367 MW**	**$9,550 million**	**$567 million**

Increased deployment of renewable energy can provide a significant economic boost for local communities. Under the 2030 Case, more than $9.5 billion is invested in building nearly 9,400 MW of new renewable energy capacity. Annual operation and maintenance needs garner another $567 million in local spending in 2030.

more than $9.5 billion in total investment between 2016 and 2030.[16] By 2030, this investment will also be providing annual operation and maintenance payments to local employees and contractors of nearly $570 million (Table 2).

Renewable energy facilities also contribute directly to local communities through payments to landowners for the use of their land and payment of property taxes. Wind developers typically pay landowners who host wind turbines a lease payment for the right to use the land—typically in the range of $2,000 per megawatt of installed capacity per year (EERE 2008). In the 2030 Case, these land lease payments represent more than $21 million in annual revenue by 2030. Property taxes paid to local governments also contribute nearly $100 million from 2014 through 2030.[19]

IMPACTS TO CONSUMERS

A 32.5 percent by 2030 RES in Michigan can be achieved while keeping electricity rates affordable. Average retail electricity prices are very similar between the Baseline Case and the 2030 Case (Figure 4).

Overall, the cumulative added cost of the 32.5 percent by 2030 RES is just 0.3 percent between 2014 and 2030 compared with the Baseline Case. Over the forecast period, rates rise initially and then drop. In 2020, the cost of developing Michigan's renewable energy adds approximately 3.5 percent to the average retail electricity prices, compared with the Baseline Case. Then, shortly after 2020, Michigan's commitment to renewable energy results in lower average retail prices, as Michigan is less dependent on coal and natural gas, the costs of which are projected to continue increasing even as wind power costs remain constant or decline slightly. In 2024, the average retail electricity prices under the 2030 Case are 4.3 percent less than under the Baseline Case, a price decline that would save the typical Michigan household about three dollars on its monthly electricity bill.[20] By 2030, electricity prices are virtually the same under the Baseline Case and the 2030 Case, with prices having dropped to 13 percent below 2014 levels.

Over the course of the modeling timeline, average retail electricity rates remain relatively consistent across both scenarios, even though a large expansion of renewable energy resources is taking place under the 2030 Case and very little capital investments (in any resource) take place under the Baseline Case. This is because the price of building new wind projects to produce electricity—which represents the vast majority of the renewable energy added in the 2030 Case—is competitive with the price of producing electricity from already-constructed fossil fuel–fired power plants. The cost of investing in Michigan's renewable energy resources is therefore comparable, over the course of the forecast period, to the cost of continuing to fuel Michigan's aging fossil fuel–fired fleet.

> ***Achieving 32.5 percent renewable energy in Michigan adds just 0.3 percent to the state's electricity costs between 2014 and 2030.***

CO_2 EMISSIONS

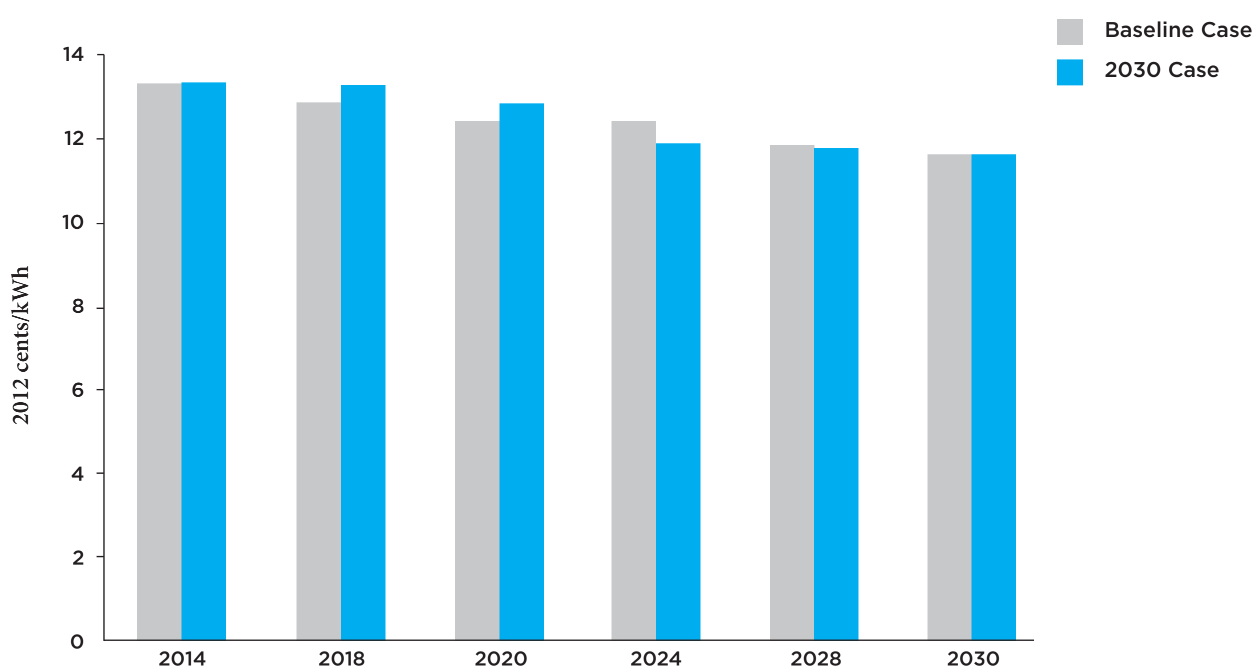
Left unchecked, heat-trapping emissions such as CO_2 will worsen global warming, which already threatens our health, economy, and environment. Failure to reduce global emissions would have significant consequences for Michigan and the rest of the Midwest—consequences that would increase in severity throughout the century. Unabated climate change will lead to more frequent and severe heat waves, more intense storms and flooding, and greater stress on agriculture throughout the Midwest (Perera et al. 2012; UCS 2012; Hayhoe et al. 2009). Fortunately, renewable energy and energy efficiency are technologically feasible, affordable ways to cut CO_2 emissions by replacing or removing the need for fossil fuel use in the electricity sector.

Michigan's increased commitment to renewable energy reduces CO_2 emissions from the electricity sector, which was responsible for more than 42 percent of the state's total emissions in 2010 (EIA 2013e). Under the 2030 Case, annual CO_2 emissions are projected to be 12 percent lower than under the Baseline Case in 2020 (8.6 million tons annually) (Figure 5, p. 16). In 2030, annual CO_2 emissions are 5 percent lower under the 2030 Case compared with the Baseline Case. Cumulatively, from 2014 to 2030, the 2030 Case reduces CO_2 emissions by 65.4 million tons compared with the Baseline Case—equivalent to the annual emissions of 15 typical-size (600 MW) coal plants.

These declines in emissions seen in the 2030 Case provide an additional benefit: that of better preparing Michigan utilities for future climate change–related regulations. While Michigan does not currently have any laws regulating CO_2 or other heat-trapping emissions, the EPA does have the authority and the obligation under the Clean Air Act to regulate these emissions because of their harmful impact on human health and well-being. The EPA is working to finalize standards governing carbon emissions from new power plants and to develop rules to limit emissions from existing power plants (White House 2013).

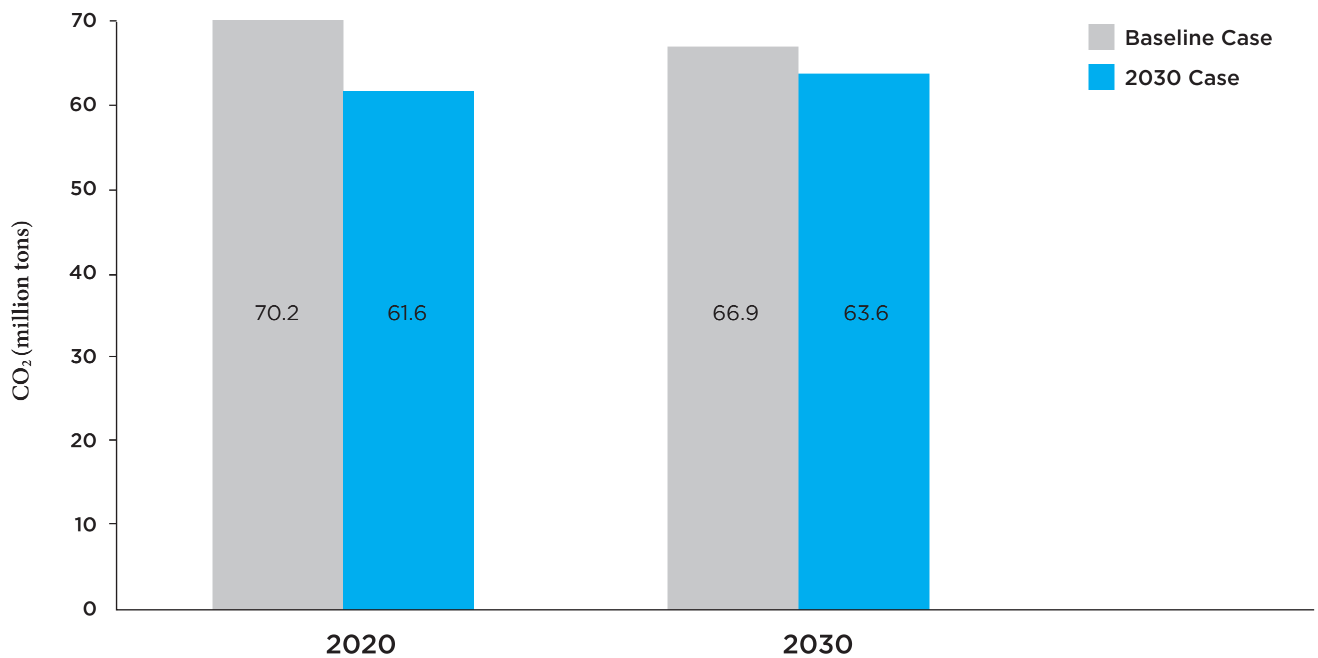
Under the provision of the Clean Air Act being used to regulate carbon emissions from existing power plants (Section 111(d)), states will be responsible for developing and implementing their own plans for achieving the standards established by the EPA. While the rules have not yet been proposed or adopted, it is likely that the EPA will grant considerable flexibility to states to use their existing programs that reduce emissions—such as Michigan's RES and energy efficiency resource standard—to count toward compliance with the power plant carbon standard. For example, states could have the flexibility to apply toward compliance those emissions reductions from policies that

FIGURE 4. Average Retail Electricity Prices, Baseline Case and 2030 Case



Our modeling shows that Michigan can pursue a stronger RES and at the same time keep electricity rates affordable for consumers. Compared with the Baseline Case, electricity prices under the 2030 Case are slightly higher from 2016 to 2022 and slightly lower from 2024 to 2028. By 2030, electricity prices are virtually the same under both cases, and 13 percent lower than rates in 2014.

FIGURE 5. Electricity-Sector CO_2 Emissions, Baseline Case and 2030 Case



Increasing Michigan's commitment to renewable energy would reduce CO_2 emissions in the electricity sector—the largest source of global warming emissions in the state. Under the 2030 Case, electricity-sector CO_2 emissions would be 12 percent lower than the Baseline Case in 2020, and 5 percent lower in 2030.

spur the deployment of renewable energy sources and invest in energy-saving technologies. By strengthening its RES requirements now, Michigan will get a valuable head start on cutting CO_2 emissions and will be better positioned to meet the federal standards in the most cost-effective way.

The reduction in fossil fuel use under the 2030 Case will help curb other harmful air pollutants from power plants as well, such as mercury, sulfur dioxide, and particulate matter. It will also limit damage to Michigan's water and land from the extraction, transport, and storage of fossil fuels and the waste generated when they are burned.

THE 2020 CASE: 17.5 PERCENT RENEWABLE ENERGY BY 2020

Under the more modest 2020 Case, which models a 17.5 percent by 2020 RES, Michigan would achieve only a fraction of the benefits that would be spurred by the 32.5 percent by 2030 RES (Table 3). Under the 2020 Case, about 4,000 MW of wind power and no utility-scale solar PV would be built to meet Michigan's renewable energy requirements. As a result, capital investments are reduced to $4.8 billion in 2030—a 50 percent decrease compared with the 2030 Case. Annual operation and maintenance payments, land lease payments to local landowners, and local tax payments are also reduced by a similar percentage.

While the benefits of renewable energy development decline under this scenario, average electricity prices remain largely the same because the costs of natural gas and coal—which make up nearly all of the difference left behind by reduced renewable energy investments—continue to increase over this period. In 2030, average electricity rates are essentially equal for all three cases.

Recommendations

Michigan's electricity demand can be met in a variety of ways over the coming decades, and we support the governor's process and his goals of increasing affordability, reliability, protection of the environment, and adaptability. The view that Michigan's energy future should include an extended and strengthened commitment to renewable energy resources has support from several quarters: information provided through the governor's process, our modeling analysis, and the state's

TABLE 3. Comparison of Key Results, 2020 Case and 2030 Case

	Average Annual Electricity Rates (2030)	Cumulative Renewable Energy Development (2015–2030)	Cumulative Capital Investments in Renewable Energy[21]	Annual CO_2 Emissions Reductions below Baseline Case in 2030
2020 Case	11.5 cents/kWh	4,063 MW	$4,760 million	2.1% lower
2030 Case	11.6 cents/kWh	9,367 MW	$9,550 million	4.9% lower

A weaker expansion of Michigan's current RES would deliver considerably fewer benefits to the state, compared with committing to a higher, longer-term renewable energy requirement. Compared with the weaker RES (17.5 percent by 2020), the strong RES (32.5 percent by 2030) more than doubles renewable energy development and new capital investments in Michigan, and would have virtually the same impact on retail electricity prices. Reductions in CO_2 emissions are also considerably greater under the stronger RES.

real-world experience of successfully meeting Michigan's current RES policy.

Governor Snyder and the Michigan legislature should be working in 2014 toward an extended and strengthened commitment to renewable energy resources and should pass an RES policy for Michigan that includes achieving at least 30 percent renewable energy by 2030. Delaying legislative action only means delaying a cleaner, more reliable, more economically beneficial energy future for Michigan. Enacting a more modest, shorter-term standard delivers fewer benefits at similar or even higher costs for consumers. Based on our analysis and the information available to date, we recommend the following:

1. **An extended, strengthened RES.** Governor Snyder and the Michigan legislature should pass in 2014 an extension of and a strengthening of Michigan's current RES, requiring Michigan utilities to achieve at least 30 percent renewable energy by 2030.
2. **Long-term power purchase agreements.** Governor Snyder and the Michigan legislature should enact policies that will encourage or require utilities' signing of long-term power purchase agreements to lock in low prices for renewable electricity for 20 years or more. This will ensure more affordable electricity for consumers over the long term and help protect against volatility in fossil fuel prices.
3. **A strong commitment to energy efficiency.** Michigan's energy efficiency resource standard should be increased, requiring utilities to reduce electricity demand by 2 percent each year—ramping up from the current standard of 1 percent annually to 2 percent annually by 2020 and each year thereafter. Aggressively developing Michigan's energy efficiency resource will hasten the state's transition to a clean energy economy and make the transition even more affordable.
4. **The adoption of supporting clean energy policies.** To ensure a successful transition to a sustainable energy infrastructure, Michigan should also boost state incentives for clean energy, adopt stronger energy efficiency codes for buildings, and implement efficient and transparent processes for planning, siting, and approving clean energy projects.
5. **The establishment of a comprehensive, long-term energy resource planning process for Michigan's utilities.** The Michigan legislature should instruct the MPSC to establish an ongoing, transparent, and comprehensive planning process for Michigan's utilities that includes a robust cost/benefit analysis of all available options—including renewable energy and energy efficiency—for meeting the state's electricity needs. Any decisions on electricity sector investments, particularly those that would extend the lifetime of Michigan's aging

Delaying legislative action only means delaying a cleaner, more reliable, more economically beneficial energy future for Michigan.

coal plants, should be considered in the context of a comprehensive strategy that meets electricity demand over the long term and minimizes the costs and risks to Michigan's residents and businesses.

In the last several years, Michigan has built strong momentum in its transition toward a clean energy economy. The state's current RES has been a success, cost-effectively driving new renewable energy development and providing important economic, public health, and environmental benefits in the process. Absent further action, however, this momentum will stall. Michigan's vast renewable energy resources would remain largely untapped, and the state would find itself increasingly vulnerable to the many risks associated with an overreliance on coal and natural gas. Michigan has the resources, technologies, skills, and experience needed to be a national leader in renewable energy. With thoughtful and determined political leadership, Michigan can maintain a reliable power supply, ensure affordable electricity for its residents and businesses, and maximize the economic returns and the public health and environmental benefits that a clean energy future brings.

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ENDNOTES

1 *A megawatt-hour is equal to 1,000 kilowatt-hours. For comparison's sake, the typical home in Michigan uses approximately 600 kilowatt-hours per month.*

2 *For a detailed description of Michigan's renewable electricity standard, visit the U.S. Department of Energy's Database of State Incentives for Renewables and Efficiency at* http://www.dsireusa.org.

3 *The surcharge is allowed for any costs of RES compliance above and beyond what it would cost the utility to acquire the electricity from other sources such as coal or natural gas. Under current law, residential customers pay approximately two-thirds of the incremental cost of RES compliance through these surcharges.*

4 *Xcel Energy, Minnesota's largest power provider, has a 30 percent by 2020 RES requirement. All other utilities in Minnesota have a 25 percent by 2025 requirement.*

5 *A gigawatt-hour is equal to 1,000 megawatt-hours, or 1,000,000 kilowatt-hours.*

6 *See, for example: NextEra energy resources selects GE's new 1.0-100 brilliant wind turbine for Michigan wind farm, online at* http://www.fortnightly.com/nextera-energy-resources-selects-ges-new-17-100-brilliant-wind-turbine-michigan-wind-farm, *accessed December 17, 2013.*

7 *Sustainable cellulosic biomass resources are those resulting from (1) the responsible management of forest resources, (2) best practices for growing energy crops and using agricultural residues, and (3) the use of only non-contaminated urban waste. Myriad ancillary benefits can accrue from sustainable biomass practices, such as the improved health of Michigan's forests, fewer forest fires, improved soil health, and reduced erosion.*

8 *For a summary of the widespread use of these tools among independent system operators, see the August 2011 ISO/RTO Council Briefing Paper "Variable Energy Resources, System Operations and Wholesale Markets," online at* http://www.isorto.org/atf/cf/%7B5B4E85C6-7EAC-40A0-8DC3-003829518EBD%7D/IRC_VERBRIEFING_PAPER-AUGUST_2011.PDF.

9 *The 50 to 60 percent reduction in CO_2 emissions from burning natural gas compared with coal refers only to the smokestack. It does not take into account the life-cycle global warming emissions of the natural gas extraction and transport process. Preliminary research indicates that fugitive methane emissions from the natural gas extraction and transport process may negate much, if not all, of natural gas's advantage over coal in terms of global warming emissions.*

10 *For more information on the ReEDS model, see the National Renewable Energy Laboratory's documentation, online at* http://www.nrel.gov/analysis/reeds/description.html.

11 *For more information on our adjustments to the ReEDS model to reflect current conditions, see Clemmer et al. 2013.*

12 *We reviewed data from a number of sources to arrive at assumptions about the cost, performance, and supply of energy technologies that most accurately reflected Michigan's circumstances. Sources of information included the Energy Information Administration's* Annual Energy Outlook 2013, *Black and Veatch Consulting, the Solar Energy Industries Association, American Wind Energy Association, and others.*

13 *A REC is a tradable certificate that represents renewable energy generation; typically one REC represents one MWh of generation. RECs are the typical method by which states measure compliance with renewable electricity standards.*

14 *Under the 2008 RES, Michigan utilities are required to reach 10 percent renewable energy over a seven-year period, meaning incremental increases in renewable energy generation averaging 1.42 percent each year.*

15 *This shift from displacing coal to displacing natural gas is likely due to the comparative economics of these resources—coal being the more expensive of the two in the earlier years and natural gas being more expensive in later years.*

16 *Net present value, discounted to 2012 dollars using a discount rate of 5.7 percent.*

17 *Cumulative figures are discounted to 2012 dollars using a real discount rate of 5.7 percent. This assumes capital costs for wind power of $2,023 per kilowatt of installed capacity and capital costs for utility-scale solar starting at $2.65 per installed watt in 2015, declining to $2.03 in 2030 as Michigan's market develops (2012$).*

18 *Assumes operation and maintenance costs of $51.92 annually per kilowatt of installed wind capacity and $27.54 annually per kilowatt of installed utility-scale solar PV (2012$).*

19 *Property tax payments are assumed to total 1 percent of capital investment cumulatively.*

20 *Based on typical household electricity usage of 600 kWh/month.*

21 *Net present value, discounted to 2012 dollars using a discount rate of 5.7 percent.*

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