Michigan’s Energy Transition

Leading Innovation Toward Michigan’s 100% Clean Grid

2021

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Please cite the following document as:

Greenlink Analytics. 2021. Michigan's Energy Transition: Leading Innovation Toward Michigan's 100% Clean Grid. https://www.greenlinkanalytics.org/reports

Contact: info@greenlinkanalytics.org

Analytics: Analysis services provided by
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Design: Document graphic design services provided by
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Efforts to achieve a clean electricity supply across the United States are extensive, from individual businesses to cities and states and beyond. By one count, nearly 200 state and local governments have committed to a 100% clean energy future for their communities.[1] In the private sector, companies with more than $6 trillion in annual revenues are committed to a zero-carbon energy future.[2] While the particulars of these goals contain nuanced differences reflecting varying political, economic, and social contexts, a technical pathway forward is visible and encouraging many to act. Reduced costs for renewable energy and battery storage, as well as the changing and highly variable economics of fossil fuels, and the improved performance of electric transportation and energy efficient appliances have all played a role in helping make a rapid clean energy transition a realistic goal.

In Michigan, climate action and clean energy efforts have a long track record, with the state first adopting a renewable and energy efficiency portfolio standard in 2008.[3] These programs have grown in ambition over time, notably in 2016 Public Act 342, which increased targets across the board. Progress by utilities, under the oversight of the Michigan Public Service Commission, has demonstrated that these efforts have been very cost effective.[4]

More recently, the Governor's Office has become an integral player in driving a clean energy transition forward, through Executive Orders (EO) 2019-12 and 2020-10, and supporting these efforts through Executive Orders 2019-06 and 2020-182. EO 2019-12 committed the State to joining the U.S. Climate Alliance and directed the State to take steps to achieve the emissions reduction goals outlined in the Paris Agreement. EO 2020-10 took this even further, calling for the State to achieve economy-wide carbon neutrality by 2050.

It is in the spirit of EO 2020-10 that this study explores decarbonization pathways for Michigan's power sector.

What are the impacts of pursuing a cost-effective energy transition?

Michigan has a large and diverse power sector, both in terms of business operation and infrastructure. The two largest utilities own about 70% of the capacity in the state, while there are over 100 utilities that own generating assets in the state. There are over 700 operating electricity generating units, with most of the existing capacity coming from fossil fuels. Furthermore, the state has two different ISOs coordinating bulk power markets—MISO (Midcontinent Independent System Operator) and PJM (Pennsylvania, New Jersey, and Maryland), with MISO covering the vast majority of the state.

Electricity demand in Michigan has been very stable over the past decade, with annual demand hovering around 103,000 GWh on average (Figure 1-1).[5] The commercial sector is the largest source of demand at 38,000 GWh (37%), followed by the residential sector (34,000 GWh, 33%) and the industrial sector (31,000 GWh, 30%). These relationships have not changed in the past decade, although the impacts of COVID-19 in 2020 are yet to be determined and might lead to some variation.

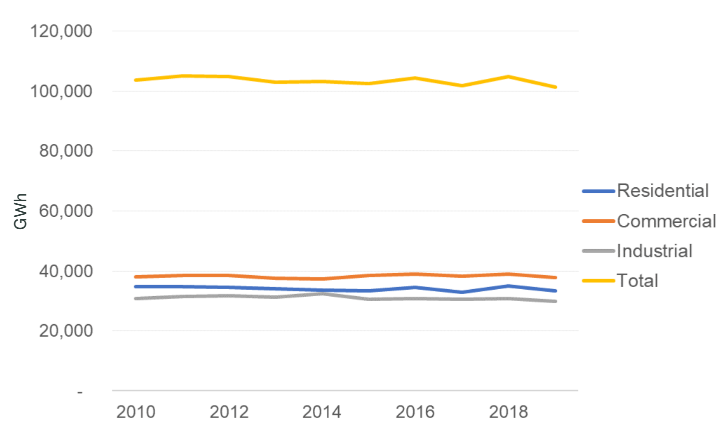

Figure 1-1. Electricity Demand in Michigan 2010-2019

While electricity demand has been very stable for Michigan recently, there are many changes underway that could disrupt these patterns. Improvements in

electric space heating technologies, a more remote workforce, expanded and rapid adoption of vehicle electrification, and more distributed on-site generation will all play a role in changing the future of electricity demand for the state. Greenlink utilizes its ATHENIA model that deploys machine learning techniques to develop highly accurate energy forecasts of Michigan's electricity demand and supply opportunities and behaviors. It follows steps familiar to other utility planning models to ensure reliability and forecast hourly system operations. Additionally, ATHENIA forecasts social and economic impacts of energy choices in a more complete fashion than typical utility models. In this report, a Baseline forecast is compared with a Clean Energy Scenario (CES) that achieves the goals of Executive Order 2020-10 in the most cost-effective way. The Baseline integrates utility plans as filed and approved by the Michigan Public Service Commission as of June 2020 and applies least-cost principles to meeting energy demand beyond the utility planning horizons. This establishes the base case against which the CES is measured.

The impacts of achieving the goals of EO 2020-10 will reach far beyond supply and demand of energy for the State of Michigan because energy is a foundational input into the economy. Billions of dollars of investments will be channeled into different kinds of infrastructure, resulting in different industries developing, different GDP forecasts, and different employment opportunities. Changes to the energy system will impact electric bills as plants are retired and new capacity is brought online. Public health and Michigan's contribution to climate change will be altered as emissions trajectories vary. Energy justice and the distribution of burdens will be affected as the percent of household income spent on energy bills shifts and the location and type of power generation resources advance and change. These socio-economic data points will paint a broader picture of the impact of the clean energy transition in Michigan, helping to evaluate the tradeoffs of these decisions.

The following chapter will briefly detail the study methodology used for this report. The results are described in the subsequent four chapters as a comparative analysis between the Baseline and CES cases. Chapter three will explore the economic development impacts by looking at the change in job creation, income, and GDP. Chapter four explains household and energy burden benefits, while chapter five will describe the effect of the CES on public health. Chapter six will show the results of a benefit-cost analysis of implementing the CES. Chapter seven takes a brief look at the cybersecurity aspect of clean energy regardless of the cases. Finally, chapter eight will present the conclusions of the report.

Chapter 2

Methodology, Assumptions, and Scenario Details

FORECAST MODELING

The Michigan electricity landscape is projected using Greenlink's award-winning ATHENIA model. This AI tool analyzes historical time-varying trends in energy generation and other market variables, such as fuel prices and generation costs, to determine which generation resources will be dispatched on an hour-by-hour basis. ATHENIA is used to analyze how the Clean Energy Scenario (CES) impacts energy bills, utility finances, statewide economic benefits, and pollution-related health effects compared to the Baseline scenario. A more detailed overview of ATHENIA can be found in Appendix A.1. Unless otherwise noted, electricity generation technology price forecasts primarily rely on the National Renewable Energy Laboratory Annual Technology Baseline.[6]

BASELINE SCENARIO FORECAST

Integrated Resource Plans (IRP) for four of Michigan's regulated utilities (DTE Energy [DTE], Consumers Energy [CE], Upper Peninsula Power Company [UPPCO], and Upper Michigan Energy Resources Corporation [UMERC]) influence the underlying assumptions for the Baseline scenario. Additional information is required beyond what is contained in each utility's IRP, as the forecast period extends the IRP planning horizon out to 2050. Energy demand profiles, electric vehicle deployment, additions and retirements of generation facilities, technology resources and costs, energy efficiency, and demand response programs are particularly important aspects.

Greenlink referenced sources such as the U.S. Energy Information Administration (EIA), Midcontinent Independent System Operator (MISO) and others detailed in the appendices, for future technology performance estimates, costs, and electricity demand growth. These sources were used to develop modeling assumptions that served as inputs into ATHENIA's power grid forecasts. Data from each utility's IRP suggest that electricity demand in the Baseline scenario is expected to grow by approximately 0.05% per year over the next few decades before considering electric vehicle (EV) demand growth. Population increases,[7] economic growth, and the electrification of both vehicles and building equipment will all increase electricity needs, while energy efficiency (EE) and demand response (DR) reduce that demand. EVs contribute the most to the Baseline demand growth.

DEMAND RESPONSE AND ENERGY EFFICIENCY

In the Baseline forecast, DR and EE efforts are expected to grow from approximately 7 to 16 million MWh in the first 10 years and remain relatively steady for the next 10 years. Greenlink's DR forecast after 2040 is assumed to be constant for the last 10 years of the study. The EE investments are not continued past the IRP horizon because such significant programs are not approved or proposed beyond the end of the IRP. As a result, EE's contribution to meeting demand tapers down in the last decade as efficient equipment degrades and is replaced. For more details on forecasting assumptions, refer to the Technical Appendix.

BASELINE CAPACITY

Due to differences in demand and capacity needs, utility-scale generation resources are deployed differently between the Baseline and CES cases. The Baseline resource deployment is mainly based on those specified in the utilities' IRP filings. The IRPs added approximately 1.2 GW of natural gas combined cycle (NGCC) and a combined 9.7 GW of utility-scale solar (UPV), solar coupled with batteries (UPV+BESS or Solar + Storage), and wind between 2019 and 2040 (see Figure 2-1). Further capacity additions to the system were determined to be necessary in the last 10 years of the study to satisfy reliability criteria.

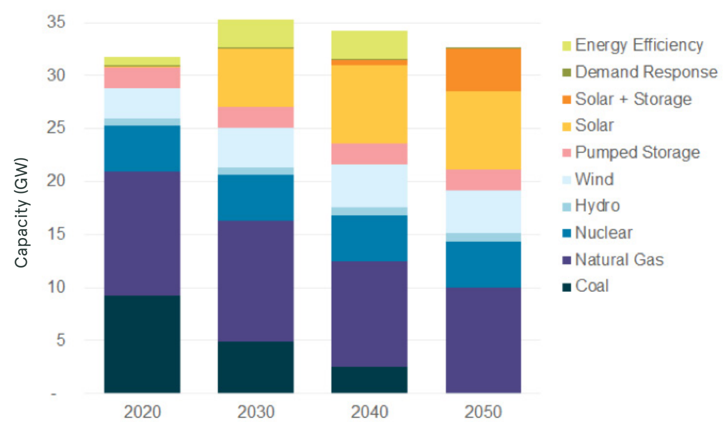

Figure 2-1. Baseline Nameplate Capacity by Source

In the Baseline, most utility-owned coal is retired by 2040 and the capacities of nuclear, natural gas, and hydro generation remain fairly constant. From a generation standpoint, retired coal generation is mainly replaced with more generation from independent power producers (IPP), power purchase agreements (PPA), UPV + BESS, and UPV (Figure 2-2).[01]

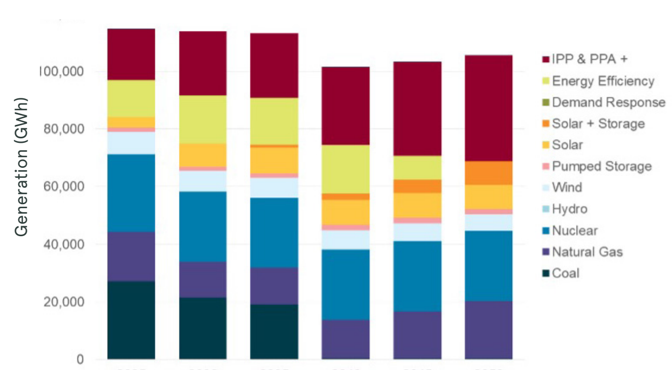

Figure 2-2. Baseline Electricity Generation Sources

[01] Michigan is currently a net electricity exporter. As such, some current generation is not fully replaced in either the Baseline (Figure 2-2) and CES (Figure 2-8) futures. By 2050, the model aims to align generation more closely with projected Statewide demand in both scenarios (Figure 2-3).

CLEAN ENERGY SCENARIO (CES)

The CES takes the same initial demand profile as the Baseline and modifies it to account for both increases in building electrification and EV policies as well as energy efficiency and solar incentives included into the Build Back Better Bill, a sweeping infrastructure plan recently approved by the Biden Administration.[8] These incentives are included to estimate the impact of some Federal action, which as of the publishing date, seems likely to occur. The resulting demand profile is shown in comparison to the Baseline demand profile in Figure 2-3. Incremental EE and DR were modeled as selectable supply-side resources and are therefore not represented as adjustments in the CES demand profile.

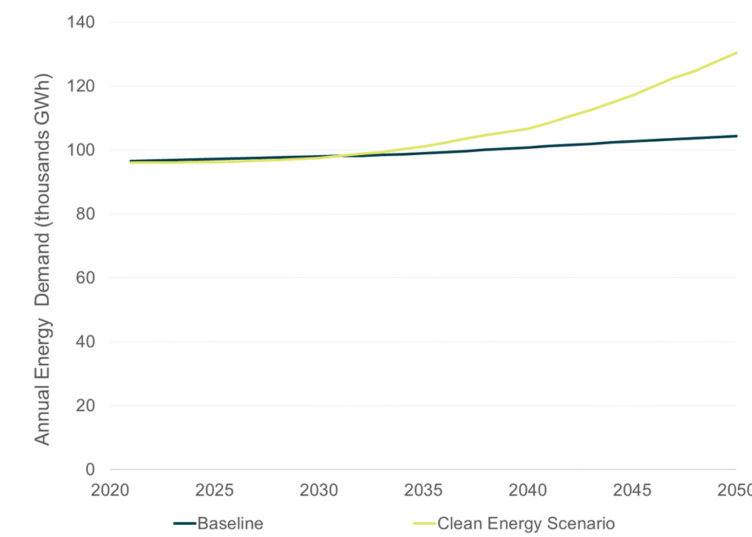

Figure 2-3. Baseline and CES Electricity Demand Forecast.

CES demand ends up being approximately 25% higher than the Baseline in 2050 because of increased electrification of residential technologies and increased deployment of EVs in the state. Incremental EE in the CES was selected if it was determined to be marginally cost-effective.[02] Two types of DR were assessed in the CES; DR using technology and pricing mechanisms and more traditional call-and-response DR. The opportunities and costs for deploying technology plus pricing DR were calculated by assessing the effectiveness of more than 100 such programs nationally, then evaluated through a series of Monte Carlo analyses with more than 10,000 simulations to estimate the median performance in Michigan for such an approach. The potential for call and response DR was determined based on achievability at program costs recently reported by Michigan utilities in EIA 861.

[02] Cost effectiveness was based on a maximum achievable energy efficiency potential available to the Michigan market each year, incorporating hundreds of technologies across the residential, commercial, and industrial sectors. Potentials were divided into five cost tiers, enabling an optimally cost-effective selection of EE as the marginal price of the next tier increased. In this way, EE could be continuously compared with other supply-side options to determine whether and how much EE would be pursued each year.

ELECTRIFICATION

Michigan's path to transitioning to 100 percent clean energy will have impacts on both the building and transportation sectors.

ELECTRIC VEHICLES

The Baseline EV forecast comes from DTE's expectation of EV penetration on its system because they were the only utility to make such a projection. DTE forecasted year-by-year EV electric demand[03] was scaled proportionately to account for the statewide impact of EVs. Alternatively, for the CES EV projection, vehicle forecasts from Bloomberg New Energy Finance, EIA, Advanced Energy Economy, and KPMG were combined to seed a Monte Carlo simulation to identify the most probable EV forecast for the state. That number of vehicles combined with charging behavior, battery capacity, and vehicle range assumptions were used to estimate additional statewide EV electricity demand. The EV demand represents less than 1% of load today and grows to 11% and 12% of the total Baseline and CES loads, respectively. The EV growth in the CES ramps up slower than in the Baseline for the first 13 years of the study period. However, by 2050, there are 34% more EVs than in the Baseline (Figure 2-4).

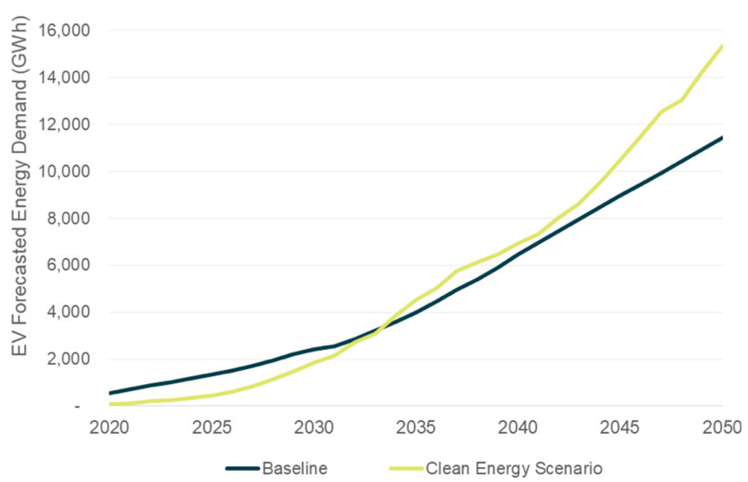

Figure 2-4. Electric Vehicle Energy Demand

BUILDING ELECTRIFICATION

The Baseline includes some level of building electrification within the utility demand forecasts. More natural gas to electricity fuel switching occurs in the CES than in the Baseline due to the envisioned incentives, resulting in changes to building codes. Projections for the extent of fuel switching in Michigan were estimated from the Princeton University Net Zero America project (NZAP).[9] The level of fuel switching incorporated was calculated as the difference between the new building equipment stock in two of the NZAP scenarios,[04] where the difference is the change added to the CES. The most significant building electrification is expected in the residential sector starting in the 2030s (Figure 2-5). Residential electrification is responsible for ~90% of the increase in building electrification demand, of which space heating is the primary factor.

[03] DTE forecasts MWh, not number of vehicles.

[04] Called Less-High Electrification and Reference cases. The most-aggressive electrification scenario from this study was not used because it would necessitate nearly 100% electrification. While such a result was not viewed as likely and falls outside of scope of this study, ongoing concerns related to climate change, public health, and equity may make such steps necessary if carbon-neutral combustible fuels do not become cost-effective.

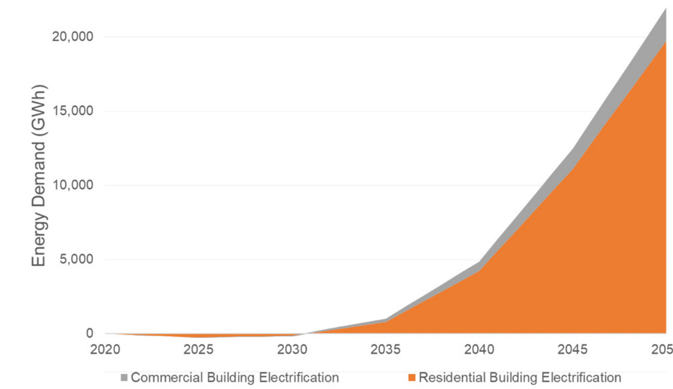

Figure 2-5. Statewide CES Electricity Increase as a Result of Fuel Switching

DEMAND RESPONSE AND ENERGY EFFICIENCY

DR's contribution to peak reduction in the CES is notable. While EE contributes about the same through 2040 (peaking around 16.7 million MWh) in both the CES and the Baseline, after 2040 the Clean Energy Scenario's EE is significantly higher. CES EE tapers off to 11 million MWh between 2040 and 2050. In both the BAU and CES, EE is the largest demand-side contributor to meeting energy needs.

SOLAR INCENTIVES

ATHENIA combines data around current and past solar prices ($/W), consumer behaviors, local weather patterns, photovoltaic (PV) system potentials, and hourly load profiles to provide a year-by-year forecast of PV demand for residential and commercial buildings. Current PV systems cost approximately $3.00/W for installed residential systems. The technical potential of solar deployment in Michigan is around 10,600 MW;[10] under the Baseline scenario, with no new incentives, residential deployment is expected to reach approximately 3,000 MW. Michigan currently has a cap of 0.75% of utility load for rooftop solar systems. Consumers Energy has doubled their cap to 1.5%, which amounts to approximately 100 MW for Consumers Energy and 82 MW for DTE. The CES was designed to include a residential per-watt incentive of $0.25/W which is expected to increase deployment to 3,500 MW, leading to 4,500 GWh in 2050 (Figure 2-6). This incentive would require an annual investment of $130M starting in 2022 and extend until 2026, after which it could ramp down to $0 by 2031.

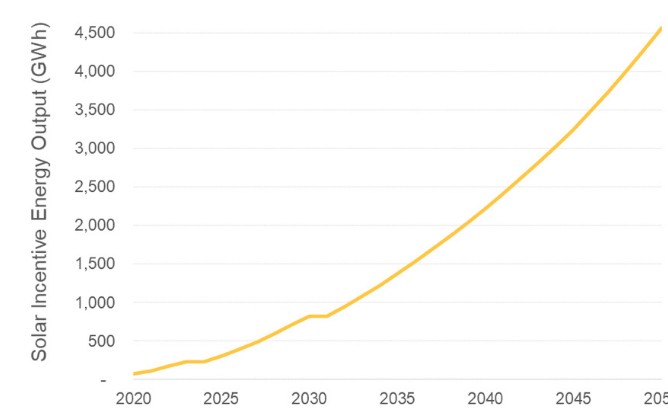

Figure 2-6. CES Annual Residential Solar Energy Generation due to a $0.25/Watt Incentive

SUPPLY-SIDE RESOURCE DEPLOYMENT

An increased demand profile from electrification will impact the generation and capacity needs of the power system as well as the years in which new generation resources are added in the CES. Aside from the demand changes made in the CES, this scenario's assumptions for supply-side generation resource additions differ from that of the Baseline due to economic feasibility of those resources. The CES incorporates federal incentives proposed in the Build Back Better plan, notably, extended wind and solar tax credits, as well as the impact of new credits for battery electric storage systems.

The CES transforms the Michigan power sector by retiring all fossil fuel generators in the Baseline and adding an additional 17 GW of clean energy resources by 2050 as shown in Figure 2-7. The CES forecast does not consider economic fossil retirements until 2026. Nonetheless, with current technologies and resources, it is economically beneficial to retire over 75% of the fossil fuel generators in the first ten years of the CES. Changes to system peaks and generation needs, driven by building and vehicle electrification, require deployment of new resources; over the forecast, UPV is typically the least-cost option and sees the greatest levels of deployment. The final CES portfolio is optimized to minimize costs while maintaining system reliability. As shown by comparing Figures 2-1 and 2-7, system capacity is roughly 7 GW greater (3.5 GW without EE and DR) in the CES, reflecting the changes in demand and resource mix.

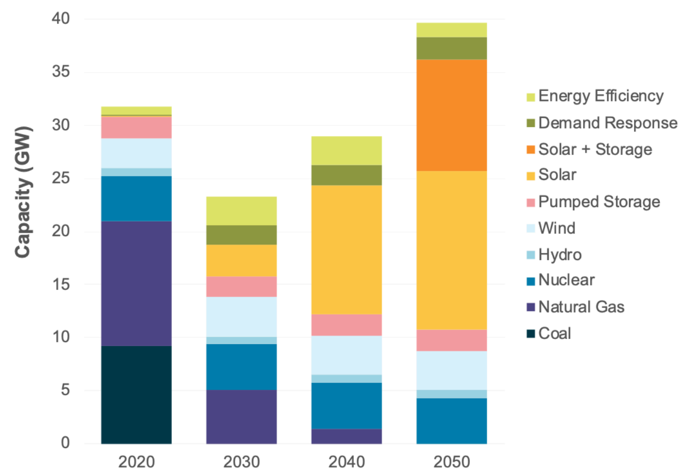

Figure 2-7. CES Capacity by Source

Unsurprisingly, the resulting generation mix in the CES is significantly cleaner than for the Baseline. Michigan has less local air pollution by 2030, as coal is no longer an electricity source, and the role of gas generation is heavily reduced (Figure 2-8). Renewable generation is roughly 3x greater by 2050 in the CES (including IPP renewables), which replaces 20,000 GWh of Baseline gas generation (Figure 2-2). Nuclear and hydro generation are the only resources seeing similar levels of usage in both scenarios.

Methodology, Assumptions, and Scenario Details

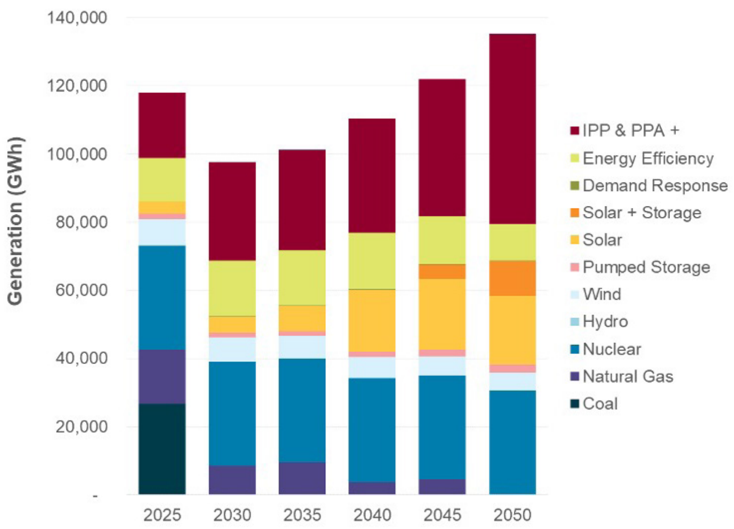

Figure 2-8. CES Generation Sources

Both the Baseline and CES scenarios see growth in UPV capacity added over the 30-year study period. However, the CES adds more than double the capacity of UPV than the Baseline. This is due to fewer plants being retired by the utilities in the Baseline and therefore less new economic resources being added to the system. By 2040, UPV as a stand-alone resource is rarely selected in the CES, opting instead for solar + storage deployment to couple low-cost generation with low-cost capacity resources. In the Baseline, both solar and natural gas generators help displace the generation currently provided by existing coal plants, which are eventually phased out in the 2040s.

KEY TAKEAWAYS

Michigan's 44,000 GWh of fossil generation in 2025 would be reduced to zero in the CES and 20,000 GWh In the Baseline. Meanwhile, CES solar and solar + storage account for almost twice as much generation by 2050 as in the Baseline.

CES electricity demand increases noticeably due to electrification of residential space heating and transportation.

The CES has a greater need for capacity additions to eliminate fossil fuels and accommodate electrification. Many renewable technologies contribute, with UPV and UPV+BESS dominating new generating options.

Demand response plays an important short and long-term role in reducing peak growth in the CES.

Chapter 3

Economic Development Impacts Across the State of Michigan

Moving Michigan towards a clean and resilient energy future should have positive impacts for employment, residential household income, and GDP.

Despite the devastating impacts of COVID-19 on Michigan's economy—with employment losses as great as 23% between March and April of 2020,[11] the state has since seen a nearly 28% resurgence in employment since April 2020.[12] This contributed to nearly $543 billion in GDP in the first quarter of 2021.[13]

Moving Michigan towards a clean and resilient energy future should have positive impacts for employment, residential household income, and GDP, particularly within the industries supplying the energy efficiency and solar sectors. This chapter will examine and compare investments related to clean energy infrastructure between the Baseline forecast and the Clean Energy Scenario (CES). Projections in these infrastructure investments will inform Michigan's employment, residential household income, and GDP through 2050.

CLEAN ENERGY IMPACTS

According to the Clean Jobs Midwest report published by Clean Energy Trust, clean energy companies in Michigan employed roughly 113,000 workers by the end of 2020, and the clean energy sector's growth is outstripping the state's overall job growth rate. Employment opportunities in the advanced clean energy industry—which is comprised of workers in fields such as renewable energy generation, battery storage, and energy efficiency—exceeded traditional energy jobs by nearly one-third; 74,000 workers were employed in energy efficiency fields alone. Investing more into clean and renewable technologies will support more jobs and will contribute to Michigan's overall economy and stability. What's more, over 20% of those jobs are located in rural areas, therefore improving the lives of residents all over Michigan, not just those located in densely populated urban centers.[14]

Michigan's Governor, Gretchen Whitmer, intends to invest millions of the $2.1 billion federal COVID-19 relief fund toward several clean energy initiatives.[15] These clean energy initiatives will be geared toward providing high-paying jobs and raising salaries, as well as educating more workers to prepare for the clean energy transition. Advanced energy advocates are supporting this decision by pushing clean energy manufacturers and suppliers to relocate to the state. As Michigan moves toward adopting more clean and renewable energy technologies, a significant but necessary shift will occur from the traditional energy economy. This analysis measures those shifts in employment, income, and GDP from the traditional energy sector to an advanced clean energy industry using IMPLAN–a widely utilized regional economic impact model.

EMPLOYMENT CHANGES

Economic gains and losses related to investments in energy efficiency, solar, demand response, and other renewable technologies are accounted for in this analysis. For example, as investments in residential energy efficiency are increased, demand for electricity generated from fossil fuels decreases, therefore shifting the need for jobs in the fossil fuel industry. Investments related to building electrification are considered through alternative fuel additions and building efficiency investments. For this analysis, a 'job' is considered one full-time equivalent job per year.

While investments in power plants fueled by coal and natural gas are $2.8 billion less in the CES, $10 billion more is invested in solar, battery storage and energy efficiency–leading to 50% more jobs than in the Baseline scenario. Figure 3-1 shows the timing and which parts of the energy industry see a job impact in the CES relative to the Baseline. For example, investments in solar are higher in the Baseline scenario for years 2026 through 2030, resulting in less net jobs during those years. In the CES, investments in solar are higher than the BAU from 2030 onward. In total, the CES nets about 96,000 new jobs cumulatively, or 3,300 net new jobs per year on average. The effects of job loss in the fossil fuel sector could be mitigated by job training programs focused on clean and renewable energy. Retiring coal plants leads to a shift of 400 jobs per year from the fossil fuel sector where renewable and clean energy sectors see growth and could integrate these workers.

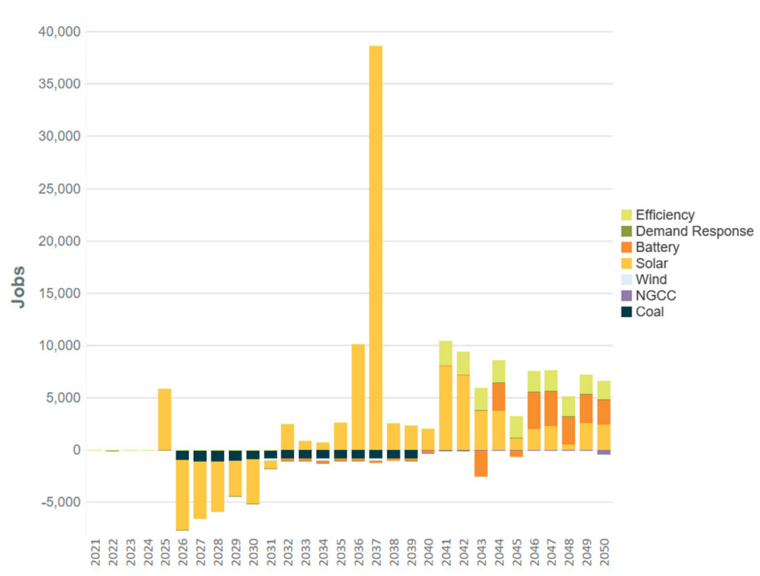

Figure 3-1. CES Net Jobs by Source

Economic Development Impacts

INCOME AND GDP

Income and GDP follow similar trends as job creation in Michigan. As shown in Figure 3-2, within Michigan's energy sector, the largest net increase of income and GDP occurs between 2036 and 2037, when large investments in solar occur. Income within Michigan's energy sector increases by 28% cumulatively across the 30-year projection. Cumulatively, investment toward clean and renewable energy leads to a $2.1 billion increase to residential household income and a $3.9 billion increase to Michigan's GDP.

Shifting Michigan away from a fossil fuel dependent energy system to one supported by clean energy is projected to provide positive net jobs, residential household earnings, and state GDP effects. While the transition leads to job losses in fossil fuel dependent industries, clean energy drives significantly more job creation. These new jobs are concentrated within construction, manufacturing, engineering, and administrative industries. These jobs are also forecast to be higher paying and more likely to provide health care and retirement benefits – energy efficiency and solar jobs in Michigan pay about twice as much in salary and wages as jobs in the fossil fuel industry.[16] The CES demonstrates that investments in clean and renewable energy in Michigan can provide growth opportunities for thousands of individuals each year, expanding residential household earnings and improving the state's economic outlook.

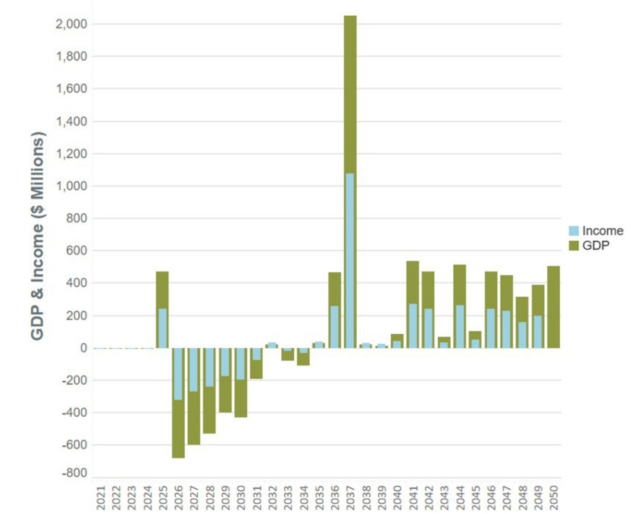

Figure 3-2. CES Net Salary and GDP Benefits

KEY TAKEAWAYS

Michigan currently employs 2.6 times more people in the energy efficiency fields than the electric power sector.

The CES invests $10 billion in energy efficiency, solar, demand response programming, and storage, while decreasing investments by $2.8 billion in fossil fuel generation (like coal). This results in the net creation of 96,000 jobs, $2.1 billion more in residential household earnings, and $3.9 billion more to the state GDP.

Most clean energy jobs are within industries such as construction, manufacturing, and engineering—industries with a large existing footprint in Michigan.

Chapter 4

Household Savings & Energy Burden Improvements

HOUSEHOLD SAVINGS

Currently Michigan's electricity rates are a little higher than the national average.[17] The Baseline includes a forecast of average electricity rates and bills in Michigan based on a sophisticated model of utility financials. The capacity additions and retirements related to decarbonizing Michigan's electricity system will lead to a totally different generation mix for the Clean Energy Scenario (CES) than what is forecasted in Michigan's Baseline. This divergent capacity future has economic impacts—directly affecting electricity rates, and most significantly, leading to savings realized by Michigan families.

The electricity rate forecast leads to higher Baseline rates then the forecast for the CES rates. By 2026, when the fossil retirements accelerate in CES, the electricity rates are expected to decline substantially relative to the Baseline.[01]

From 2026 to 2034, utility rates are on average ~20% lower in the CES than in the Baseline. By 2036, rates are about the same again, as new UPV investments offset savings from retiring fossil fuel plants. However, by 2042, rates are projected to be consistently lower in CES than in Baseline. Recalling Chapter 2, EV and building electrification leads to more electricity use and less natural gas and gasoline use, meaning electricity rates and bills do not tell the whole story of how consumer costs are expected to change.

Residential customers are expected to save ~$8 billion by 2035 under the comparatively lower rates in the CES compared to the Baseline, before accounting for reduced gasoline purchases for cars. This leads to an average annual savings of over $1,600 per household by 2035. The blue and orange lines in Figure 4-1 show the combined average residential annual costs for electricity and natural gas for each future. Gasoline savings also accrue to residential customers who are paying more in order to charge EVs. Gasoline savings, not included in Figure 4-1, is concentrated at the end of the forecast, and accounts for an additional estimated saving of $3 billion for EV owners.

[01] This is primarily related to ~$1 billion/year of operations and maintenance savings, which is mostly attributable to coal and natural gas fuel savings.

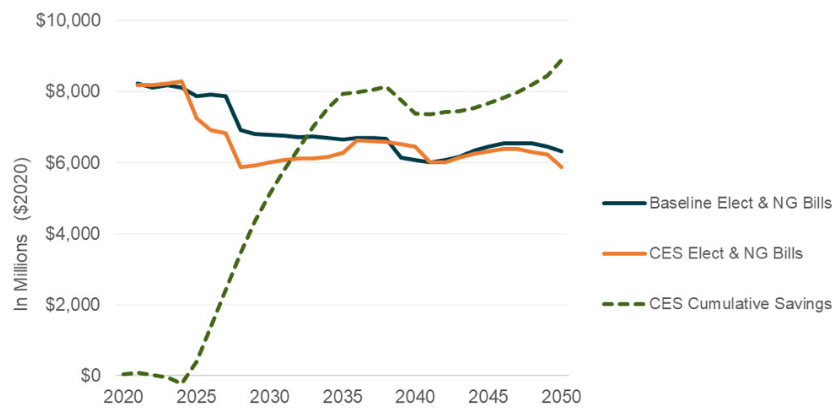

Figure 4-1. Michigan Residential Elect & Natural Gas Bill Changes

The differences in utility rates across the two scenarios are driven by the resource addition and retirement choices described in Chapter 2. Namely, retirement of expensive fossil fuel plants is accelerated under the CES beginning in the mid-2020s, and cost-effective demand-side management programs are also scaled up considerably during this timeframe relative to Baseline. Further, solar and storage resource additions are scaled up but deployed later in the CES compared to the Baseline, thereby capturing additional benefits from continuing technology cost declines over time.

ENERGY BURDEN REDUCTION IN MICHIGAN

Decarbonizing Michigan’s energy grid through deployment of clean, renewable, and energy efficient technologies not only provides relief in the form of decreased energy rates and bills, this transition to a zero-carbon future can also improve energy equity across the state. The reductions in energy bills discussed in the previous chapter should cut household energy burden. Energy burden is the proportion of income a household pays toward their electricity and/or natural gas bills. Typical factors contributing to the distribution of high energy burdens can be rate structures, poor housing stock, inefficient appliances, behaviors in energy consumption, and low incomes. In Michigan, locational factors, such as higher prices for efficient equipment in low-income neighborhoods, have also been identified as drivers.[18] This chapter discusses how changes to energy use patterns impact Michigan’s household energy burden.

A **high** energy burden is defined as energy bills at or greater than 6% of a household’s Income, while a **severe** energy burden are energy bills exceeding 10%. The effects of high or severe energy burden on a household can have devastating impacts and are felt most strongly by minorities and low-Income households.[19] Residents may forgo necessities such as food or medicine in order to stay on top of their utility bills and elderly are at higher risk of suffering from heat exhaustion.[20]

All households experience some level of energy burden, but the impact depends on the financial security of the household. For example, households

with a $2,000 monthly income paying $100 in monthly energy bills experiences significantly higher energy burdens than households making $6,000 a month with the same bill (5% vs. 1.7%). Figure 4-2 shows Michigan’s median energy burden at the county scale for 2017. The state of Michigan currently experiences an average energy burden of 5.4%, with some counties suffering average energy burdens as high as 8%. In Michigan, over 1.4 million households live with high energy burden (6%) and about 830,000 households live with severe energy burden (10% or more).

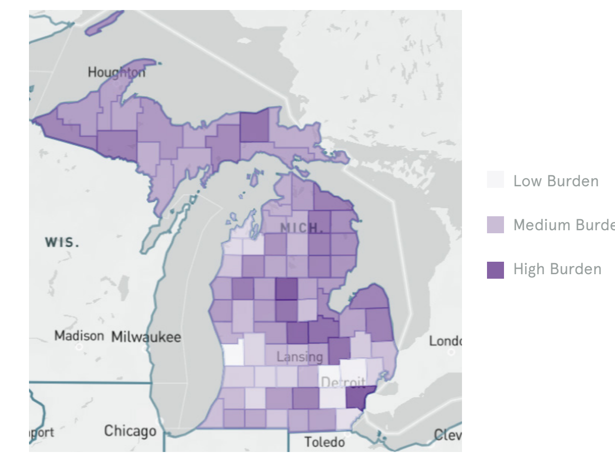

Figure 4-2. Michigan’s Range of Energy Burden by County In 2017[27]

High or severe household energy burdens can have negative effects on an individual’s mental and physical health. Households with high levels of energy burden may be forced to choose between basic human comfort, necessary medication, and/or food.[21, 22] Families living in these conditions may experience extreme levels of stress and sleep deprivation; children growing up in these households often find it difficult to focus in school due to discomfort and lack of other amenities necessary to educational success.[23, 24] Given these implications of household energy burden, even incremental reductions carry great significance. A county-wide reduction of energy burden from 8% to 7%, for example, may seem minor, though likely translates to a profound difference for the highest burdened individuals within that county. A targeted program to reach low-income residents will be more effective in reaching the most energy burdened communities than a low-cost program.[25]

Fortunately, improvements in household appliances, home weatherization, and reduced energy costs are solutions to relieving energy burden and are strong opportunities throughout Michigan’s energy transition. As Michigan starts to rely less on fossil fuels and more on energy efficiency, solar, and battery storage, the model results show residents experiencing lower energy rates and bills and therefore, expanded economic options.

The projected decrease in utility rates and bills as well as an increase in median household income, results in significant energy burden reductions by 2035 in both the Baseline and CES. Figure 4-3 shows the projected energy burden for each scenario in greater detail. The CES projects a lower energy burden across all of Michigan’s counties by about 0.3%, and a number have been specifically called out in the figure below. The most burdened county (Lake County) in 2021 experienced an energy burden of 7.8%—this is projected to be reduced to 5% in the CES by 2035, whereas this number is 5.4% in the Baseline.

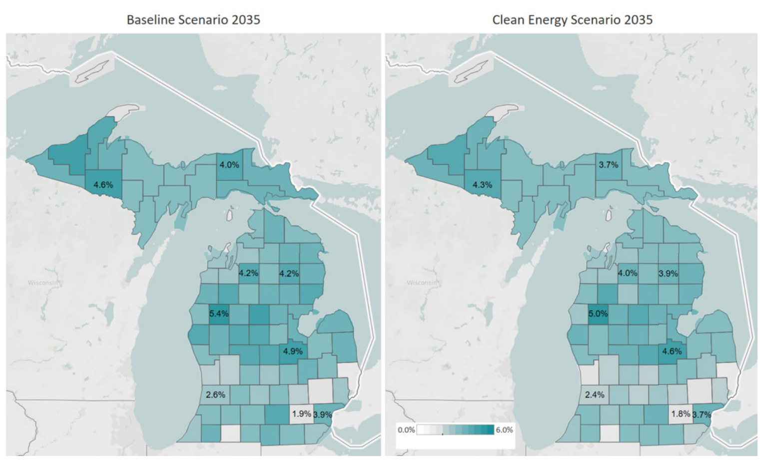

Figure 4-3. Energy Burden Consistently Improves more in CES than Baseline

Further, Figure 4.5 shows the year-by-year changes in energy burden under the Baseline and CES. For Michigan as a whole, average energy burden decreases substantially and steadily in both cases over the next 30 years, reaching 2.1% in the CES. This analysis considers not only changes in residential utility rates, but changes in income as well. Changes in income follow the 2020 U.S. Energy Information Administration’s macroeconomic trends for gross household income; the CES modifies these impacts by the net effect of the economic development.[26]

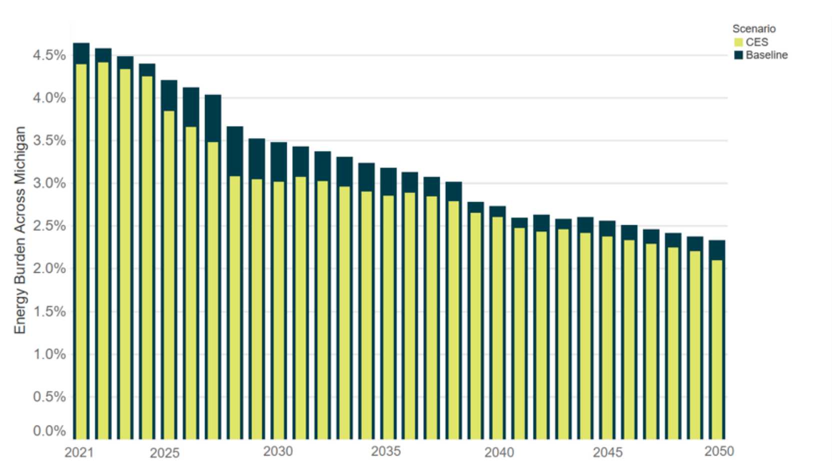

Figure 4-5. Annual Energy Burden across Michigan in Baseline and CES Scenarios

KEY TAKEAWAYS

Households will benefit financially from a clean electricity grid. Reduced spending on coal, natural gas, and gasoline and increasing spending on targeted energy efficiency and solar more than offsets both additional electricity usage and investments in clean generating technologies.

Short-term CES benefits correlate with lower electricity rates and lead the average household to saving $1,600 by 2035 relative to Baseline expenses, when including household natural gas savings.

Increased use of EVs is expected to lead to saving $3 billion in gasoline costs by 2050.

Michigan currently experiences an average energy burden of 5.4%, with some counties suffering average energy burdens as high as 8%; over 1.4 million households live with high energy burden (6%) and about 830,000 households live with severe energy burden (10% or more).

Decarbonizing Michigan’s energy grid would reduce energy burden from 5.4% today to 2.1% in the CES. Energy burdens are forecasted to decline in both the Baseline and CES.

Targeted investments in energy efficiency would likely lead to greater energy burden reductions if low-income households end up with reduced energy bills.

Chapter 5

Benefits of Michigan's Zero Carbon Future: Public Health

Shifting Michigan's energy supply to a carbon-free future would provide non-monetary benefits as a result of cleaner air, thereby reducing short and long-term health issues residents currently face. In 2008, asthma rates in Michigan's adults were as high as 15% in some communities, impacting nearly 800,000 individuals. Of those individuals, Black, Indigenous, and people of color are more affected, especially in densely populated cities such as Detroit.[28] Today, asthma rates in Flint and Detroit are as high as 13-14%.[29] This chapter discusses the environmental and public health implications of Michigan's current energy mix, and the benefits of decarbonizing Michigan's energy grid as envisioned by the Clean Energy Scenario (CES).

EMISSIONS IMPACTS UNDER BASELINE

Pollutants, particularly sulfur dioxide (SO_2), particulate matter (both 2.5 and 10 microns in diameter) ($PM_{2.5}$, PM_{10}), nitrous/nitric oxide (NO_x), ammonia (NH_3), volatile organic compounds (VOCs), and carbon dioxide (CO_2), are tracked by ATHENIA. The federal government's social cost of carbon is used to monetize the damages caused by CO_2. Localized public health impacts are a composite of damages from SO_2, NO_x, VOCs, $PM_{2.5}$, and PM_{10} emissions. Under Baseline conditions, the damages from localized pollutants start at $1.6 billion in 2021 and reach a cumulative present-value total of $10.1 billion through 2050, while social and global pollutant damages from CO_2 start at $2.6 billion in 2021 and reach a cumulative present-value total of $35.6 billion through 2050. Annual pollutant-related damages decrease in the Baseline over time because of reduced coal generation.

AVOIDED EMISSIONS

The CES demonstrates how Michigan's electricity demand can be met without coal and natural gas by 2050. This type of transition will result in a multitude of public health benefits, such as improved respiratory health outcomes, decreased mortality rates, and reduced hospital visits caused by heart attacks. The largest quantity of avoided emissions occurs from 2026 to 2030, particularly for SO_2 and NO_x emissions, due to the retirement of many coal-fired power plants. Coal and natural gas-fired power plants also produce $PM_{2.5}$ and PM_{10}; the reduction in electricity generation from these sources in the CES produces more public health benefits.

The power sector emissions that occur in the Baseline from 2021 to 2050 that do not occur in the CES are shown in Figure 5-1. Particulate matter of any size that is inhaled by the lungs can cause adverse health effects such as asthma and both acute and chronic bronchitis. Respiratory issues can also occur from inhaling various levels of NO_x, depending on the duration and level of exposure. Cumulative $PM_{2.5}$ and PM_{10} emissions under the Baseline scenario are expected to reach 19,900 and 29,800 metric tons, respectively. In the CES, the cumulative emissions from $PM_{2.5}$ and PM_{10} are expected to decrease by 57% and 61%, respectively. Cumulative NO_x emissions are expected to be cut by 54%, from roughly 263,000 tons in the Baseline to 121,000 tons in the CES (2021–2050).

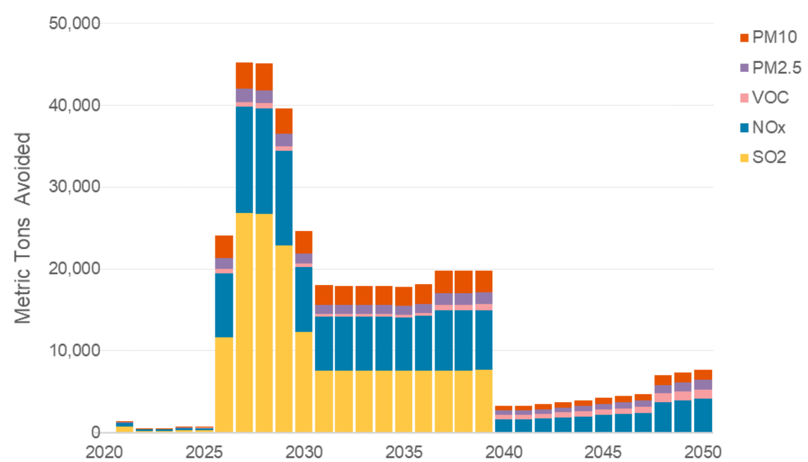

Figure 5-1. SO_2, NO_x, VOC, $PM_{2.5}$, and PM_{10} Emission Reductions Relative to Baseline

SO_2 is primarily produced by coal-fired power plants and can produce many adverse health impacts related to respiratory and mental health. VOCs are precursors to many toxic aerosols and gases. In the Baseline scenario, cumulative SO2 emissions reach 363,000 metric tons through 2050, whereas these levels are cut by 47% in the CES. VOC emissions are expected to reach approximately 16,000 metric tons cumulatively in the Baseline scenario and will be halved in the CES.

Thirty years' worth of CO_2 emissions from electricity generation are expected to produce 752 million metric tons cumulatively in the Baseline scenario. In the CES, cumulative CO_2 emissions are expected to be cut by roughly 60%.

In addition to power sector emissions savings in a cleaner future, Michigan would also see ground-level emissions savings due to the increased electrification of buildings and vehicles. Figure 5-2 shows the annual CO_2 emissions savings between the Baseline and CES. The high annual CO_2 savings between 2026 and 2039 is due to the acceleration of fossil fuel generator retirements in the CES beyond the Baseline rate. Figure 5-2 also shows that there are CO_2 emissions savings due to a switch from natural gas to electric appliances primarily in the residential sector. The increased electrification of building appliances in the CES results in an additional cumulative CO_2 emissions savings of around 41 million metric tons (MMT). Similarly, the

increased penetration of electric vehicles (EVs) in the CES compared to the Baseline results in a cumulative CO_2 savings of 16.8 MMT between 2021 and 2050.[01]

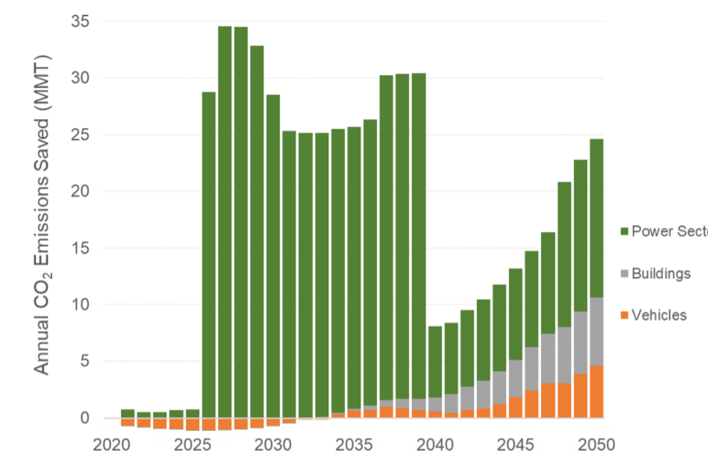

Figure 5-2. Annual CO_2 Emissions Savings in CES by Sector

AVOIDED SOCIAL AND ECONOMIC DAMAGES

The link between air pollution and a suite of social and economic damages is well established.[30] For local air pollution (non-carbon emissions), ATHENIA assigns plant specific damages associated with each emission's links to human health, agricultural damages, and other physical effects derived from the AP2 model. The damages for each scenario and the net improvement from the CES are shown in Figure 5-3. Baseline damages reach $10 billion cumulative (present value), while CES damages only reach $6 billion, so the net benefit across all years is $4 billion.

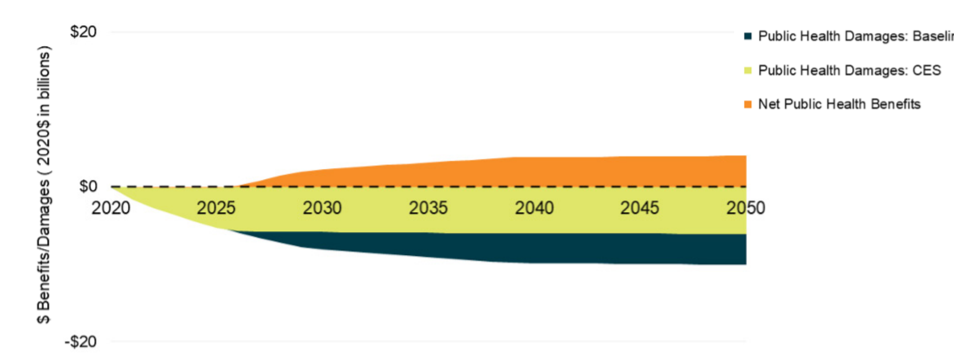

Figure 5-3. Cumulative Public Health Damages and CES Benefits

For CO_2 emissions, damages are derived from the social cost of carbon found in the Technical Update to the U.S. Government's Interagency Working Group Social Cost of Carbon.[31] The corresponding economic impacts are shown in Figure 5-4. The social cost of carbon accounts for changes to agricultural productivity, sea level rise, rainfall changes, extreme weather, and risks to human health. The social cost of carbon is a global measure of the damages resulting from CO_2 emissions, whereas other pollutants'

[01] There is an increase in emissions from vehicles in certain years. This is because the deployment of EVs between 2021 and 2033 is more aggressive in the Baseline than the CES. This switches by 2034, as shown in Figure 5-2.

damages are more regional in nature, and thus more likely to concentrate the bulk of their economic damages in or near Michigan. As such, these damages are shown separately.

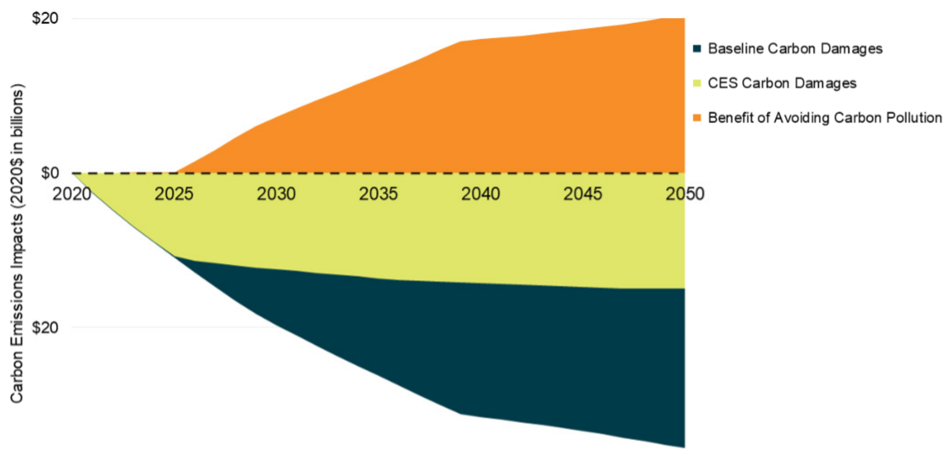

Figure 5-4. Cumulative Carbon Damages and CES Benefits

There is a wide range of public health benefits for Michigan's residents resulting from the reduced pollution in the CES relative to Baseline (see Table 5-1). These are shown as a range of improved outcomes and are determined using the U.S. Environmental Protection Agency's Co-Benefits Risk Assessment (COBRA) Health Impact Screening and Mapping model. ATHENIA determines the emissions that are used as inputs to COBRA. Decreased mortality is a major outcome; the reduction in pollution cuts down premature deaths by 500-625 through 2050. Heart attacks, asthma attacks that result in hospitalization, and other cardiopulmonary conditions also see improvement in the CES relative to the Baseline. Worker productivity also sees a significant improvement gaining back roughly 25,000 –30,000 work days otherwise lost to health-related problems.

Table 5-1. Reduction in Health Problems (Cumulative, Shown as Range)

CONDITION	LOW	HIGH
Asthma, Exacerbation	5,000	6,300
Emergency Room Visits, Asthma	100	130
Work Loss Days	25,000	30,000
Mortality	500	625
Heart Attacks	81	101

It is important to note that these health benefits are specific to the state of Michigan, driven by four pollutants; these benefits do not include any CO_2 impacts on human health, nor do they address the health benefits that would be experienced outside the state. Emissions do not respect state boundaries; a coal-fired power plant in southwest Michigan may carry negative health consequences to the state and its neighbors. Thus, these health impacts are conservative estimates, and the true benefits likely exceed the values above.

KEY TAKEAWAYS

Shifting away from fossil fuels to power Michigan's energy grid would reduce overall pollution from CO_2, NO_X, SO_2, PM_{10}, and $PM_{2.5}$. This shift should lead to hundreds fewer deaths, tens of thousands less workdays lost to Illness, and dozens of fewer heart attacks and asthma-related emergency room visits.

The CES reduces carbon emissions over the course of 30 years by 60% in the power sector as well as by 9.5% in the transportation sector by shifting toward electric vehicles.

The pollution avoidance strategy embodied by the CES realizes over $4 billion from air pollutants, while the benefit of reducing CO_2 emissions over the course of 30 years leads to $20 billion in avoided damages. This does not include any benefits after 2050, when the electric grid should be fossil/carbon free.

Chapter 6

Benefit Cost Analysis

A benefit-cost analysis for Michigan and its residents was performed to evaluate the impacts of the Clean Energy Scenario's (CES) aggressive clean electricity actions, from an economic perspective. A benefit-cost analysis speaks to whether the benefits exceed the costs of a given program. A more nuanced look at costs and benefits can help evaluate the scale of the impact by identifying what scale of costs are associated with achieving a particular level of benefits. Following the guidance of the U.S. Office of Management and Budget, a discount rate of 3% is used throughout.

This analysis primarily compares the various benefits (dollars saved and cleaner air) with investment costs for a decarbonized electricity system. For this analysis, the relevant CES benefits and costs are those that are incremental to Baseline costs and benefits.

Several elements from previous chapters are brought together for assessing the costs and benefits of the CES relative to Baseline. The specific costs are incremental capital investments in clean electricity capacity (which includes extra investments in UPV and BESS) as well as efficiency and demand response programs. Benefits begin with monetary savings related to less fuel purchased for buildings due to electrification, and lower fuel and O&M expenses for power plants. Benefits also include the monetary value of improved public health (Chapter 5) due to reduced pollution from both electricity generation and tailpipe emissions. Pollution benefits from avoided CO_2 are valued using the Social Cost of Carbon.

Money that is transferred from the federal government to consumers (i.e., residential solar tax credits) is not considered costs or benefits, as those policy choices may affect who benefits but not the dollar value of costs and benefits. We calculated a range of costs and benefits for the transportation sector; they ranged from negative $8.4 billion (costs) and positive $8.6 billion (benefits).

The value of incremental differences between the Baseline and CES are illustrated in Table 6-1. This analysis shows that for every dollar invested to achieve a CES future, $7.70 of benefits are expected. Without taking into account CO2 benefits, $3.80 of benefits will accrue for each dollar invested.

The present value of additional power sector costs between 2021 to 2050 is large, over $5 billion, though those are exceeded by power sector savings. Meanwhile, the value of local health benefits and residential fuel savings both surpass half the investment costs. Reductions in Michigan's carbon dioxide emissions are valued at $20.6 billion.

[01] This includes change in damages from tailpipe emissions, the cost of purchasing EVs, and savings from vehicle operations and maintenance. There is a wide range of uncertainty related to cost deltas between ICE and electric vehicles sticker prices and maintenance costs for the most impactful years, those between 2045 and 2050, when the forecasts indicate large differences in number of EVs. Using the pessimistic estimate does not change the CES's net positive BCA ratio and the best estimate increases the scale of the positive impacts shown in Table 6-1.

Table 6-1. Incremental Benefit-Cost Analysis 2020 (present value in millions $)

	COSTS	BENEFITS	RATIO
Additional Capital Investments	$5,410		
Benefit of Reduced O&M Costs		$13,100	
Local Health Benefits		$4,000	
CO_2 Benefits		$20,600	
Electrification Residential NG Fuel Savings		$3,700	
Subtotal All	$5,410	$41,400	
w/o CO_2 Benefits	$5,410	$20,800	
Benefit-Cost Ratio All			7.7
w/o CO_2 Benefits			3.8
Net Benefits		$36,000	
w/o CO_2		$15,400	

A benefit-cost ratio should not be used in isolation. The scale of benefits and costs may be very small, very large, or in between and is not evident from the ratio itself; the net results need consideration. Including the quantified values gives us a central estimate of a benefit-cost ratio of 7.7 and net benefits of $36 billion dollars. Further, intangible benefits and other public value preferences are also important elements to consider. For example, benefits from reduced heart attack rates or longer citizen lifespans are not fully captured in the numerical or monetized terms of cost-benefit analysis.

KEY TAKEAWAYS

The incremental CES benefits are expected to exceed CES costs decidedly for Michigan, by between $15 and $36 billion.

The benefit-cost ratio also shows a large benefit within the utility sector and beyond. For every dollar invested in the clean energy transition leads to between $3.80 and $7.70 in direct savings and health benefits.

Chapter 7

Cybersecurity and the Internet of Things

The internet of things (IOT) is a framework in which technologies can share information over a network. In the electricity sector, IOT leads to opportunities to cycle appliances differently to reduce peak and/or save electricity costs. Utilities can use IOT to monitor and manage technologies and alter consumption patterns to optimize current systems.

The proliferation of appliances that are connected to both the electricity grid and the internet means that increasingly, electricity grid operators need to take cybersecurity threats more seriously. The 2020 SolarWinds cybersecurity attack revealed the vulnerabilities of the nation's grid, with a quarter of the power utilities exposed to the compromised software. Although the hack did not lead to outages, there was potential for the malicious code to remain in utilities' systems and modify or steal their data.[32] Considering the increasing threat to grid security, the federal government initiated a 100-day effort earlier this year to encourage power industry leaders to bolster grid security—including an emphasis on.[33]

This issue is important well beyond clean energy. Google, for example, is investing billions in cybersecurity programs and education.[34] Grid resilience to cyberthreats needs to be taken seriously in any energy future, but especially a more connected one.[01] Increasingly, smart demand response technologies present an opportunity to provide system savings and flexibility. The accompanying challenge is that smart technologies may increase security risks if not effectively and proactively managed.

Of course, this is not a new challenge for utilities. However, considering the sensitive nature of breaches, it is unclear how well this is being managed. Over the past decade, several utilities have been investigated and occasionally fined by the Federal Energy Regulatory Commission (FERC) for violating cyber or physical security protocols, including failure to maintain proper logs and not providing enough protection to essential facilities.[35]

This report does not attempt to capture costs of cybersecurity or even estimate if the CES and Baseline should expect similar costs for equivalent levels of cybersecurity. All systems will have flaws and vulnerabilities if connected to the internet in some way, and electric utilities have several critical points that can be attacked, including generation, transmission, and distribution. Minimizing risks will involve a multifaceted approach that utilizes industry partnerships, upgrading operational technology (OT) systems, and integrating response plans and intelligence reporting into companies' culture.[36] These measures will be needed to reduce the ever-increasing cyberthreats, like service disruption, data theft and/or erasure, and networks controlled by bad actors, facing the energy sector.[37]

[01] We acknowledge that grid resiliency is impacted by a myriad of threats aside from cyberattacks; outages caused by storms, scarce water resources, and other climate events must be accounted for when designing or upgrading electric grids. A discussion of these risks is beyond the scope of this chapter.

Chapter 8

Conclusion

Michigan has been developing its clean energy and energy efficiency policy portfolio for over a decade. In the past two years, the state committed to joining the U.S. Climate Alliance and aims to achieve economy-wide carbon neutrality by 2050. This transition will have far-reaching impacts on the state's public health, employment, and power sector infrastructure. There are many ways to navigate to carbon neutrality; one cost-effective way, the Clean Energy Scenario (CES), was evaluated throughout this report.

The CES demonstrates how shifting Michigan's energy supply to support a carbon-free future by 2050 can produce net environmental, health, and economic benefits (including household bill savings). The transition envisioned by the CES requires significant investments. However, that investment is dwarfed by the value of realized health benefits and financial savings that will fundamentally improve Michigan's energy equity landscape. Each dollar invested will return between \$3.80 and \$7.70 in direct and health related benefits.

Michigan can transition to a 100% carbon free grid by 2050, while greatly improving the lives of its residents.

FINDINGS FROM THIS ANALYSIS INCLUDE:

The CES would result in a 3.3% reduction in energy burden through 2050. Targeted investments in energy efficiency for particularly high burdened households could establish and accelerate an equitable distribution of reduced burden.

Michigan's 44,000 GWh of fossil generation in 2025 will be reduced to zero under the CES. During this time, utility-scale solar photovoltaics and battery storage will be key in building renewable generating capacity.

Under the Clean Energy Scenario, \$10 billion will be invested in energy efficiency, solar, demand response and smart grid programming, as well as storage. This will result in a net creation of 96,000 jobs and provide a net increase of \$2.1 billion in household earnings. These jobs will primarily be in construction, manufacturing, and engineering (industries that already have a large footprint in Michigan).

Through investments in clean generating technologies and increased energy efficiency, households will see several financial benefits. Near-term, in the Clean Energy Scenario, households will realize \$1,600 in annual savings on average through 2035.

By shifting away from fossil fuels, Michigan will see reductions in CO_2, NO_X, SO_2, PM_{10}, and $PM_{2.5}$ pollutants. Declining pollution will result in major health impacts for Michigan residents, including fewer heart attacks, fewer asthma attacks requiring hospitalization, and overall lower mortality rate. Air pollution benefits are valued at over \$4 billion, and when combined with reduced CO_2 damages, leads to \$20 billion in benefits over 30 years.

Benefits exceed costs by between \$15 and \$36 billion for CES over the Baseline forecast.

Appendices

Appendix A: Glossary

BAU: Business as Usual.

BESS: Battery Energy Storage Systems.

CE: Consumers Energy

CES: Clean Enery Scenario

DR: Demand Response

DTE: DTE Energy

EE: Energy Efficiency

EIA: U.S. Energy Information Administration

EV: Electric Vehicle

IPP: Independent Power Producers

IRP: Integrated Resource Plans

KPMG: KMPG

MISO: Midcontinent Independent System Operator

NGCC: Natural Gas Combined Cycle

NZAP: Net Zero America Project

PJM: Pennsylvania, New Jersey, Maryland

PV: Photovoltaic

UMERC: Upper Michigan Energy Resources Corporation

UPPCO: Upper Peninsula Power Company

UPV: Utility-Scale Photovoltaic

Appendix B: Technical

B.2 METHODOLOGY

ATHENIA

ATHENIA utilizes a deep-learning neural network architecture to learn and project hourly dispatch behavior at the unit level for generation plants meeting electricity demand in Michigan. With different generator technologies and capacities brought online and retired throughout the various scenarios, ATHENIA's least-cost planning module determines what resources should be selected to satisfy base load and peak demand requirements to maintain system reliability.

Supply-Side Resources and Baseline Capacity Forecast

This report evaluated the IRPs of four of Michigan's regulated utilities: DTE Energy, Consumers Energy, Upper Peninsula Power Company, and Upper Michigan Energy Resources Corporation to assess trends for the state-wide Baseline forecast. Other utilities such as Indiana Michigan Power (a subsidiary of American Electric Power), have units explicitly included in this analysis. Other supply sources are aggregated, labeled "IPP & PPA +" in Figures 2-2 and 2-8 and are further explained below.

Energy Efficiency Trends

The Baseline energy efficiency (EE) investments are not continued past the IRP horizon because such significant programs are not approved or proposed beyond the end of the IRP forecasting horizon, roughly from 2040 onward. This follows the industry standard assumption[1,2] that energy resources, including EE, are extended only so far as they have been expressly approved to operate. As a result, EE's contribution to meeting demand slowly declines in the last decade, as efficient equipment degrades and is replaced.

Independent Power Producer Resources and Power Purchase Agreements

Figures 2-2 and 2-8 display the mixture of projected baseline electricity generation sources until 2050, including independent power producers (IPPs)—these are a mixture of plant technologies serving electricity to meet Michigan's demand via power purchase agreements (PPAs), as well as electricity generated by smaller, independent power producers within Michigan that were not explicitly modeled in ATHENIA's hourly forecast. These include all conventional generator technologies as well as renewables. The fuel mix and corresponding pollutant emission rates related to these sources are assumed to be congruent to the annual average of Michigan's electricity grid in both the Baseline and the CES, updated year-to-year.

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B.3 ECONOMIC DEVELOPMENT

Trends for Solar Jobs

Solar net jobs are increasing and decreasing in the first 15 years of the forecast as shown in Figure 3-1. Figure 3-1 reflects capacity that is summarized in Figure 2-2 and Figure 2-7. The different pattern of adding solar jobs does not reflect job losses, rather different years of expected capacity additions.

The jobs analysis reflects net jobs between the two scenarios and the solar buildout for each of the scenarios is not smooth and uses different approaches. The CES investments are part of the modeling exercise, while in the Baseline, solar investments are taken from utility plans as described in Chapter 2. Ultimately, this points to more solar jobs earlier in the Baseline. In the CES, ATHENIA adds capacity based on state-wide reserve margin calculations and economic analysis, so the CES solar capacity growth is higher in 2025 than in the Baseline and then lower until 2031 when the trend is reversed.

B.6 BENEFIT COST ANALYSIS

Calculations for the Transportation Sector

Chapter 6 pointed out a wide range of uncertainty for transportation sector costs or benefits. The benefit was estimated to be between negative $8.4 billion and positive $8.6 billion. The basis for this range is almost entirely a result of uncertainty as to the future price difference between new electric and internal combustion engine light-duty vehicles. Both a conservative and a more optimistic estimate were evaluated for price differential. The conservative estimate kept a flat price premium of $5,500 between those vehicles between 2032 and 2050, while the optimistic estimate had the price premium slowly drop to $1,400 by 2050. Greenlink notes this element may be an important element to revisit. However, to avoid confusing car price uncertainty with the rigorous power sector analysis, the transportation values were not included in Table 6-1.

The average of the high and low transportation sector costs or benefits is a benefit of $130 million, including public health and avoided gasoline purchases. As the additional electricity demand is included in Table 6.1 and the $130 million in benefits is not included, this approach was deemed to be appropriately conservative.

Appendix B

Appendix C: References

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